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Hanford Site Groundwater Monitoring for Fiscal Year 1997

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Abstract

This report presents the results of groundwater and vadose-zone monitoring for fiscal year (FY) 1997 on the Hanford Site, Washington.

Soil-vapor extraction continued in the 200-West Area to remove carbon tetrachloride from the vadose zone. Characterization and monitoring of the vadose zone comprised primarily spectral gamma logging, soil-vapor monitoring, and analysis and characterization of sediments sampled below a vadose-zone monitoring well. Source-term analyses for strontium-90 in 100-N Area vadose-zone sediments were performed using recent groundwater-monitoring data and knowledge of strontium's ion-exchange properties.

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. Water levels over most of the Hanford Site continued to decline between June 1996 and June 1997. Water levels near the Columbia River increased during this period because the river stage was unusually high.

Groundwater chemistry was monitored to track the extent of contamination, to note trends, and to identify emerging groundwater-quality problems. The most widespread radiological contaminant plumes were tritium and iodine-129. Concentrations of technetium-99, uranium, strontium-90, and carbon-14 also exceeded drinking water standards in smaller plumes. Plutonium and cesium-137 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 tritium, uranium, strontium-90, and plutonium in small plumes or single wells.

Nitrate is the most extensive chemical contaminant. Carbon tetrachloride, chloroform, chromium, cis-1,2-dichloroethylene, fluoride, and trichloroethylene also were present in smaller areas at levels above their maximum contaminant levels. Cyanide concentrations were elevated in one area but were below the maximum contaminant level.

Resource Conservation and Recovery Act of 1976 groundwater monitoring continued at 25 waste management units: 16 under detection programs during FY 1997 and data indicate that they are not adversely affecting groundwater, 9 under groundwater quality assessment or compliance programs to assess possible contamination. Assessment reports for single-shell tank waste management areas S-SX, T, and TX-TY were prepared, concluding that they have probably contributed to contamination in the area. An assessment report for waste management area B-BX-BY is being prepared; those tank farms also appear to have contaminated groundwater. A final assessment report for the 216-U-12 crib concluded that it has contaminated groundwater with nitrate. An assessment program for the 216-B-3 pond concluded the site had not contaminated groundwater, so the site will revert to detection monitoring in FY 1998.

Groundwater remediation under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* includes pump-and-treat systems in the 100-N Area (strontium-90); the 100-K, 100-D, and 100-H Areas (chromium); and the 200-West Area (separate systems for carbon tetrachloride and technetium-99/uranium).

A three-dimensional, numerical, groundwater model was applied to the Hanford Site to predict contaminant-flow paths and the impact of operational changes on site groundwater conditions. Other models were applied to assess the performance of three separate pump-and-treat systems and to support testing of permeable barrier technology.

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Summary

This report summarizes the results of fiscal year (FY) 1997 groundwater- and vadose-zone-monitoring activities on the Hanford Site. This report is designed to provide a comprehensive, current interpretation of groundwater conditions on the site and in adjacent areas, including a description of site hydrogeology, groundwater flow, and groundwater contaminant distribution. This report fulfills reporting requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA), other Washington Administrative Codes, and the *Atomic Energy Act of 1954* as implemented by U.S. Department of Energy (DOE) orders. This report also summarizes results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semiconsolidated sediments deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are locally confined by layers of silt and clay. Confined aquifers occur within the underlying basalt flows and associated sedimentary interbeds. Groundwater in the unconfined aquifer system 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 large volumes of artificial recharge at wastewater-disposal facilities. These mounds are declining, and groundwater flow is gradually returning to earlier patterns.

Water levels are monitored across the Hanford Site and to the east and north of the Columbia River. These measurements are used to determine the water-table configuration for the unconfined aquifer system, to monitor changes in water-table elevation resulting from site operational and offsite changes, and to assess impacts of the changes on monitoring networks. A site water-table map for June 1997 was constructed and used to infer groundwater-flow directions. Water levels over most of the site declined during FY 1997, continuing the trend caused by reduction in liquid effluent disposal. The water table rose in wells near the Columbia River because the river stage was unusually high through the spring and summer of 1997. Water levels are also measured in wells completed in the upper basalt-confined aquifer. No significant changes were observed in this aquifer in FY 1997.

Vadose Zone

Because untreated wastewater is no longer discharged to the ground at the Hanford Site, areas of residual vadose-zone contamination are the most significant sources of possible groundwater contamination. The rate of movement of contaminants to the groundwater depends on contaminant chemistry, stratigraphy, and drainage of water through the vadose zone.

Three soil-vapor-extraction systems continued to operate in the 200-ZP-2 Operable Unit as an expedited response action under CERCLA to remove the carbon tetrachloride source from the vadose zone. Soil-vapor extraction began in February 1992, and through September 1997, 75,000 kg of carbon tetrachloride have been removed. While the soil-vapor-extraction systems were shut down from November 1996 through June 1997, a study was conducted to evaluate the magnitude and rate of carbon tetrachloride concentration rebound in the soil vapor.

Characterization and monitoring of the vadose zone during FY 1997 comprised primarily in situ borehole spectral gamma logging, soil-gas sampling and analysis, and characterization of sediments obtained through drive-barrel and split-spoon sampling below a vadose-zone-monitoring well at the SX single-shell tank farm. Source-term analyses for strontium-90 in 100-N Area vadose-zone sediments were conducted using recent groundwater-monitoring data collected during high-water conditions and knowledge of strontium's ion-exchange properties

Vadose-zone remediation continued in the 100-B,C Area and was initiated in the 100-D Area at high-priority liquid waste-disposal sites. Remedial action at these sites entails excavation, transportation, and disposal of contaminated soil and structures from the upper 5 m of the vadose zone.

Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

RCRA groundwater monitoring continued at 25 waste management areas. At the end of FY 1997, 16 were being monitored under detection programs and do not appear to be adversely affecting groundwater. The others were monitored under assessment or compliance programs. The following paragraphs summarize highlights of RCRA monitoring during FY 1997.

Four single-shell tank waste management areas were monitored under assessment investigations in FY 1997. Contamination from chemically similar sources such as nearby cribs made it difficult to determine whether the tank farms were the source but the assessment investigations indicate that they were. The T, TX, and TY tank farms (200-West Area) have been monitored under an assessment program since 1993 because of elevated specific conductance. An assessment report concluded that the tanks probably have contaminated the groundwater with technetium-99. The S and SX tank farms (200-West Area) began their assessment program in FY 1996 and appear to have contaminated the groundwater with technetium-99, nitrate, and hexavalent chromium. The B, BX, and BY tank farms (200-East Area) appear to have contaminated the groundwater with technetium-99.

The results of an assessment program for the 216-U-12 crib (200-West Area) were released in FY 1997. The crib has contaminated the groundwater with nitrate and technetium-99 and will remain in assessment until final-status monitoring requirements are implemented.

Results of the 216-B-3 pond (200-East Area) assessment program were released in FY 1997, concluding that the site has contributed no definable hazardous waste contamination to groundwater, despite erratic elevated total organic halides. The site reverted to an indicator evaluation program in October 1997.

The 183-H solar evaporation basins (100-H Area) were monitored under final-status regulations during FY 1997. The basins have contaminated the groundwater with technetium-99, uranium, nitrate, and chromium at levels exceeding applicable concentration limits. Corrective action will be addressed under the CERCLA program, and an interim remedial action (pump-and-treat system) for chromium began operation in FY 1997. Groundwater monitoring to meet RCRA requirements will continue during the remediation.

The 316-5 process trenches (300 Area) changed from interim-status assessment to final-status compliance monitoring in December 1996. After the first sampling event, cis-1,2-dichloroethylene, trichloroethylene, and uranium were above their respective concentration limits in some downgradient wells. The exceedances were confirmed and the State of Washington Department of Ecology was notified. As required, a corrective-action plan was submitted and will be implemented in 1998. Natural attenuation of the contaminants is the corrective action chosen under the CERCLA record of decision. Groundwater monitoring will continue under RCRA to monitor the decline in concentrations.

Background concentrations of total organic halides were reestablished at the 216-S-10 pond and ditch (200-West Area) because the constituent had increased in the upgradient well.

The RCRA-monitoring programs for the 216-A-10, 216-A-36B, and 216-A-37-1 cribs (200-East Area) were combined into a single assessment program in FY 1997. The 216-A-10 and 216-A-36B cribs were formerly monitored under separate indicator evaluation programs, and the 216-A-37-1 was monitored to meet DOE orders. Specific conductance was elevated downgradient of the cribs, and there is evidence that the cribs have contaminated groundwater with tritium and nitrate.

Groundwater Contamination

Monitoring wells were sampled during FY 1997 to satisfy requirements of RCRA, CERCLA, Washington Administrative Code, and DOE orders. Approximately 700 wells were sampled during the period.

The extent of major radionuclides at levels above the interim drinking water standards (DWSs) is shown in Figure S.1. Tritium, iodine-129, technetium-99, and strontium-90 were present at levels above the U.S. Environmental Protection Agency (EPA) or State of Washington interim DWSs, and uranium concentrations exceeded the EPA's proposed maximum contaminant level (MCL). Minor radiological contamination above DWS includes carbon-14 (100-K Area), cesium-137, and plutonium (216-B-5 injection well). Derived concentration guide (DCG)[1] levels were exceeded for strontium-90 in the 100-K, 100-N, and 200-East Areas (near the 216-B-5 injection well). The DCG for uranium was exceeded near U Plant. The DCG for tritium was exceeded in one well near cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant. The DCG for plutonium was exceeded in one well in the 200-East Area (near the 216-B-5 injection well). Cobalt-60 concentrations exceeded the 100-pCi/L interim DWS in recent years but were below the DWS in FY 1997. Results for individual constituents are summarized below.

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[1] The DCG is based on a 100-mrem/yr exposure standard and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios.

The extent of major chemical constituents at levels above the primary MCLs is shown in Figure S.2. Carbon tetrachloride, chloroform, chromium, cis-1,2-dichloroethylene, fluoride, nitrate, and trichloroethylene were present in groundwater samples at levels above their MCLs. Cyanide concentrations were elevated in wells near the BY cribs but were below the 200-µg/L MCL. Results for individual constituents are summarized below.

The volume of unconfined groundwater chemically affected by site activities at levels exceeding an MCL or DWS was estimated to be ~1.4 billion m^3 based on the contaminant distributions during FY 1997. The estimate has a high uncertainty because of a lack of knowledge of the vertical extent of contaminant plumes. Plume thickness is estimated to be 20 m, except in the 100, 300, and Richland North Areas, where it is estimated to be 5 m. The porosity of the aquifer is not well-characterized; for the purpose of the calculation, the porosity is assumed to be 30%. The estimate does not include water in the vadose zone.

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. As a result, tritium reflects the maximum extent of contamination in the groundwater.

Tritium concentrations greater than the 20,000-pCi/L interim DWS were detected in FY 1997 in portions of the 100-B,C, 100-K, 100-N, 100-D, 200, 400, and 600 Areas. Tritium also exceeded the DWS in the 100-F Area in the past, but the well with the highest concentrations was not sampled in FY 1997 because it is on a biannual schedule. The highest tritium concentrations in the 200-East Area (exceeding the 2,000,000-pCi/L DCG in one well) continued to be found in wells near cribs that received effluent from the PUREX Plant.

Tritium in the 400 and 600 Areas can be related to migration from sources in the other operational areas. In particular, tritium migration from sources in the 200-East Area near the PUREX Plant affected that part of the 600 Area downgradient to the east and southeast, the 400 Area, and the 300 Area. This plume discharges to the Columbia River along a stretch extending from the Old Hanford Townsite to the 300 Area. 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 and the hydraulic gradient has decreased.

Portions of the 600 Area north of Gable Mountain and Gable Butte are contaminated with tritium at levels below the DWS. The major sources appear to be the 100 and 200-East Areas.

Iodine-129

The presence of iodine-129, a moderately low-activity-yield fission product, in groundwater is significant because of its relatively low, 1-pCi/L interim DWS; 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 activity in Hanford Site groundwater. Iodine-129 is transported in groundwater as the anionic species, which is fairly mobile. Wastes containing iodine-129 were historically disposed of in the 200 Areas. Extensive plumes at levels above the interim DWS are found in the

200 Areas and in downgradient portions of the 600 Area. The major plume extends toward the southeast from the 200-East Area. A smaller arm of the plume is moving toward the north between Gable Mountain and Gable Butte.

Technetium-99

Technetium-99 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Technetium is transported in groundwater as a negatively charged species that is highly mobile. Technetium tends to be associated with uranium through the fuel-processing system, but uranium is less mobile in groundwater on the Hanford Site. Technetium-99 concentrations greater than the 900-pCi/L interim DWS continue to be observed in the 100-H Area downgradient of the 183-H solar evaporation basins, where fuel-fabrication waste leaked to the ground. Concentrations of technetium-99 greater than the DWS were also observed in FY 1997 in wells in the 200-West Area, where 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 to contain the plume.

One well near the T single-shell tank farm continued to show a rapid increase in technetium-99 activity in FY 1997. Technetium-99 is also elevated in wells monitored for the TX-TY, S-SX, and B-BX-BY tank farms. These sites are undergoing RCRA assessment investigations because of elevated specific conductance.

Elevated technetium-99 levels apparently associated with the BY cribs (200-East Area) continued to be observed in FY 1997. A well formerly used for groundwater extraction in treatability testing contained up to 9,910 pCi/L of technetium-99 in 1995. This well was sampled in FY 1997 for the first time after the completion of the test, and the technetium-99 concentration was only 730 pCi/L. The maximum average annual level of technetium-99 detected in the area north of the 200-East Area in FY 1997 was 2,000 pCi/L.

Uranium

There are numerous potential sources of uranium release on the Hanford Site, including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium mobility is dependent on both Eh and pH, and its migration is slower than that of tritium and technetium-99. At Eh/pH conditions in the unconfined aquifer, U^{6+} is the most mobile state.

The EPA proposed a 20-µg/L MCL for uranium. Uranium was detected at concentrations above the proposed MCL 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 FY 1997 (exceeding the DCG) were in the 200-West Area near the 216-U-1 and 216-U-2 cribs, and this plume extends into the 600 Area to the east. Like technetium-99, this plume is being contained by a pump-and-treat system.

Another area of elevated uranium concentrations is observed in the 300 Area, downgradient of the 316-5 process trenches. A pulse of uranium contamination appears to be moving from the vicinity of the process trenches toward the southeast. An expedited response action was performed on the trenches in mid-1991 to reduce the uranium source in that area. Use of the trenches for disposal of cooling water was resumed after the expedited response action was completed and discharges ceased in December 1994. Uranium levels decreased sharply after the expedited response action but rose again after 1994, when discharge to the trenches ceased.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is, therefore, present in waste streams associated with fuel processing; it may also be released 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 FY 1997, strontium-90 concentrations exceeded the 8-pCi/L interim DWS in wells in all of the 100 and 200 Areas and near the former Gable Mountain Pond. Strontium-90 concentrations exceeded the 1,000-pCi/L DCG in wells in the 100-K, 100-N, and 200-East Areas and near the former Gable Mountain Pond.

The most widespread, high concentrations of strontium-90 (greater than the DCG) continue to be observed in the 100-N Area. Strontium-90 activity increased in some wells in the 100-N Area because a high water table apparently remobilized contamination formerly sorbed to sediments above the average water-table elevation. The overall extent of the 100-N Area strontium-90 plume is not increasing perceptibly. A pump-and-treat system operates in the 100-N Area to reduce the flux of strontium-90 to the Columbia River.

Strontium-90 concentrations continued to exceed the DCG in a well near the 216-B-5 injection well and in one 100-K Area well. Changes in concentration in the 100-K Area may be linked to infiltration of water from natural or artificial sources, thus mobilizing vadose-zone contamination. New wells near the 116-K-2 trench provided additional data on strontium distribution in that area, where it exceeds the interim DWS. Strontium-90 near the former Gable Mountain Pond is related to past disposal of waste in this area. Concentrations of strontium-90 above the interim DWS were detected in one well south of the PUREX Plant in the 200-East Area. Strontium-90 activity increased to 63 pCi/L in a well completed in the confined aquifer in the 100-B Area, but the sample was not believed to represent groundwater conditions in the area because of poor well construction and high sample turbidity.

Carbon-14

Carbon-14 exceeded the 2,000-pCi/L interim DWS in two small plumes near waste-disposal facilities adjacent to the K-West and K-East Reactor buildings. The maximum average concentration in FY 1997 was 29,000 pCi/L.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with wastes 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 onsite sediments and is rarely observed in groundwater unless complexed by other chemicals. Wells located north of the 200 Areas, in an area that is affected by waste disposed to the BY cribs, consistently show the presence of detectable cobalt-60. In FY 1997, the maximum annual average cobalt-60 detected in this vicinity remained below the 100-pCi/L interim DWS. 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.

Very low levels of cobalt-60 were detected in groundwater downgradient of the PUREX Plant as far as the Old Hanford Townsite. Although levels are far below the interim DWS and are declining, this indicates that cobalt-60 may be mobilized by a complexing agent other than cyanide in some Hanford Site wastes. The moderately short half-life of cobalt-60 (5.3 years) means that its concentration onsite has been decreasing rapidly since production operations ended.

A well between the 200-East Area and Gable Mountain completed in the confined aquifer showed cobalt-60 concentration greater than the DWS in 1995 but that well was not sampled in FY 1996 or FY 1997 because of scheduling errors. An adjacent confined aquifer well showed no detectable cobalt-60 in 1995 or in subsequent samples.

Cesium-137

Cesium-137 is produced as a high-yield fission product and 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 FY 1997 reached 1,600 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 DWS for cesium-137 is 200 pCi/L.

Cesium-137 is a potential contaminant of concern at the S and SX single-shell tank farms because it was detected in vadose-zone sediments in FY 1996. Low concentrations of cesium-137 continued to be detected in one groundwater well in this area, but 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 DCG for plutonium-239 is 30 pCi/L. There is no explicit interim DWS for plutonium-239; however, the gross alpha MCL of 15 pCi/L is applicable. Alternatively, if the DCG (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the interim DWS, 1.2 pCi/L would be the relevant guideline. Plutonium generally binds strongly to sediments, so its mobility in groundwater is limited.

The only significant detection of plutonium in FY 1997, as in previous years, is associated with the 216-B-5 injection well in the 200-East Area. The maximum concentration of plutonium-239/-240 detected near this injection well in FY 1997 declined to 25.6 pCi/L in an unfiltered sample. The concentration in a filtered sample from the same well was 0.95 pCi/L. Plutonium had been detected at low levels in the past in a well ~150 m northwest of this injection well, but was below the detection limit in FY 1997.

Nitrate

Nitrate contamination in the unconfined aquifer system reflects the extensive use of nitric acid in decontamination and chemical-processing operations. Like tritium, nitrate can be used to define the extent of contamination because it is present in many waste streams and is mobile in groundwater. However, additional sources of nitrate are located offsite to the south and west.

Nitrate was measured at concentrations greater than the MCL (45 mg/L as the NO_3^- ion) in wells in all operational areas. However, the single value exceeding the MCL in the 100-B,C Area was believed to be erroneous, and nitrate contamination greater than the MCL in the 100-N Area was restricted to a few, scattered wells. Although elevated nitrate levels were found throughout the extensive plume emanating from the vicinity of the PUREX Plant in the 200-East Area, only proportionally small areas contained nitrate at levels above the MCL. 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 MCL are observed near the 400 Area and 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 was also 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. The State of Washington's MCL for chromium has been changed from 50 to 100 µg/L to agree with the EPA's MCL. Chromium was elevated in each of the 100 Areas, but the major plumes exceeding 100 µg/L are related to operations in the 100-K, 100-D, and 100-H Areas and portions of the 600 Area between. Hexavalent chromium was detected in the Columbia River substrate adjacent to these areas and is a hazard to aquatic life. Therefore, interim actions are under way to pump and treat groundwater in these areas to reduce the amount of chromium reaching the river. The chromium plumes are not well-defined in the area east of the 100-K Area and in the area between the 100-D and 100-H Areas. Chromium distribution in the western portion of the 100-D Area was better defined during FY 1997 by data from new monitoring wells.

Chromium concentrations were also found at levels above the 100-µg/L MCL near T Plant in the 200-West Area. There were no new data on a chromium plume previously observed south of the 200-East Area. The source of this plume was not established.

Carbon Tetrachloride

As in previous years, carbon tetrachloride contamination was found in FY 1997 to be above the 5-µg/L MCL beneath much of the 200-West Area. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume onsite. The contamination is principally from waste-disposal operations associated with the Plutonium Finishing Plant, where it was used in plutonium processing. The well with the highest concentration averaged 7,000 µg/L in FY 1997. A groundwater pump-and-treat system is operating in this area to prevent further movement of the central portion of the plume. 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. The total area of the carbon tetrachloride plume in FY 1997 (5-µg/L contour) was ~11,000,000 m^2, which is the same as FY 1996.

Field activities in late 1997 provided information on the vertical distribution of carbon tetrachloride. Concentrations were highest in the first 5 m of the aquifer and decreased with depth to near zero at the basalt. However, concentrations greater than the MCL were detected 60 m below the water table in one well.

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. The MCL for chloroform is 100 µg/L (total trihalomethanes). The distribution of chloroform was not precisely defined in FY 1997 because of difficulties in obtaining accurate analyses from the laboratory in the presence of high carbon tetrachloride concentrations.

Trichloroethylene

Trichloroethylene (TCE) was commonly used on the Hanford Site in the 1960s and 1970s as a degreasing compound. TCE was detected at concentrations greater than the 5-µg/L MCL in FY 1997 in wells in the 100-K, 100-F and adjacent upgradient 600 Areas, 200-West, 300, and Richland North Areas. Concentrations of TCE were also detected in wells near the Solid Waste Landfill but were below the MCL.

Concentrations of TCE exceeded the MCL in the 200-West Area to the west of T Plant, to the east of U Plant, and in one well near the REDOX Plant. Some TCE at levels above the MCL is also associated with the carbon tetrachloride plume near the Plutonium Finishing Plant.

The 5-µg/L MCL for TCE was exceeded in the northwest point-of-compliance well for the 1100-EM-1 Operable Unit and in other wells near the Siemens Power Corporation and the Horn Rapids Landfill. The plume appears to have lengthened to the northeast in FY 1997.

cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene continued to increase in a well that monitors the bottom of the unconfined aquifer near the 316-5 process trenches. The average cis-1,2-dichloroethylene concentration in this well in FY 1997 was 166 µg/L (MCL = 70 µg/L). The source of this constituent is believed to be anaerobic biodegradation of TCE.

Cyanide

A cyanide plume 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. The MCL for cyanide is 200 µg/L. The maximum average annual concentration of cyanide detected in FY 1997 was 120 µg/L.

Fluoride

Fluoride was detected above the primary 4-mg/L MCL in a small plume near the T Plant waste-disposal facilities (200-West Area). Two wells in the Richland North Area also exceeded the MCL, and the contamination is believed to come from an offsite source.

Ingestion Dose and Risk Estimates

Results of groundwater monitoring are compared to the DWSs for individual radiological constituents. These interim DWSs use the methodology set out in the Code of Federal Regulations (CFR) (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 mrem/yr from consumption of each individual constituent. Similarly, DCGs provide estimates of concentrations that could result in a 100-mrem/yr 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.

Figure S.3 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer system on the Hanford Site. These estimates were made by summing the interpolated groundwater concentrations for carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, plutonium, 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 concentrations to ingestion dose equivalents were taken from DOE Order 5400.5. The dose presented in Figure S.3 represents the cumulative dose equivalent from all major radionuclides in Hanford Site groundwater.

The dose estimates presented in Figure S.3 show that areas above the 100-mrem/yr dose standard are restricted to localized parts of the 100-K, 100-N, and 200 Areas. Areas above 4 mrem/yr are more restricted than the area above the interim DWS for individual constituents because the dose map used more recent conversion factors than those used in calculating the interim DWSs. Dose estimates for portions of the 100, 200, 300, and 600 Areas exceed 4 mrem/yr.

Figure S.4 illustrates the estimated lifetime incremental cancer risk that would be experienced by an individual 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 summing interpolated groundwater concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, trichloroethylene, cis-1,2-dichloroethylene, nitrate, and hexavalent chromium. The calculation assumes that a person weighing 70 kg consumes 2 L of groundwater every day for 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, and this contour closely resembles the cumulative dose map (see Figure S.3). An additional area of cancer risk greater than 0.0001 is observed in the 200-West Area, a result of the carbon tetrachloride plume.

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 toxicities other than cancer (in Hanford Site groundwater, these include nitrate, hexavalent chromium, uranium, and strontium). The calculation assumes that a person weighing 70 kg consumes 2 L of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). The only part of the Hanford Site with a hazard quotient greater than 5 is a small portion of the 200-West Area. Hazard quotients greater than 0.3 are present in all of the operational areas and in parts of the 600 Area, primarily those areas with nitrate contamination.

Groundwater Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. One sitewide model and several local-scale models were applied to the Hanford Site in FY 1997.

A three-dimensional numerical model, representing nine hydrogeologic layers within the unconfined aquifer system, was initially applied in 1995 and was refined in FY 1997. The model was updated to a new version of the Coupled, Fluid, Energy, and Solute Transport (CFEST) code and used to simulate groundwater-flow conditions through the year 2500 under assumed future recharge scenarios. The movements of existing tritium, iodine-129, technetium-99, uranium, and strontium-90 plumes originating from the 200 Areas plateau were also predicted for this time period. Each of the transport simulations was based on predicted future transient flow conditions.

Flow-modeling results suggested that the water table may decline enough in the future that the aquifer will dry out in the area south of Gable Mountain along the eastern extension of the Gable Butte anticline. This could create a hydrologic separation between the unconfined aquifer north and south of the Gable Butte anticline and cut off northward flow through this area. The overall water table, including groundwater mounds near the 200 Areas, will decline. Groundwater movement from the 200 Areas plateau will shift to a more west-to-east pattern with discharge to the Columbia River occurring between the Old Hanford Townsite and the 300 Area.

One of the remedial actions being considered for the strontium-90 plume at the 100-N Area is the installation of an in situ treatment zone. The treatment zone would be placed close to the shore of the Columbia River to capture any strontium-90 moving from the aquifer into the river. To support this effort, a modeling study analyzed the interaction between the Columbia River and the unconfined aquifer using the Subsurface Transport Over Multiple Phases (STOMP) model. The study compared the movement of water particles located close to the river's edge between transient and steady-state simulations. These simulations show the steady-state assumption is inappropriate for near-river conditions. The model also estimated the volume of groundwater flow leaving the 100-N Area unconfined aquifer for the Columbia River.

Additional models based on the Micro-FEM© code (C. J. Hemker, Amsterdam, The Netherlands) were applied to the design of pump-and-treat operations at the 200-UP-1 and 200-ZP-1 Operable Units. Groundwater modeling for the 200 UP-1 plume indicated that most of the targeted plume will be captured under the current well configuration. Modeling for the 200-ZP-1 plume showed that the high concentration area of the plume will be captured, and a recirculation cell will be established.

Groundwater Remediation

Groundwater remediation conducted under CERCLA during FY 1997 included the following pump-and-treat systems:

- 100-KR-4 Operable Unit – An interim action to address chromium contamination near the 116-K-2 trench was initiated in FY 1997, reaching full operation by October 1997. Groundwater is extracted from six wells between the trench and the river, treated to remove chromium, and injected into wells upgradient of the trench.

- 100-NR-2 Operable Unit – 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 system was upgraded to a larger capacity (227 L/min) in the fall of 1996. During FY 1997, ~102,971,000 L of water were processed, and ~0.1 Ci of strontium-90 was removed.

- 100-D Area chromium hot spot – A demonstration of in situ redox manipulation technology is under way in the 100-D Area to determine the feasibility of using the technology to reduce hexavalent chromium in groundwater. The project's goal is to create a permeable treatment zone in the subsurface where chemical reducing agents will reduce the highly soluble hexavalent chromium to an insoluble state. The first injection/withdrawal was conducted in September 1997.

- 100-HR-3 Operable Unit, 100-D Area – A pilot-scale system for extracting groundwater and removing chromium near the 100-D Reactor building was shut down in August 1996, and a new, interim action, pump-and-treat system was put into operation in FY 1997. The new system removes chromium-contaminated groundwater from wells near the river and pipes it to the 100-H Area for treatment and injection.

- 100-HR-3 Operable Unit, 100-H Area – An interim action pump-and-treat system began to operate in FY 1997. The system removes chromium from wells around the 183-H solar evaporation basins, treats it to remove chromium, and injects the water into wells in the southwestern part of the area.

- 200-UP-1 Operable Unit – An interim action pump-and-treat system designed to contain and treat elevated concentrations of technetium-99 and uranium continued to operate in FY 1997. In February 1997, the system was changed so that extracted water is piped to the 200 Areas Effluent Treatment Facility instead of being treated on site. From April to September 1997, more than 32,400,000 L of this water were treated, resulting in the removal of 0.89 kg of carbon tetrachloride, 2,260 kg of nitrate, 5.6 g of technetium-99, and 11 kg of uranium.

- 200-ZP-1 Operable Unit – 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. During FY 1997, groundwater was extracted from three wells at a combined rate of ~570 L/min and injected into a single injection well. In August 1997, the system was upgraded to six extraction wells and five injection wells. The treatability test began in August 1994, and through September 1997, more than 258,000,000 L of water were treated, resulting in the removal of 860 kg of carbon tetrachloride.

Well Maintenance

Several hundreds of well-maintenance activities were carried out during FY 1997. These activities included well or pump repair, cleaning, and maintenance.

In FY 1997, the well-decommissioning strategy was revised to focus on two drivers: 1) potential risk for a well to provide a contaminant pathway to deeper zones and 2) compatibility with the Hanford Site's long-range environmental restoration schedule. Once the risk potential was assigned to wells, the scheduling for decommissioning is primarily driven by the long-range environmental restoration schedule. In general, areas adjacent to the Columbia River are to be remediated first. In FY 1997, 109 Hanford Site wells were decommissioned. Only one of these was located in the central portion of the Hanford Site; a high-risk well that had a potential to provide a contaminant pathway for carbon tetrachloride to move into the confined aquifer system.

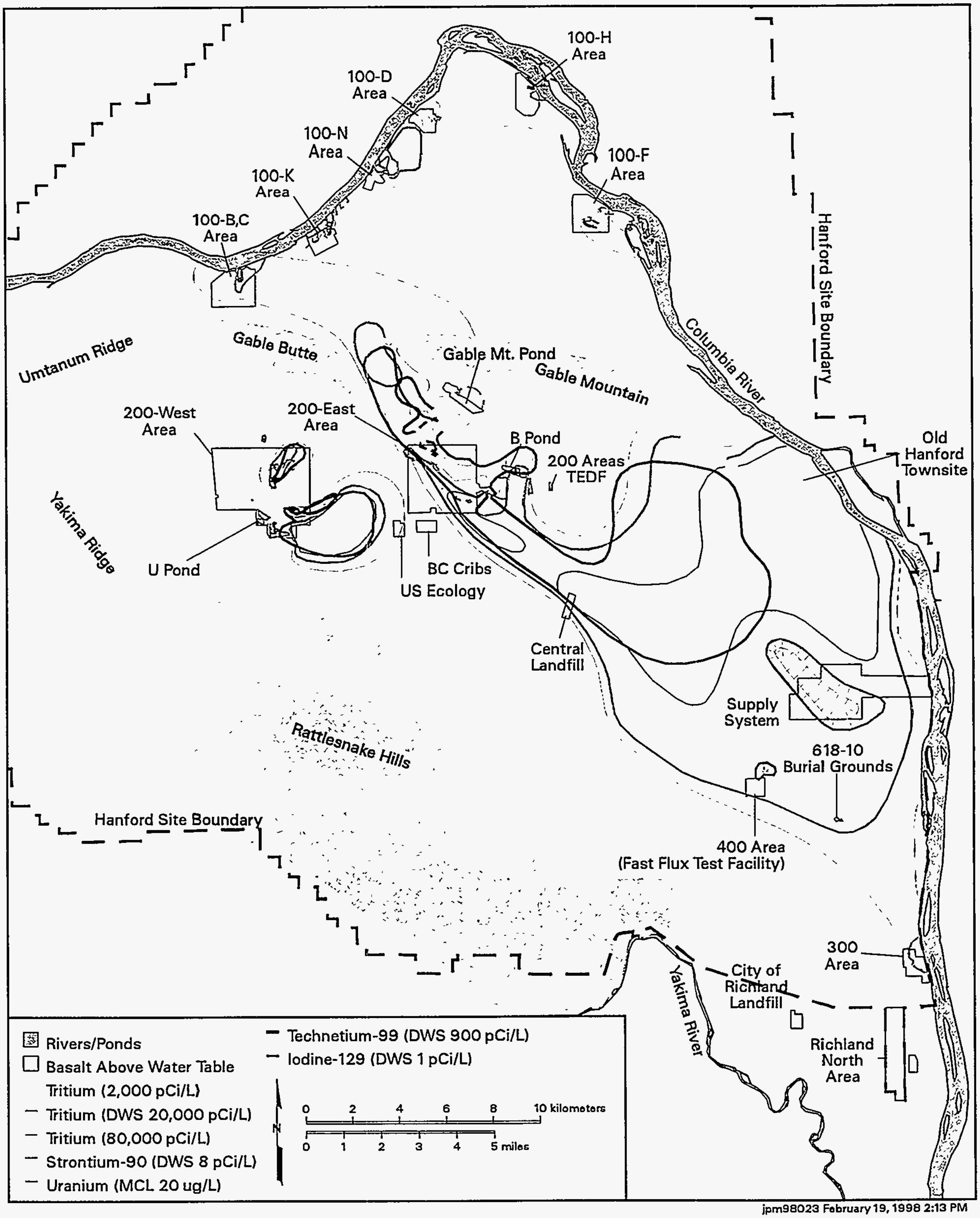

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Figure S.1. Distribution of Major Radionuclides in Groundwater at Concentrations Above Maximum Contaminant Levels or Interim Drinking Water Standards, Fiscal Year 1997

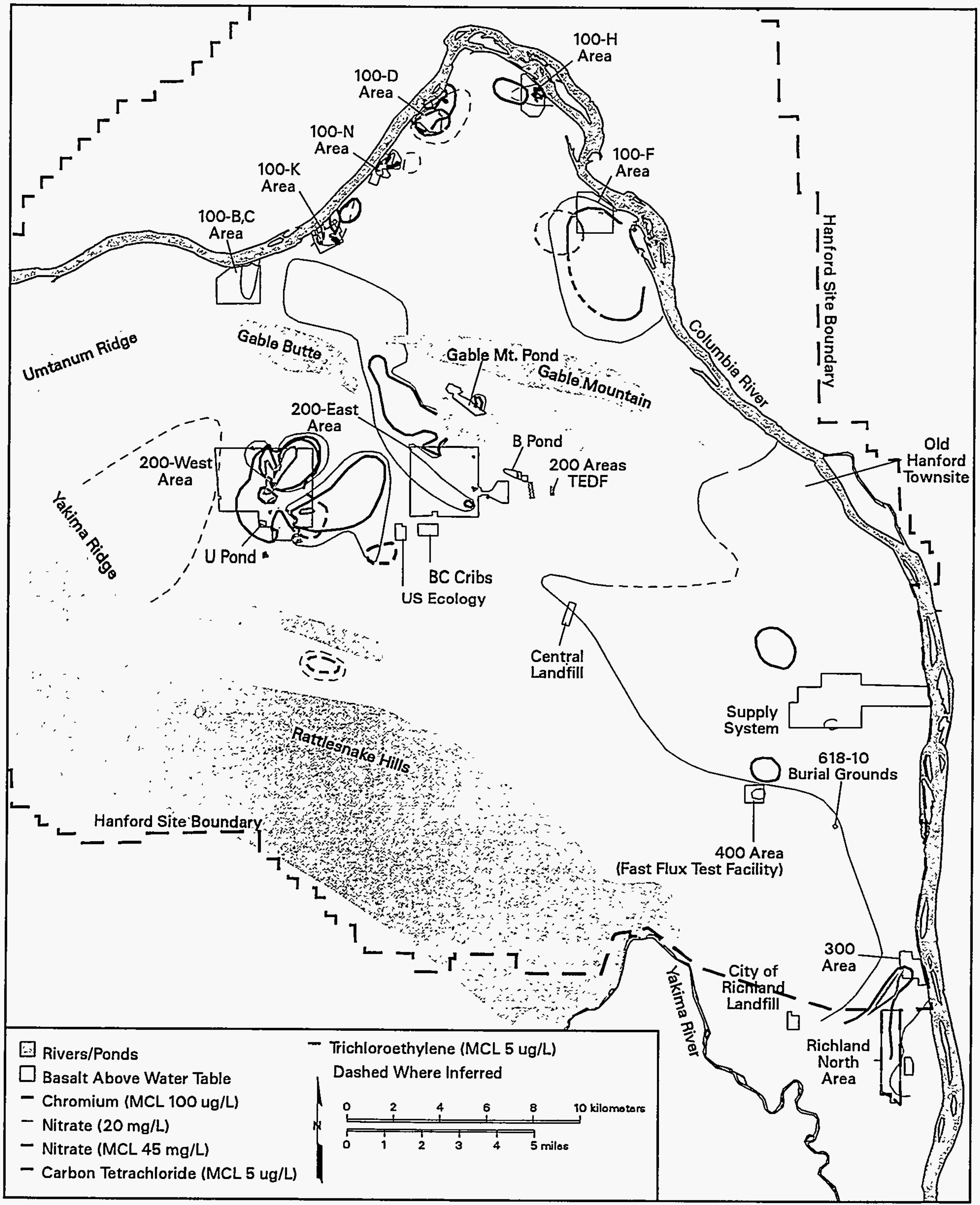

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Figure S.2. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above Maximum Contaminant Levels, Fiscal Year 1997

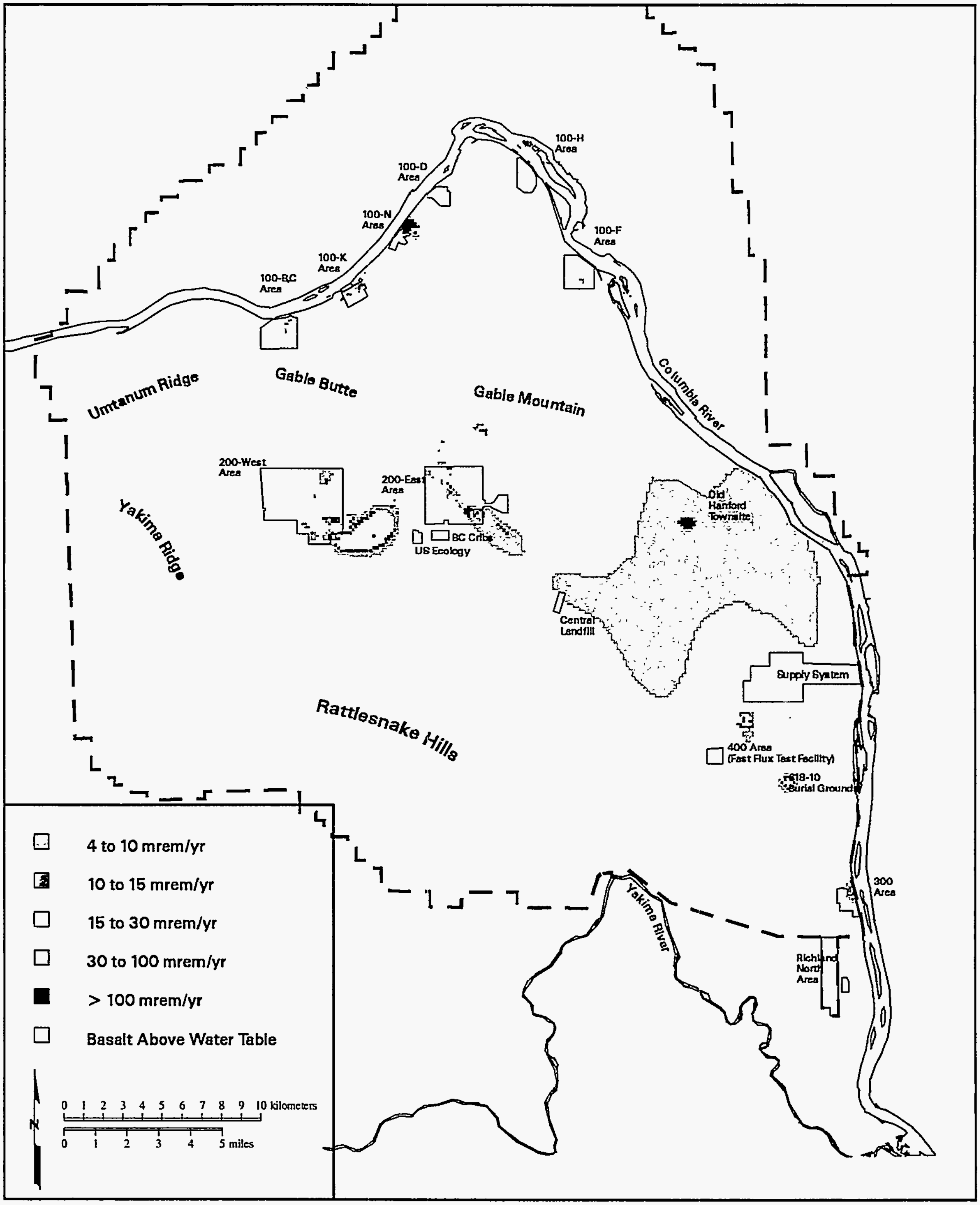

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Figure S.3. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 1997

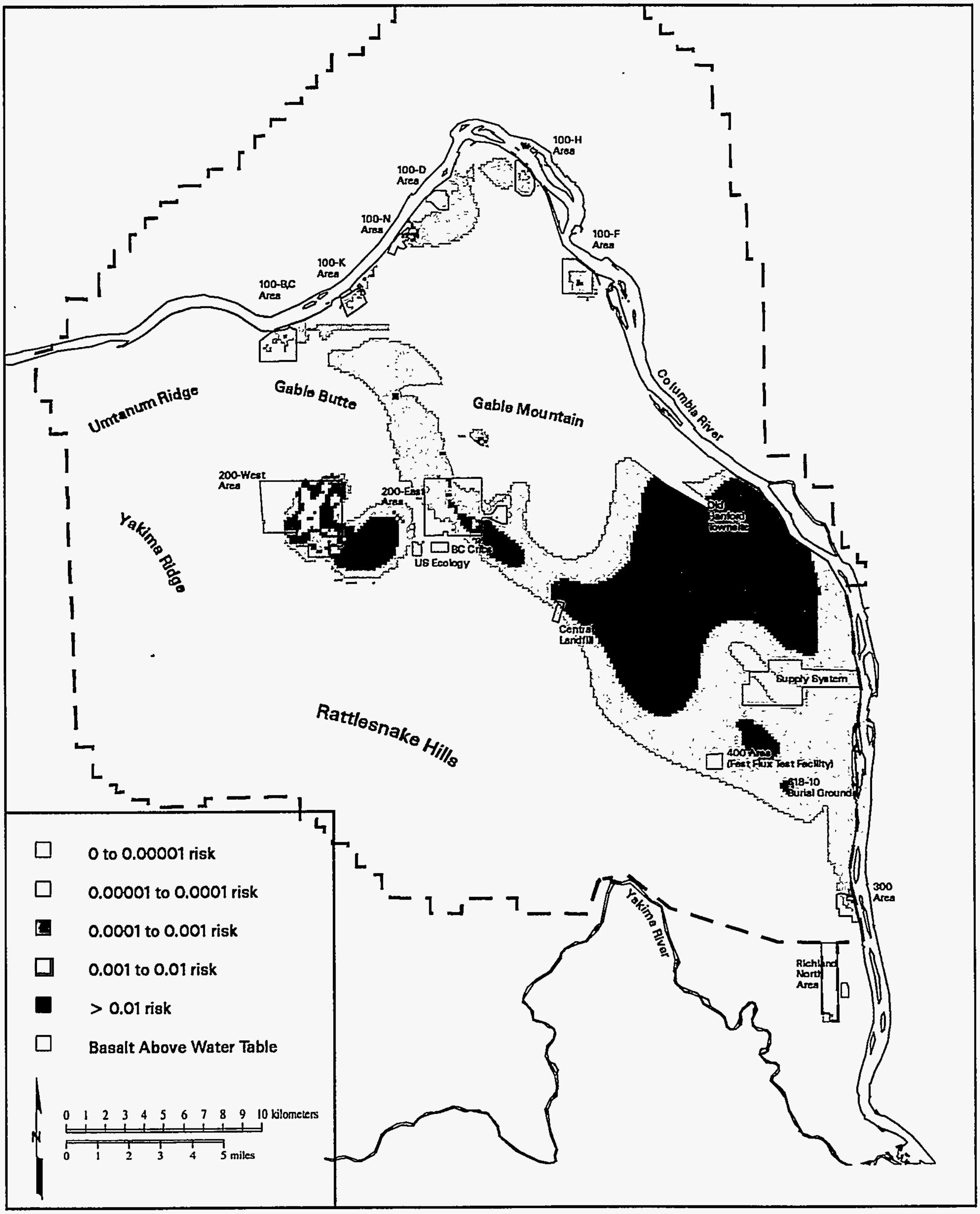

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Figure S.4. Cancer Risk Estimates from Ingestion of Groundwater, Fiscal Year 1997

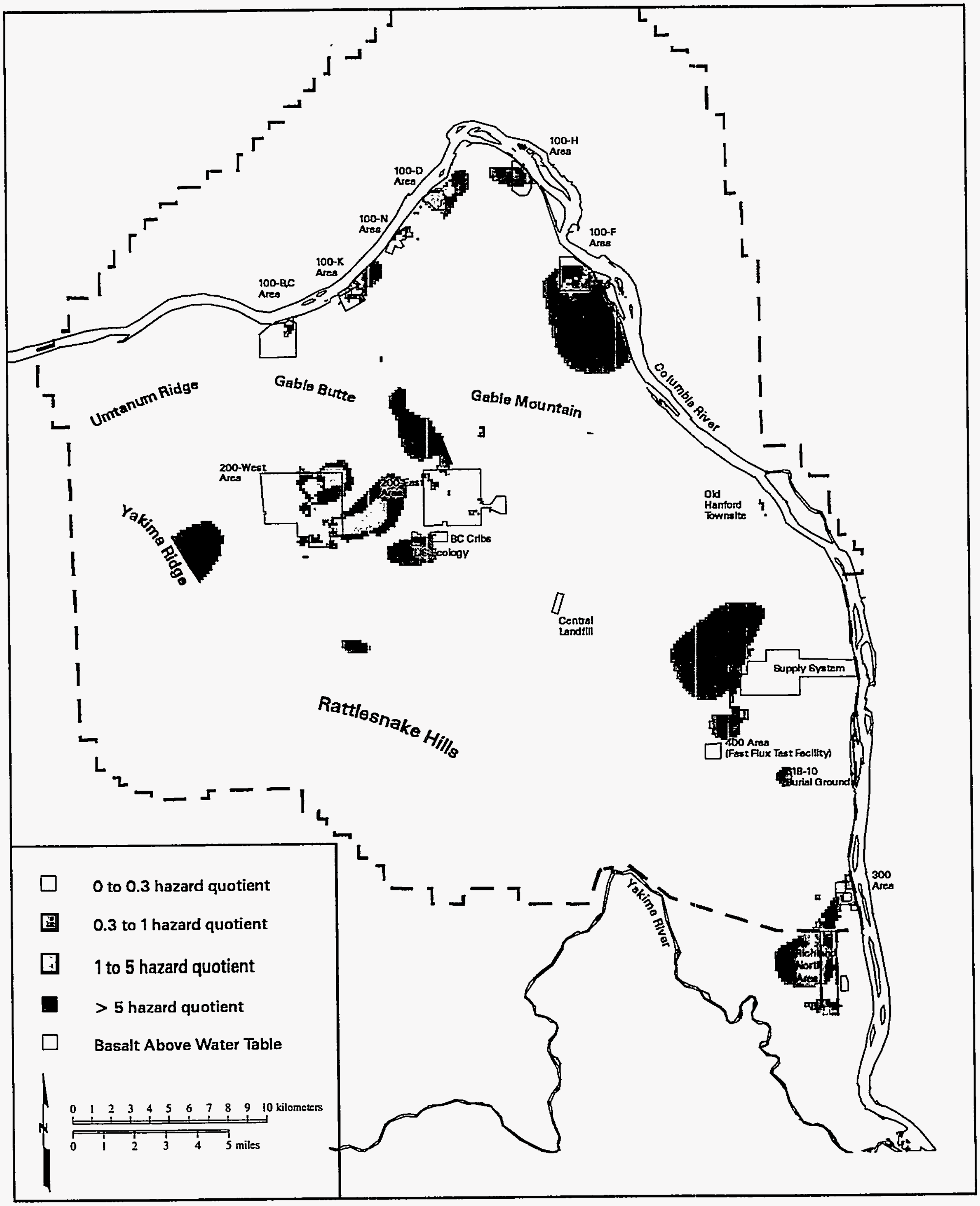

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Figure S.5. Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 1997

Acknowledgments

This report represents the efforts of dozens of individuals who contribute to the Hanford Groundwater-Monitoring Project from planning and scheduling through data interpretation and publishing.

Ron Smith and Stuart Luttrell, Pacific Northwest National Laboratory (PNNL), managed the Hanford Groundwater Monitoring Project and the Groundwater Monitoring Task, respectively. Staff of PNNL, Bechtel Hanford, Inc. (BHI), and Waste Management Federal Services of Hanford, Inc. scheduled and coordinated sampling and measured water levels. Data management teams at PNNL and BHI made sure new and historical data were at our fingertips. Bill McMahon (CH2MHill Hanford, Inc.) provided transducer data. John Evans (PNNL) provided peer review.

JoAnne Rieger, John McDonald, and David Lanigan (PNNL) produced the multitude of graphics. Bill Hanf (PNNL) with the assistance of Dennis Brunson (Lockheed Martin Hanford Corporation) designed the cover.

Report editing and production were the responsibility of PNNL: Bev Johnston, editor; Barbara Wilson, Publications Assistant. Text processing was a major task met by the skill of Kathy Neiderhiser, Rose Urbina, and Lila Andor. Duplication of this report was provided by the ROB and 337 Building duplicating crews.

Contents

Computer Disk Contents
Historical Bibliography (formatted in ASCII)
Selected Water-Level Measurements from Unconfined Aquifer System Wells (formatted in delimited ASCII text file)
Chemical and Radiological Data (formatted in delimited ASCII text file)

Tables

Figures

1.0 Introduction

M. J. Hartman

1.1 Purpose

Groundwater monitoring is conducted on the Hanford Site to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA), *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), U.S. Department of Energy (DOE) Orders, and the Washington Administrative Code. Interpretations based on results of monitoring are presented in this *Hanford Site Groundwater Monitoring for Fiscal Year 1997*.

The interpretations contained in this report primarily rely on data from samples collected between October 1, 1996 and September 30, 1997. Data received from the laboratory after November 7, 1997 may not have been considered in the interpretations.

This report is designed to meet the following objectives:

- provide a comprehensive, current interpretation of groundwater conditions on the Hanford Site and adjacent areas (Figure 1.1), including a description of hydrogeology, groundwater flow, and groundwater-contaminant distribution.
- meet 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
- summarize the maintenance, reconfiguration, and decommissioning of Hanford Site monitoring wells.

The Groundwater Monitoring Project is conducted for DOE by Pacific Northwest National Laboratory (PNNL)[1]. Environmental restoration work, which includes groundwater cleanup and associated monitoring of pumping wells, is the responsibility of Bechtel Hanford, Inc. (BHI). The distribution of monitoring wells used for these programs is illustrated in Figure 1.2.

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[1] PNNL is operated by Battelle for DOE.

1.2 Organization

This report is organized by primary subject areas and geographic region (Table 1.1). Chapter 2.0 defines the DOE groundwater protection program and associated requirements for groundwater monitoring. Chapter 3.0 describes the hydrogeologic setting of the Hanford Site and groundwater-flow patterns. Chapter 4.0 presents the results of vadose-zone studies and monitoring. Chapter 5.0 describes groundwater-contaminant distribution, organized by the constituents of concern in each geographic area. Chapter 6.0 presents the results of groundwater modeling, and Chapter 7.0 summarizes well maintenance, reconfiguration, and decommissioning activities. Chapter 8.0 gives the references cited in the text. Additional references are provided in an historical bibliography on the computer diskette included with this report.

Supporting information is organized in appendixes, and groundwater data are included on the computer diskette. Large plate maps are included in the back of this report that show the wells used for monitoring, the Hanford Site water table, and the distribution of widespread groundwater contaminants (tritium, nitrate, and iodine-129) in the uppermost aquifer.

The organization of this report is designed for the reader interested in groundwater and vadose-zone activities at the Hanford Site. Readers interested in results related to specific regulatory requirements will find required elements in several chapters. Appendix A is designed to guide the reader interested primarily in the RCRA program.

1.3 Related Reports

Other reports and databases relating to Hanford Site groundwater in fiscal year 1997 include the following:

- *Hanford Site Environmental Report for Calendar Year 1996* (PNNL-11472) – This annual report summarizes environmental data, describes environmental management performance, and reports the status of compliance with environmental regulations. Topics include effluent monitoring, surface-water and sediment surveillance, soil and vegetation sampling, vadose and groundwater monitoring, radiological surveys, air surveillance, and fish and wildlife surveillance.

- Hanford Environmental Information System (HEIS) – This is the main environmental database for the Hanford Site that stores groundwater chemistry and water-level data, as well as other environmental data (e.g., soil chemistry, survey data).

- Quarterly data transmittals – Letters are transmitted quarterly by DOE to the State of Washington 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.

- *Hanford Site Background: Part 3, Groundwater Background* (DOE/RL-96-61) – This report describes the natural background chemistry of groundwater unaffected by Hanford Site operations based on historical data and on data collected specifically to evaluate groundwater background.

- *Decision Process for Hanford Sitewide Groundwater Remediation* (BHI-00455, Rev. 1) – This report describes a decision process for planning investigations and remediation of contaminated groundwater.

- *Hanford Sitewide Groundwater Remediation Strategy* (DOE/RL-94-95, Rev. 1) – This report describes how the Hanford Site groundwater remediation will be accomplished. The strategy addresses objectives and goals, prioritizing activities, and technical approaches for groundwater cleanup.

Table 1.1. Organizational Matrix for this Report

Subject Area (listed alphabetically)	Hanford Site	100-B,C Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	200-West Area	200-East Area	400 Area	600 Area	300 Area	Richland North	Confined Aquifer
Drinking water standards	Appendix A Table 5.1-1	5.3.2	5.4.2	5.5.2	5.6.2	5.7.2	5.8.2	5.9.2	5.10.2	5.11.2	5.12.2	5.13.2	5.14.2	5.15
Groundwater contaminants (data on diskette included with this report)														
Carbon tetrachloride	NA	NA	NA	NA	NA	NA	NA	5.9.3	NA	NA	5.12.3	NA	NA	NA
Cesium-137	NA	NA	NA	NA	NA	NA	NA	5.9.3	5.10.3	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	5.5.3	NA	NA	NA	5.9.3	NA	NA	5.12.3	NA	NA	NA
Chromium	5.2	5.3.3	5.4.3	5.5.3	5.6.3	5.7.3	5.8.3	5.9.3	5.10.3	NA	5.12.3	NA	NA	NA
Cobalt-60	5.2	NA	NA	NA	NA	NA	NA	NA	5.10.3	NA	NA	NA	NA	5.15
Cyanide	5.2	NA	NA	NA	NA	NA	NA	NA	5.10.3	NA	NA	NA	NA	5.15
Fluoride	NA	NA	NA	NA	NA	5.7.3	NA	5.9.3	NA	NA	NA	NA	5.14.3	NA
Iodine-129	5.2, Pl. 5	NA	NA	NA	NA	NA	NA	5.9.3	5.10.3	NA	NA	NA	NA	5.15
Nitrate	5.2, Pl. 4	5.3.3	5.4.3	5.5.3	5.6.3	5.7.3	5.8.3	5.9.3	5.10.3	5.11.3	5.12.3	NA	5.14.3	5.15
Plutonium	NA	NA	NA	NA	NA	NA	NA	5.9.3	5.10.3	NA	NA	NA	NA	NA
Specific conductance	NA	NA	NA	5.5.3	5.6.3	NA	NA	5.9.3	5.10.3	NA	5.12.3	NA	NA	5.15
Strontium-90	NA	5.3.3	5.4.3	5.5.3	5.6.3	5.7.3	5.8.3	NA	5.10.3	NA	5.12.3	5.13.3	NA	5.15
Technetium-99	5.2	NA	NA	NA	NA	5.7.3	NA	5.9.3	5.10.3	NA	NA	NA	5.14.3	5.15
Trichloroethylene	NA	NA	5.4.3	NA	NA	NA	5.8.3	5.9.3	NA	NA	5.12.3	5.13.3	5.14.3	NA
Tritium	5.2, Pl. 3	5.3.3	5.4.3	5.5.3	5.6.3	5.7.3	5.8.3	5.9.3	5.10.3	5.11.3	5.12.3	NA	5.14.3	5.15
Uranium	5.2	NA	NA	NA	NA	5.7.3	5.8.3	5.9.3	5.10.3	NA	5.12.3	5.13.3	5.14.3	NA
Groundwater remediation	NA	NA	5.4.4	5.5.4	5.6.4	5.7.4	NA	5.9.4	NA	NA	NA	NA	NA	NA
Hydrogeology and groundwater flow	3.2, 3.3, Pl. 2	3.5.1	3.5.2	3.5.3	3.5.4	3.5.5	3.5.6	3.6	3.6	3.7	3.7	3.8	3.8	3.10
Modeling	6.1	NA	NA	6.2	NA	NA	NA	6.3, 4.4.4	NA	NA	NA	NA	NA	NA
RCRA	Appendix A	NA	NA	5.5	5.6	5.7	NA	5.9	5.10	NA	5.12	5.13	NA	NA

Table 1.1. (contd)

Subject Area (listed alphabetically)	Hanford Site	100-B,C Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	200-West Area	200-East Area	400 Area	600 Area	300 Area	Richland North	Confined Aquifer
Regulatory requirements	2.0	2.0, 5.3.2	2.0, 5.4.2	2.0, 5.5.2	2.0, 5.6.2	2.0, 5.7.2	2.0, 5.8.2	2.0, 5.9.2	2.0, 5.10.2	2.0, 5.11.2	2.0, 5.12.2	2.0, 5.13.2	2.0, 5.14.2	NA
River	NA	3.5, 5.3.3	3.5, 5.4.3	3.5, 5.5.3	3.5, 5.6.3	3.5, 5.7.3	3.5, 5.8.3	NA	NA	NA	NA	3.8	3.8	NA
Vadose zone (unsaturated)	NA	4.5	NA	4.5	4.5	NA	NA	4.2, 4.3, 4.4	4.2	NA	4.4.6	NA	NA	NA

NA = Not applicable.
RCRA = Resource Conservation and Recovery Act of 1976.

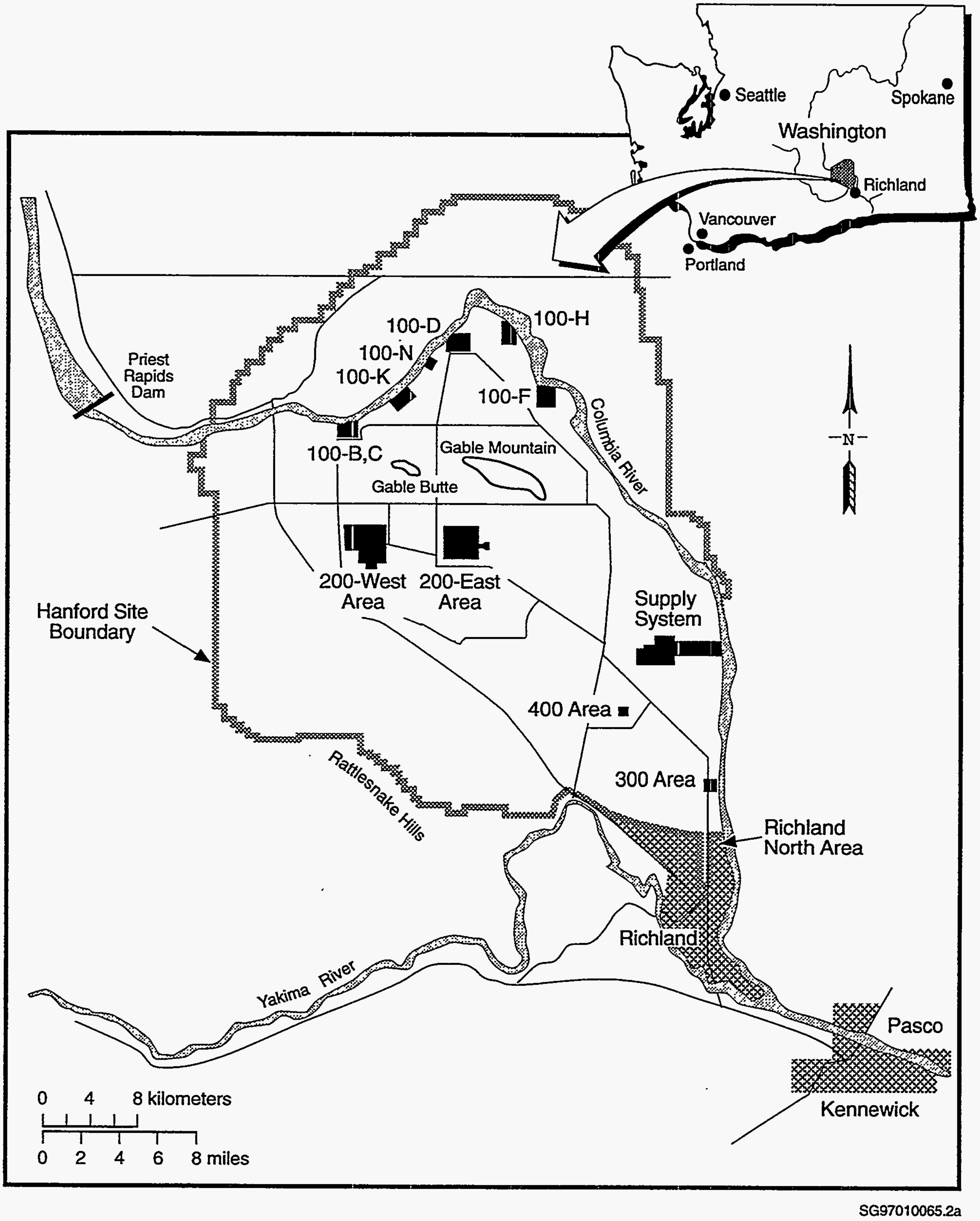

Figure 1.1. Hanford Site Location Map

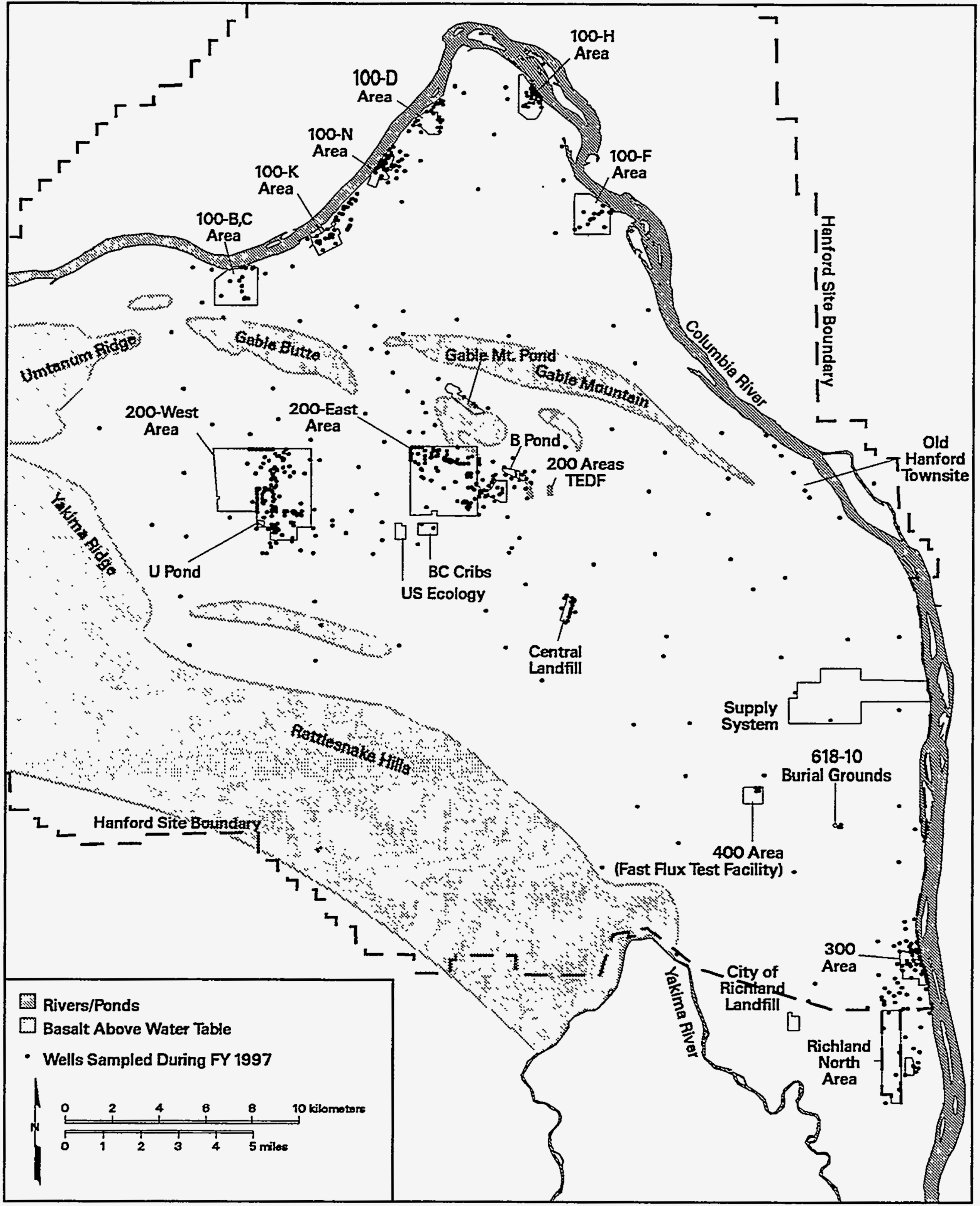

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Figure 1.2. Location of Groundwater-Monitoring Wells Sampled, Fiscal Year 1997

2.0 Groundwater-Monitoring Requirements

B. A. Williams

This chapter describes the regulatory framework governing the monitoring of the Hanford Site's groundwater. That framework consists of various federal and state regulations, orders, and agreements. Pursuant to those regulations, orders, and agreements, the groundwater monitoring performed at the Hanford Site during fiscal year 1997 is in compliance.

Under the *Atomic Energy Act of 1954*, as amended, the U.S. Department of Energy (DOE) is obligated "...to regulate its own activities so as to provide radiation protection for both workers and public."

The environmental standards and regulations applicable for groundwater protection/management and environmental monitoring are described in DOE Order 5400.1. These environmental protection standards are categorized as 1) those imposed by federal regulations, 2) those imposed by state and local regulations, and 3) those imposed by DOE directives. The objectives of DOE's groundwater protection and environmental monitoring projects (as defined in DOE Order 5400.1) are to demonstrate compliance with regulations imposed by applicable federal, state, and local agencies; to confirm adherence to DOE environmental protection policies; and to support environmental management decisions.

The Hanford Site's environmental monitoring plan (DOE/RL-91-50, Rev. 2) and the groundwater protection management plan (DOE/RL-89-12, Rev. 2) summarize the groundwater and program integration activities and regulatory reporting requirements for those activities. These plans integrate the following:

- near-field monitoring at active or inactive waste treatment, storage, or disposal (TSD) facilities to comply with the *Resource Conservation and Recovery Act of 1976* (RCRA), applicable State of Washington regulations, and operational monitoring required at nuclear facilities and untreated liquid waste-disposal sites

- sitewide and offsite monitoring of groundwater-contaminant migration required by DOE Order 5400.1

- site-specific groundwater monitoring to support groundwater remediation projects under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

The following sections discuss the specific requirements in more detail.

2.1 Environmental Monitoring

Groundwater monitoring is a critical element of DOE's environmental monitoring project at the Hanford Site because an unconfined aquifer and a system of deeper confined aquifers underlie the site.

Groundwater from the unconfined aquifer that enters the Columbia River provides one of the most significant pathways for transporting contaminants offsite.

Because the Hanford Site has multiple, extensive, and unique groundwater pollution problems, DOE has integrated groundwater monitoring to ensure protection of the public and the environment while improving the efficiency of monitoring operations. The environmental monitoring plan (DOE/RL-91-50, Rev. 2) documents the various elements of the groundwater-monitoring project currently operating at the Hanford Site. As required by DOE Order 5400.1, the plan addresses the high-priority elements of *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T). The relationship of the environmental monitoring plan to DOE Order 5400.1 and to the various groundwater-monitoring projects and reporting requirements is shown in Figure 2.1.

The Groundwater Monitoring Project also conducts integration activities through the data quality objectives process involving DOE, regulators, contractors, Native Americans, and other stakeholders (EPA/600/R-96-055).

2.2 Groundwater Protection

DOE/RL-89-12, Rev. 2 provides a framework for coordinating the existing onsite groundwater protection activities conducted by DOE's contractors, establishes the policy and strategies for groundwater protection/management at the Hanford Site, and proposes an implementation plan to meet goals (and milestones). These goals include 1) improving coordination between the federal and state regulations applicable to groundwater activities, 2) maintaining/achieving regulatory compliance of all groundwater activities), and 3) achieving cost-effective groundwater program administration. The relationship of DOE/RL-89-12, Rev. 2 to DOE Order 5400.1 and to the various groundwater-monitoring, remedial activities, and reporting requirements was shown in Figure 2.1.

2.2.1 General Environmental Protection Program

Groundwater-monitoring projects are established under DOE Order 5400.1 to meet the requirements of 1) DOE Order 5400.5, which deals with radiation protection of the public and the environment and 2) federal and state regulations. DOE Order 5400.1 requires that groundwater-monitoring projects be designed and implemented in accordance with the Code of Federal Regulations (40 CFR 264 or 40 CFR 265, Subpart F). DOE Order 5820.2, which deals with radioactive waste management, is also covered under the 5400.1-series requirements. The groundwater-monitoring requirements for federal and state regulations are presented in Sections 2.4 and 2.5.

Because of the Hanford Site's unique groundwater pollution problems, radiation protection of the public and the environment is an integral part of DOE's groundwater-monitoring project. The radiation management requirements are found in DOE Order 5820.2, established to satisfy the groundwater-monitoring objectives listed above. The objectives of the DOE orders relative to groundwater monitoring include the following:

- verify compliance with other applicable groundwater regulations
- characterize and define hydrogeologic, physical, and chemical trends in the groundwater system

- establish baselines of groundwater quality
- provide a continuing, independent assessment of groundwater-monitoring and remediation activities
- identify and quantify new or existing groundwater contamination and quality problems.

The Groundwater Monitoring Project assesses radionuclides and other hazardous effluent-disposal impacts of non-RCRA facilities on groundwater quality and monitors and documents the overall distribution and movement of radionuclides and other hazardous contaminants in groundwater beneath and adjacent to the Hanford Site in accordance with DOE Orders 5400.1 and 5400.5.

2.2.2 Radiation Protection of the Public and the Environment

Standards and requirements are established in DOE Order 5400.5 for DOE and its contractors to operate the facilities and conduct the activities so that radiation exposure to the public is maintained within the limits established in the order (e.g., public dose limits and derived concentration guides for air and water) and to control radioactive contamination through the management of real and personal property. In addition, it is DOE's objective to protect the environment from radioactive contamination to the extent practical.

2.3 Hanford Federal Facility Agreement and Consent Order

A key element to Hanford Site compliance is the *Hanford Federal Facility Agreement and Consent Order* (also known as the Tri-Party Agreement) (Ecology et al. 1989). Compliance and waste-cleanup timetables and implementation milestones are established in the Tri-Party Agreement to ensure that cleanup progresses and to enforce environmental protection. Tri-Party Agreement Milestone M-13-81A established DOE/RL-89-12, Rev. 2 as the vehicle to be used to coordinate groundwater protection and remedial action efforts and to manage the Hanford Site groundwater resource. The Tri-Party Agreement is a contract between the U.S. Environmental Protection Agency (EPA), State of Washington Department of Ecology (Ecology), and DOE for achieving compliance (enforceable by law) with the remedial action provisions of CERCLA and the TSD unit regulation and corrective action provisions of RCRA.

This annual report contains the results of applicable groundwater protection, cleanup, and monitoring activities as scheduled in the Tri-Party Agreement action plan. Table 2.1 provides a general listing of those applicable major milestones. Details for each milestone are described in the Tri-Party Agreement.

2.4 Applicable Federal Regulations

This section describes the federal regulations that govern groundwater monitoring, remedial investigation, and remediation. The institutional and regulatory interfaces are defined by the Tri-Party Agreement (Ecology et al. 1989) and are outlined in Section 2.6.

2.4.1 Comprehensive Environmental Response, Compensation, and Liability Act of 1980/Superfund Amendments and Reauthorization Act of 1986

These Acts establish a federal program authorizing waste cleanup at inactive sites. The Hanford Site was listed on the National Priorities List (Appendix B of 40 CFR 300) based on the EPA's hazard-ranking system that subdivided the Hanford Site into four National Priorities List sites: 100, 200, 300, and 1100 Areas. Preliminary assessments revealed ~1,400 known waste management units where hazardous substances may have been disposed. The four listed sites were further divided into 74 source and 10 groundwater operable units (i.e., a grouping of individual waste units based primarily on geographic area and common waste sources).

The groundwater operable units currently being studied were selected as a result of negotiations on the Tri-Party Agreement (Ecology et al. 1989). Table 2.2 defines the current groundwater operable unit monitoring projects, listed according to Tri-Party Agreement priority, and also defines the Tri-Party Agreement regulatory unit designation and lead regulatory agency responsible for the operable unit (described more fully in Section 2.6).

The *Hanford Past-Practices Strategy* (DOE/RL-91-40) provides the framework for streamlining the CERCLA remedial investigation process and accelerating remediation of groundwater and past-practice waste sites through expedited response actions and interim remedial measures. The bias-for-action principles of the strategy were vigorously pursued in accelerating the groundwater remediation project through the investigative phases and into pilot-scale treatability studies, both of which gathered important data necessary to begin full-scale remediation activities through implementation of interim remedial measures.

The interim actions consist primarily of hydraulic containment actions using pump-and-treat technologies and are designed to halt the continued migration of the most-contaminated portions of the plumes into the Columbia River or out of aquifers underlying the 100 and 200 Areas. DOE plans to continue the interim remedial measures already under way and to supplement and expand the system, where needed, to meet remediation objectives.

The *Hanford Sitewide Groundwater Remediation Strategy* (DOE/RL-94-95, Rev. 1) establishes an overall goal of restoring groundwater to its beneficial uses in terms of protecting human health and the environment and its use as a natural resource. In recognition of the Hanford Future Site Uses Working Group (Drummond 1992) and public values, the strategy establishes that the sitewide approach to groundwater cleanup is to remediate the major plumes found in the reactor areas and to contain the spread and reduce the mass of the major plumes found in the 200 Areas. This remediation strategy is documented in DOE/RL-89-12, Rev. 2 and DOE/RL-94-95, Rev. 1.

The scope of this decision process encompasses all contaminated groundwater (CERCLA and/or RCRA past-practice projects) at the Hanford Site. Currently, six pump-and-treat projects in five groundwater operable units address the following plumes:

- 100-KR-4 Operable Unit – hexavalent chromium
- 100-HR-3 Operable Unit – hexavalent chromium in the 100-D and 100-H Areas
- 100-NR-2 Operable Unit – strontium-90

- 200-UP-1 Operable Unit – technetium
- 200-ZP-1 Operable Unit – carbon tetrachloride (and associated organics).

These pump-and-treat systems are discussed more fully in Chapter 5.0.

Groundwater monitoring is performed at operable units to evaluate the pump-and-treat performance assessment and for contaminant monitoring (i.e., no groundwater remediation). Individual requirements as defined under CERCLA are described in the work plans and/or records of decision. See Table 2.2 for the sites that are currently under contaminant or assessment monitoring.

Under the EPA's interpretation of CERCLA, contaminated groundwater generally must be cleaned up to meet maximum contaminant levels or maximum contaminant-level goals established under the *Safe Drinking Water Act of 1974* if the groundwater, prior to contamination, could have been used at some future date as a drinking water source. Using the EPA's groundwater classification as well as Ecology's highest beneficial use assumption in Washington Administrative Code (WAC) 173-340-720, almost all Hanford Site groundwater is, by definition, a potential future source of drinking water. The classification is based on groundwater quality characteristics and not related to land-use designations, which are tied to the source or surface operable unit remediation. These cleanup levels are identified in the applicable operable unit's record of decision (ROD 1995a, 1996a, 1996b, 1997) or action memorandum (Ecology and EPA 1994).

Certain areas of the Hanford Site may require restrictions to groundwater use. The Hanford Future Site Uses Working Group, supported by DOE, Ecology, and EPA, recognizes that contaminated soils and groundwater beneath the 200 Areas plateau will be difficult to clean up and may not be able to achieve cleanup levels/requirements. The group has recommended that the water beneath the 200 Areas plateau be excluded from use and managed to limit or restrict access by the public (Drummond 1992).

2.4.2 Resource Conservation and Recovery Act of 1976

Regulatory standards for the generation, transportation, storage, treatment, and disposal of hazardous wastes are established in RCRA and relate to ongoing waste management and permitting at those facilities. Ecology and EPA designated the Hanford Site as a single RCRA facility with over 60 individual liquid and solid waste TSD units. The Tri-Party Agreement (Ecology et al. 1989) recognized that all of the TSD units cannot be permitted simultaneously and set up a schedule for submitting unit-specific Part B RCRA/dangerous waste permit applications and closure plans to Ecology and EPA. Of the 60 TSD units, 27 required groundwater monitoring in fiscal year 1997 to determine if operations are impacting the uppermost aquifer or to assess the nature, extent, and rate of contaminant migration.

The RCRA groundwater-monitoring requirements for the 27 active TSD units fall under one of two categories: interim status or final status. A permitted or closed RCRA TSD unit requires final-status groundwater monitoring as specified in 40 CFR 264. Nonpermitted RCRA units require interim-status groundwater monitoring as specified in 40 CFR 265. Ecology was authorized by the EPA to implement its dangerous waste program in lieu of the EPA's. Ecology's interim-status TSD requirements, established in WAC 173-303-400, invoke 40 CFR 265 that governs RCRA groundwater-monitoring activities.

RCRA final-status TSD units follow WAC 173-303-645, which specifies the groundwater-monitoring requirements. Table 2.3 provides a list of the 27 active RCRA units requiring groundwater monitoring and the status of the unit.

This annual report also includes groundwater results for the Environmental Restoration Disposal Facility. This facility is a landfill authorized under CERCLA that is constructed to meet final-status RCRA technical requirements (40 CFR 264). The facility is not a RCRA TSD unit but utilizes a 4-well RCRA-style groundwater-monitoring network and conducts monitoring in accordance with WAC 173-303-645 as outlined in BHI-00070.

RCRA groundwater monitoring is conducted under one of three possible phases: 1) indicator parameter/detection, 2) assessment (or final-status compliance), and 3) corrective action (via administrative order or during final status). Initially, a detection-level program is developed to determine and monitor the impact of facility operations on the groundwater. If the detection-monitoring results indicate a statistical increase in the concentrations of key indicator parameters or dangerous waste constituents in the groundwater, then an assessment (or final-status compliance) phase of monitoring and investigation is initiated. If the source of the contaminants is determined to be the TSD unit; and those concentrations exceed maximum contaminant levels (i.e., concentration limits) as defined in the monitoring program plan or permit, then Ecology may require corrective action to reduce the contaminant hazards to the public and environment. Table 2.3 also indicates when the site is scheduled for incorporation under the site permit. The comparisons and details of these three phases of groundwater monitoring and the specific requirements of the interim- and final-status groundwater-monitoring projects are provided in Appendix B.

The Groundwater Monitoring Project is currently applying EPA's data quality objective process (EPA/600/R-96/055) to develop a strategy that will allow the use of technically improved and more site-responsible methodology (e.g., groundwater network design, sampling and analysis, statistical analysis) while maintaining RCRA groundwater compliance. This process will improve the overall efficiency of monitoring groundwater at multiple facilities/projects and creates a cost-effective, flexible approach because it will be less restrictive than the current interim-status groundwater requirements.

2.5 Applicable State Regulations

2.5.1 Dangerous Waste Regulations

As stated in Section 2.4.2, Ecology was authorized by EPA to implement state groundwater regulations. WAC 173-303-400 and WAC 173-303-600 provide the requirements for interim- and final-status TSD units. The state interim-status regulations invoke the EPA regulations (40 CFR 265) that govern the RCRA groundwater-monitoring activities. RCRA final-status TSD units follow WAC 173-303-645, which specifies the groundwater-monitoring requirements for operating or closed facilities.

2.5.2 State Waste Discharge Program

Non-RCRA TSD units are regulated by DOE Orders and the Tri-Party Agreement (Ecology et al. 1989). These consist primarily of soil-column-disposal facilities that receive cleaned water (treated effluent) derived from liquid waste that was associated with nuclear material processing, refining, and waste-treatment activities. An agreement was reached in December 1991 to regulate these non-RCRA TSD units and to include all miscellaneous waste streams and/or any new waste streams discharged to the groundwater under the waste discharge permit system defined in WAC 173-216. All major discharges of untreated wastewater were terminated in June 1995.

Groundwater monitoring is conducted at three of the WAC 173-216 permit sites: 4608 B/C ponds (also called the 400 Area process ponds), 200 Areas Treated Effluent-Disposal Facility, and the 616-A crib (also called the State-Approved Land-Disposal Site) (Ecology 1995a, 1995b, 1996). Monitoring and reporting requirements for the latter two facilities are specified in the monitoring plans (DOE/RL-89-12, Rev 2; WHC-SD-C018H-PLN-004, Rev. 1).

2.5.3 Minimum Functional Standards for Solid Waste Handling

The Solid Waste Landfill is a disposal facility that is not a RCRA hazardous waste site and is not addressed under the Tri-Party Agreement (Ecology et al. 1989). WAC 173-304 regulates the current operations of this landfill. A permit application was submitted to the Benton-Franklin District Health Department in 1991 (DOE/RL-90-38, Rev. 0). Responsibility for the site was subsequently assumed by Ecology (DOE/RL-90-38, Rev. 1). Groundwater-monitoring activities conducted at this landfill comply with requirements stipulated in WAC 173-304-490. WAC 173-304 requires that data for specific groundwater parameters be reported annually. This requirement is fulfilled by the data and interpretations included in this report.

2.5.4 Model Toxics Control Act – Cleanup

Through WAC 173-340, Ecology defined straightforward cleanup standards that govern the decisions for toxic waste cleanup. These standards are designed to direct and expedite cleanup at hazardous waste sites that come under the scope of the *Superfund Amendments and Reauthorization Act of 1986*. The funding for this type of waste cleanup is through a state tax on disposal of hazardous substances.

2.6 Regulatory Authority Interface

2.6.1 Regulatory Programs

The RCRA, CERCLA, and WAC regulations and DOE Orders that govern groundwater monitoring, remedial investigations, and remediation overlap in many areas. The following sections clarify how, through the Tri-Party Agreement (Ecology et al. 1989), these programs must interface to achieve an efficient regulatory program to integrate the groundwater projects and to minimize redundancy.

2.6.2 Waste Unit Categories

There are three waste unit categories and related regulatory authorities addressed in the Tri-Party Agreement action plan: TSD, RCRA past-practice, and CERCLA past-practice.

The TSD units requiring groundwater monitoring were listed in Table 2.3. TSD units are defined as units receiving a RCRA permit (i.e., based on the nature of waste and timing of disposal) for either operation or postclosure care and must be closed to meet WAC 173-303-610 and the *Hazardous and Solid Waste Amendments of 1984*. These units shall remain classified as RCRA TSD units, rather than CERCLA units, even if they are investigated in conjunction with CERCLA units. All TSD units that undergo closure, irrespective of permit status, must be closed pursuant to the authorized regulations in WAC 173-303-610.

The RCRA and CERCLA past-practice units are waste management units wherein hazardous substances from sources (other than TSD units) have been disposed, as addressed by CERCLA, regardless of date of receipt at the units.

2.6.3 Waste Unit Management

Since the Hanford Site was placed on the National Priorities List (Appendix B of 40 CFR 300), Ecology, EPA, and DOE agreed that the units managed as RCRA past-practice units shall address all CERCLA hazardous substances for the purposes of corrective action. An agreement was also made that all of the waste regulated by WAC 173-303 (RCRA) will be addressed as part of any CERCLA response action or RCRA corrective action.

Section 121 of CERCLA requires that remedial actions attain a degree of cleanup that meets applicable or relevant and appropriate federal and state environmental requirements (ARARs). Based on this, the Tri-Party Agreement (Ecology et al. 1989) requires that 1) all state-only hazardous wastes will be addressed under CERCLA and 2) RCRA standards for cleanup or TSD requirements (for applicable RCRA TSD units) will be met under a CERCLA action. This eliminates many discrepancies between the two programs and lessens the significance of whether an operable unit is placed in one program or the other.

All inactive units within an operable unit are designated as either RCRA or CERCLA past-practice. This designation ensures that only one past-practice program is applied at each operable unit. The corrective action process selected for each operable unit must be sufficiently comprehensive to satisfy the technical requirements of both statutory authorities and the respective regulations.

The authority in CERCLA will be used for operable units consisting primarily of past-practice units (i.e., no TSD units or relatively insignificant units). The CERCLA authority will also be used for past-practice units in which remediation of CERCLA-only materials is the majority of work to be done in that operable unit. The RCRA past-practice authority generally is used for operable units that contain significant TSD units and/or lower-priority past-practice units. Currently assigned RCRA and CERCLA past-practice designations were shown in Table 2.2.

2.6.4 Waste Unit Interface

There are several cases where TSD units are closely associated with past-practice units, both geographically or through similar processes and waste streams. A procedure to coordinate the TSD unit closure or permitting activity with the past-practice investigation and remediation activity is necessary to prevent overlap and duplication of work, thereby economically and efficiently addressing the contamination. Based on criteria defined in Section 2.6.3, selected TSD groups/units were assigned to corresponding operable units and the information necessary for performing RCRA closures/postclosure within an operable unit is provided in various RCRA facility investigation/corrective measure reports. The initial work plan contains a sampling and analysis plan for the associated RCRA units and outlines the manner in which RCRA closure/postclosure requirements are met in the work plan and subsequent documents. The selected closure/postclosure method and associated design details, submitted as part of the corrective measure report, must 1) meet RCRA closure standards and requirements, 2) be consistent with closure requirements specified in the sitewide RCRA permit (Ecology 1994), and 3) be coordinated with the recommended remedial action for the associated operable unit. Each remedial facility investigation/corrective measure report closure document must be structured such that RCRA closure/ postclosure requirements can be readily identified for a separate review/approval process and so the RCRA closure/ postclosure requirements can be incorporated into the RCRA permit.

It was agreed by Ecology, EPA, and DOE that past-practice authority may provide the most efficient means for addressing mixed waste groundwater-contamination plumes originating from a combination of TSD and past-practice units. However, to ensure that TSD units within the operable units are brought into compliance with RCRA and state hazardous waste regulations, Ecology intends that all response or corrective actions, excluding situations where there is an imminent threat to the public health or environment, will be conducted in a manner that ensures compliance with the technical requirements of the Revised Code of Washington 70.105, *Hazardous Waste Management.*

2.6.5 Lead Regulatory Agency Concept

The EPA and Ecology selected a lead regulatory agency approach to minimize duplication of effort and to maximize productivity. Either the EPA or Ecology will be the lead regulatory agency for each operable unit, TSD group/unit, or milestone. Currently assigned lead regulatory agency designations for groundwater operable units were listed in Table 2.2.

Table 2.1. Groundwater Management Requirements

Hanford Site Groundwater Program	Tri-Party Agreement Milestones[(a)]	Regulations/Orders
Resource Conservation and Recovery Act of 1976 (RCRA)		
RCRA/TSD unit monitoring	M-20-00 M-24-00	40 CFR 264 40 CFR 265 40 CFR 257 WAC 173-303-400, -600
Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)		
CERCLA operable unit remedial assessment monitoring	M-15-00 M-16-00	40 CFR 300
Atomic Energy Act of 1954		
Sitewide environmental surveillance and operational monitoring		DOE Orders 5400.1, 5400.5, and 5820.2
Liquid Effluent-Disposal Facilities		
Facility-specific monitoring (SALDS, TEDF)	M-17-00b	WAC 173-216
400 Area process ponds		WAC 173-216

(a) TPA M-20-00 – Submit Part B permit applications or closure/postclosure plans for all RCRA TSD units.

TPA M-24-00 – Install RCRA groundwater-monitoring wells at the rate of up to 50/yr (after 1990) as scheduled in interim milestones until all land disposal units and single-shell tanks are determined to have RCRA-compliant monitoring systems.

TPA M-15-00 – Complete remedial investigation/feasibility study (or RCRA facility investigation/corrective measure study) process for all operable units.

TPA M-16-00 – Complete remedial actions for all non-tank farm operable units.

TPA M-17-00b – Complete implementation of best available technology/all known available and reasonable methods of prevention, control, and treatment for all Phase II liquid effluent streams at the Hanford Site.

CFR = Code of Federal Regulations.
DOE = U.S. Department of Energy.
SALDS = State-Approved Land-Disposal Site.
TEDF = 200 Areas Treated Effluent-Disposal Facility.
TSD = Treatment, storage, and disposal (units).
WAC = Washington Administrative Code

Table 2.2. Groundwater Operable Unit Monitoring Status

Tri-Party Agreement Priority[a]	Groundwater Operable Unit	Monitoring Status	Regulatory Unit Designation	Lead Regulatory Agency
1	1100-EM-1	Contaminant monitoring	CERCLA past practice	EPA
2A	300-FF-5	Contaminant monitoring	CERCLA past practice	EPA
4A	100-HR-3	Assessment monitoring for pump-and-treat containment project	RCRA past practice	Ecology
6A	100-BC-5	Contaminant monitoring	CERCLA past practice	EPA
7A	100-KR-4	Assessment monitoring for pump-and-treat containment project	CERCLA past practice	EPA
9	100-NR-2	Assessment monitoring for pump-and-treat containment project	RCRA past practice	Ecology
10A	100-FR-3	Contaminant monitoring	CERCLA past practice	EPA
13	200-BP-5	Contaminant monitoring	CERCLA past practice	EPA
20A	200-UP-1	Assessment monitoring for pump-and-treat containment project	RCRA past practice	Ecology
20A	200-ZP-1	Assessment monitoring for pump-and-treat containment project	CERCLA past practice	EPA
20B	200-PO-1	Contaminant monitoring	RCRA past practice	Ecology

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(a) Listed from highest to lowest.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980.
Ecology = State of Washington Department of Ecology.
EPA = U.S. Environmental Protection Agency.
RCRA = Resource Conservation and Recovery Act of 1976.

Table 2.3. Interim- and Final-Status Groundwater-Monitoring Projects (as of September 1997)

	Interim-Status TSD Unit Groundwater Monitoring		Final-Status TSD Unit Groundwater Monitoring				
TSD Units, Date Initiated	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Regulations	Associated (CERCLA) Groundwater Operable Units	Year Scheduled for Part B or Closure
1301-N LWDF, December 1987	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1999(b)
1324-N/NA LWDF, December 1987	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1998(b)
1325-N LWDF, December 1987	X				40 CFR 265.93(b) WAC 173-303-400	100-NR-2	1999(b)
120-D-1 ponds, April 1992	X				40 CFR 265.93(b) WAC 173-303-400	100-HR-3	1998(b)
183-H solar evaporation basins, June 1985				X	WAC 173-303-645(10)	100-HR-3	1994(b)
216-S-10 pond and ditch, August 1991	X				40 CFR 265.93(b) WAC 173-303-400		>2000(b)
216-U-12 crib, September 1991		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-UP-1	>2000(b)
216-B-3 pond, November 1988		X, 1990			40 CFR 265.93(b) WAC 173-303-400	200-PO-1	2000(b)
216-A-29 ditch, November 1988	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	2000(b)
216-A-10 crib,(c) November 1988		X, 1997			40 CFR 265.93(d) WAC 173-303-400	200-PO-1	>2000(b)
216-A-36B crib,(c) May 1988		X, 1997			40 CFR 265.93(d) WAC 173-303-400	200-PO-1	>2000(b)
216-A-37-1 crib,(c) 1997		X, 1997			40 CFR 265.93(d) WAC 173-303-400	200-PO-1	1998(b)
216-B-63 trench, August 1991	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000(b)

Table 2.3. (contd)

	Interim-Status TSD Unit Groundwater Monitoring		Final-Status TSD Unit Groundwater Monitoring				
TSD Units, Date Initiated	Indicator Parameter Evaluation(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Regulations	Associated (CERCLA) Groundwater Operable Units	Year Scheduled for Part B or Closure
LERF, July 1991	X				40 CFR 265.93(b) WAC 173-303-400		1997(d)
LLWMA 1, September 1988	X				40 CFR 265.93(b) WAC 173-303-400		1997(d)
LLWMA 2, September 1988	X				40 CFR 265.93(b) WAC 173-303-400		1997(d)
LLWMA 3, October 1988	X				40 CFR 265.93(b) WAC 173-303-400		1997(d)
LLWMA 4, October 1988	X				40 CFR 265.93(b) WAC 173-303-400	200-ZP-1	1997(d)
WMA A-AX, February 1990	X				40 CFR 265.93(b) WAC 173-303-400		>2000(b)
WMA B-BX-BY, February 1990		X, 1996			40 CFR 265.93(d) WAC 173-303-400		>2000(b)
WMA C, February 1990	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000(b)
WMA S-SX, October 1991		X, 1996			40 CFR 265.93(d) WAC 173-303-400	200-UP-1	>2000(b)
WMA T, February 1990		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-ZP-1	>2000(b)
WMA TX-TY, September - October 1991		X, 1993			40 CFR 265.93(d) WAC 173-303-400	200-ZP-1	>2000(b)
WMA U, October 1990	X				40 CFR 265.93(b) WAC 173-303-400	200-ZP-1	>2000(b)
NRDWL, October 1986	X				40 CFR 265.93(b) WAC 173-303-400	200-PO-1	>2000(b)

Table 2.3. (contd)

	Interim-Status TSD Unit Groundwater Monitoring		Final-Status TSD Unit Groundwater Monitoring				
TSD Units, Date Initiated	Indicator Parameter Evaluation[a]	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Regulations	Associated (CERCLA) Groundwater Operable Units	Year Scheduled for Part B or Closure
316-5 process trenches, June 1985				X, 1996	WAC 173-303-645(10)	300-FF-5	1996[b]

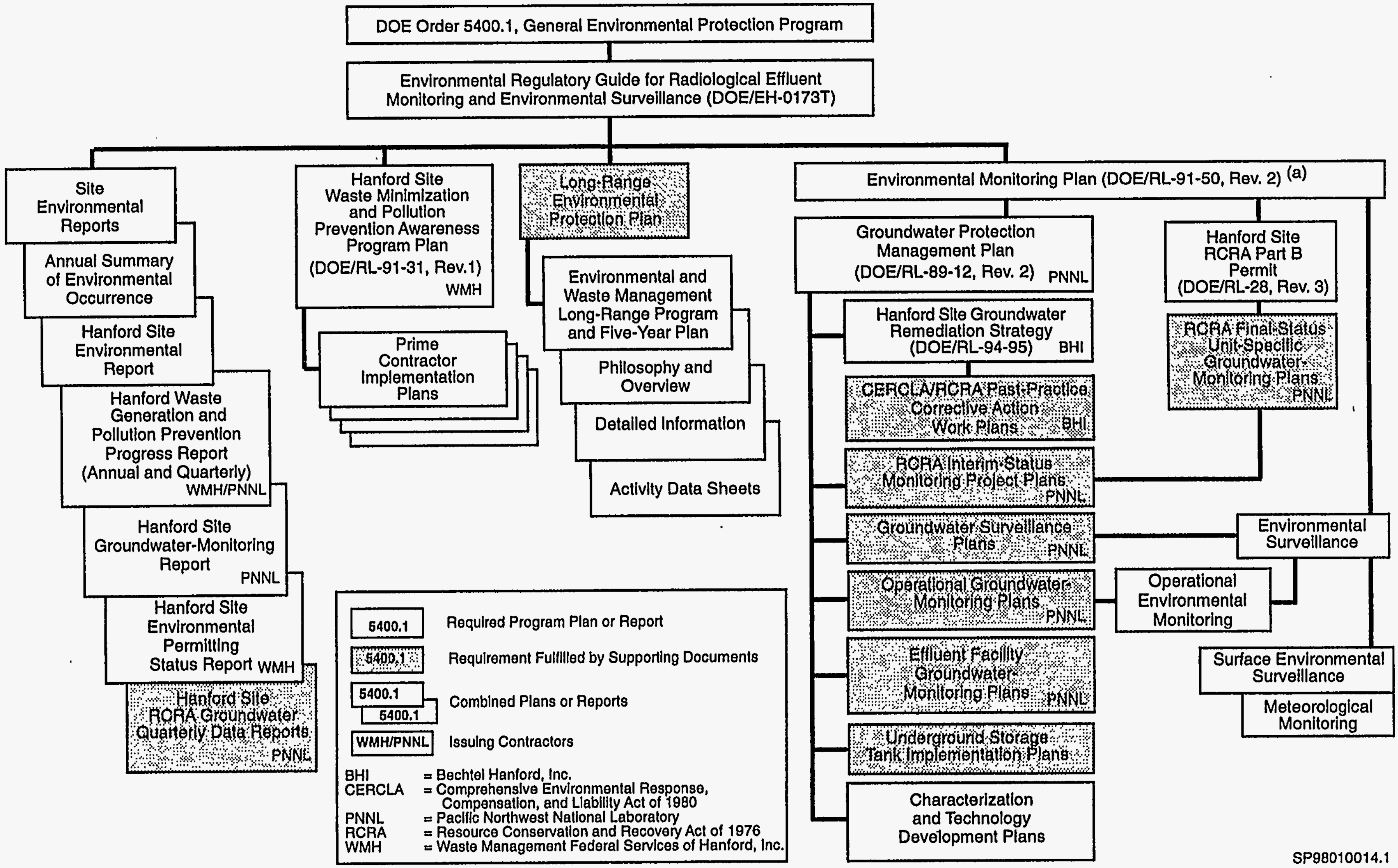
(a) Specific parameters (pH, specific conductance, total organic carbon, and total organic halides) used to determine if a facility is affecting groundwater quality. Exceeding the established limits means that additional evaluation and sampling are required (groundwater quality assessment). An X in the assessment column indicates whether an evaluation was needed or an assessment was required.

(b) Closure/postclosure plan; TSD unit will close under final status.

(c) Combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim-status groundwater quality assessment requirements.

(d) Part B permit; TSD unit will operate under final-status regulations beginning in year indicated.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980.
LERF = Liquid effluent-retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste-disposal facility.
NRDWL = Nonradioactive Dangerous Waste Landfill.
RCRA = Resource Conservation and Recovery Act of 1976.
TSD = Treatment, storage, or disposal (unit).
> = Beyond the year 2000.



(a) All groundwater-monitoring projects are being integrated through the data quality objectives process.

Figure 2.1. Relationship Between Environmental Protection Programs and Plans

3.0 Hydrogeologic Setting

Understanding the groundwater-flow system is important in assessing the potential for contaminants to migrate from the site through the groundwater pathway. Hydrogeologic information is used in the determination of the designs and locations of the monitoring wells. The information also provides the basis for numerical modeling of groundwater flow and understanding contaminant plume migration.

This chapter provides an overview of the hydrogeology of the Hanford Site and describes groundwater flow within the unconfined and upper basalt-confined aquifers. The geology and groundwater hydrology of the Hanford Site are provided in Sections 3.1 and 3.2, respectively. Descriptions of the water-level-monitoring programs and groundwater flow in the unconfined aquifer system are given in Section 3.3. A description of the hydrogeology, including unconfined aquifer groundwater flow within specific areas in and adjacent to the Hanford Site, is provided in Sections 3.4 through 3.9. Groundwater flow within the upper basalt-confined aquifer is discussed in Section 3.10. Water-level data are presented in electronic form on the diskette included with this report.

3.1 Geologic Setting

S. P. Reidel

The Hanford Site lies in the Columbia Plateau, a broad plain situated between the Cascade Range to the west and the Rocky Mountains to the east. The Columbia Plateau was formed by a thick sequence of Miocene-Age tholeiitic basalt flows, called the Columbia River Basalt Group, that erupted from fissures in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979). The Columbia Plateau is often called the Columbia Basin because it forms a broad lowland surrounded by mountains. In the central and western sections of the Columbia Plateau, where the Hanford Site is located, the Columbia River Basalt Group is underlain by continental sedimentary rocks from earlier in the Tertiary Period.

The basalt and sedimentary rocks have been folded and faulted over the geologic past, creating broad structural and topographic basins separated by asymmetric anticlinal ridges. Sediments up to 518 m in thickness accumulated in some of these basins. Basalt flows are exposed along the anticlinal ridges, where they have been uplifted as much as 1,097 m above the surrounding area. Overlying the basalts in the synclinal basins are sediments of the late Miocene, Pliocene, and Pleistocene Ages. The Hanford Site lies within one of the larger basins, the Pasco Basin, that is bounded on the north by the Saddle Mountains and on the south by Rattlesnake Mountain and the Rattlesnake Hills. The Yakima and Umtanum Ridges trend into the basin and subdivide it into a series of anticlinal ridges and synclinal basins. The largest syncline, the Cold Creek syncline, lies between Umtanum and Yakima Ridges and is the principal structural basin containing the U.S. Department of Energy's (DOE's) waste management areas (WMAs). Figure 3.1-1 shows the surface geology and major structural features of the Pasco Basin. The geology of the Hanford Site is described in detail in DOE/RW-0164.

Figure 3.1-2 shows the stratigraphic units underlying the Hanford Site. These include, in ascending order, the Columbia River Basalt Group, Ringold Formation, Plio-Pleistocene unit (including the early

Palouse soil), and Hanford formation. A regionally discontinuous veneer of Holocene alluvium, colluvium, and/or eolian sediments overlies the principal geologic units. The hydrogeologic and geologic stratigraphic columns in Figure 3.1-2 show differences in stratigraphy, primarily within the Hanford and Ringold Formations. The geologic column on the right defines the lithostratigraphic units, based on physical properties of the sediments, modified from BHI-00184. The hydrogeologic column on the left defines hydrostratigraphic units based on hydraulic properties (PNL-8971). The various stratigraphic units found within the Hanford Site boundaries are described below.

3.1.1 Columbia River Basalt Group

There are approximately 50 basalt flows beneath the Hanford Site with a combined thickness of more than 3,000 m (DOE/RW-0164). The most recent, laterally extensive basalt flow underlying the Hanford Site is the Elephant Mountain Member of the Saddle Mountains Basalt. However, the younger Ice Harbor Member is found in the southern part of the site (DOE/RW-0164). Sandwiched between various basalt flows are sedimentary interbeds, collectively called the Ellensburg Formation, which includes fluvial and lacustrine sediments consisting of mud, sand, and gravel deposited between volcanic eruptions. Along with the porous basalt flow tops and bottoms, these sediments form basalt-confined aquifers that extend across the Pasco Basin. The Rattlesnake Ridge interbed is the uppermost laterally extensive hydrogeologic unit of these sedimentary interbeds.

3.1.2 Ringold Formation

The Pliocene-Age Ringold Formation sediments overlie the basalts and are overlain by late Pliocene- and Pleistocene-Age deposits. Ringold Formation sediments consist of a heterogeneous mix of variably cemented and compacted gravel, sand, silt, and clay deposited by the ancestral Columbia and Snake Rivers in the geologic past (Fecht et al. 1987, Reidel et al. 1994, WHC-SD-EN-EE-004). The depositional system was a braided stream channel with the two rivers joining in the area of the present White Bluffs. The deposits at the Hanford Site represent an eastward shift of the Columbia River from the west side of the Hanford Site to the east side. The Columbia River first flowed across the west side of the Hanford Site (where Dry Creek is now) crossing over the Rattlesnake Hills. The river eventually shifted to a course that took it through the gap between Gable Mountain and Gable Butte and south across the present 200-East Area.

Traditionally, the Ringold Formation in the Pasco Basin is divided into several informal units. In ascending order, these units are the 1) gravel, sand, and paleosols of the basal unit; 2) clay and silt of the lower unit; 3) sand and gravel of the middle unit; 4) mud and lesser sand of the upper unit; and 5) basaltic detritus of the fanglomerate unit (DOE/RW-0164, Newcomb 1958, Newcomb et al. 1972, RHO-BWI-ST-4, RHO-ST-23, SD-BWI-DP-039). Ringold strata also have been divided on the basis of facies types (RHO-BWI-ST-14) and fining upward sequences (Puget Sound Power and Light Company 1982). More recently, the Ringold sediment facies have been described on the basis of lithology, stratification, and pedogenic alteration (WHC-SD-EN-TI-012). The facies types identified include the following:

- fluvial gravel facies – These consist of matrix-supported granule to cobble gravels with a sandy silt matrix and intercalated sands and muds. The facies were deposited in a gravelly fluvial braidplain characterized by wide, shallow, shifting channels.

- fluvial sand facies – These consist of cross-bedded and cross-laminated sands that are intercalated with lenticular silty sands, clays, and thin gravels. Fining upward sequences are common. Strata comprising the association were deposited in wide, shallow channels.

- overbank facies – These consist of laminated to massive silt, silty fine-grained sand, and paleosols containing variable amounts of pedogenic calcium carbonate. Overbank deposits occur as thin lenticular interbeds in the gravels and sands and as thick, laterally continuous sequences. These sediments record deposition in proximal levee to more distal floodplain conditions.

- lacustrine facies – These are characterized by plane laminated to massive clay with thin silt and silty sand interbeds displaying some soft-sediment deformation. Deposits coarsen downward. Strata were deposited in a lake under standing water to deltaic conditions.

- alluvial fan facies – These are characterized by massive to crudely stratified, weathered to unweathered basaltic detritus. These deposits generally are found around the periphery of the basin and record deposition by debris flows in alluvial fan settings and in sidestreams draining into the Pasco Basin.

As described and illustrated in the geologic column on the right side of Figure 3.1-2, the upper part of the Ringold Formation is composed of interbedded fluvial sand and overbank facies, which are overlain by mud-dominated lacustrine facies (BHI-00184, WHC-SD-EN-EE-004). The lower part of the Ringold Formation contains five separate stratigraphic intervals dominated by the fluvial gravel facies. These gravels, designated Units A, B, C, D, and E, are separated by intervals containing deposits typical of the overbank and lacustrine facies. The lowermost of the fine-grained sequence units, overlying Unit A, is designated the lower mud sequence. The lithofacies defined in WHC-SD-EN-EE-004 were regrouped into 9 hydrogeologic units to support development of a layered, three-dimensional, groundwater-flow and -transport model (PNL-8971, PNL-10195, PNL-10886). A comparison of these units with the stratigraphic column of BHI-00184 is shown in Figure 3.1-2. Additional information on the definition of hydrogeologic units for the model is provided in Chapter 6.0.

3.1.3 Plio-Pleistocene Unit and Early Palouse Soil

The laterally discontinuous Plio-Pleistocene unit unconformably overlies the Ringold Formation and is found only in the western part of the Hanford Site (DOE/RW-0164). This unit consists of sidestream alluvial deposits and buried soil horizons with significant caliche in some areas and is generally above the current water table.

The Pleistocene-Aged early Palouse soil is a buried eolian unit that overlies part of the Plio-Pleistocene unit. Because of the difficulty in distinguishing the early Palouse soil from the Plio-Pleistocene unit, these two are commonly grouped together and called the Plio-Pleistocene unit. The early Palouse soil consists of up to 20 m of massive, brown-yellow, and compact, loess-like silt and minor fine-grained sand (DOE/RW-0164, RHO-ST-23). The early Palouse soil is found only in the vicinity of the 200-West Area. The early Palouse soil and the fine-grained and caliche portions of the Plio-Pleistocene unit, both of which are found in the 200-West Area, form a low-permeability layer that significantly affects migration of water through the vadose zone.

3.1.4 Hanford Formation and Pre-Missoula Gravels

The informally named Hanford formation consists of deposits from a series of Pleistocene-Age cataclysmic floods. The floods occurred when ice dams gave way, releasing water from Lake Missoula, a large glacial lake that formed in the Clark Fork River valley. Flood episodes may have occurred as many as 40 times, with the released water spreading across eastern Washington. The floodwaters collected in the Pasco Basin and formed Lake Lewis, which slowly drained through the gap in the Horse Heaven Hills, called Wallula Gap (Allison 1933). Three principal types of deposits were left behind by the floods: 1) high-energy deposits, consisting of gravel; 2) low-energy, slackwater deposits, consisting of rhythmically bedded silt and sand of the Touchet Beds; and 3) coarse- to fine-sand deposits, representing an energy transition environment. The fluvial pre-Missoula gravels underlie the Hanford formation gravel deposits in the central part of the Hanford Site. The pre-Missoula deposits are difficult to distinguish from the Hanford gravels, so they are usually grouped together.

The Hanford formation is divided into a variety of sediment types, facies, or lithologic packages. Recent reports dealing with the Hanford formation (WHC-MR-0391, WHC-SD-EN-EE-004) recognized three basic facies: gravel, sand, and silt dominated. These facies generally correspond to the coarse gravels, laminated sands, and graded rhythmites, respectively (Baker et al. 1991, DOE/RW-0164, WHC-SD-ER-TI-003). The Hanford formation ranges in thickness from <1 to >100 m.

Gravel-dominated strata consist of coarse-grained sand and granule to boulder gravel that display massive bedding, plane to low-angle bedding, and large-scale cross-bedding in outcrop. Matrix commonly is lacking from the gravels, giving them an open-framework appearance. The sand-dominated facies consist of fine- to coarse-grained sand and granules that display plane lamination and bedding and, less commonly, plane and trough cross-bedding in outcrop. Small pebbles and pebbly interbeds (<20 cm thick) may be encountered. The silt-dominated facies consist of silt and fine- to coarse-grained sand that form normally graded rhythmites. Plane lamination and ripple cross-lamination are common in outcrop.

Figure 3.1-3 is a map view of the hydrogeologic units that were intersected by the water table during 1997. The figure shows that the water table lies within the Hanford formation over most of the eastern and northern parts of the Hanford Site. The Hanford formation lies entirely above the water table in the western part of the site and in some other localized areas. Figure 3.1-4 shows a geologic cross-section of the Hanford Site and the location of the water table in 1997. This cross-section represents A-A' on the map in Figure 3.1-3. This cross-section shows that the saturated sediments of the Hanford formation represent a small portion of the total saturated sediments above basalt.

3.1.5 Holocene Surficial Deposits

Holocene surficial deposits, consisting of silt, sand, and gravel, form a thin (<5-m) veneer across much of the Hanford Site. In the 200-West Area and southern part of the 200-East Area, these deposits consist dominantly of laterally discontinuous sheets of wind-blown silt and fine-grained sand. They are generally found above the water table.

3.2 Hydrologic Setting

P. D. Thorne

This section provides general information on the Hanford Site groundwater-flow system. Additional details concerning hydrogeologic conditions at each of the *Resource Conservation and Recovery Act of 1976* (RCRA) sites is provided in the following sections.

Groundwater is present in both unconfined and confined aquifers at the Hanford Site. The unconfined aquifer is generally located in the unconsolidated to semiconsolidated Ringold and Hanford formations that overlie the basalt bedrock. In some areas, low-permeability mud layers form aquitards that create local, confined, hydraulic conditions in the underlying sediments. However, these aquitards are not continuous across the Hanford Site, and the entire suprabasalt aquifer is hydraulically connected on a site-wide scale. Consequently, from a regional perspective, the entire suprabasalt aquifer is referred to as the unconfined aquifer system in this report. The following discussion focuses on the Hanford Site unconfined aquifer system because, as the uppermost aquifer system, it is the most likely to be affected by contaminants released from Hanford Site sources. Monitoring data confirm that almost all of the groundwater contamination is found within the upper part of the unconfined aquifer system. From a local perspective, the unconfined aquifer is referred to as the saturated zone above low-permeability mud units for some areas.

The saturated thickness of the unconfined aquifer system is >180 m in areas near the Central Landfill, west of the 200-West Area, and north of Gable Butte near the 100-B,C and 100-K Areas, but pinches out along the flanks of the basalt ridges. Depth to the water table ranges from <1 m near the Columbia River to >100 m near the 200 Areas. Perched water-table conditions have been encountered in sediments above the unconfined aquifer system in the 200-West Area (PNL-8597, WHC-MR-0206) and in irrigated offsite areas east of the Columbia River (RHO-BWI-C-56).

Groundwater in the unconfined aquifer system generally flows from recharge areas in elevated regions near the western boundary of the Hanford Site toward the Columbia River (discussed more fully in Sections 3.3 and 3.4), which is a discharge zone for the unconfined aquifer on both sides of the river. The Yakima River lies southwest of the Hanford Site and is generally regarded as a source of recharge to the unconfined aquifer system between the southern part of the site and the Richland North Area.

A sequence of basalt-confined aquifers is present within the Columbia River Basalt Group beneath the Hanford Site. These aquifers are composed of sedimentary interbeds and the relatively permeable tops of basalt flows. The dense interior sections of the basalt flows form confining layers. Groundwater in the basalt-confined aquifers also generally flows from elevated regions at the edge of the Pasco Basin toward the Columbia River (PNL-10817). However, the discharge zone locations are also influenced by geologic structures that increase the vertical permeability of the confining basalt layers. Additional information on the upper basalt-confined aquifer system is available in DOE/RW-0164, PNL-10158, and PNL-10817.

3.2.1 Unconfined Aquifer System Recharge and Discharge

Natural recharge to the unconfined aquifer system occurs from infiltration of runoff from elevated regions along the western boundary of the Hanford Site, infiltration of springwater and upwelling of groundwater that originates from the basalt-confined aquifer system, and infiltration of precipitation falling across the Hanford Site. Some recharge also takes place along the Yakima River. Recharge from precipitation is highly variable, both spatially and temporally, ranging from near zero to >100 mm/yr, depending on climate, vegetation, and soil texture (Gee et al. 1992, PNL-10285). Recharge from precipitation is highest in coarse-textured soils with little or no vegetation, which is the case for most of the industrial areas on the site. A map showing estimated average natural recharge based on distributions of soil and vegetation types is shown in Figure 3.2-1 (PNL-10285).

Since the start of Hanford Site operations in the mid-1940s, artificial recharge from wastewater-disposal facilities has been several times greater than the estimated recharge from natural sources. This caused an increase in the water-table elevation over most of the Hanford Site and the formation of groundwater mounds beneath major wastewater-disposal facilities. However, since 1988, all production activities on the Hanford Site have been curtailed, resulting in a decrease in wastewater disposal and subsequent decreases in water-table elevation over much of the site. As the Hanford Site's mission changed to include environmental cleanup and restoration and through the efforts of the Waste Minimization and Pollution Prevention Program (DOE/RL-91-31, Rev. 1), the volume of wastewater discharged to the soil column has been greatly reduced. For example, ~34 billion L of liquid effluents were discharged to the soil column in 1985, ~14 billion L were discharged to the soil column in 1990, and ~6.2 billion L were discharged to the soil column in 1996 (HNF-EP-0527-6). The reduction of wastewater discharge to the ground was accompanied by elimination of many discharge sites, including the 216-U-10 pond (U Pond) in the 200-West Area (decommissioned in 1985) and Gable Mountain Pond north of the 200-East Area (decommissioned in 1984-1988). By the end of 1995, only 18 of the original 33 liquid effluent streams identified in WHC-EP-0196-1 were still active. Section 3.3.3 discusses the locations of the discharge sites associated with the 33 major liquid-effluent streams that were active in 1988.

During fiscal year (FY) 1997, disposal of wastewater from these 18 remaining waste streams was consolidated to the following facilities:

- 216-B-3C expansion pond (discharge ceased in August 1997)
- 200 Areas Treated Effluent-Disposal Facility (located east of the 216-3 B pond [B Pond])
- 616-A Crib (located just north of the 200-West Area) (also called the State-Approved Land-Disposal Site)
- 4608 B/C ponds that discharge to the soil column (also called the 400 Area process ponds)
- 300 Area Treated Effluent-Disposal Facility (located north of the 300 Area that discharges to the Columbia River).

3.2.2 Unconfined Aquifer System Hydraulic Properties

Hydraulic property data for the unconfined aquifer system are derived mainly from well-pumping and slug tests and, in a few cases, laboratory permeameter tests of sediment samples. These results were documented in dozens of published and unpublished reports over the past 50 years. A summary of available data for the unconfined aquifer system is provided in DOE/RW-0164, and an updated summary is provided in PNL-8337 together with an evaluation of selected pumping test analyses. Additional tests were conducted to support several specific Hanford Site projects. Examples are presented in BHI-00917, PNL-8332, PNL-8971, PNL-10195, PNL-10422, PNL-10633, WHC-SD-C018H-RPT-003, WHC-SD-EN-DP-052, WHC-SD-EN-TI-052, and WHC-SD-EN-TI-294.

The distribution of unconfined aquifer transmissivity, which is the product of the vertically averaged horizontal hydraulic conductivity and the aquifer thickness, is shown in Figure 3.2-2. This distribution was determined from the results of well-pumping tests combined with a flow-model calibration procedure (PNNL-11801). The model calibration is discussed in more detail in Chapter 6.0. In Figure 3.2-2, the zone of high transmissivity that extends from northwest to southeast across the site generally corresponds with the main flow channel of the catastrophic proglacial floods that deposited the Hanford formation gravels. Thickness of the unconfined aquifer system, which includes all the saturated sediments above basalt, is shown in Figure 3.2-3. Where they are found below the water table, the Hanford formation gravels make up the most-permeable zones of the unconfined aquifer system. The hydraulic conductivity of these sediments is generally 10 to 100 times greater than the hydraulic conductivity of Ringold Formation gravels. In some areas of the Hanford Site, including the 200-West Area, the water table is below the bottom of the Hanford formation (see Figures 3.1-3 and 3.1-4). The aquifer transmissivity in these areas is generally much lower than the transmissivity in areas where Hanford formation sediments are saturated.

Aquifer specific yield, which is a measure of the volume of water released from aquifer storage in response to a change in the water-table elevation, is more difficult to measure than hydraulic conductivity and generally requires relatively long-duration aquifer-pumping tests with observation wells (PNL-8539) or slug tests with observation wells (PNL-10835, Spane 1996). Even for these tests, the calculated specific yield is subject to errors that result from nonideal test conditions, such as aquifer heterogeneity, anisotropy, and partially penetrating wells (PNL-8539). Specific yield values calculated from several multiple well tests are listed in PNL-10886. These results range from 0.02 to 0.38 and have a mean of 0.15. For an unconfined aquifer, specific yield is approximately equal to effective porosity, which is important in calculating contaminant travel times.

3.3 Groundwater Flow

W. D. Webber

This section describes groundwater flow beneath the Hanford Site within the unconfined and upper basalt-confined aquifers. The primary focus is the unconfined aquifer system because it is the aquifer most impacted by wastewater discharged to the ground on the Hanford Site and by irrigation practices offsite and is the most likely path for offsite migration of contaminants in groundwater. An assessment of a facility's impact on the unconfined aquifer is required for RCRA groundwater compliance. Groundwater-flow-system dynamics discussed in this section are used in the determination of groundwater-flow directions, interpretation of contaminant plume distribution (Chapter 5.0), and modeling of groundwater flow and contaminant transport (Chapter 6.0).

3.3.1 Description of Water-Level-Monitoring Program

Water-level data are used to delineate groundwater-flow patterns and to evaluate flow-system dynamics in the unconfined and upper basalt-confined aquifers. Water levels are measured in June of each year in selected wells completed in the unconfined aquifer system beneath the Hanford Site and outlying areas. The purpose of the measurements is to monitor changes in water-table elevation that affect the direction and velocity of groundwater flow and transport of associated contaminants. More frequent measurements are made at a few of the same wells to monitor seasonal variations. Water-table maps are produced annually. Water-table maps of the unconfined aquifer system beneath the Hanford Site have been prepared for selected times since 1944 (see Water-Table Maps in the Historical Bibliography provided on the diskette included with this report).

Groundwater-monitoring plans for individual RCRA sites specify requirements for water-level monitoring. These data aid in determining the direction of groundwater flow beneath the RCRA units and in determining if the monitoring network is adequate. Water-level-measurement frequency varies from monthly to semiannually, depending on factors such as the site's groundwater gradient and the variability of water levels.

Groundwater-monitoring plans for individual *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) projects specify requirements for water-level monitoring. These data aid in determining the direction of groundwater flow beneath the CERCLA projects and the area affected by groundwater withdrawal and/or injection associated with pump-and-treat operation. Water-level-measurement frequency varies from hourly to annually, depending on the local groundwater gradient, variability of water levels and project requirements.

Water levels are also measured in the upper basalt-confined aquifer to monitor changes in the potentiometric surface for this aquifer. Changes in the potentiometric surface can affect the direction and velocity of groundwater flow within the upper basalt-confined aquifer and its potential for hydraulic communication with the overlying unconfined aquifer system. A preliminary potentiometric map and an evaluation of the flow-system dynamics for the upper basalt-confined aquifer were prepared and presented in PNL-8869.

In addition to the water-level measurements described above, where possible, water levels are measured prior to each groundwater-sampling event.

3.3.1.1 Monitoring Network

Locations of groundwater wells are shown in Plate 1. Wells north and east of the Columbia River that are numbered by the U.S. Geological Survey's well-numbering system are not shown in Plate 1 but can be located by well name, which includes the township, range, and section numbers. These wells are shown on Plate 1 of PNL-8122. The areas where basalt occurs above the water table were identified by comparing the top-of-basalt surface with the 1997 water-table surface.

During June 1997, water levels were measured in more than 600 wells completed in the unconfined aquifer system on the Hanford Site, all in Benton County, and in 38 Bureau of Reclamation wells north and east of the Columbia River in Adams, Franklin, and Grant Counties. Monitoring wells used to measure water levels for the unconfined aquifer system were selected using the following criteria:

- open interval does not extend more than 10 m below the water table and does not monitor perched, semiconfined, or confined conditions
- well location and elevation are accurately known.

Exceptions were made where no alternative wells exist and vertical gradients are small relative to horizontal gradients. For example, no wells in the B Pond-monitoring network are completed in the upper part of the aquifer where the water table lies above the Ringold lower mud unit. Therefore, wells completed below this unit were used. In some areas, not all wells that met these criteria were selected because an adequate number of nearby wells exist.

In addition to water levels measured during June in wells across the Hanford Site, water levels were measured more frequently and at more closely spaced wells in the vicinity of the Hanford Site operational facilities, groundwater remediation projects, and the Richland North Area. These data are used to evaluate local groundwater-flow patterns associated with those areas. Artificial recharge to the unconfined aquifer system in many of these areas has resulted in groundwater mounding that influences groundwater flow and is discussed in Sections 3.4 through 3.9.

During June 1997, water levels were measured in 54 wells completed in the upper basalt-confined aquifer beneath the Hanford Site and outlying areas. Monitoring wells used to measure water levels in the upper basalt-confined aquifer system are completed in stratigraphic units within the upper Saddle Mountains Basalt (Rattlesnake Ridge interbed, Elephant Mountain interflow contact, Levey interbed).

3.3.1.2 Methods

Procedures developed in accordance with the techniques described in American Society for Testing and Materials (1988), Garber and Koopman (1968), OSWER 9950.1, and U.S. Geological Survey (1977) were followed to measure water levels in piezometers and wells across the Hanford Site. Water levels were measured with steel tapes or laminated steel electric sounding tapes that were standardized by comparison to a calibrated steel tape. Only those standardized steel tapes that deviated in length from the calibrated steel tape by <0.03 m for at least 85 m were used. Water levels are reported as elevations above the National Geodetic Vertical Datum (NGVD29). The more recent National Geodetic Vertical Datum of 1988 (NGVD88) is not used because many of the wells have not been surveyed to this datum and conversion of the NGVD29 survey data to the NGVD88 datum for the remaining wells and historic water levels is not yet complete. In general, NGVD88 is ~1 m greater than NGVD29 but the conversion is not precisely the same at all locations across the site.

A few wells completed in the upper basalt-confined aquifer are under flowing artesian conditions; where the potentiometric surface is above the top of the well or piezometer. For these wells, which are pressure sealed from the atmosphere, a pressure gauge or transducer is used to measure the equivalent head above the top of the surveyed elevation.

Pressure transducers and data loggers were used to measure and record the heads in a few wells where water levels change rapidly (e.g., near the Columbia River and near groundwater-extraction or -withdrawal wells). Pressure transducer and data loggers were also used to measure river stage to provide spatial and temporal control as it relates to groundwater levels near the river. River-stage-monitoring stations, which support CERCLA activities, are located at the 100-B,C, 100-H, 100-N, 100-F, and 300 Areas. The data-logger systems generally recorded pressure head at 1-hour intervals.

3.3.1.3 Data Quality

The procedures developed for determining water levels were designed to ensure the integrity and representativeness of the data. Interpretation of water-level data assumes that the measurements are temporally and spatially representative. However, various sources of error and uncertainty that limit the accuracy of the data and affect their representativeness include the following:

- temporal variations in water table caused by natural external stresses (e.g., barometric pressure fluctuations, earth tides, changes in river stage, recharge) or man-made activities (e.g., wastewater disposal)
- vertical gradients associated with the length of the screened interval
- vertical gradients associated with the depth of the screened interval
- well deviations from vertical
- errors in surveyed elevations of measuring points
- limits of measuring tape precision and accuracy.

To reduce the effect of seasonal and other long-term water-level changes, water-level measurements for the site water-table map were made within a 1-month period (June 1997). The most significant short-term water-level changes measured within this period were in wells influenced by fluctuations in Columbia River stage. These short-term water-level fluctuations in wells introduce uncertainty in representing the water-table surface adjacent to the river. Therefore, the water-table-elevation contours adjacent to the river have a lower confidence in representing the water-table surface for June 1997 than other contours.

The effect of open-interval depth below the water table on water levels depends on the vertical gradient in a given area. For the scale and contouring interval of the site map and of most local maps, any well screened within 10 m of the water table is acceptable (see Section 3.3.1.1).

The sources of error listed above generally are only significant in areas of very low horizontal gradients (e.g., the 200-East Area). In some of these areas, water-level data alone are insufficient to determine the direction of groundwater flow, and other information (e.g., contaminant plume configuration, regional groundwater-flow patterns) must be used.

Water-level data were screened for outliers (obvious errors and extreme data) before producing the water-table maps presented in this report. Outliers were not used in preparation of or plotted on the water-table maps shown in this report but are included in the data tables provided on the diskette included with this report. Outliers were generally included on the water-level trend plots; however, outliers outside the limits of the plot scale were removed. Data from data-logger and pressure-transducer systems were compared to manual measurements to evaluate and correct for transducer drift.

3.3.1.4 Data Management

The Hanford Environmental Information System (HEIS) database is used to store and maintain manual hydraulic head measurements. In FY 1997, ~3,040 hydraulic head measurements were entered into this database. Through HEIS, hydraulic head data are made available to federal and state regulators for retrieval. Pressure transducer data were stored in project databases.

3.3.1.5 Interpretive Techniques

The June 1997 water-level measurements were used to construct contour maps that show the elevation of the potentiometric surface for the unconfined aquifer system, which is referred to as the water table. The water-table-contour map primarily represents groundwater head conditions in the upper part of the unconfined aquifer system. Assuming isotropic hydraulic conductivities, uniform fluid density, and no vertical flow, the direction of groundwater flow is perpendicular to contours of equal potentiometric surface elevation. Potentiometric surface maps can be used for the following

- identify the recharge and discharge areas
- evaluate the influence of wastewater discharges on groundwater-flow patterns
- evaluate the influence of river stage on groundwater flow (i.e., river-stage effects)
- determine the hydraulic gradient, which can be used to estimate the average linear velocity of groundwater and contaminants
- provide information required to calibrate groundwater-flow and contaminant-transport models
- improve the design of the monitoring well network.

Maps showing the June 1997 water-table-elevation contours for the unconfined aquifer system are presented in Plate 2. A contour interval of 2 m is used to show regional water-table features on the Hanford Site. The inset maps of operational areas use a contour interval of 0.5 m to show detail. Selected FY 1997 water-level data, including the measured depth to water, the reference-point elevation, and the calculated water-table elevation for each well can be located on the diskette included with this report.

The contour map was constructed by preparing a water-level-elevation grid to represent the water-table surface for the Hanford Site from which contours were derived using the computer program

EarthVision™ (Dynamic Graphics Inc., Alameda, California). Preparation of the water-table-elevation grid using EarthVision™ includes the following:

- selection of data (see Sections 3.3.1.1 and 3.3.1.3)
- calculation of mean water-level elevation for June 1997 at each selected well
- calculation of simulated, mean, river-stage elevations for June 1997 along the Hanford Reach of the Columbia River
- determination of grid boundary and break lines
- computer-automated gridding of selected water-level elevations
- manual editing of the grid using utilities supplied in the EarthVision™ software.

Editing of the water-level-elevation grid is done to add control where data distribution is insufficient for automated gridding. When editing is complete, contour lines are generated from the grid. Contour lines are then posted with mean water-level elevations and reviewed. Final editing of the contour lines is done where the grid resolution was insufficient to represent the local water-table features.

Because water-table elevations north and east of the Columbia River are much greater than on the Hanford Site and water-level changes are small relative to the regional water-table gradient, water-level measurements are not collected in all offsite monitoring wells each year. The June 1997 map of water-table elevations for the Hanford Site and outlying areas is presented in Figure 3.3-1. The contour intervals are 2 m on the Hanford Site west and south of the Columbia River. A 50-m contour interval was used north and east of the river because the water-table gradients are much steeper. Contours of the water-table surface north and east of the Columbia River were constructed based on June 1995 and June 1997 water-level measurements. Changes in the elevation of the water-table surface in this area is strongly controlled by recharge from canal seepage and applied irrigation (Drost et al. 1997). The water table in some parts of Franklin County has risen by more than 150 m since 1948, when the South Columbia Basin Irrigation District began operation. However, trend plots indicate that water levels in most wells in this area have reached a state of equilibrium (Drost et al. 1997) and thus do not change significantly, relative to the water-table gradient, from year to year.

A preliminary map of the potentiometric surface for March 1993 was provided in PNL-8869. An updated map was prepared using data for June 1996. The map was constructed by manually contouring the values of water-level elevations. The contour intervals are 3 m on the Hanford Site west and south of the Columbia River and are variable north and east of the river. Groundwater flow in the upper basalt-confined aquifer is discussed in Section 3.10.

The RCRA regulations require an annual determination of the direction and rate of groundwater or contaminant movement for sites in assessment- or compliance-level monitoring (40 CFR 265.94[b][2], WAC 173-303-645[10][e]). For most of the RCRA sites described in this chapter, the rate of groundwater flow is estimated using a form of the Darcy equation

$$V = Ki/n_e \tag{3.1}$$

where V = average linear groundwater velocity, m/d
K = hydraulic conductivity, m/d
i = hydraulic gradient
n_e = effective porosity.

Representative values of hydraulic conductivity, effective porosity, and current (FY 1997) hydraulic gradient were used for each site. Values of hydraulic conductivity were taken from published hydrologic test results that best represent the uppermost part of the unconfined aquifer. The value for effective porosity was chosen within the range of values (i.e., 0.1 to 0.3) typical for unconfined aquifer conditions. The hydraulic gradient was estimated from the wells monitoring the RCRA facility. However, for some sites where the slope of the water table is too gentle, the hydraulic gradient was uncertain; thus, it was estimated from the regional water-table contours.

Estimates of groundwater-flow rates and directions for the RCRA facilities are presented in Table 3.3-1. In some cases, other methods were used to estimate groundwater- or contaminant-flow rates and direction, including the migration of contaminant plumes or numerical groundwater-flow modeling. Contaminant plume maps were used to estimate groundwater-flow directions to confirm or provide better confidence than flow directions determined by the water-table contours. Groundwater-flow meters have been used in the past, but are not currently used regularly.

3.3.2 Interpretation of Water-Table Data

The June 1997 water-table map for the Hanford Site was shown in Figure 3.3-1 and Plate 2. Figure 3.3-1 also showed the water table north and east of the Columbia River. This section describes general groundwater-flow patterns on the Hanford Site. Water-table features at various locations are discussed in more detail in Sections 3.4 through 3.9.

The water table for the unconfined aquifer system beneath the Hanford Site is generally located in the unconsolidated to semiconsolidated Ringold and Hanford formations (see Figure 3.1-3). The Ringold and Hanford formations have vastly different hydrologic properties (see Section 3.2.2). Steep gradients in the western region of the Hanford Site are due to groundwater recharge at the western edge of the Pasco Basin and to lower hydraulic conductivities than at the eastern region of the site. Possible sources of recharge include infiltration of runoff from rain and snowmelt at higher elevations and irrigation of offsite agricultural land in the Cold Creek Valley. Steep gradients north and east of the Columbia River 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 at the river. However, unusually high-river stage along the Hanford Reach in FY 1997 resulted in increased bank storage and diverted groundwater flow near the riverbank.

Wastewater discharge to the ground associated with Hanford Site operations resulted in groundwater mounding and significantly affected the groundwater-flow system on the Hanford Site. Past discharges at

U Pond and smaller discharges to other 200-West Area disposal facilities are apparent from the shape of the contours passing through the 200-West Area. The steep gradient just east of the 200-West Area results partially from this groundwater mounding and partially from the relatively low transmissivity (from low hydraulic conductivity and aquifer thinning) of the aquifer in this area. The hydraulic gradient decreases abruptly between the 200-West and 200-East Areas, corresponding to an increase in transmissivity caused by the presence of the highly permeable Hanford formation sediments below the water table. The steep gradient in the gap between Umtanum Ridge and Gable Butte results partially from recharge coming from Cold Creek Valley, groundwater mounding in the 200-West Area, and restriction of the unconfined 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, except for the groundwater mound around B Pond where process cooling water and other liquid wastes were discharged to the ground. The presence of highly permeable sediments of the Hanford formation below the water table results in a relatively flat water table in spite of the large discharges in past years. For the past several years, the annual volumes of discharges to the soil column resulting from 200-East Area operations is significantly higher than discharges from 200-West Area operations (see Section 3.2.1).

A local groundwater mound exists ~2 km north of Gable Mountain (between Gable Mountain and the 100-F Area). Jenkins (1922) reported the area of elevated groundwater levels, which have persisted to the present, long before the Hanford Site was established. Data suggest that this mound is associated with a subsurface topographic “high” of low-permeability sediments (primarily clay) of the Ringold Formation. One likely source of recharge is conveyance losses associated with past seasonal irrigation use of the Hanford Canal that transversed the groundwater mound area between 1908 and 1943. Other potential sources of recharge that may contribute to the groundwater high include upwelling from the upper basalt-confined aquifer and infiltration from surface runoff. The slow dissipation of the recharge water is attributed to the presence of significant thicknesses of clay in the Ringold Formation sediments. There is insufficient information to distinguish whether the groundwater in this area is locally perched or is part of the regional unconfined groundwater-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 m above mean sea level at Wanawish (formerly Horn Rapids) Dam. This implies that infiltration from the Yakima River recharges the unconfined 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 offsite areas east of the Yakima River may also recharge the unconfined aquifer system in this area. Operation of the City of Richland’s North Well Field recharge basins resulted in a groundwater mound in the Richland North Area.

3.3.3 Changes in Water Levels

This section describes changes in the water table over the periods 1944-1979, 1979-1995, and 1996-1997. 1944 was chosen to illustrate the water table before it was affected by Hanford Site effluent discharges. 1979 is representative of maximum, steady volumes of effluent discharge. 1995 marks the reduction and consolidation for many waste streams. The 1996-1997 changes are discussed to illustrate the most recent variations in Hanford Site water-table elevations. A discussion of variations in the water-table from 1995-1996 can be found in Section 5.3 of PNNL-11470.

Between 1944 and 1979, water-level elevations at the Hanford Site increased in most areas, with the greatest increases occurring near facilities where wastewater was discharged to the ground (Figure 3.3-2). Groundwater mounds associated with wastewater discharge to the ground formed in the 100, 200, and 300 Areas and in parts of the 600 Area. The two most prominent formed near U Pond in the 200-West Area and near B Pond in the 200-East Area. Figure 3.3-3 shows the volume of wastewater discharged to the ground in each of the major Hanford Site operational areas and net recharge (infiltration less pumping) of Columbia River water at the City of Richland's North Well Field recharge basins from 1944 through 1996. This figure does not include large volumes of water discharged at the 100 Areas in the 1940s, 1950s, and 1960s. Figure 3.3-3 indicates that, in the past, the largest volumes discharged to the soil column occurred in the 200-East and 200-West Areas, which corresponds to the two most prominent groundwater mounds. These mounds altered the natural flow pattern of the unconfined aquifer system. Water levels in the unconfined aquifer system changed continually during Hanford Site operations because of variations in the volume and location of wastewater discharged to the ground. Consequently, the movement of groundwater and its associated constituents also changed with time. Figure 3.3-4 shows the discharge locations of the major past and present waste streams at the Hanford Site.

Reduced wastewater discharge to the soil column resulted in declining water levels for most of the Hanford Site. Figure 3.3-5 indicates that the greatest water-level-elevation decline from 1979 through 1995 occurred in the 200-West Area near U Pond. The trend of declining water levels in most areas of the Hanford Site continued from June 1995 through June 1997. The declining trend between June 1995 and June 1996 is shown in Section 5.0 of PNNL-11470. The areas of greatest water-level-elevation decline between June 1996 and June 1997 occurred in the 200-West Area near the former location of U Pond, in the area near B Pond, and in the area near the city's north well field (Figure 3.3-6).

The Columbia River stage was unusually high throughout most of FY 1996 and FY 1997, resulting in a rising water table near the river. Unusually high-river stage resulted in increased bank storage and diverted groundwater flow near the riverbank. River stage was higher than the elevation of the adjacent water table throughout most of FY 1997, which indicates that groundwater flow did not discharge to the river during those times. River stage affected groundwater flow in the 100, 300, and Richland North Areas and is discussed in Sections 3.5 and 3.8.

3.4 Hydrogeology of Upper Cold and Dry Creek Valleys

D. R. Newcomer, S. P. Reidel

The upper Cold Creek Valley is a narrow valley that lies between Umtanum Ridge to the north and Yakima Ridge to the south. The valley is controlled by the Yakima Ridge fault, a thrust fault along the north side of Yakima Ridge. A thin veneer of sediments overlies the basalt bedrock in the upper valley. Springs occur along the valley floor, are controlled by the fault, and provide limited recharge to Cold Creek. To the east where the valley widens, the veneer of sediments above the basalt thickens into the Cold Creek depression. Upper Cold Creek sediments are primarily alluvia; farther east, the basalt is overlain by the Ringold and Hanford formations. Sporadic flash flooding in upper Cold Creek has resulted in debris flows at the surface on the western part of the Hanford Site.

Dry Creek Valley lies between the Rattlesnake Hills-Snively Basin area to the south and Yakima Ridge to the north. The upper portion of Dry Creek flows on a thin veneer of alluvium overlying

Columbia River basalt; farther east, these sediments increase in thickness into the Cold Creek depression. Suprabasalt sediments consist of the Ringold Formation; the Hanford formation Touchet Beds; alluvial fan deposits shed off the Rattlesnake Hills; and a thick, ~10-m deposit of post-Missoula flood alluvium. The suprabasalt sediments have been incised 10 m in the past 10,000 years by Dry Creek. Dry Creek emerges from the sediments as a spring (Rattlesnake Spring) and flows east for several kilometers until it disappears beneath the Hanford formation. Secondary streams supplied by spring lines along faults on the Rattlesnake Hills provide water for Dry Creek.

The water table in the western part of the Hanford Site may have responded to irrigation practices in the upper Cold Creek Valley (PNL-5506). Figure 3.4-1 shows a hydrograph of well 699-43-104, located downgradient from the irrigated fields in upper Cold Creek Valley. The hydrograph indicates that the water table declined steadily between 1988 and 1997. The water-level decline between 1988 and 1997 may have been caused by decreased recharge resulting from changes in irrigation practices at Ste. Michelle Vineyards, upgradient of the site. Between 1982 and 1983, the vineyards converted their irrigation system from sprinkler to drip, which reduced consumption between 40% and 50% (PNL-7498). Declining water levels in the unconfined aquifer also may have been associated with decreases in the hydraulic heads of the underlying confined aquifers in this area. It is estimated that the hydraulic heads in the upper basalt-confined aquifer dropped more than 55 m in the Cold Creek Valley since the early 1900s (DOE/RW-0164). Thus, the upward gradient from the confined to the unconfined aquifer is not as strong as it once was. Well construction may also be a factor. Well 699-43-104 was open originally to both the unconfined and the upper basalt-confined aquifers (1957 to 1978). In 1978, a cement plug was placed in the well but was removed sometime before 1994. In 1994, a cement plug was placed in the bottom of the well casing to isolate the basalt section and prevent aquifer intercommunication (PNL-10195). In 1997, the water level rose ~0.4 m. At this time, it is uncertain what the causative factors are for this recent increase in water level.

The relationship of the water table to the top of the basalt surface in upper Dry Creek Valley was reevaluated for this report. Based on an elevation contour map of the top of basalt and the June 1997 water-level data from wells 699-26-89 and 699-19-88, it was inferred that groundwater exists above the basalt surface in a small saddle at the western end of the Yakima Ridge extension (see Plate 2).

3.5 Hydrogeology of 100 Areas

M. J. Hartman, J. W. Lindberg, D. R. Newcomer, M. D. Sweeney

The 100 Areas include 6 separate areas where retired plutonium-production reactors and associated support facilities are located. The hydrogeology of these areas is somewhat unique because of their location along the Columbia River in the northern part of the Hanford Site. The unconfined aquifer in the 100-B,C, 100-K, 100-N, and 100-D Areas is composed of either the Unit E Ringold gravels or Unit E combined with the Hanford gravels, depending on the location of the water table (BHI-00917). In the 100-H and 100-F Areas, Ringold Unit E gravel is missing and the Hanford formation lies directly on the paleosol/overbank deposits of the Ringold Formation. In most of the 100 Areas, this unit forms a local aquitard, and the Ringold gravels below this mud are locally confined. Additional information on the hydrogeology of the 100 Areas is presented in BHI-00917, WHC-SD-EN-TI-023, and WHC-SD-EN-TI-294.

The water table in the 100 Areas is shallower than in the more-elevated central regions of the Hanford Site. The depth to groundwater ranges from <1 m adjacent to the river to >30 m farther inland. Groundwater flow is generally toward the river in these areas, particularly during low-river stage. However, in some areas along the river (e.g., west of 100-B,C Area), groundwater flow appears to approximately parallel the river during most of the year. This may reflect the influence of buried river-channel deposits. Groundwater mounds resulting from previous disposal of wastewater also influenced groundwater flow in some areas in the past.

In FY 1997, the greatest groundwater-level changes in the 100 Areas were in response to Columbia River stage (see Plate 2). Changes in Columbia River stage also cause periodic reversals in the direction of groundwater flow immediately adjacent to the river. River stage was unusually high in the spring and summer of 1997, as shown in the river-stage hydrographs constructed from pressure transducer data for the 100-B,C, 100-N, 100-H, and 100-F Areas (Figure 3.5-1). When the river stage is higher than the water table in the adjacent aquifer, water moves into the banks of the river, resulting in bank storage. When the river stage drops, water moves back toward the river, often appearing as riverbank seepage. The distance that water moves into the aquifer from the river depends on the magnitude in river stage above groundwater elevation, the hydraulic properties of the aquifer, and the duration of the elevated river stage. The reversal of flow adjacent to the river also causes a pressure pulse in the aquifer that affects water levels in wells up to several hundred meters inland. The effects of bank storage on contaminant transport in the 100 Areas are discussed in Chapter 5.0.

3.5.1 100-B,C Area

The stratigraphy beneath the 100-B,C Area consists of the Hanford and Ringold Formations. The thickness of the Hanford formation is uncertain because the contact between it and the underlying Ringold Formation is not well defined. The Hanford formation, a gravel-dominated sequence with sandy and silty intervals, was reported to range from ~14 m near the Columbia River to over 30 m thick in the southern part of the area (Newcomb et al. 1972, WHC-SD-EN-TI-133). The Ringold Formation includes Unit E and the underlying paleosols and overbank deposits (BHI-00917, WHC-SD-EN-TI-133). Unit E, which varies in thickness across the 100-B,C Area, is dominated by silty, sandy gravel with subordinate sand- and silt-dominated interbeds.

The unconfined aquifer beneath the 100-B,C Area lies within silt, sand, and gravels belonging primarily to the Ringold Formation and is ~34 m thick. The upper portion of the unconfined aquifer lies locally within the lowermost Hanford formation. The top of the paleosols and overbank deposits of the Ringold Formation form the bottom of the unconfined aquifer. The depth to the water table varies from <1 m near the river to >30 m farther inland. Local confined aquifers lie within the Ringold Formation between the paleosol/overbank deposits and the top of the basalt.

River-stage fluctuations dominate groundwater flow beneath the 100-B,C Area. The direction of groundwater flow within the unconfined aquifer is generally north toward the Columbia River. However, the flow direction periodically shifts to the southeast when river stage is high (see inset on Plate 2). During this high-river stage, the groundwater gradient was estimated to be 0.0004. Hydraulic conductivity of the unconfined aquifer in the 100-B,C Area ranges from 4.3 to 17 m/d (BHI-00917). Using this range for hydraulic conductivity, the 0.0004 gradient, and an estimated effective porosity of 0.2, the groundwater-flow velocity ranges from 0.03 to 0.009 m/d.

3.5.2 100-K Area

Geologic units beneath the 100-K Area from the surface downward include eolian silty sand, Hanford formation (sandy gravel, gravelly sands, sand), Ringold Formation Unit E (sandy gravel, gravelly sand), and Ringold Formation paleosols and overbank deposits (silt, sandy silt) (WHC-SD-EN-TI-155). The water table is at ~22 m below ground surface near the 105-KE and 105-KW Reactor buildings, within Unit E. Locally, the bottom of the unconfined aquifer is the top of the paleosols and overbank deposits at ~49 m below ground surface (WHC-SD-EN-TI-294).

Groundwater in the unconfined aquifer generally flows from the southeast to northwest toward the river in the 100-K Area. However, the flow direction occasionally changes when the river stage is high. In FY 1997, the unusually high-river stage caused groundwater to flow east near the riverbank and north to northeast farther inland (see Plate 2). Effects of river stage on groundwater levels typically range over a 2-m rise along the riverbank and gradually decrease to a fraction of a meter at 1,000 m from the riverbank. In FY 1997, groundwater levels ranged over a 3-m rise near the river. The horizontal hydraulic gradient typically varies between 0.003 (high-river stage) and 0.005 (low-river stage), depending on Columbia River stage. Hydraulic conductivity of Ringold Formation Unit E ranges from 0.98 to 44 m/d (BHI-00917, WHC-SD-EN-TI-294). Using a geometric mean of 6.1 m/d for hydraulic conductivity, the 0.003 to 0.005 gradient, and an estimated 0.2 effective porosity, the average groundwater velocity ranges from 0.09 to 0.15 m/d.

3.5.3 100-N Area

The 100-N Area is the most recently active of the reactor areas and includes three RCRA-regulated liquid waste-disposal facilities that affected groundwater flow (1301-N, 1324-N/NA, and 1325-N; see Plate 1). All of the wells monitoring these facilities are completed at shallow depths, but deep boreholes drilled for characterization in the 1970s provided information on stratigraphy.

The unsaturated zone in the 100-N Area lies in the Hanford formation and the upper part of the Ringold Formation. The unconfined aquifer is contained in the sands and gravels of Ringold Unit E. The depth to the water table in the 100-N Area varies from <1 m near the Columbia River to ~21 m farther inland. The base of the unconfined aquifer is a clay-rich unit ~12 m beneath the water table. One well is completed in a thin sand unit within this clay. Although no wells are completed in sandy units deeper in the Ringold Formation, information from deep boreholes near the 100-N Area indicate that these units may also act as local confined aquifers. Basalt lies at a depth of ~150 m below ground surface. The hydrogeology of the 100-N Area is described in more detail in WHC-SD-EN-EV-027.

When the major liquid-waste-disposal units in the 100-N Area were active, the water table in the entire area was elevated by up to 7 m (see Figure 3.13 in WHC-SD-EN-EV-027). Discharge to all the facilities ceased by 1991, resulting in a sharp water-table decline in the early 1990s and stabilization by 1994. The water table fluctuated up to 2.5 m beneath the 100-N Area RCRA sites during FY 1997 in response to changes in river stage (Figure 3.5-2).

Groundwater normally flows toward the northwest (toward the river) beneath the 1301-N and 1324-N/NA facilities and toward the north beneath the 1325-N facility (Figure 3.5-3). During the past year, however, high-river stage affected the gradient, resulting in changes in groundwater-flow directions.

In June 1997, the hydraulic gradient sloped toward the southeast beneath 1301-N and toward the east beneath 1324-N/NA (see Plate 2). The water-table map indicates that flow beneath 1325-N converged from the northwest and southwest and flowed to the east. In FY 1997, estimated groundwater-flow rates ranged between 0.001 and 1.1 m/d during high-river stage and between 0.007 and 0.84 m/d during low-river stage (see Table 3.3-1). These groundwater-flow rates are based on a hydraulic conductivity range of 6.1 to 37 m/d (PNL-8335).

A pump-and-treat system was active in the 100-N Area during FY 1997. Water was extracted from wells near the 1301-N facility and reinjected into a well or wells near the 1325-N facility (see Plate 1).

Vertical gradients are not well known in the 100-N Area. Wells adjacent to the Columbia River show an upward gradient in the unconfined aquifer (WHC-SD-EN-EV-027). Farther inland, there is no significant difference in head between wells completed at the water table and wells completed at the base of the aquifer, which are ~6 m deeper. Limited data prevent a clear comparison of vertical heads in the unconfined and shallowest locally confined Ringold Formation aquifers.

3.5.4 100-D Area

The unsaturated zone in the 100-D Area lies in the Hanford formation and the upper portion of the Ringold Formation. The unconfined aquifer is a sand and gravel unit, ~3 to 9 m thick, which corresponds to Ringold Unit E. Depth to the water table varies from <1 m near the river to ~25 m farther inland. The base of the aquifer is a fine-grained overbank interval, which is ~15 m thick. The deeper Ringold Formation is believed to comprise more layers of clay, silt, and sand, based on interpolations between wells elsewhere in the 100 Areas. The depth to basalt is inferred to be ~125 m (DOE/RL-92-71).

Groundwater in the unconfined aquifer beneath the 100-D Area generally flows toward the north and northwest (Figure 3.5-4). However, prolonged high-river stage resulted in a reversed gradient with flow toward the southeast in 1997 (see Plate 2).

The 120-D-1 ponds are a small RCRA site that was formerly used for disposal of effluent from a water-treatment plant in the 100-D Area. Water levels in three of the wells that monitor these ponds are plotted in Figure 3.5-5. The water table responded to changes in river stage and fluctuated up to 1.7 m during FY 1997. During times of high-river stage, the head in the downgradient wells, as defined in the RCRA groundwater-monitoring plan, is higher than in well 199-D5-13, defined as an upgradient well (WHC-SD-EN-AP-048). Estimated groundwater-flow rates ranged between 0.0084 and 0.8 m/d (reversed gradient) during high-river stage and between 0.0014 and 0.14 m/d during low-river stage (see Table 3.3-1).

Groundwater remediation of a chromium plume in the 100-D Area began in the summer of 1997. Water was extracted from wells in the northern part of the area near the river (see Plate 1), treated, and reinjected in the 100-H Area.

An upward vertical gradient was estimated to range from 0.007 to 0.02 between wells 199-D8-54A and 199-D8-54B in 1993 (Section 3.3 in DOE/RL-93-88). Well 199-D8-54A is completed across the water table, and well 199-D8-54B is completed 22.6 m deeper than well 199-D8-54A in a thin layer of silty sand that is confined beneath 15 m of clay. Well 199-D8-54A is now an extraction well, increasing the upward gradient in the vicinity.

3.5.5 100-H Area

The unsaturated zone in the 100-H Area lies completely in the Hanford formation. The unconfined aquifer in the 100-H Area resides in unconsolidated sands and gravels of the Hanford formation. Depth to the water table ranges from <1 m near the river to ~12 m farther inland. The saturated portion of the Hanford formation ranges in thickness from 2 to 6 m (Peterson and Connelly 1992). Hydraulic conductivity is high, ranging up to 1,800 m/d (PNL-6728). This hydrogeologic unit is underlain by the more-consolidated fluvial sands and overbank deposits of the Ringold Formation, which have much lower hydraulic conductivity. Ringold gravels below this unit are locally confined. Depth to basalt is ~96 m. A comprehensive description of 100-H Area stratigraphy is presented in WHC-SD-EN-TI-132.

The 183-H solar evaporation basins were used to treat and dispose RCRA waste during the 1970s and 1980s. The general direction of groundwater flow beneath the basins under normal river-stage conditions is toward the east (toward the Columbia River) (Section 3.3 in DOE/RL-94-136). The prolonged period of high-river stage in 1997 influenced groundwater flow in the area, creating a potential for groundwater to flow toward the southwest (see Plate 2). Estimates of groundwater-flow rates during FY 1997 ranged between 0.12 and 3.2 m/d during high-river stage and between 0.13 and 3.5 m/d during low-river stage (see Table 3.3-1). Water levels in three of the wells that monitor the basins are plotted in Figure 3.5-6. The water table responded to changes in river stage and fluctuated up to 3.5 m during FY 1997. When river stage is very high (e.g., June 1997), the head in wells 199-H4-3 and 199-H4-4, defined as downgradient wells according to the RCRA groundwater-monitoring plan, is higher than in well 199-H3-2A, defined as an upgradient well (WHC-SD-EN-AP-180).

Groundwater remediation of a chromium plume in the 100-H Area began in the summer of 1997. Water was extracted from five wells, treated, and reinjected into three wells in the southwestern part of the area (see Plate 1).

3.5.6 100-F Area

The unsaturated zone and unconfined aquifer in the 100-F Area lie in the Hanford formation (BHI-00917). The unconfined aquifer in the 100-F Area lies within unconsolidated sediments in the lower part of the Hanford formation. Sandy gravel and silty sandy gravel dominate these sediments. Underlying the Hanford formation are the Ringold paleosols and overbank deposits, which are dominated by silt and clay with sandy interbeds. The top of the paleosol/overbank deposits locally forms the bottom of the unconfined aquifer in the 100-F Area. The unconfined aquifer thickness ranges up to a maximum of 9 m. Depth to the water table ranges from <1 m near the river to ~14 m farther inland. The depth to the top of the basalt is estimated to be ~110 m below ground surface.

River-stage fluctuations dominate groundwater flow beneath the 100-F Area. The general direction of unconfined groundwater flow beneath the 100-F Area under normal river-stage conditions is east toward the Columbia River (BHI-00917). However, prolonged high-river stage resulted in groundwater flow toward the southwest near the river and toward the southeast farther inland (see inset on Plate 2).

During the high-river stage in June 1997, the groundwater gradient was estimated to be 0.0003 near the center of the 100-F Area where flow is to the southeast. Hydraulic conductivity of the Hanford formation in the 100-F Area ranges from 9.1 to 69 m/d (BHI-00917). Using this range for hydraulic conductivity, the 0.0003 gradient, and an estimated effective porosity of 0.2, the groundwater-flow velocity ranges from 0.01 to 0.10 m/d.

3.6 Hydrogeology of 200 Areas

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The 200-East and 200-West Areas, jointly referred to as the separations areas, are located on the central plateau of the Hanford Site. The geology and hydrology of these areas have been extensively studied because they contain major sources of groundwater contamination; RHO-ST-42 describes the hydrology. The hydrogeology of these areas was described in WHC-SD-EN-TI-019 and WHC-SD-EN-TI-014, respectively. These documents provide references to many other studies conducted to support specific projects.

The 200-West Area is underlain by sediments of the Hanford formation, the Plio-Pleistocene unit, and the Ringold Formation. The unconfined aquifer in this area lies almost entirely in Ringold Unit E gravels, the saturated portion of which varies from ~65 to >150 m. The Ringold lower mud unit, the top of which defines the base of the unconfined aquifer in much of the 200-West Area, is absent in an area immediately north of the 200-West Area (WHC-SD-EN-TI-014). Where the lower mud unit is absent, the top of the basalt defines the bottom of the unconfined aquifer. The depth to the water table in the 200-West Area varies from ~50 to >100 m.

In the 200-West Area, groundwater flows from the basalt ridges and Cold Creek Valley to the west of the Hanford Site and flows out primarily to the north and east (see Plate 2). The groundwater mound associated with U Pond dominates the water table in the 200-West Area. Water-level data, beginning in 1948 for well 699-39-79 located near U Pond, indicate that elevations rose steadily until 1957, then fluctuated somewhat until 1984, after which they began to decline steadily (Figure 3.6-1). The maximum elevation of this mound, which last occurred in 1984, was ~146 m above mean sea level (~20 m above preoperational conditions). Since 1984, water levels declined over 6 m because of reduced discharges to cribs and unlined trenches and are expected to continue to decline. Groundwater withdrawal and injection at pump-and-treat systems in the 200-West Area affected water levels locally. These systems are discussed in Section 5.9.

The 200-East Area is located on the southern flank of the Gable Mountain anticlinal structure (see Figure 3.1-1). Sediments lying on this structure in the 200-East Area include the Hanford and Ringold Formations. In the past, the water table was within the Hanford formation in much of the northern part of the 200-East Area (WHC-SD-EN-TI-019). However, as a result of recent declines in the water table, the water table in this area is now primarily contained within the Ringold Formation. In the central and northern parts of the 200-East Area, the unconfined aquifer lies mostly in Ringold Unit A gravels but also within remnants of the Ringold lower mud unit. In the southern part of the 200-East Area, the unconfined aquifer lies primarily in Ringold Unit E gravels. The depth to the water table in the 200-East Area varies from ~65 to 100 m. The thickness of the saturated zone above the top of the basalt varies from <10 m in the north to ~80 m in the south.

In most of the 200-East Area, the unconfined aquifer lies within gravels of the Hanford and Ringold Formations. Therefore, the aquifer transmissivity is generally higher. However, the water table has dropped below the bottom of the Hanford formation in much of the 200-East Area during the last few years. This has decreased the aquifer transmissivity in this area and altered groundwater-flow patterns (WHC-SD-EN-TI-019). Groundwater-flow patterns in the 200-East Area are also influenced by lower permeability units of the Ringold Formation, which extend above the water table in some areas of the 200-East Area.

In the 200-East Area, groundwater flows primarily to the northwest through Gable Gap (located between Gable Mountain and Gable Butte) and to the southeast toward the Columbia River (see Plate 2). The location of the divide between flow to the northwest and flow to the southeast is not discernible using water-level-elevation data because the water table in most of the 200-East Area and vicinity is nearly flat. The very gently sloping water table corresponds to a high transmissivity zone that extends through the 200-East Area (see Figure 3.2-2).

The water table in the 200-East Area and vicinity is nearly flat, except for a groundwater mound beneath B Pond (see Plate 2). At B Pond, groundwater flows radially outward from the mound. This mound is attributed to wastewater discharge to B Pond; however, hydrogeologic conditions beneath B Pond are controlling factors in the magnitude and extent of the mound. The aquifer beneath B Pond lies primarily within the Ringold Formation, which has significantly lower transmissivity than the Hanford formation. The aquifer beneath B Pond is locally confined to the south and southeast.

Water-level data beginning in 1949 for well 299-E26-1, located in the northeastern portion of the 200-East Area, indicate that water levels rose until 1965, declined slightly from 1972 to 1983, rose to a maximum elevation in 1988, and declined steadily from 1988 through 1997 (Figure 3.6-2). The water-table elevation has been declining since 1988 because wastewater discharges to disposal facilities in the 200-East Area and B Pond were reduced. During FY 1996, however, this decline in water-table elevation slowed, as indicated by the hydrographs of wells 299-E32-2 (northwestern corner of the 200-East Area) and 299-E34-2 (northeastern corner of the 200-East Area) (Figure 3.6-3). During FY 1997, the rate of decline increased.

The water-level declines in the 200-West and 200-East Areas affected the integrity of the monitoring well network for some of the RCRA facilities. For some monitoring wells, the head dropped below the bottom of the well screens. In other monitoring wells, the head is low and is expected to drop below the bottom of the well screens within the next few years, assuming the rate of water-level decline continues. The monitoring well network for these RCRA facilities is discussed in the following subsections.

An area of increased intercommunication between the unconfined aquifer and the upper basalt-confined aquifer was identified in the area north of the 200-East Area based on chemical and hydraulic head evidence (PNL-6313, RHO-RE-ST-12P). The increased communication is likely caused by local erosion of the upper basalt-confining layer in this area (RHO-RE-ST-12P).

3.6.1 216-S-10 Pond and Ditch

The stratigraphic section at the 216-S-10 pond and ditch, as represented by data from well 299-W27-2, includes the Hanford formation, the Plio-Pleistocene unit, and the Ringold Formation (WHC-SD-EN-DP-052). The Hanford formation is composed predominantly of sand with minor amounts of gravel and of rhythmically bedded silt and fine sand at the base. The Plio-Pleistocene unit contains caliche-cemented gravel. The Ringold Formation consists of the upper Ringold unit, Unit E, and the lower mud unit. The upper Ringoldd unit contains predominantly sand with minor amounts of gravelly sand. Unit E contains predominantly sandy gravel and gravelly sand. The lower mud unit contains predominantly silt.

The water table is in the lower part of the upper Ringold unit at a depth of ~68 m and is declining at ~0.4 m/yr (Figure 3.6-4). During the operation of U Pond, the groundwater-flow direction at this facility was toward the southeast to east-southeast because of the influence of the large groundwater mound emanating from U Pond. Now that the wastewater discharges have ceased to U Pond, the mound is declining and the groundwater-flow direction in the vicinity of this facility is returning to its prior direction (i.e., from west to east). The groundwater-flow rate is estimated to be 0.007 to 0.3 m/d (see Table 3.3-1).

3.6.2 216-U-12 Crib

The unsaturated sediments beneath the 216-U-12 crib are composed of unconsolidated sandy gravel and sand of the Hanford formation, sandy silt and silt of the Plio-Pleistocene unit, and silty sandy gravel to gravelly sand of Ringold Unit E. The unconfined aquifer is within the silty, sandy gravels of lower Ringold Unit E and is ~54 m thick. The depth to the water table is ~74 m below ground surface. The top of the Ringold lower mud unit defines the base of the unconfined aquifer beneath the crib. Details of the stratigraphy beneath the crib may be found in WHC-SD-EN-AP-108.

Water levels declined an average of 0.65 m during FY 1997 under this crib (Figure 3.6-5), just slightly greater than in FY 1996. Water levels continued to drop at this increased rate since 1995. The water table beneath this crib during June 1997 is illustrated in Plate 2, indicating that the groundwater flow is still in an east-southeast direction. While the direction of groundwater flow beneath the crib is relatively unchanged from FY 1996 to FY 1997, the average groundwater velocity has been slowly decreasing as a result of a slight flattening of the water table in the vicinity of the crib. The average gradient in FY 1997 was 0.0017. Estimates of linear groundwater velocity for September 1997 are 0.53 m/d (see Table 3.3-1).

3.6.3 200-West Area Single-Shell Tank Farms

In general, the single-shell tank WMAs in the 200-West Area are underlain by the Hanford and Ringold Formations. Groundwater monitoring wells in these WMAs are screened primarily in Ringold Unit E gravels, which contain the water table in these areas. A description of the stratigraphy beneath these tank farms may be found in Section 4.1.3 of DOE/RL-93-88, which also contains numerous cross-sections through the 200-West Area. Details of the stratigraphy beneath these tank farms may be found in WHC-SD-EN-AP-012, Rev. 0 and Rev. 1.

3.6.3.1 WMAs S-SX and U Single-Shell Tank Farms

The unsaturated sediments beneath WMAs S-SX and U are composed of the unconsolidated glacial flood deposits of the Hanford formation, the silts and sands of the Plio-Pleistocene unit, and the sands and gravels of Ringold Unit E. Depth to the water table is ~64 and ~68 m below ground surface at WMAs S-SX and U, respectively. The unconfined aquifer beneath these WMAs is contained entirely within the sands and gravels of Ringold Unit E and is ~65 and ~70 m thick, respectively. The top of the Ringold lower mud unit defines the base of the unconfined aquifer.

The strongest influence on groundwater levels and flow directions beneath these WMAs has historically been the groundwater mound beneath U Pond. Water-table elevations in the vicinity of these WMAs have fallen rapidly since the decommissioning of U Pond in 1985. Figure 3.6-6 shows hydrographs for wells 299-W19-1, located ~50 m southeast of the WMA U boundary, and 299-W23-4, located ~90 m west of the WMA S-SX boundary. These hydrographs indicate a 7.3- to 7.6-m drop in the water-table elevation between 1984 and 1995. Hydrographs in Figure 3.6-7 illustrate the water-level declines and elevation relationships between wells monitoring WMA S-SX. The hydrographs indicate that water-table elevations beneath WMA S-SX continue to decline at a rate of ~0.5 m/yr between June 1996 and June 1997 and during the remainder of FY 1997. Figure 3.6-7 also shows that the hydraulic gradient decreased with time. Plate 2 shows the water-table map of the 200-West Area, which includes these WMAs, for June 1997.

When U Pond was decommissioned in 1985, effluent discharge was diverted to other facilities, particularly the 216-Z-20 crib, which is located north of WMA S-SX. The result of the discharge to this crib was a shift in the peak of the declining groundwater mound northward toward the crib, thus changing the groundwater-flow direction under the WMA from approximately west to east to its present direction of southeast. Estimates of linear groundwater velocity beneath the WMA range from 0.004 to 0.55 m/d (see Table 3.3-1). The estimates of hydraulic conductivity used to calculate these velocities are believed to represent the lower range of hydraulic conductivity expected for Ringold Unit E; therefore, these groundwater velocities should be considered lower limits (Section 4.11 in DOE/RL-96-01).

Since the monitoring well network for WMA U was established in the early 1990s, the groundwater-flow direction under WMA U changed from slightly north of east to slightly south of east (see Plate 2). The rate of decline in the water-table elevation slowed as the result of several large discharges to the 216-U-14 ditch, located near U Plant, in 1991 and 1993 (WHC-EP-0698). In the case of the 1993 discharge, the recharge influx to groundwater temporarily reversed the direction of groundwater flow beneath WMA U toward the northwest (Section 4.11 in DOE/RL-96-01). This reversal in flow direction was facilitated by the greatly reduced discharge to the 216-Z-20 crib at that time (WHC-EP-0595). This reversal is illustrated graphically in Figure 3.6-8, which shows hydrographs for monitoring wells 299-W18-25 and 299-W19-32, located, respectively, in the southwestern and southeastern corners of WMA U (see Plate 1). While the water-table elevations were declining, the rate of decline in well 299-W19-32 slowed relative to that in well 299-W18-25, reversing the up- and downgradient relationships within the monitoring network in mid-1993. In late 1995, the original relationship was reestablished as a result of an increased rate of water-level decline in well 299-W19-32 relative to that in well 299-W18-25. The 216-Z-20 crib was active until 1995.

The effect of discharge to the 216-U-14 ditch is complicated because of the existence of perched water beneath the ditch. Figure 3.6-9 shows hydrographs of two wells (299-W19-91 and 299-W19-92) that monitor the perched water table beneath the ditch. The result of the 1993 discharge was a rapid 6-m rise in the level of the perched water table from a depth of ~34 to ~28 m below ground surface. The effect of this rapid rise is a greater lateral distribution of water as it drains downward from the perched water table. This is implied by the water-level trends following the 1993 discharge event, which shows a gradual decline in water levels (see Figure 3.6-9).

Estimates of groundwater-flow velocity within the unconfined aquifer beneath WMA U range from 0.1 to 0.7 m/d (see Table 3.3-1).

3.6.3.2 WMAs T and TX-TY Single-Shell Tank Farms

The unsaturated sediments beneath WMAs T and TX-TY are composed of the unconsolidated glacial flood deposits of the Hanford formation, the silts and sands of the Plio-Pleistocene unit, and the sands and gravels of Ringold Unit E. Depth to the water table is ~71 and ~66 m below ground surface at WMAs T and TX-TY, respectively. The unconfined aquifer beneath these WMAs is contained entirely within the sands and gravels of Ringold Unit E and is ~60 m thick. The top of the Ringold lower mud unit defines the base of the unconfined aquifer.

The groundwater-flow direction beneath WMAs T and TX-TY was primarily to the north when the groundwater mound developed beneath U Pond. As the mound began to recede following decommissioning of U Pond in 1985, the groundwater-flow direction shifted from the north to the northeast. In FY 1997, the groundwater-flow direction was to the northeast (see Plate 2). With further decline of the U Pond mound, the direction of groundwater flow beneath these WMAs is expected to shift to the regional west-to-east direction. At WMA T, the hydraulic gradient is 0.0013, and the estimated groundwater-flow velocity is 0.13 m/d (see Table 3.3-1). The gradient beneath WMA TX-TY is 0.0006, and the groundwater-flow velocity is estimated to range from 0.09 to 0.33 m/d (see Table 3.3-1).

Water-level-elevation trends for wells monitoring WMAs T and TX-TY are presented in Figures 3.6-10 and 3.6-11, respectively. The water-level trends are similar for both sets of hydrographs and show sharp increases in the rate of water-level decline in 1995. However, the hydraulic gradient at WMA TX-TY decreased; at WMA T it has not. The rates of water-level declines increased from ~0.2 to ~1.2 and ~0.3 to ~1.3 m/yr at WMAs T and TX-TY, respectively. These changes in the rate of decline coincide with the cessation of surface effluent discharge in the 200-West Area. In FY 1997, the rates of water-level declines slowed to ~0.6 and ~0.5 m/yr at WMAs T and TX-TY, respectively.

3.6.4 200-West Area Low-Level Burial Grounds

Burial grounds 218-W-3A, 218-W-3AE, and 218-W-5 make up Low-Level Waste Management Area 3 (LLWMA 3), which is located in the north-central portion of the 200-West Area (see Plate 1). LLWMA 4 is located in the south-central portion of the 200-West Area and comprises burial grounds 218-W-4B and 218-W-4C. LLWMA 5, located in the north-central portion of the 200-West Area, has not been monitored for groundwater since FY 1996 because the burial ground never received waste.

The 200-West Area burial grounds (LLWMA 3, 4, and 5) are underlain by the Ringold and Hanford formations. The unconfined aquifer is entirely within Ringold Unit E. There are indications that the aquifer is locally semiconfined beneath the northern portions of LLWMAs 3 and 5. Depth to the water table is ~67 and 64 to 74 m below ground surface at LLWMAs 3 and 4, respectively. The saturated thickness is ~62 to ~75 m beneath LLWMA 3 and is ~62 to ~72 m beneath LLWMA 4. At LLWMA 3, because of stratigraphic discontinuity, either the top of the Ringold lower mud unit or the top of the basalt defines the base of the unconfined aquifer.

The groundwater-flow direction beneath LLWMA 3 is to the northeast (see Plate 2). The eastward component is increasing with time, as expected, resulting from the decreased liquid disposal in the 200-West Area. The rate of groundwater flow beneath LLWMA 3 is estimated to be ~0.0003 to 0.14 m/d (see Table 3.3-1).

Water-level data from the two groundwater wells that monitor the base of the unconfined aquifer beneath LLWMA 3 indicate that the vertical groundwater gradient in this area is downward. The water-level elevations in shallow downgradient well 299-W7-2 are consistently greater, ~0.25 m, than those in nearby deep well 299-W7-3; this results in a downward gradient of ~0.004. Water-level elevations in shallow upgradient well 299-W10-13 are generally 0.15 m greater than in deep well 299-W10-14, for a downward gradient of 0.0027.

The groundwater-flow direction beneath LLWMA 4 has changed dramatically in the past year. Prior to FY 1996, the groundwater-flow direction had been primarily to the west, trending to northwest in the northern portions and slightly to the southwest in the extreme southern portion (Section 4.10 in DOE/RL-96-01). This flow direction was the result of past disposal practices in the 200-West Area. The groundwater mound created by liquid disposal has been declining in recent years, and the flow direction beneath LLWMA 4 in FY 1996, although uncertain, was estimated to be west-to-northwest. In FY 1997, the groundwater-flow direction reversed and is now primarily from west to east. The start of Phase II of the 200-ZP-1 Operable Unit carbon tetrachloride pump-and-treat program, which began in August 1996, further affects the groundwater-flow regime. Although the change in flow direction observed in FY 1997 was expected despite the pump-and-treat program, the pump-and-treat program may have hastened the change. Extraction at wells 299-W15-32, 299-W15-33, 299-W15-34, 299-W15-35, 299-W15-36, and 299-W15-37 to the east and injection at wells 299-W15-29, 299-W18-36, 299-W18-37, 299-W18-38, and 299-W18-39 to the west of LLWMA 4 are expected to influence groundwater flow in this area. More information on the pump-and-treat system, including a summary of its effects on groundwater flow, is included in Section 5.9.4.

The estimated groundwater-flow velocity beneath LLWMA 4 is 0.25 m/d (see Table 3.3-1). This is based on a hydraulic gradient beneath LLWMA 4 on the order of 0.001, an effective porosity of 0.1, and an average hydraulic conductivity of 24 m/d for the uppermost portion of the aquifer.

The vertical groundwater gradient in the unconfined aquifer beneath LLWMA 4 is downward based on water levels from the wells that monitor the base of the saturated zone (wells 299-W15-17 and 299-W18-22). The water levels in these wells are consistently lower than in the nearby wells monitoring the top of the unconfined aquifer. The differences are ~0.02 m between wells 299-W15-16 and 299-W15-17 and ~0.09 m between wells 299-W18-21 and 299-W18-22. Downward gradients of 0.00026 and 0.0012, respectively, were calculated for the paired wells.

3.6.5 216-A-10, 216-A-36B, and 216-A-37-1 Cribs

These cribs (also known as the plutonium-uranium extraction [PUREX] cribs) are located in the southeastern portion of the 200-East Area (see Plate 1). The ground surface is relatively flat, but slopes gently toward the north. Elevation of the ground surface ranges from ~220 m near the 216-A-10 and 216-A-36B cribs to ~205 m near the 216-A-37-1 crib.

The general stratigraphy in the vicinity of these cribs includes, from the surface downward, a discontinuous and thin veneer of Holocene-Age eolian sand, the Hanford formation, and the Ringold Formation (PNNL-11523). The Hanford formation consists predominantly of sand, but contains substantial percentages of gravel in the lowermost and uppermost portions of the unit. The Ringold Formation contains thick layers of river gravel intercalated with sequences of overbank silts and fine-grained paleosols.

Although the stratigraphy at all three crib sites contains the general stratigraphic sections described above, there are differences between the 216-A-10 and 216-A-36B cribs and the area near the 216-A-37-1 crib. To the southwest near the 216-A-10 and 216-A-36B cribs, the Ringold Formation contains three mappable units, including coarse-grained fluvial Units A and E (WHC-SD-EN-TI-012) that are separated with the fine-grained lower mud unit. However, in the vicinity of the 216-A-37-1 crib (northeast), the lower mud unit and Unit E are missing (pinched out). There, the Hanford formation rests directly on Ringold Unit A.

Near the 216-A-10 and 216-A-36B cribs, the unconfined aquifer is in the saturated portion of Ringold Unit E. The water table lies at ~122 m above mean sea level. The base of the unconfined aquifer is the top of the lower mud unit at ~100 m above mean sea level. Monitoring wells are screened entirely in the unconfined aquifer. Below the lower mud unit, Ringold Unit A forms a locally confined aquifer, which is ~24 m thick. Near the 216-A-37-1 crib, the unconfined aquifer is within the lowest portion of the Hanford formation or the upper part of the Ringold Formation (Unit A). The lower mud unit is not present, so the saturated zone is entirely unconfined to the base of the Ringold Formation at ~85 m above mean sea level. Therefore, the thickness of the unconfined aquifer system near the 216-A-37-1 crib is ~37 m.

Groundwater-flow direction in the area northeast of the PUREX cribs, interpreted from water-table maps, is predominantly from the northeast to the southwest because of the influence of B Pond, where groundwater is flowing radially outward. However, to the west and northwest, the water table is extremely flat, making estimates of groundwater-flow direction and rate difficult. Estimates from contaminant plume maps suggest that the groundwater-flow direction in the area west and northwest of the PUREX cribs is to the southeast. Therefore, groundwater from the B Pond area most likely joins groundwater from the west and northwest (200-East Area) and flows toward the south and southeast. The flow rate beneath the 216-A-10 and 216-A-36B cribs is estimated to be between 0.05 and 0.1 m/d. Flow-rate estimates beneath the 216-A-37-1 crib range from 0.2 to 0.4 m/d (see Table 3.3-1).

3.6.6 216-A-29 Ditch

The stratigraphy underlying the 216-A-29 ditch consists of the Hanford and Ringold Formations. The Hanford formation, ~85 m thick, is predominantly composed of a loose, sandy, pebble-cobble gravel and a gravelly sand with a thick layer of sand and/or muddy sand. The sand-dominated facies occur between sequences of gravel-dominated facies west to east along the margin of the ditch (WHC-SD-EN-TI-019, WHC-SD-EN-TI-071). Where this occurs, the Hanford formation is subdivided into an upper gravel sequence, a sandy sequence, and a lower gravel sequence. The top gravel unit is discontinuous north and south of this ditch. Sediments of the Ringold Formation consist of Units A and E gravel and sand sequences and the lower mud unit (WHC-SD-EN-TI-019, WHC-SD-EN-TI-071, WHC-SD-EN-TI-290). The unconfined aquifer beneath the ditch lies mainly within the gravelly sediments of Ringold Unit A. The saturated thickness ranges between ~2 m at the discharge (lower) end of the ditch to ~24 m at the head (upper) end. The depth to the water table is ~76 m below ground surface.

The direction of groundwater flow beneath the ditch is west-southwest at ~S 60° W, based on tritium and nitrate plume maps (Plates 3 and 4, respectively) and on water-level elevations in the monitoring wells. The tritium plume map (see Plate 3) shows that the groundwater-flow direction swings to the southeast as groundwater flows to the southeastern corner of the 200-East Area. The groundwater gradient was estimated to be ~0.0001 at the headend of the ditch and yielded a groundwater velocity of 0.009 m/d (see Table 3.3-1). At the discharge end of the ditch, the 0.003 gradient yielded a groundwater velocity of 0.063 m/d (see Table 3.3-1). The gradient, and hence groundwater velocity, at the discharge end of the ditch is higher than at the headend because the discharge end lies near the steep western flank of the B Pond groundwater mound.

The water table beneath the ditch has declined significantly since discharges to the B Pond system decreased. Figure 3.6-12 shows that water levels are continuing to decline in wells monitoring the head and discharge ends of the ditch.

3.6.7 216-B-3 Pond

The shallowest aquifer beneath B Pond occurs primarily within sediments of the Ringold Formation. The vadose zone under most of the facility is composed of Hanford formation sediments. Ringold Formation sediments here consist of Unit A gravel and the lower mud unit, which is discontinuous in this area. The Hanford formation consists of silty sand to sand and gravel. The water table is generally near the contact between the Hanford and Ringold Formations, and the aquifer is locally confined, especially to the south and southeast of the pond. Depths to the water table range from ~30 m northeast to ~72 m southwest of the main pond.

Groundwater flows essentially radially outward from the groundwater recharge mound, the apex of which is located in the vicinity of the 216-B-3B expansion pond (see Plate 2). Large volumes of wastewater recharging the aquifer and significantly altering the original groundwater-flow pattern of the area created the mound. In the past, the mound was even more extensive than at present because of larger volumes of effluent discharge to the system. As the rate of effluent discharge decreased, water levels in wells within the influence of the mound generally declined with time. Based on June 1997 water-level measurements, the horizontal component of hydraulic gradient near B Pond is estimated to be from ~0.001 northeast of the mound apex to ~0.005 west-southwest of the former location of the main pond.

During FY 1997, the decline of water levels in most wells in the network accelerated noticeably. The most dramatic water-level declines occurred in wells 699-42-39A, 699-43-43, and 699-44-39B, all of which fell ~1 m during the period. This trend is illustrated in the composite hydrograph of Figure 3.6-13.

The projected life of wells at the Hanford Site (PNL-10196) was modeled using the Coupled Fluid, Energy, and Solute Transport (CFEST) model. In the B Pond-monitoring network, 7 wells were predicted to be dry before the year 2000. Most of the wells projected to be dry are located near the main pond. Three of the wells having the greatest drop in water levels during FY 1997 coincide with those predicted to go dry. The water level in well 699-44-42 apparently fell below the pump intake during FY 1997.

The Variably Saturated Analysis Model in Three Dimensions with Preconditioned Conjugate Gradient Matrix Solvers (VAM3DCG) numerical modeling code was used to predict future water levels in the aquifer beneath B Pond as they respond to diversion of effluent from the main pond to the 216-B-3C expansion pond (WHC-EP-0813). This model forecasted that the water table beneath the main pond would fall by as much as 1.5 m from 1992 to 1997 and that, during the same period, a new groundwater recharge mound ~0.5 m in height would develop beneath the 216-B-3C expansion pond. In fact, water levels in wells near the main pond have fallen by a substantial amount during the modeled period, though by less than predicted. No detectable mound has developed in the aquifer beneath the 216-B-3C expansion pond. Furthermore, no wells are installed above the Ringold lower mud unit in the B Pond-monitoring network. This region, from the lower mud unit to the surface, was initially within the unsaturated zone. However, it must be assumed that since discharges were diverted to the 216-B-3C expansion pond, an artificial, perched aquifer has been created beneath the site. Most wells around B Pond do display an abrupt rise in water levels from early 1994 to mid-1995, but it is uncertain whether this rise is due to the shift of effluent to the 216-B-3C expansion pond or is a reflection of earlier discharges to the main pond site. Interpretations of the water table/potentiometric surface indicate that the center of the mound remained essentially in the same location for several years.

Estimates of groundwater-flow rates near the B Pond system are mostly based on numerical modeling and by the tracking of tritium migration from the 200-East Area operations to the Columbia River (PNL-6328, PNWD-1974 HEDR). The average horizontal groundwater-flow rate determined by these methods is estimated to range from 0.2 to 2.7 m/d (see Table 3.3-1).

The vertical hydraulic gradient was calculated for four well pairs in the network, representing deep and shallow completions. All four pairs indicate a downward hydraulic gradient. Because the screens in each of these wells are open to several meters of aquifer thickness, potentiometric measurements used for the calculations should be considered approximations. The well pairs and the calculated approximate vertical hydraulic gradients for March 1997 are, respectively, wells 699-40-40A/B, 0.02; wells 699-42-39A/B, 0.006; wells 699-43-41E,G, 0.09; and wells 699-43-42J/699-42-42B, 0.18. Compared with FY 1996, the downward vertical hydraulic gradient in FY 1997 increased between well pairs 699-43-41E,G and 699-43-42J/699-42-42B (northern portion of the pond system) but decreased slightly between well pairs 699-40-40A,B and 699-42-39A,B (southern portion of the pond system).

3.6.8 216-B-63 Trench

The stratigraphy beneath the 216-B-63 trench consists of the Hanford formation and the Elephant Mountain Member of the Saddle Mountains Basalt. The Ringold Formation is absent beneath this trench; however, some remnants of reworked Ringold Formation sediments may be incorporated into the Hanford formation. The Hanford formation consists of unconsolidated pebble to boulder gravel, fine- to coarse-grained sand, and silt. These deposits are divided into the gravel-, sand-, and silt-dominated facies, respectively (WHC-SD-EN-TI-008, WHC-SD-EN-TI-012). The unconfined aquifer underlying the trench occurs within the lower 3.4 to 6.1 m of the Hanford formation. The depth to water is ~73 m below ground surface, and the top of the basalt forms the base of the unconfined aquifer.

The water table under the trench is nearly flat. Based on regional flow patterns, the groundwater-flow direction under the trench is generally from east to west. Flow paths constructed on a water-table map of the regional area indicate that B Pond to the east is the primary source of groundwater beneath the trench. The groundwater gradient was estimated to be on the order of 0.00004, using measured water levels from wells monitoring the trench. The groundwater-flow rate was estimated to be between 0.01 and 0.04 m/d (see Table 3.3-1).

Groundwater levels beneath the trench are strongly affected by the dissipating B Pond mound. Figure 3.6-14 shows that water levels in wells monitoring the trench continued to decline in FY 1997.

3.6.9 200-East Area Single-Shell Tank Farms

In general, the single-shell tank farms in the 200-East Area are underlain by the Hanford and Ringold Formations. The Hanford formation beneath these tank farms consists of the gravel-dominated facies, sand-dominated facies, and basal interbedded sand and gravel facies. The underlying Ringold Formation consists of the lower mud unit and Unit A. Because of erosion, the lower mud unit is discontinuous beneath these tank farms. Details on the stratigraphy under each of the 200-East Area tank farms can be found in WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-TA-004.

3.6.9.1 WMA A-AX Single-Shell Tank Farms

The unsaturated sediments beneath WMA A-AX range between ~81 and 90 m thick and consist predominantly of the uppermost gravel-dominated facies, the sand-dominated facies, and the basal interbedded sand and gravel facies of the Hanford formation (WHC-SD-EN-TA-004). The saturated aquifer thickness beneath this WMA is estimated to be 27 m. The water table lies primarily in erosional remnants of the Ringold lower mud unit. However, in the southern part of the WMA, the lower mud unit does not exist and the water table lies in Ringold Unit A, which consists of partially cemented gravels.

The direction of groundwater flow, approximated from the regional water-level-elevation contours, was estimated to be to the west-southwest (see Plate 2). The groundwater-flow rate was estimated to be between 0.007 and 0.07 m/d (see Table 3.3-1).

The hydrographs in Figure 3.6-15 show that the water-level elevations in the monitoring wells are not consistent with the slope of the water table based on regional water-level-elevation contours. For example, the water-level elevations in wells 299-E24-20 and 299-E25-46, defined as downgradient wells according to the RCRA groundwater-monitoring plan, were consistently higher over time than those in well 299-E25-41, defined as an upgradient well (WHC-SD-EN-AP-012, Rev. 1). The maximum water-level-elevation change across the WMA was 0.09 m. These discrepancies in water-level elevations cannot be attributed to measurement error because measurement error is random and would not likely yield consistently higher water-level elevations over time. Resolution of these discrepancies in water-level elevations will require further investigation to better understand the local groundwater-flow conditions beneath this WMA.

Historical water-level trends in the wells monitoring WMA A-AX were presented in Figure 3.6-15. The elevation of the water table continues to decline because of reduced discharges to cribs, trenches, and ponds. Water-level elevations decreased ~0.22 m between June 1996 and June 1997. This compares to a decline of 0.09 m between June 1995 and June 1996. These water-level declines are not great, compared to the ~3-m water columns in the network wells. Assuming the rate of decline does not increase, the network wells will be usable for monitoring for at least the next 5 years.

3.6.9.2 WMA B-BX-BY Single-Shell Tank Farms

The unsaturated sediments beneath WMA B-BX-BY range between ~73 and 80 m thick and consist predominantly of the gravel-dominated facies, the sand-dominated facies, and the basal interbedded sand and gravel facies of the Hanford formation (WHC-SD-EN-TA-004). The saturated aquifer thickness beneath this WMA is ~3.6 m. The unconfined aquifer sediments are composed of basal interbedded sand and gravel facies, Ringold lower mud unit, and Ringold Unit A. However, the presence and thickness of each unit within the unconfined aquifer depend on the location. The water table lies in the basal interbedded sand and gravel facies, which are thin and laterally discontinuous in the northern part of the WMA and lie either in the thin Ringold lower mud unit or in Ringold Unit A in the southern part.

As with WMA A-AX, the groundwater-flow direction beneath WMA B-BX-BY could not be determined from water-level-elevation data from the monitoring well network because the water table is nearly flat. The general groundwater-flow direction is toward the northwest and is approximated from the regional nitrate plume and technetium-99 distribution (see Plate 4 and Figure 5.10-1, respectively). The rate of groundwater flow beneath WMA B-BX-BY was estimated to be between 0.05 and 0.11 m/d (see Table 3.3-1).

The hydrographs in Figure 3.6-16 show that the water-level elevations in the monitoring wells are not consistent with groundwater-flow patterns determined from the plume maps. For example, the water-level elevations in wells 299-E33-41 and 299-E33-42, defined as downgradient wells according to the RCRA groundwater-monitoring plan, were consistently higher than those in well 299-E33-33, defined as an upgradient well (WHC-SD-EN-AP-012, Rev. 1). The water table has a maximum elevation change of 0.10 m across the site based on water-level data from the monitoring wells. These discrepancies in water-level elevations cannot be attributed to measurement error because measurement error is random and would not likely yield consistently higher water-level elevations over time. Resolution of these discrepancies in water-level elevations will require further investigation to better understand the local groundwater-flow conditions beneath this WMA.

Historical water-level trends in the wells monitoring WMA B-BX-BY were shown in Figure 3.6-16. The elevation of the water table continues to decline because of the reduced discharges to cribs, trenches, and ponds. The annual decrease in water-level elevation ranged from 0.18 to 0.22 m between June 1996 and June 1997. These water-level declines are not great, compared to the height of the water columns in the network wells. All the network wells have ~3-m water columns, except well 299-E33-42 that has a ~2-m water column. Assuming the rate of decline does not increase, the network wells will be usable for monitoring for at least the next 5 years.

3.6.9.3 WMA C Single-Shell Tank Farm

The unsaturated sediments beneath WMA C range between ~ 71 and 82 m thick. The unsaturated sediments consist primarily of the gravel-dominated facies, the sand-dominated facies, and the basal interbedded sand and gravel facies of the Hanford formation and the Ringold lower mud unit (WHC-SD-EN-TA-004). Beneath the Hanford formation, the Ringold lower mud unit transitions into the underlying Ringold Unit A. The saturated zone beneath this WMA lies within Ringold Unit A and is estimated to be ~8 m thick.

The groundwater-flow direction is toward the southwest based on regional water-level-elevation contours (see Plate 2). Groundwater-flow rates are estimated to be between 0.06 and 0.28 m/d (see Table 3.3-1).

The groundwater-flow direction based on regional flow patterns is consistent with that determined using water-level data from the wells monitoring this WMA. The FY 1997 water-level data in Figure 3.6-17 indicate that well 299-E27-7, located along the WMA's northeastern edge, is generally upgradient from the other monitoring wells. The maximum water-table-elevation change across the site was 0.15 m.

Historical water-level trends in the wells monitoring this WMA were shown in Figure 3.6-17. The elevation of the water table continues to decline because of the reduced discharges to cribs, trenches, and ponds. Water-level-elevation decreases ranged between 0.16 and 0.23 m between June 1996 and June 1997. These water-level declines are not great compared to the height of the water columns in the network wells. Assuming the rate of decline does not increase, the network wells will be usable for monitoring for at least the next 5 years.

3.6.10 200-East Area Low-Level Burial Grounds

LLWMA 1 is located in the northwestern corner of the 200-East Area (see Plate 1). All of the 218-E-10 burial ground is included in this LLWMA. LLWMA 2 is located in the northeastern corner of the 200-East Area and includes all of burial ground 218-E-12B.

The burial ground in LLWMA 1 is underlain by the Hanford and Ringold Formations, and the burial ground in LLWMA 2 is underlain by the Hanford formation. The unconfined aquifer beneath LLWMA 1 is contained in sands and gravels of the Hanford formation and in sediments of the Ringold lower mud unit and Ringold Unit A. The unconfined aquifer beneath LLWMA 2 is contained in the sands and gravels of the Hanford formation, which directly overlie the basalt. The top of the basalt defines the base of the unconfined aquifer beneath LLWMAs 1 and 2. Depth to the water table ranges between 71 and 87 m below ground surface at LLWMA 1 and 57 and 74 m below ground surface at LLWMA 2. The aquifer thickness ranges from ~3 to ~8 m beneath LLWMA 1 and from 0 to ~2 m beneath LLWMA 2.

The groundwater-flow direction in the area of LLWMA 1 is difficult to determine using only water-level data from the monitoring wells around the burial ground because the groundwater gradient in this area is extremely low. A better estimate of the groundwater-flow direction can be inferred from contaminant plume maps (e.g., Plates 3 and 4). The contamination distribution suggests that the general direction of flow is to the northwest beneath LLWMA 1. An estimate of groundwater-flow velocity beneath LLWMA 1 was calculated to be 0.5 m/d or less (see Table 3.3-1). The groundwater-flow velocity is uncertain because the hydraulic gradient is extremely low, on the order of 0.00006 or less. The hydraulic gradient was determined from water-table contours of the regional flow system.

As with LLWMA 1, water-level data from LLWMA 2 monitoring wells cannot be used to determine the groundwater-flow direction because the gradient is extremely low. The groundwater-flow direction in this area is primarily from east to west based on water-table contours of the regional flow system. The basalt high located north and east of LLWMA 2 and the continued presence of the B Pond mound affect groundwater flow. The linear velocity of groundwater flow beneath LLWMA 2 is estimated to be 0.7 m/d (see Table 3.3-1). This estimate is uncertain because the groundwater gradient beneath LLWMA 2 is low, on the order of 0.00004.

3.6.11 Liquid Effluent-Retention Facility

The stratigraphy beneath this facility is primarily composed of gravel-dominated sediments of the Hanford formation with occasional interbedded fine-grained zones. Isolated erosional remnants of Ringold Unit A exist locally between the Hanford formation and the underlying basalt bedrock (WHC-SD-EN-TI-012, WHC-SD-EN-TI-019, WHC-SD-EN-TI-071, WHC-SD-EN-TI-290). Thin (few meters or less) pockets of Ringold Formation occur to the south (i.e., well 299-E25-9).

The unconfined aquifer beneath this facility is predominantly composed of sediments of the Hanford formation. The thickness of the unconfined aquifer beneath this facility is thin, ranging from 0.2 to 2.1 m. The depth to the water table is ~59.5 to 61.0 m below ground surface. The top of the basalt defines the base of the unconfined aquifer.

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 groundwater-flow direction is generally to the west. The groundwater gradient is ~0.002 and reflects the western flank of the B Pond groundwater mound to the east. The groundwater-flow velocity is estimated to range from 0.06 to 1.2 m/d (see Table 3.3-1).

Figure 3.6-18 shows the water-level trends for wells monitoring this facility. In general, the trends indicate that the water table continues to decline in response to a decline in the B Pond mound.

3.7 Hydrogeology of 400 and 600 Areas

F. N. Hodges, P. D. Thorne

The 400 Area is located in the south-central portion of the Hanford Site (see Figure 1.1 and Plate 1). The Fast Flux Test Facility and its associated facilities, including the 400 Area process ponds and water-supply wells, are located in the 400 Area. The 600 Area includes all of the Hanford Site that is not within other designated operational areas. Facilities in the 600 Area include the Nonradioactive Dangerous Waste Landfill (NRDWL) and the Solid Waste Landfill (SWL), also known collectively as the Central Landfill. These landfills are located in the central part of the Hanford Site southeast of the 200-East Area (see Plate 1).

3.7.1 400 Area

At the 400 Area, the Hanford formation consists mainly of the sand-dominated facies. The water table is located near the contact of the Hanford and Ringold Formations, which is ~49 m below ground surface (WHC-EP-0587). The depth to the water table in the 400 Area varies from ~45 to 50 m. Hanford formation sediments dominate groundwater flow in the 400 Area because of their relatively high permeability compared to that of sediments in the Ringold Formation. The Ringold Formation consists, in ascending order, of fluvial gravels and overbank and lacustrine silt and clay, silty sands, sandy gravels, and gravelly sands. The saturated aquifer thickness is ~140 m. The top of the basalt is at a depth of ~185 m. Additional details concerning the geology and the construction of wells near the 400 Area facilities are provided in WHC-EP-0587.

The Hanford Site water-table map (see Plate 2) shows the groundwater-level contours for the 400 Area. The water-table map indicates that groundwater generally flows from west to east across the 400 Area.

3.7.2 600 Area

The NRDWL and SWL are underlain by ~180 m of Hanford and Ringold Formation sediments. The Hanford formation beneath these landfills consists of sands and gravels, dominated by sands near the surface and gravels in the deeper portions of the formation. Thin, discontinuous, silt layers, as well as clastic dikes, are common in the upper part of the formation (WHC-EP-0021). The Ringold Formation consists of the upper Ringold; Ringold Units A, B, C, and E; and Ringold lower mud. The upper Ringold contains a thin, silt-rich layer that may be locally confining (WHC-EP-0021). Ringold Units B, C, and E lie below the Hanford formation and are in contact at a depth of ~70 m, except where remnants of the upper Ringold are present. The upper Ringold has been eroded away over parts of the central Hanford Site. The Ringold lower mud is relatively continuous in this area and acts as a local confining unit to Ringold Unit A that overlies the basalt. Additional details concerning the geology and the construction of wells near these facilities are provided in WHC-EP-0021 and PNL-6852.

The water table in the central Hanford Site, where the NRDWL and SWL are located, is in the Hanford formation gravels (see Figure 3.1-4). At the NRDWL and SWL, the depth to the water table varies from ~38 to 41 m below ground surface. The saturated thickness above the top of the basalt is ~140 m.

A map of the water table in the vicinity of the NRDWL and SWL based on June 1997 data is presented in Figure 3.7-1 (also see Plate 2). This map indicates low hydraulic gradients in the vicinity. The low gradients are attributed to a zone of very high transmissivities beneath the landfills that extends to the northwest beneath the 200-East Area (see Figure 3.2-2). Transmissivity is high beneath the landfills because the unconfined aquifer lies within the main flow channel of the catastrophic floods that deposited the Hanford formation gravels. Groundwater flows into this highly transmissive zone from the B Pond groundwater mound to the north and from the U Pond mound and Cold Creek recharge areas to the west.

Groundwater input from the B Pond mound strongly affects the water-table elevations over a wide area, including the vicinity of these landfills. Figures 3.7-2 and 3.7-3 show that water-table elevations beneath the NRDWL and SWL have dropped more than 1.5 and 1.6 m, respectively, since December

1988. These declines were primarily the result of decreased discharge to B Pond. The rate of decline slightly increased in FY 1997 after nearly all discharges to B Pond were terminated in FY 1996.

The movement of tritium and nitrate plumes and the measurement of water-levels infer groundwater-flow directions beneath the NRDWL and SWL. The tritium and nitrate plumes (see Plates 3 and 4, respectively), which originate in the 200-East Area and pass beneath the landfills, indicate that the principal direction of groundwater flow is ~125 degrees east of north (Section 17.0 in DOE/RL-91-03), a direction that has remained relatively constant since 1990. Groundwater-flow directions based on water-level elevations range between ~96 and ~139 degrees east of north. These directions are uncertain because of the low gradient, as indicated by the small differences in elevations between hydrographs (see Figure 3.7-3). The difference in water-table elevations across the area of the landfills is commonly on the order of 0.01 m.

The rate of groundwater flow beneath the landfills is uncertain based exclusively on water-level data. On the basis of site-specific hydrologic testing and the observed hydraulic gradients, the groundwater-flow velocities were estimated to be on the order of 1.2 to 1.8 m/d (see Table 3.3-1). However, indicators of groundwater velocity yield values that range from 6 to in excess of 30 m/d (see Table 3.3-1). The groundwater-flow rate was estimated by the recent decrease in tritium and nitrate concentrations across the landfills. Tritium and nitrate, which have upgradient sources, exhibit nearly identical time-concentration variation in certain upgradient and downgradient well pairs with quarterly sampling. This correspondence indicates that the time required for the contaminants to traverse the site is on the order of 3 months. This traverse time indicates a groundwater-transport rate of ~6 m/d. Groundwater-velocity estimates >30 m/d were determined from tracer test results (HW-60601); however, the hydraulic gradient was higher than that determined from tritium and nitrate concentration variations.

At the NRDWL, two well pairs (699-25-33A/699-25-34A and 699-26-35A/699-26-35C) sample the top of the unconfined aquifer and the top of the Ringold Formation. The lack of a detectable head difference in each of the well pairs indicates that the vertical gradient within the upper portion of the aquifer is negligible.

3.8 Hydrogeology of 300 and Richland North Areas

T. L. Liikala, J. W. Lindberg

The 300 and Richland North Areas are located in the southern part of the Hanford Site and vicinity (see Figure 1.1). The 300 Area is adjacent to the Columbia River and was the site of reactor fuel-fabrication facilities and research-and-development functions. The Richland North Area is an informal designation for the southernmost part of the Hanford Site and northern part of the City of Richland.

3.8.1 300 Area

The unconfined aquifer in the 300 Area consists of Hanford formation gravels and sands and Ringold Formation gravels and sands with varying amounts of silt and clay (WHC-SD-EN-TI-052). The water table is within the Hanford formation in most of the 300 Area. West of the 300 Area, the water table is in Ringold Unit E (see Unit 5 on Figure 3.1-3), below the bottom of the Hanford formation. Channeling in the top of the Ringold Formation (PNL-2949, WHC-SD-EN-TI-052) is a factor in controlling groundwater movement in the unconfined aquifer. The Ringold lower mud unit is found below the unconfined Ringold gravels and forms a local confining unit for thin Ringold gravel deposits that lie directly above the basalt. The depth to the water table beneath the 300 Area ranges from <1 m near the Columbia River to ~18 m farther inland. Detailed information on the hydrogeology of the 300 Area is provided in WHC-SD-EN-TI-052.

At the 316-5 process trenches (RCRA site), the Hanford formation is 9 to 12 m thick and is composed of gravelly sand and sandy gravel. The Ringold Formation is ~40 m thick and comprises two major facies groups. The upper half is interbedded sandy gravels, gravelly sands, and silty sands of Unit E. The lower half is composed of sandy and clayey silt of the Ringold lower mud unit, which overlies basalt at this location. The water table at the process trenches is close to the position of the Hanford-Ringold Formation contact.

The primary influence on groundwater-elevation changes in the 300 Area is the fluctuation in Columbia River stage (see Figure 3.5-1). Changes in Columbia River-stage elevation can be correlated to changes in water-level elevations at wells as far as ~360 m from the river (PNL-8580). In FY 1997, river stage was slightly elevated during the winter and early spring, but in June rose to more than 3.5 m higher than a typical river stage in June. This unusually high-river stage caused the highest water levels ever recorded in wells near the 316-5 process trenches.

Groundwater-flow directions in the 300 Area vary in response to the rise and fall of river stage. During low to average stages, groundwater in the unconfined aquifer converges at the 300 Area from the northwest and southwest, flows beneath the 300 Area in a west-to-east or northwest-to-southeast direction, and eventually discharges to the river. During high-river stages, when the water table rises above the Hanford-Ringold Formation contact, groundwater temporarily flows in a southwestern to southern direction (see Plate 2). In the immediate vicinity of the 316-5 process trenches, the groundwater-flow direction was primarily to the southeast during FY 1997. During low to average stage, groundwater flow in the vicinity of these trenches is generally to the southeast or east (see Section 6.1 in DOE/RL-96-01).

The flow rate in the top of the unconfined aquifer was ~31 m/d near the process trenches based on data from tetrachloroethylene spills that occurred in 1982 and 1984 while the trenches were in use (DOE/RL-89-14) (see Table 3.3-1). Because the trenches artificially recharged groundwater, the water table was steeper when this estimate was made than it is now. The gradient, and hence groundwater velocity, decreased after discharge to the trenches ceased. In FY 1997, the water table was flatter than normal because of the long period of high-river stage. Velocity estimates based on hydraulic gradients were 20 m/d to the southeast in January 1997 and 0.5 m/d to the southwest in June 1997 (see Table 3.3-1).

There is a vertical head difference, with the gradient in an upward direction, between the unconfined aquifer above the Ringold lower mud unit and the gravels beneath the lower mud unit. In June 1997, the head in well 399-1-17C was 7.4 m higher than in well 399-1-17A. Well 399-1-17C is screened 42 m deeper than 399-1-17A; thus, the vertical gradient is 0.18 upward. Confined aquifers within the basalt at depth, below the confining Ringold lower mud unit, also display higher hydraulic heads than the overlying unconfined aquifer that cause an upward flow direction.

3.8.2 Richland North Area

The Richland North Area is located in the southern part of the Hanford Site (see Figure 1.1 and Plate 1), and though not formally defined, includes the 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.

The unconfined aquifer beneath the Richland North Area occurs within the predominant sands and gravels of the Hanford and Ringold Formations. The depth to water ranges from <2 m along the riverbank and adjacent to the Tri-Cities Enterprise Association to ~30 m beneath the Richland Landfill. Aquifer thickness varies, ranging from ~7 to 32 m. Silty clays overlying the Saddle Mountains Basalt form the aquifer base. Silt and clay lenses in the eastern part of the Richland North Area may result in local, semiconfined to confined conditions within the aquifer. Perched water is found locally in north Richland during the summer irrigation season. Additional details on the hydrogeology of the Richland North Area can be found in DOE/RL-90-18 and PNL-10094.

Groundwater beneath the Richland North Area generally flows from west to east between the Yakima and Columbia Rivers. Figure 3.8-1 shows the June 1997 water-table elevations for this area. The contours indicate that, in the vicinity of the 300 Area, groundwater converges from the northwest, west, and southwest and discharges to the Columbia River. South of the 1100 Area, groundwater flow is to the southeast. This flow field is the result of at least the following regional and local influences:

- groundwater recharge from the Yakima River
- agricultural irrigation and infiltration between the Yakima River and the 1100 Area
- net recharge to the City of Richland's North Well Field
- fluctuations in the Columbia River stage.

The City of Richland's North Well Field, located in the south-central portion of the Richland North Area, is the primary influence on groundwater-elevation changes in this area. The well field serves as the City of Richland's secondary drinking water-supply system. This system consists of a settling basin and two recharge basins that recharge the unconfined aquifer with water from the Columbia River. The sediments lower the turbidity of the infiltrating riverwater, while the riverwater reduces the hardness of the groundwater. Water is then pumped from the aquifer via the well field and dispensed to city lines for use. The well field is used primarily when the city's filtration plant is shut down for annual maintenance (January) and during peak water use in the summer months.

Historical data indicate that the ratio of recharge to discharge at this well field has varied from 2:1 to 4:1 (PNL-10094). Because of this net recharge, a groundwater mound formed in this area, and its elevation varies accordingly with the volume of recharge. The hydrograph for well 699-S40-E14, located immediately west of the well field, illustrates this effect (see Figure 3.8-1). Operation of the well field impacts water-table elevations in wells throughout the Richland North Area. In the past, wells as far as 1.6 km to the north and south of the well field have been identified with water-level changes corresponding to the net recharge to the aquifer (e.g., well 699-S32-E13A). However, in 1996 and 1997, water-level changes attributed to well-field impacts were disguised in well 699-S32-E13A by unusually high river stage. Hydrographs for wells nearest the well field have the highest correlation. The amplitude of water-level response decreases with distance from the well field, decreasing more rapidly to the west and east than to the north and south (PNL-10094).

Water-level changes in well 699-S43-E7A, located near the Tri-Cities Enterprise Association, may be a combined effect from the well field, irrigation of agricultural land, wastewater discharge at the Lamb-Weston, Inc. plant to the southwest, and natural recharge. Water-level changes to the north at well 699-S27-E14, located near the southern boundary of the 300 Area, appear to be dominated by fluctuations in Columbia River stage.

Irrigation of ~1 km^2 of agricultural fields began in the area between the Yakima River and the 1100 Area in 1989. The total irrigated land was expanded to ~30 km^2 by 1991. Irrigation water was initially pumped from shallow irrigation wells but is now supplied solely by the Columbia River. Increasing water levels have been observed to the north of these fields as a result of the irrigation and are shown in the hydrograph for well 699-S31-1 (Figure 3.8-2). The water level in this well has risen ~1.1 m since 1989. An additional 2 km^2 of irrigated land were added in 1997, immediately west of Siemens Power Corporation. Continuous monitoring in Siemens Power Corporation wells GM-2 and GM-12 was initiated in July 1997 to assess local water-level changes and impacts on groundwater-flow direction. Data are limited at this time; however, the general trend for both wells, as represented by the hydrograph for well GM-2, clearly indicates irrigation ceasing in September 1997 (Figure 3.8-3).

3.9 Hydrogeology of Areas East and North of Columbia River

D. R. Newcomer, S. P. Reidel

The Wahluke Slope is that area extending from Umtanum Ridge and the Columbia River north to the Saddle Mountains. The south flank of the Saddle Mountains anticline controls the gentle south slope. The Wahluke syncline lies between Umtanum Ridge and the Saddle Mountains. The principal rock units on the Wahluke Slope are the Columbia River Basalt Group, the Ringold Formation, and the Hanford formation. All three units thin onto the Saddle Mountains. Ringold Formation sediments consist principally of alluvial fan material shed from the Saddle Mountains as the mountains were uplifted; these gravels are intercalated to the south with Columbia River sediments of Ringold age. The Hanford formation consists of gravel deposits near the river and finer slackwater Touchet Bed sediments along the flanks of the Saddle Mountains.

The Columbia River east of the Hanford Site marks the western edge of the Palouse Slope. The Palouse Slope consists of gently west-dipping basalt flows overlying rocks that make up the Paleozoic North American craton. Along the eastern boundary of the Hanford Site, the Ringold Formation and Hanford formation overlie the basalt bedrock. The Ringold Formation consists of ancestral Columbia River and Salmon/Clearwater River gravels that are, in turn, overlain by finer silts, sands, and lake deposits. The Hanford formation consists of gravels and Touchet Bed deposits near the Columbia River but, farther east, the gravels give way to only Touchet Bed deposits. At ~15 km east of the Hanford Site, both the Ringold and Hanford formation deposits pinch out, and basalt bedrock is either exposed at the surface or covered by a thin deposit of loess.

Water-level elevations north and east of the Columbia River are much greater than on the Hanford Site. As indicated in Figure 3.3-1, the water-table elevation to the east of the Columbia River is currently from 50 to 150 m higher than the water-table elevation on the Hanford Site. Groundwater flow in the unconfined aquifer system north and east of the Columbia River follows the bedrock structure and is toward the Columbia River. The water-table configuration in these areas is heavily influenced by recharge from irrigation with Columbia River water. The irrigated areas are part of the South Columbia Basin Irrigation District. Recharge to the unconfined aquifer system in this area is caused by leakage from canals, wasteways, and ponds and by seepage from irrigated fields (Ebbert et al. 1991). Pumping from wells that tap the unconfined aquifer system is mostly for domestic, stock, and irrigation purposes but yield is commonly low (Bauer et al. 1985). For this reason, pumping from the unconfined aquifer system in this area has little influence on the configuration of the regional water-table surface.

The water-table map (see Figure 3.3-1) shows a steep hydraulic gradient along the eastern bank of the Columbia River east of Gable Mountain in the area known as White Bluffs. A similar steep gradient is exhibited in the area east of the river and north of the 300 Area. These steep gradients represent a series of springs and seepage faces along the bluffs, where groundwater flow intersects the ground surface. Groundwater flow in these areas is controlled primarily by low-permeability zones (i.e., caliche) near the top of the bluffs and other low-permability horizons in the upper Ringold Formation.

Water-table maps by the U.S. Geological Survey (Drost et al. 1989, 1993; Ebbert et al. 1995) indicate that the elevation of the water table north of the Columbia River, extending from Wahluke Slope southeast to Columbia Flat, is controlled primarily by the topography of the land surface and the underlying basalt. Comparison of water-level data indicates that the water-table elevation in this area did not change significantly between 1989 and FY 1997. Water-table-elevation contours in the nonirrigated portion of Wahluke Slope north of the Columbia River are inferred because data are limited (i.e., there are few wells for measuring water levels). The sources of information used to infer the contours include the elevation of water in ponds and seeps in the Saddle Mountain National Wildlife Refuge, located across the Columbia River from the 100-N and 100-K Areas. These data, used in conjunction with topographic elevations, indicate that the 150-m contour extends south and east of the ponds (see Figure 3.3-1). Along the northeastern border of the Hanford Site, contour flexures are inferred from topographic elevations.

3.10 Hydrogeology of Upper Basalt-Confined Aquifer System

D. B. Barnett, W. D. Webber

The upper basalt-confined aquifer system is defined as the groundwater occurring within basalt fractures and joints, interflow contacts, and intercalated sedimentary interbeds within the upper Saddle Mountains Basalt (see Figure 3.1-2). Groundwater is confined by the dense, low-permeability interior portions of basalt flows and by Ringold Formation silt and clay units overlying the basalts.

Hydraulic head distribution and flow dynamics of the upper basalt-confined aquifer system were evaluated and reported in PNL-8869, which identified several prominent hydrologic features, including the following:

- a broad recharge mound extending northeastward from Yakima Ridge in the 200-West Area
- a small recharge mound 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 recharge attributed to agricultural activities.

Recharge to the upper basalt-confined aquifer system is believed to result from natural recharge from precipitation and surfacewater infiltration where the basalt and interbeds are exposed at ground surface. Recharge also may occur through the unconfined aquifer system, where there is artificial recharge associated with offsite irrigation and wastewater discharge from Hanford Site facilities. 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). Maps of the upper basalt-confined and unconfined aquifer potentiometric surfaces indicate that a downward hydraulic gradient from the unconfined aquifer to the upper basalt-confined aquifer occurs in the vicinity of the B Pond recharge mound (PNL-6313, WHC-EP-0142-3, WHC-EP-0142-4, WHC-EP-0394-3).

The groundwater-flow system imposed by the features discussed above is presented in Figure 3.10-1. This figure presents a preliminary potentiometric map for the upper basalt-confined aquifer system based on June 1996 water-level measurements. With few exceptions, the potentiometric map features shown in Figure 3.10-1 are nearly the same as those exhibited for 1993 as reported in PNL-8869. Minor hydraulic head differences in the FY 1996 map, in comparison to 1993, are evident in the vicinity of the 200-West and 200-East Areas and near the Columbia River.

The potentiometric map in Figure 3.10-1 indicates that, south of the Umtanum Ridge-Gable Mountain structural area, groundwater flows from east to west across the site toward the Columbia River, which represents the regional discharge area for groundwater-flow systems. In the region northeast of Gable Mountain, the potentiometric contours suggest that groundwater flows southwest and discharges primarily to underlying confined aquifer systems in the Umtanum Ridge-Gable Mountain structural area (PNL-8869). Therefore, the Columbia River does not represent a major discharge area for upper basalt-confined groundwater along the northern reach of the river.

Water levels in wells monitoring the upper basalt-confined aquifer system north, east, and south of the 200-West Area show a continuing slow decline of up to 0.3 m between FY 1996 and FY 1997. Water levels in confined-aquifer-monitoring wells near the northern boundary of the 200-East Area and immediately east of the 200-East Area near B Pond also show a continuing decline of up to ~0.2 m and ~0.4 m, respectively. These declines are a response to curtailed effluent-disposal activities at the 200 Areas and are consistent with water-level declines in the overlying unconfined aquifer system. PNL-8869 reported that the recharge mound in the basalt-confined aquifer system and unconfined aquifer system near B Pond is associated with artificial recharge from effluent-disposal activities at B Pond (see Section 3.6.7).

Wells in the area between Gable Mountain and the northern boundary of the 200-East Area experienced steadily declining water levels between FY 1987 and FY 1995. Since FY 1995, however, the decline ceased and even reversed in some wells. Between FY 1996 and FY 1997, water levels rose up to 0.2 m in this area. At this time, it is uncertain what the causative factors are for these recent localized increases in water levels.

Wells that monitor the upper basalt-confined aquifer system near the Columbia River show minor variations in hydraulic head from year to year. Trends in hydraulic head in wells along the Columbia River from year to year are not discernible because 1) water levels in these wells respond nearly instantaneously to external stresses imposed by river-stage and barometric fluctuations and 2) water levels are measured too infrequently and the well coverage is too widely spaced. At well 199-B3-2P, water levels have increased significantly since FY 1993. However, as noted in PNL-10817, the integrity of this well is in question and data reflect poor well completion. Subsequent information during abandonment activities at this well in late FY 1997 substantiates this. It is now believed that the integrity of the well was compromised during the well's construction, thus invalidating all water-level data collected from this well.

Table 3.3-1. Estimates of Groundwater-Flow Rates

				Input to Darcy Equation			
RCRA Site	Direction of Flow (river stage)	Rate of Flow, m/d (date)	Method	Hydraulic Conductivity, m/d	Effective Porosity[a]	Gradient (date)	Comments
1301-N LWDF	NW (low) SE (high)	0.047 to 0.84 (January 1997) 0.045 to 0.81 (June 1997)	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0023 (January 1997) 0.0022 (June 1997)	Gradient calculated between wells 199-N-34 and 199-N-2. Reversed flow in June.
1324-N/NA LWDF	NW (low) E (high)	0.007 to 0.13 (January 1997) 0.061 to 1.1 (June 1997)	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.00036 (January 1997) 0.0030 (June 1997)	Gradient calculated between wells 199-N-72 and 199-N-25. Reversed flow in June.
1325-N LWDF	N (low) E (high)	0.028 to 0.51 (January 1997) 0.001 to 0.02 (June 1997)	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0014 (January 1997) 0.0005 (June 1997)	Gradient calculated between wells 199-N-28 and 199-N-81 in January; between wells 199-N-33 and 199-N-42 in June.
120-D-1 ponds	NW (low) SE (high)	0.0014 to 0.14 (January 1997) 0.0084 to 0.80 (June 1997)	Darcy	1.2 to 40 (WHC-SD-EN-DP-043)	0.1 to 0.3	0.00034 (January 1997) 0.0021 (June 1997)	Gradient calculated between wells 199-D5-13 and 199-D8-4. Reversed flow in June.
183-H solar evaporation basins	E (low) SW (high)	0.13 to 3.5 (November 1996) 0.12 to 3.2 (June 1997)	Darcy	15 to 140 (PNL-6728)	0.1 to 0.3	0.0025 (November 1996) 0.0023 (June 1997)	Gradient calculated between wells 199-H3-2A and 199-H4-12A. Reversed flow in June. Flow meter in wells 199-H4-7 and 199-H3-2A (Section 3.3 in DOE/RL-96-01).
		0.65 to 4.9	Flow meter				
216-S-10 pond and ditch	ESE	0.007 to 0.3	Darcy	10 (WHC-SD-EN-DP-052) 12 to 150 (BNWL-1709)	0.1 to 0.3	0.0002 (June 1997)	
216-U-12 crib	ESE	0.53	Darcy	6.2	0.2	0.0017 (September 1997)	Hydraulic conductivity is geometric mean of values in WHC-MR-0208.
216-B-3 pond	Radial	0.2 to 2.7	Numerical modeling; plume migration	NA	NA	0.001 to 0.005 (June 1997)	PNL-6328, PNWD-1974 HEDR.

Table 3.3-1. (contd)

RCRA Site	Direction of Flow (river stage)	Rate of Flow, m/d (date)	Method	Input to Darcy Equation			Comments
				Hydraulic Conductivity, m/d	Effective Porosity[(a)]	Gradient (date)	
216-A-29 ditch	WSW	0.009 (headend of ditch) 0.063 (discharge end of ditch)	Darcy	18 (WHC-SD-EN-DP-047)	0.20	0.0001 at head-end (June 1997) 0.003 at discharge end (June 1997)	
216-A-10 crib 216-A-36B crib	SE	0.05 to 0.1	Darcy	150 to 300 (WHC-SD-EN-TI-019)	0.25	0.00008 (June 1997)	
216-A-37-1 crib	SW	0.2 to 0.4	Darcy	150 to 300 (WHC-SD-EN-TI-019)	0.25	0.0003 (June 1997)	
216-B-63 trench	W	0.01 to 0.04	Darcy	52 to 200 (WHC-SD-EN-EV-002)	0.2	0.00004 (June 1997)	Gradient calculated between wells 299-E27-16 and 299-E27-9.
LERF	W	0.06 to 1.2	Darcy	6.1 to 120 (PNNL-11620)	0.2	0.002 (June 1997)	
LLWMA 1	NW	<0.5	Darcy	73 to 760 (PNL-6820)	0.1	<0.00006 (June 1997)	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.
LLWMA 2	W	0.7	Darcy	430 to 2,000 (PNL-6820)	0.1	0.00004 (June 1997)	Gradient calculated between wells 299-E27-16 and 299-E27-9.
LLWMA 3	NE	0.0003 to 0.14	Darcy	0.02 to 9.8 (PNL-6820)	0.1	0.0011 (June 1997)	
LLWMA 4	E	0.25	Darcy	24 (PNL-6820)	0.1	0.001 (June 1997)	
WMA A-AX	WSW	0.007 to 0.07	Darcy	7.3 to 34 (WHC-SD-EN-TI-147)	0.1 to 0.2	0.0002 (June 1997)	Gradient calculated between wells 299-E25-41 and 299-E24-20. Flow direction inferred from water-table elevation contours.
WMA B-BX-BY	NW	0.05 to 0.11	Darcy	98 (WHC-SD-EN-TI-147)	0.1 to 0.2	0.0001 (June 1997)	Gradient calculated between wells 299-E33-33 and 299-E33-42. Flow direction inferred from plume maps.

Table 3.3-1. (contd)

RCRA Site	Direction of Flow (river stage)	Rate of Flow, m/d (date)	Method	Input to Darcy Equation			Comments
				Hydraulic Conductivity, m/d	Effective Porosity[(a)]	Gradient (date)	
WMA C	SW	0.06 to 0.28	Darcy	49 to 120 (WHC-SD-EN-TI-147)	0.1 to 0.2	0.0002 (June 1997)	Gradient calculated between wells 299-E27-7 and 299-E27-12. Flow direction inferred from water-table elevation contours.
WMA S-SX	SE	0.004 to 0.55	Darcy	0.43 to 27 (WHC-SD-EN-DP-042)	0.1 to 0.2	0.002 (June 1997)	Lower bound for hydraulic conductivity and velocity.
WMA T	NE	0.13	Darcy	10 (WHC-SD-EN-TI-147)	0.1	0.0013 (June 1997)	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W10-16 and 299-W11-28.
WMA TX-TY	NE	0.09 to 0.33	Darcy	15 to 55 (WHC-SD-EN-DP-042)	0.1	0.0006 (June 1997)	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W15-22 and 299-W14-12.
WMA U	E	0.1 to 0.7	Darcy	6 to 37 (WHC-SD-EN-DP-042)	0.1	0.002 (June 1997)	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W18-31 and 299-W19-32.
SWL	96±28° E of N to 139±15° E of N (based on water-level data); 125° E of N (based on plume maps)	1.2 to 1.8	Darcy	NA	NA	NA	See WHC-EP-0021 for Darcy velocity. See Section 18.0 in DOE/RL-91-03; Section 19 in DOE/RL-92-03, DOE/RL-93-09; Section 5.3 in DOE/RL-93-88; Section 5.2 in DOE/RL-94-136 for direction of flow.
		6	Recent plume movement				
		>30	Tracer tests				See HW-60601 for tracer tests. Hydraulic gradient during tracer test was higher than in 1997.
NRDWL	62 to 90° E of N (based on water-level data); 125° E of N (based on plume and regional water-table maps)	See estimated above for SWL	NA	NA	NA	NA	See Section 17.0 in DOE/RL-91-03, Section 5.2 in DOE/RL-93-88, and WHC-EP-0021 for direction of flow.

Table 3.3-1. (contd)

				Input to Darcy Equation			
RCRA Site	Direction of Flow (river stage)	Rate of Flow, m/d (date)	Method	Hydraulic Conductivity, m/d	Effective Porosity(a)	Gradient (date)	Comments
316-5 process trenches		31 (DOE/RL-89-14)	Movement of PCE spill				
	SW (high)	0.5 (SW) to 20 (SE)	Darcy	150 to 15,000 (PNL-6716)	0.1 to 0.3	0.0004 (January 1997)	
	SE (average)					0.0001 (June 1997)	

(a) Effective porosity assumed to be between 0.1 and 0.3, a representative range for the unconfined aquifer system.

LERF = Liquid effluent-retention facility.
LLWMA = Low-level waste management area.
LWDF = Liquid waste-disposal facility.
NA = Not applicable.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PCE = Tetrachloroethylene.
SWL = Solid Waste Landfill.
WMA = Waste management area.

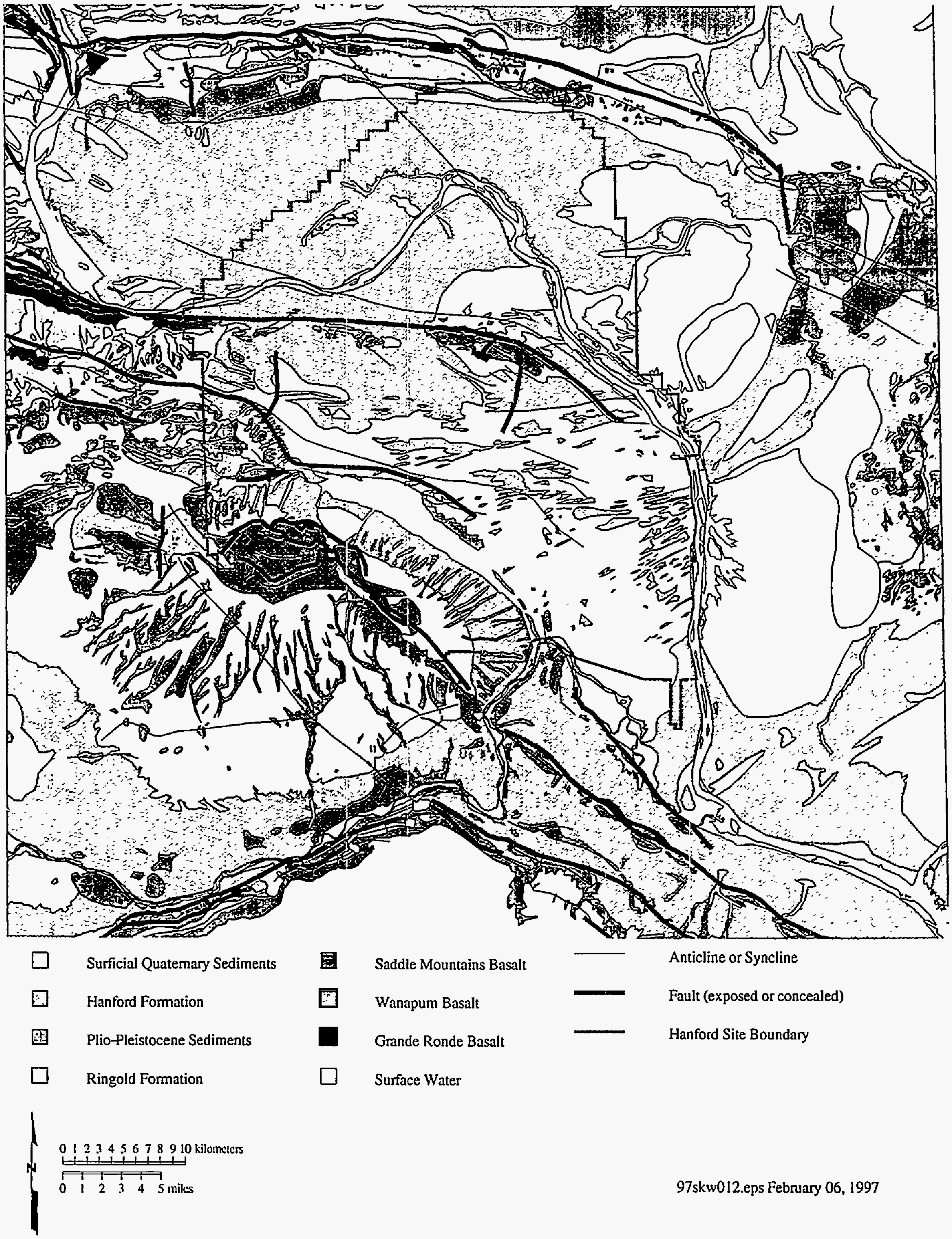

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Figure 3.1-1. Pasco Basin Surface Geology and Structural Features (after Reidel and Fecht 1994a, 1994b)

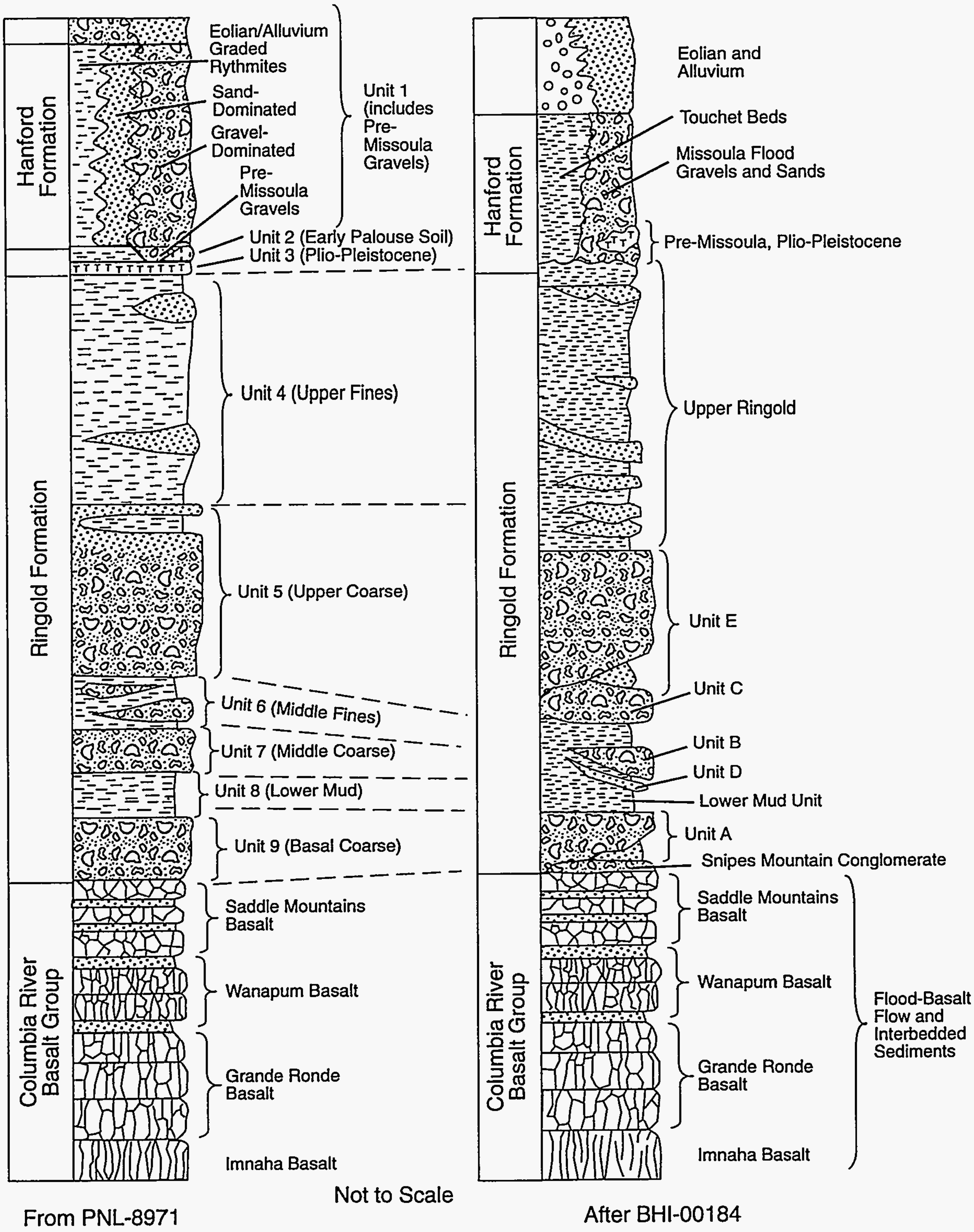

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Figure 3.1-2. Comparison of Generalized Hydrogeologic and Geologic Stratigraphy

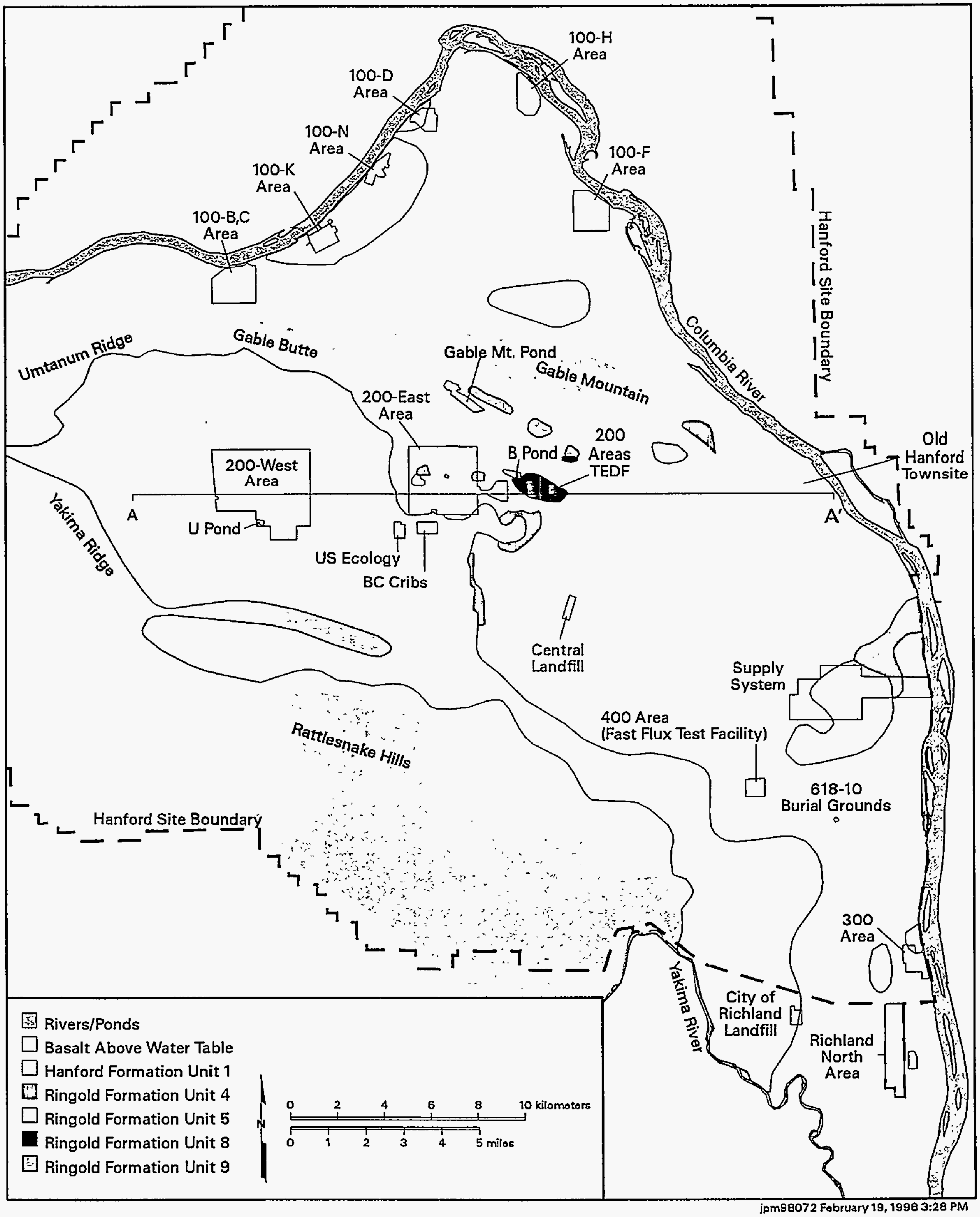

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Figure 3.1-3. Hydrogeologic Units Present at Water Table, June 1997

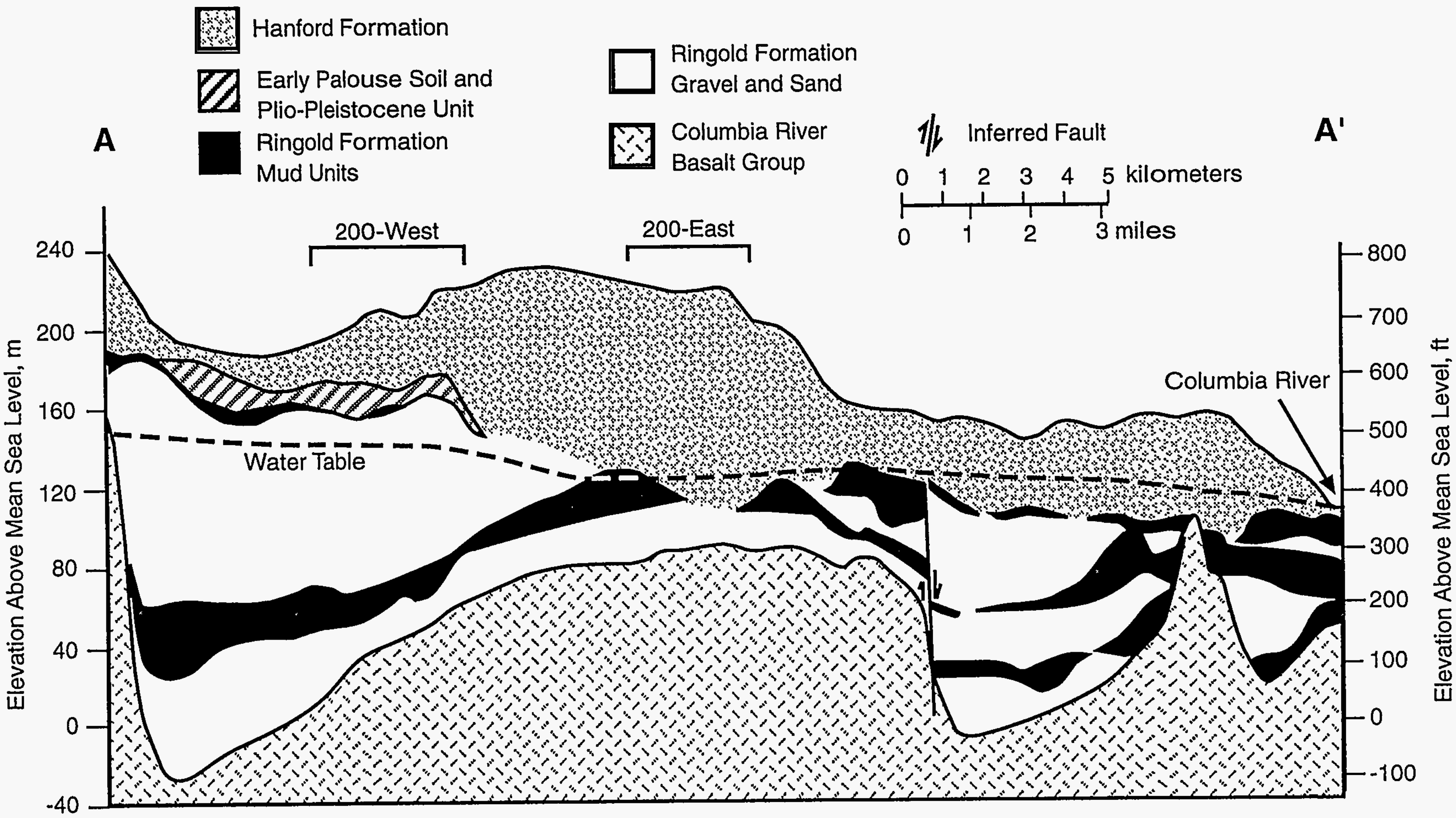

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Figure 3.1-4. Hanford Site Geologic Cross-Section

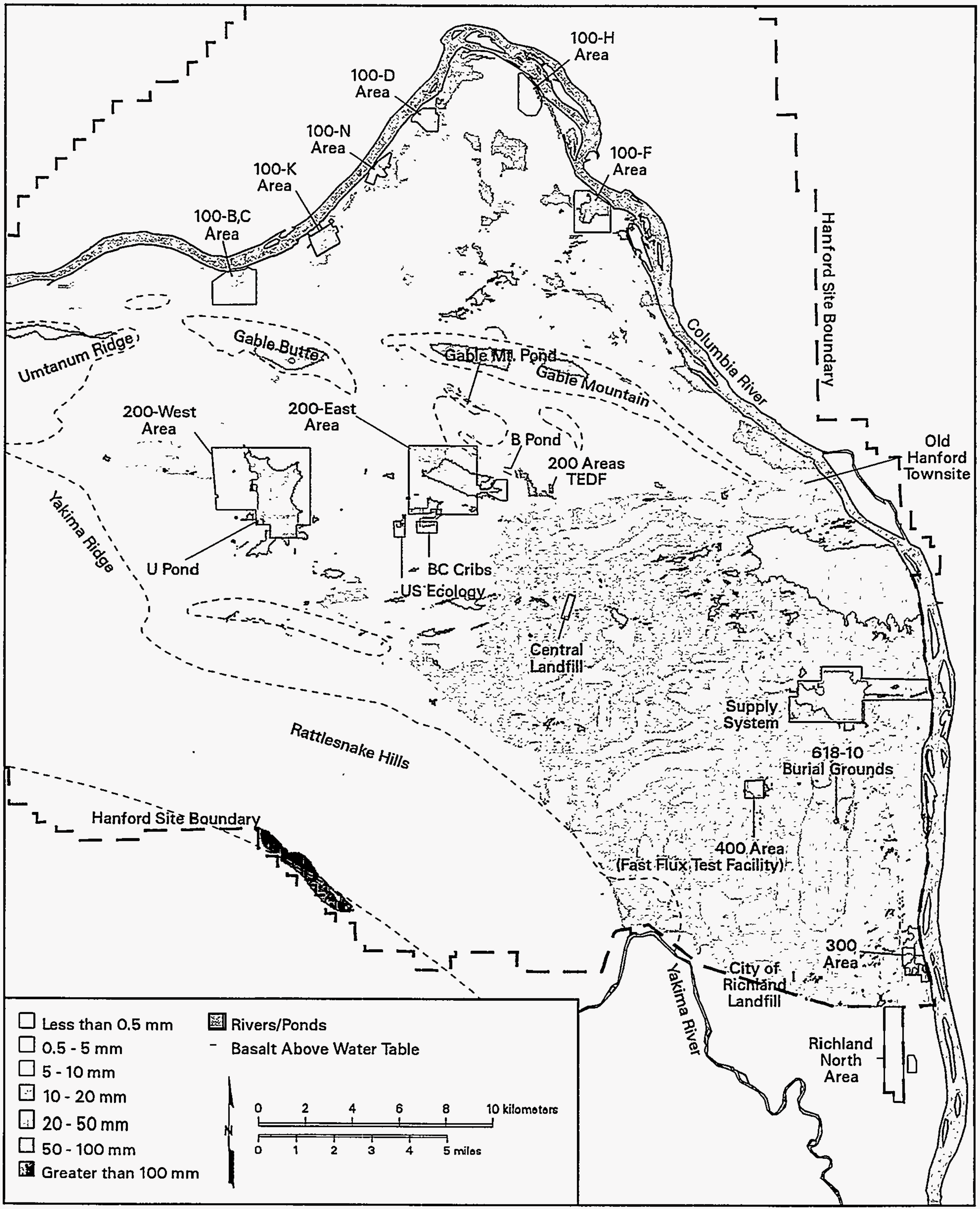

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Figure 3.2-1. Estimated Annual Recharge from Infiltration of Precipitation and Irrigation (from PNL-10285)

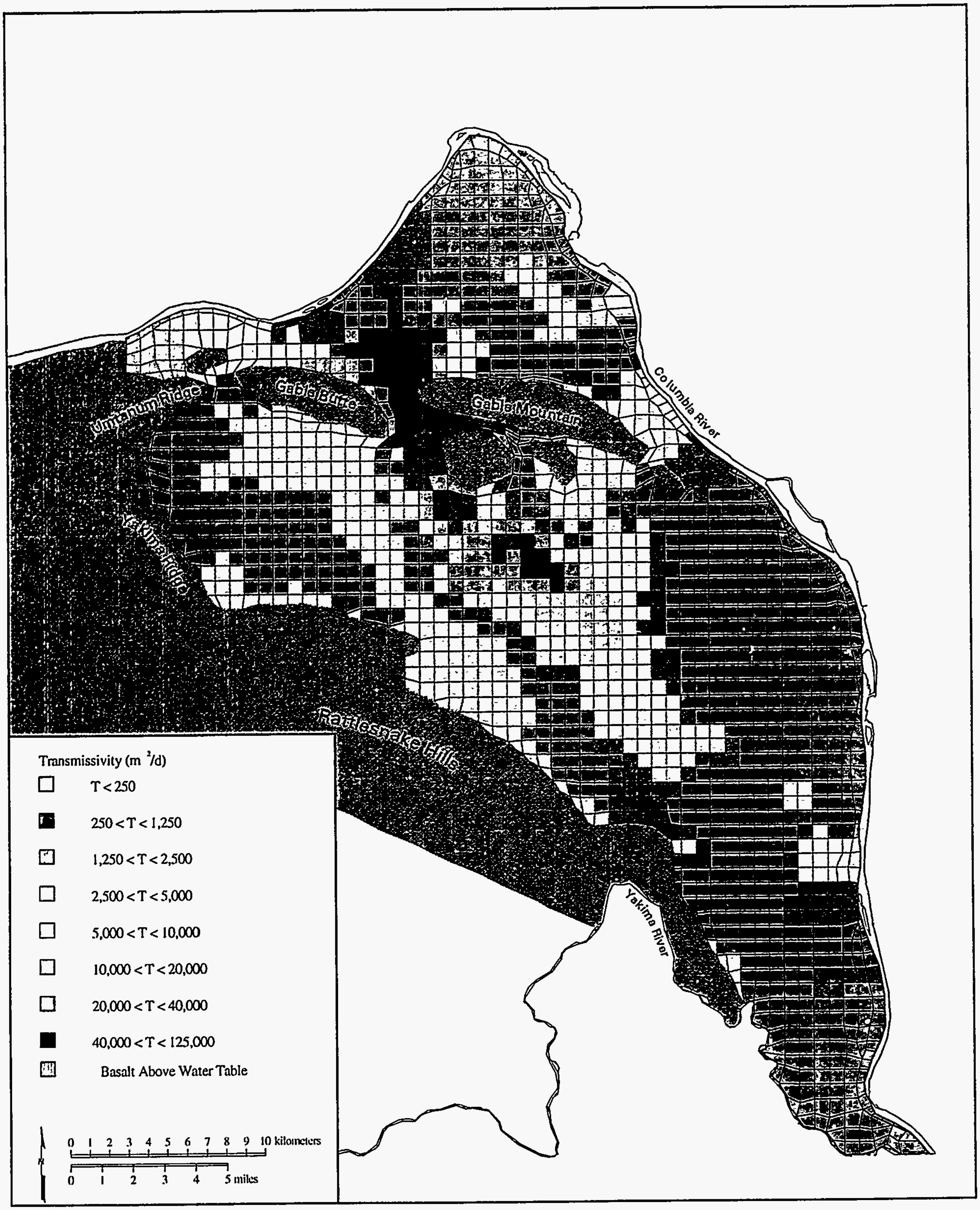

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Figure 3.2-2. Transmissivity Distribution from Model Calibration

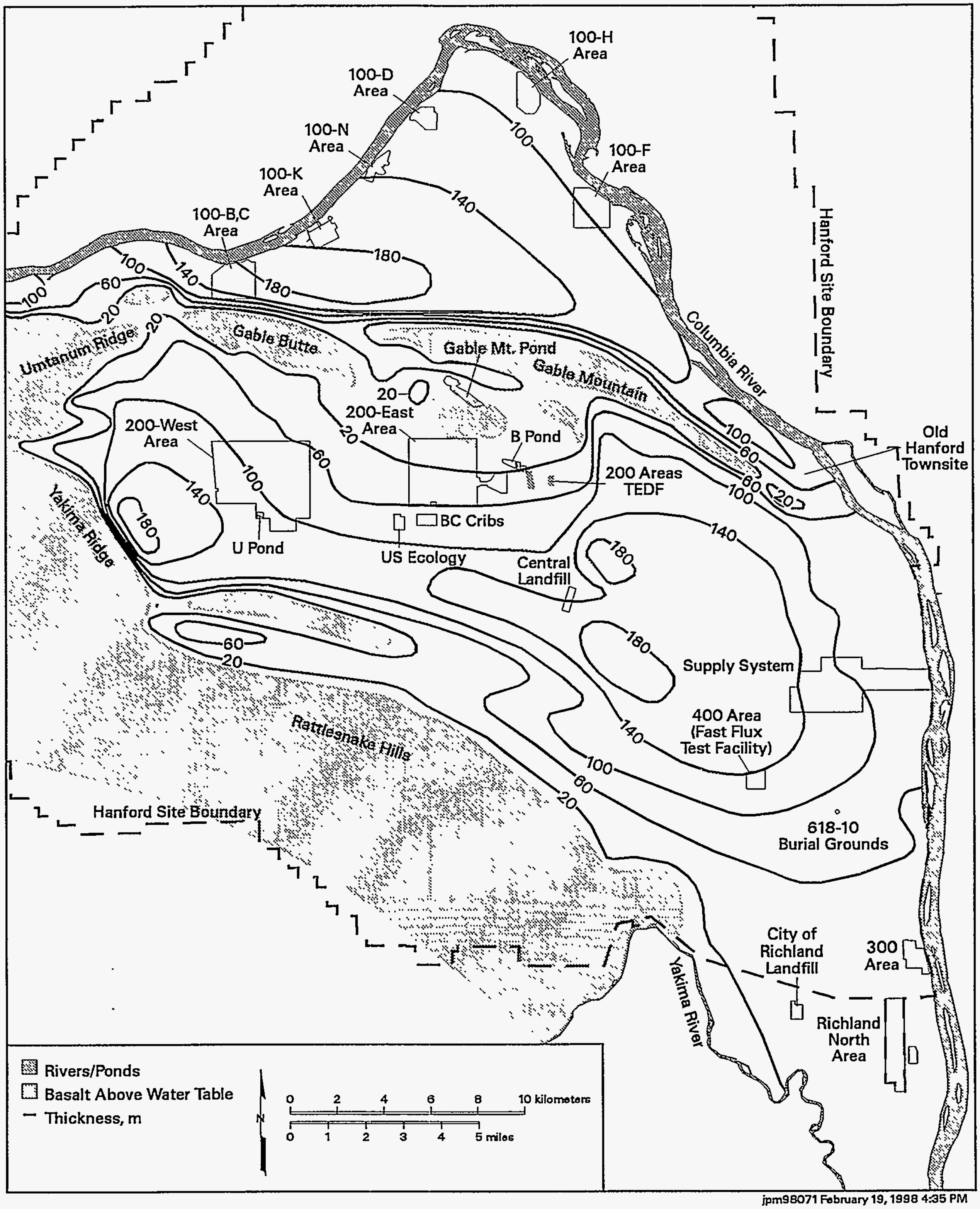

Figure 3.2-3. Saturated Thickness of Unconfined Aquifer System

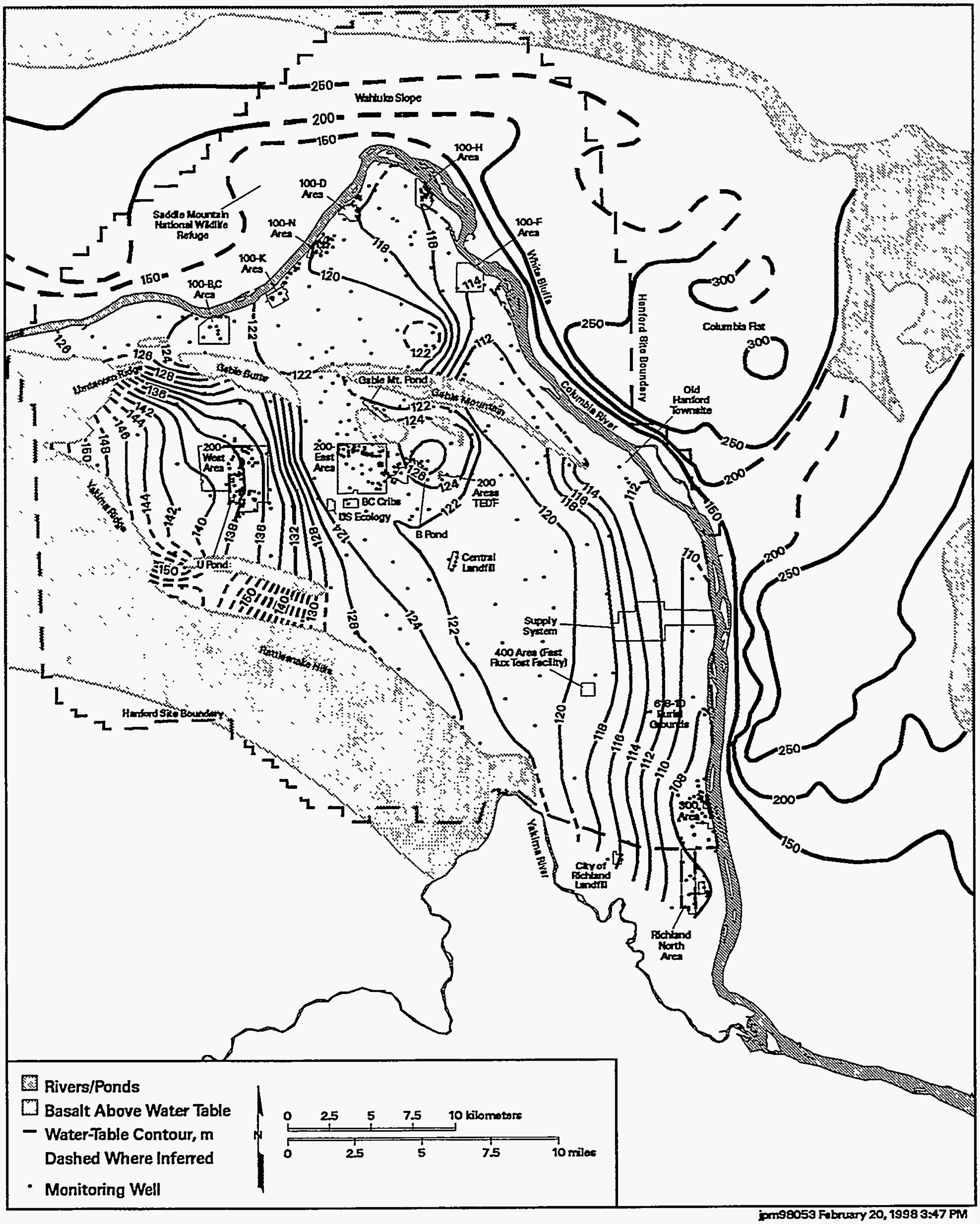

Figure 3.3-1. Hanford Site and Outlying Areas Water-Table Map, June 1997

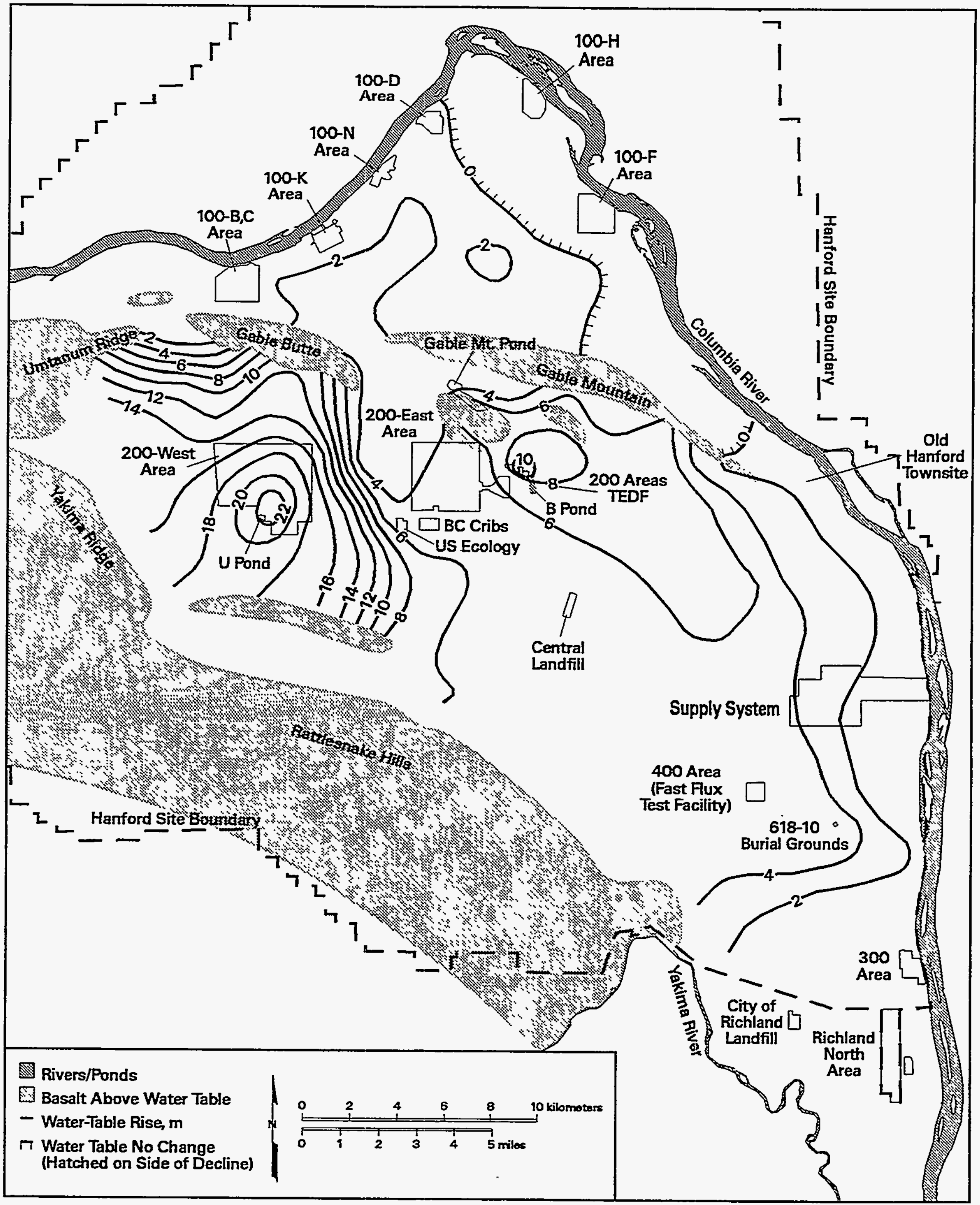

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Figure 3.3-2. Changes in Water-Table Elevations, 1944 Through 1979

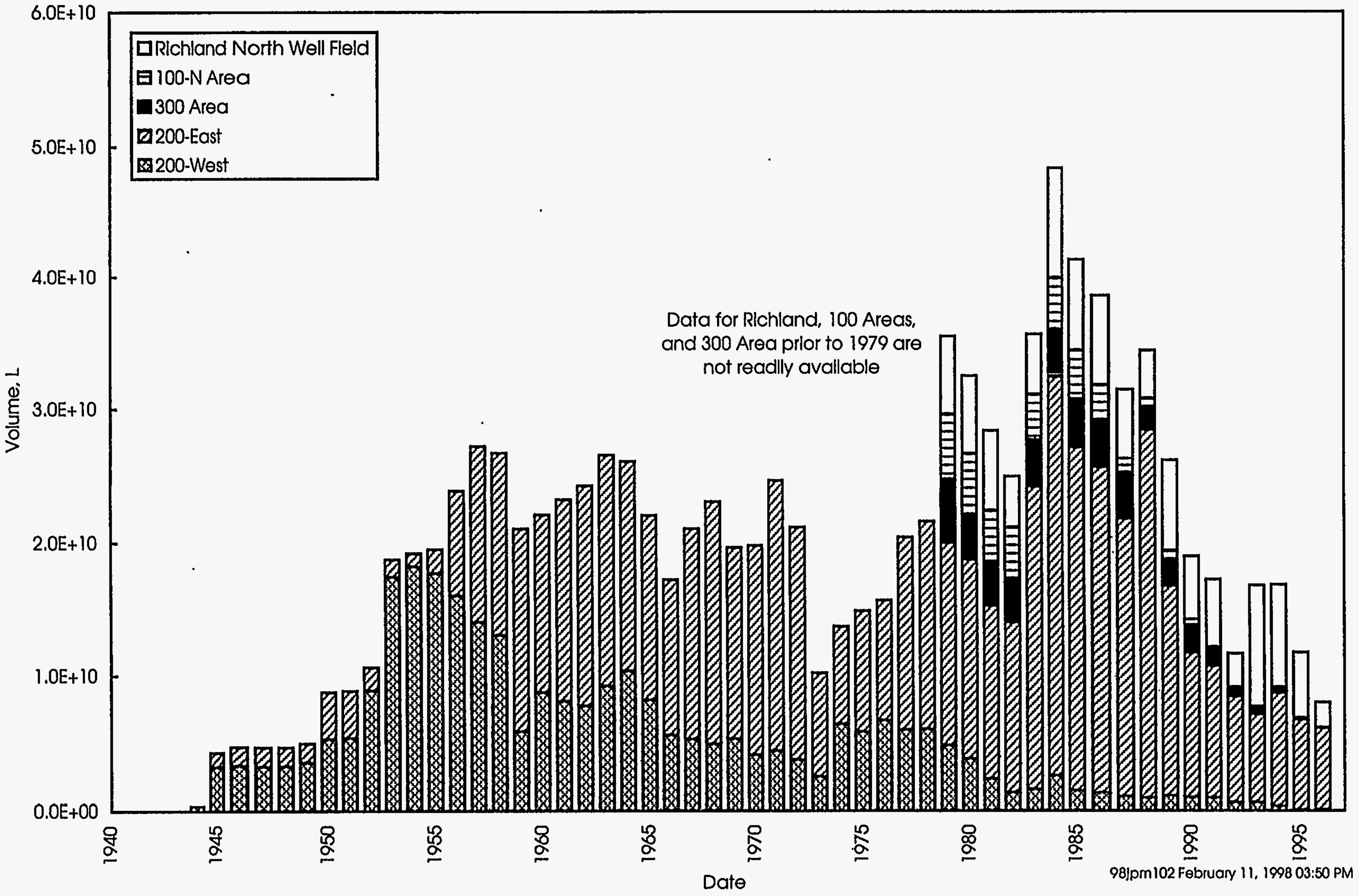

Figure 3.3-3. Annual Volumes of Major Liquid Effluent Streams Discharged to Hanford Site Soil Column and Net Recharge at City of Richland's North Well Field

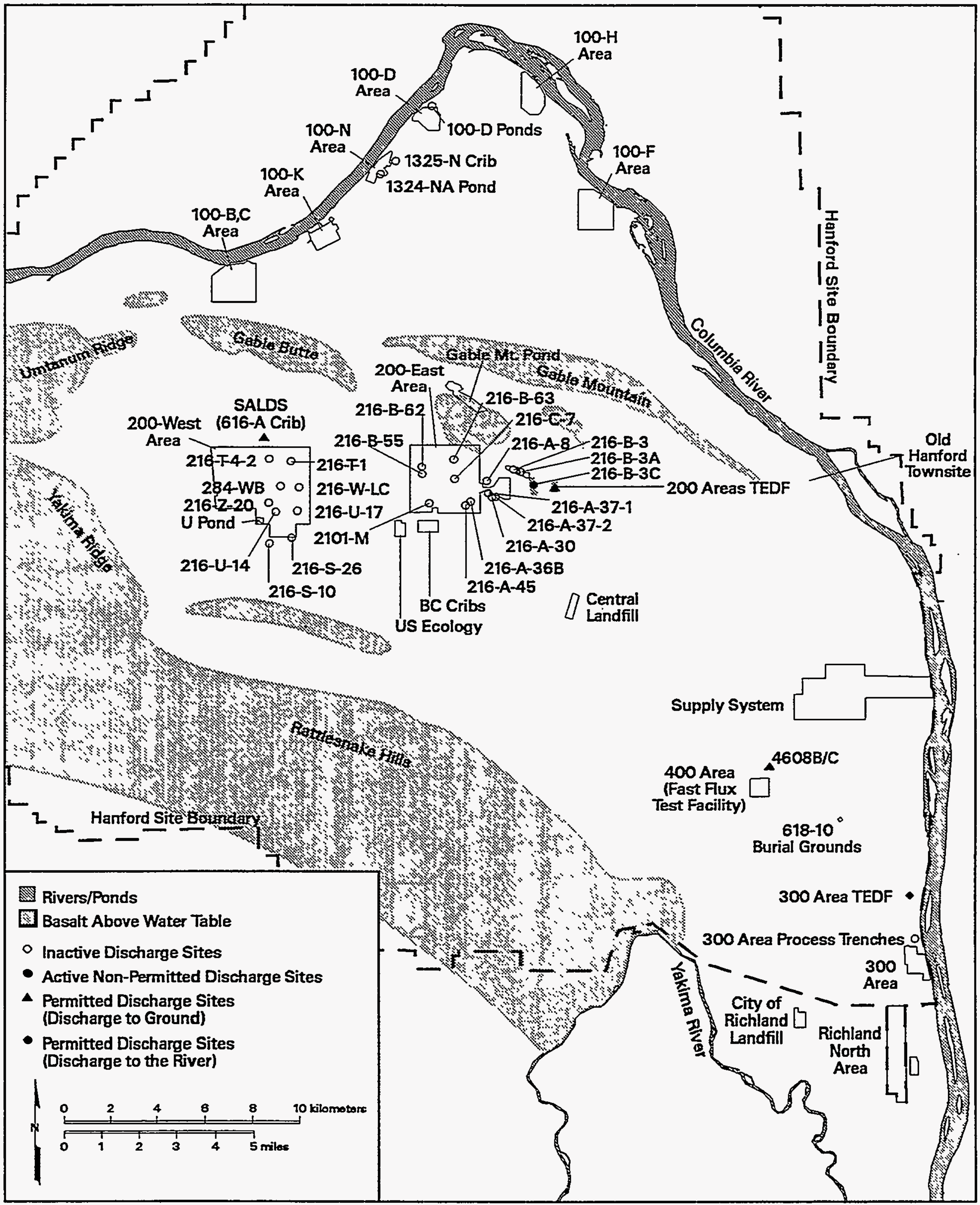

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Figure 3.3-4. Discharge Sites Associated With the 33 Major Liquid Effluent Streams Identified in 1988 (after WHC-EP-0196-1)

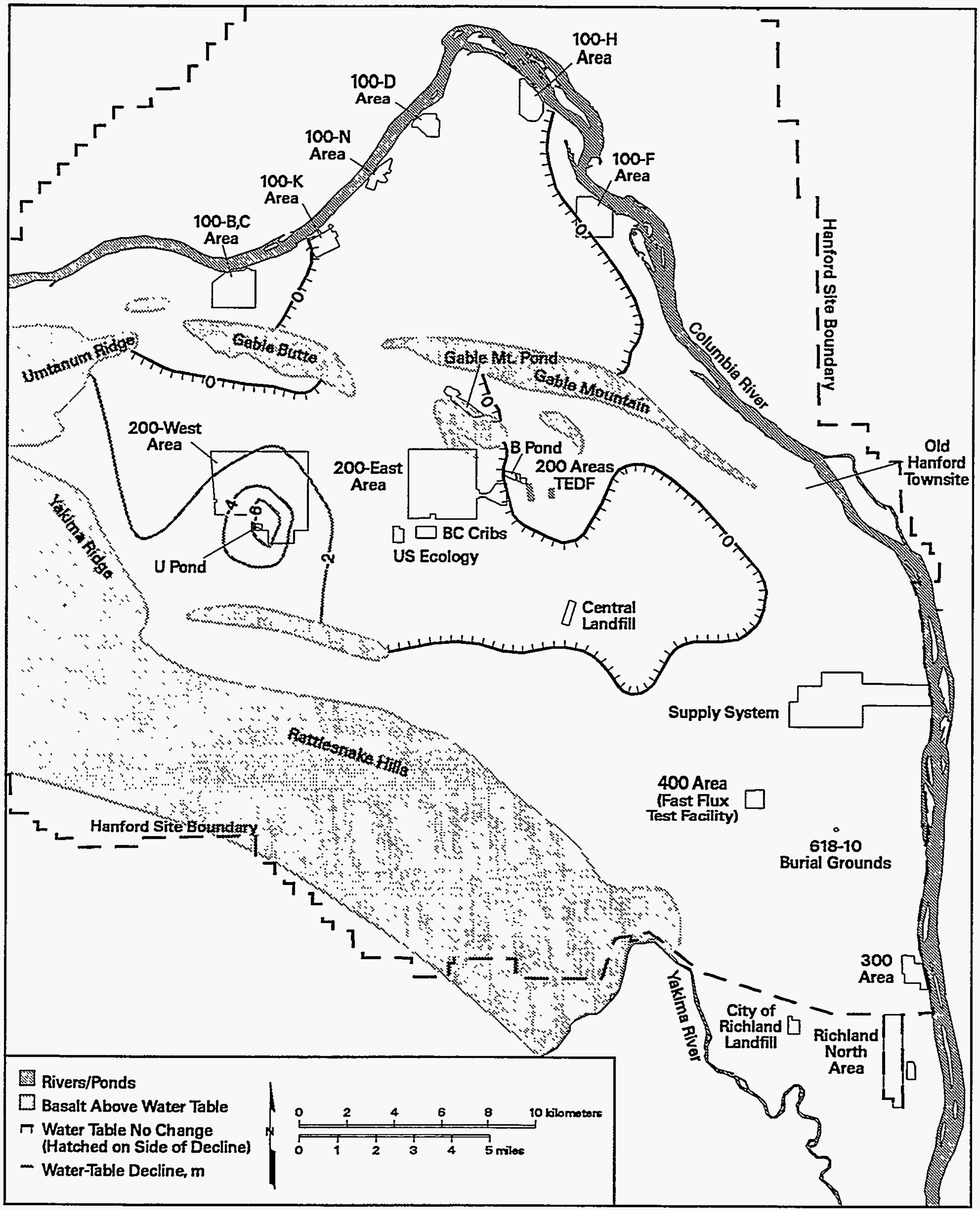

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Figure 3.3-5. Changes in Water-Table Elevations, 1979 Through 1995

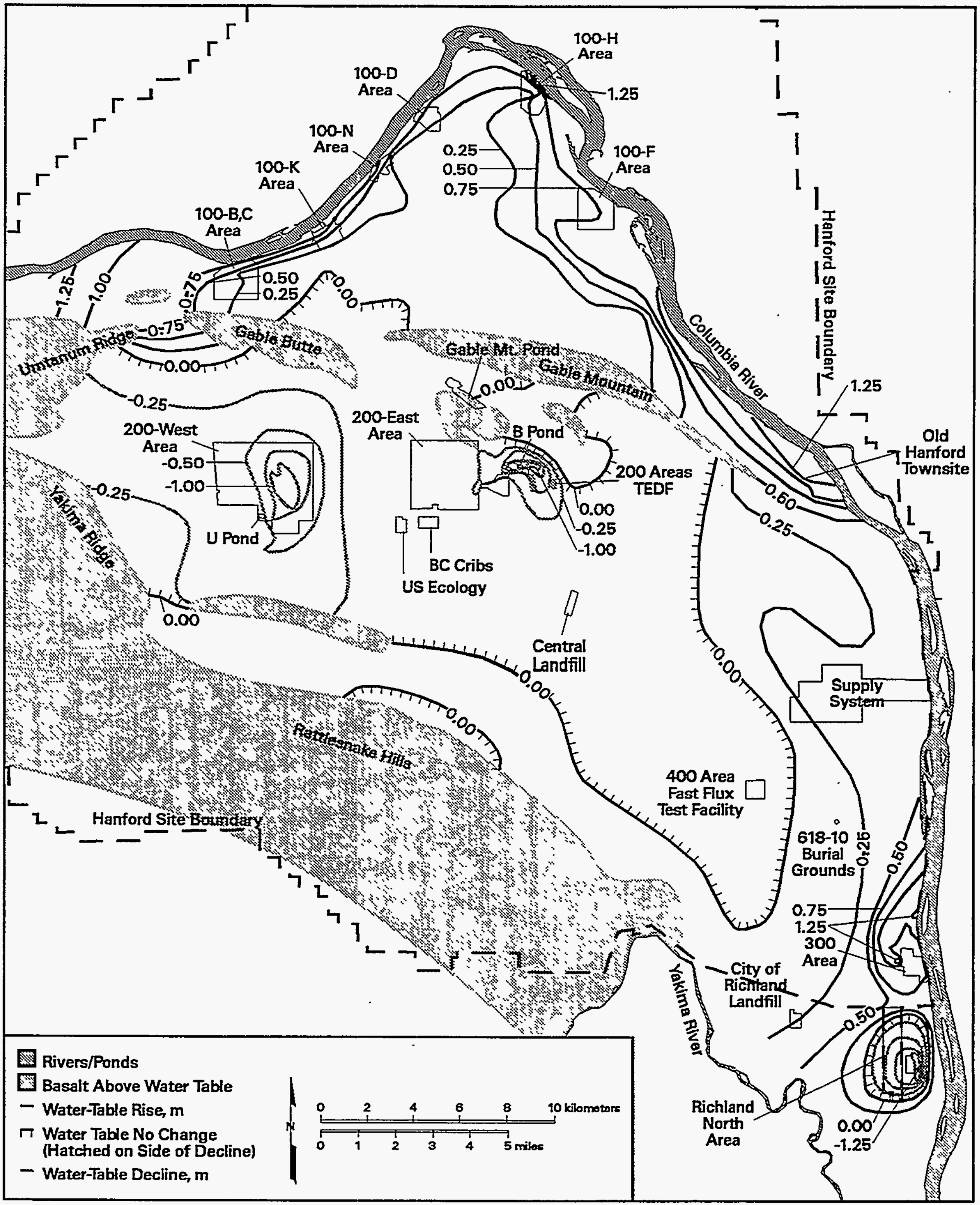

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Figure 3.3-6. Changes in Water-Table Elevations Between June 1996 and June 1997

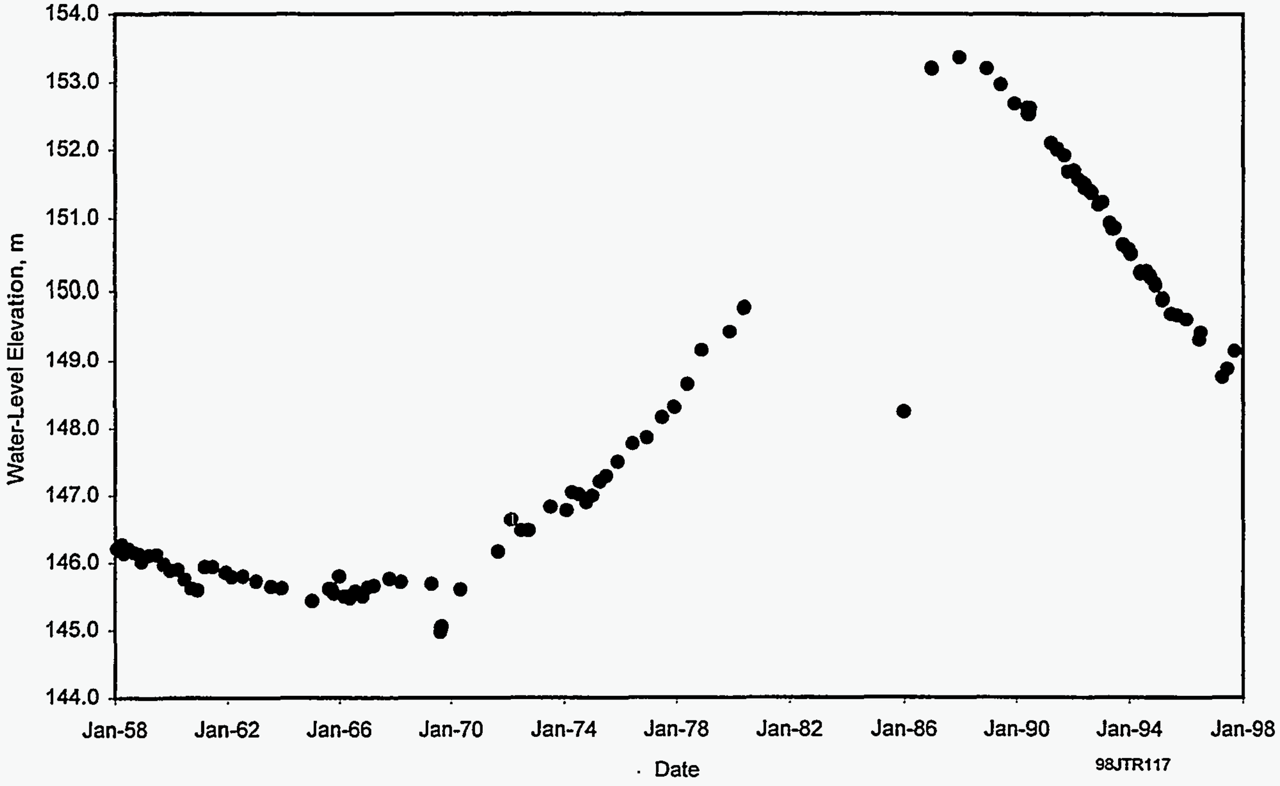

Figure 3.4-1. Water-Table Elevations in Well 699-43-104

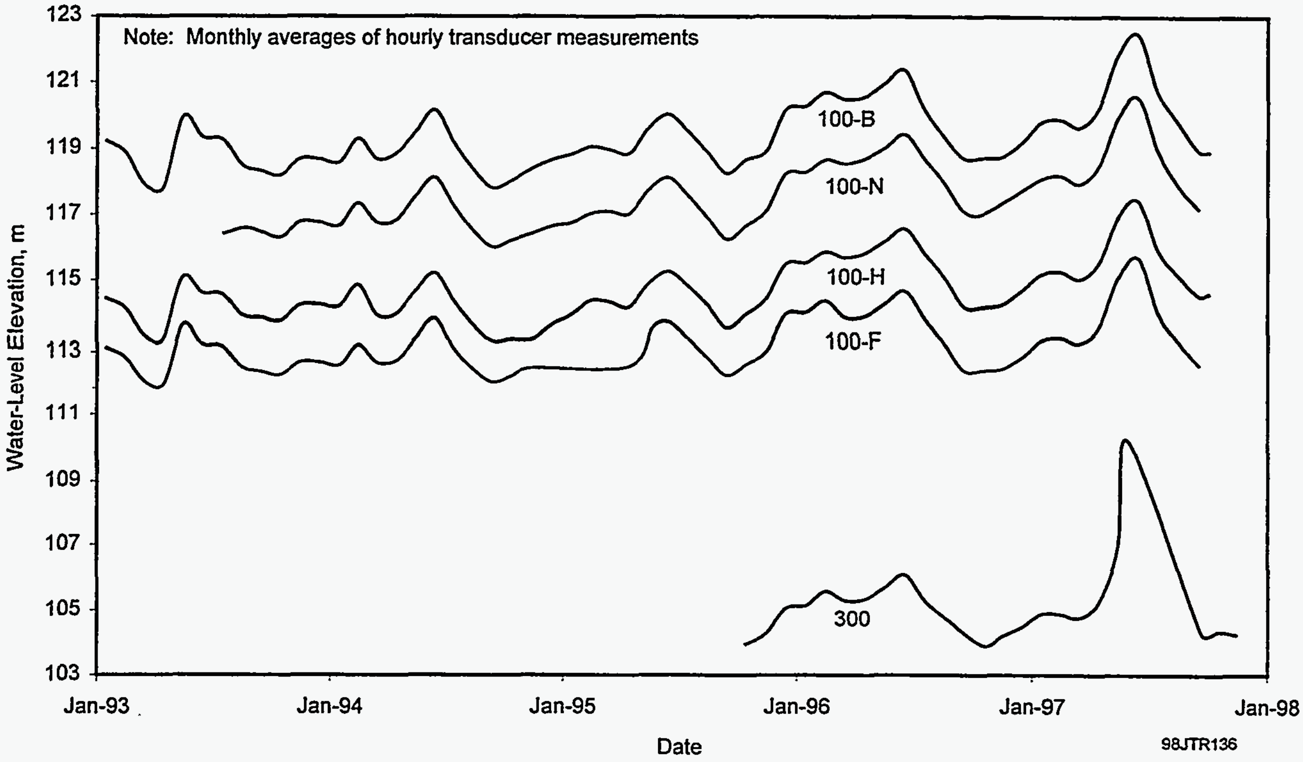

Figure 3.5-1. Columbia River Stage at 100 and 300 Areas

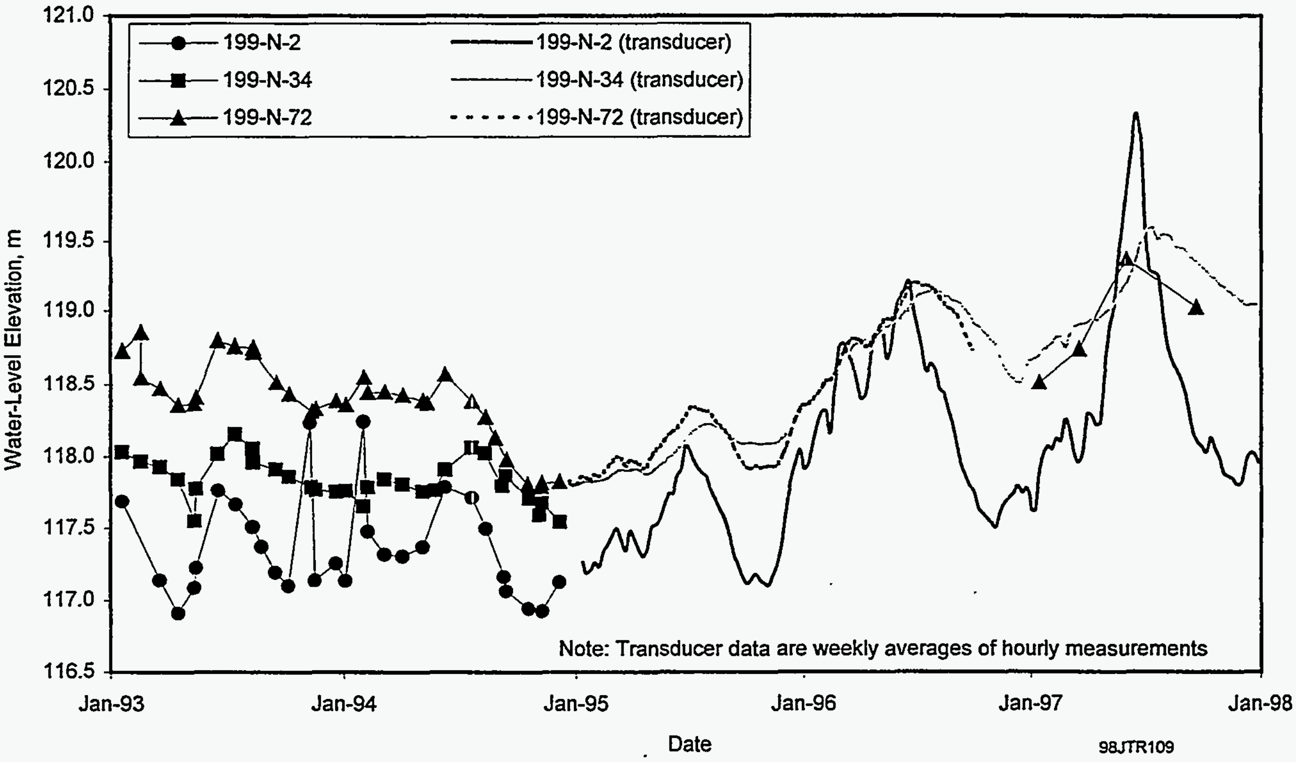

Figure 3.5-2. Water-Table Elevations in Wells Monitoring 100-N Area

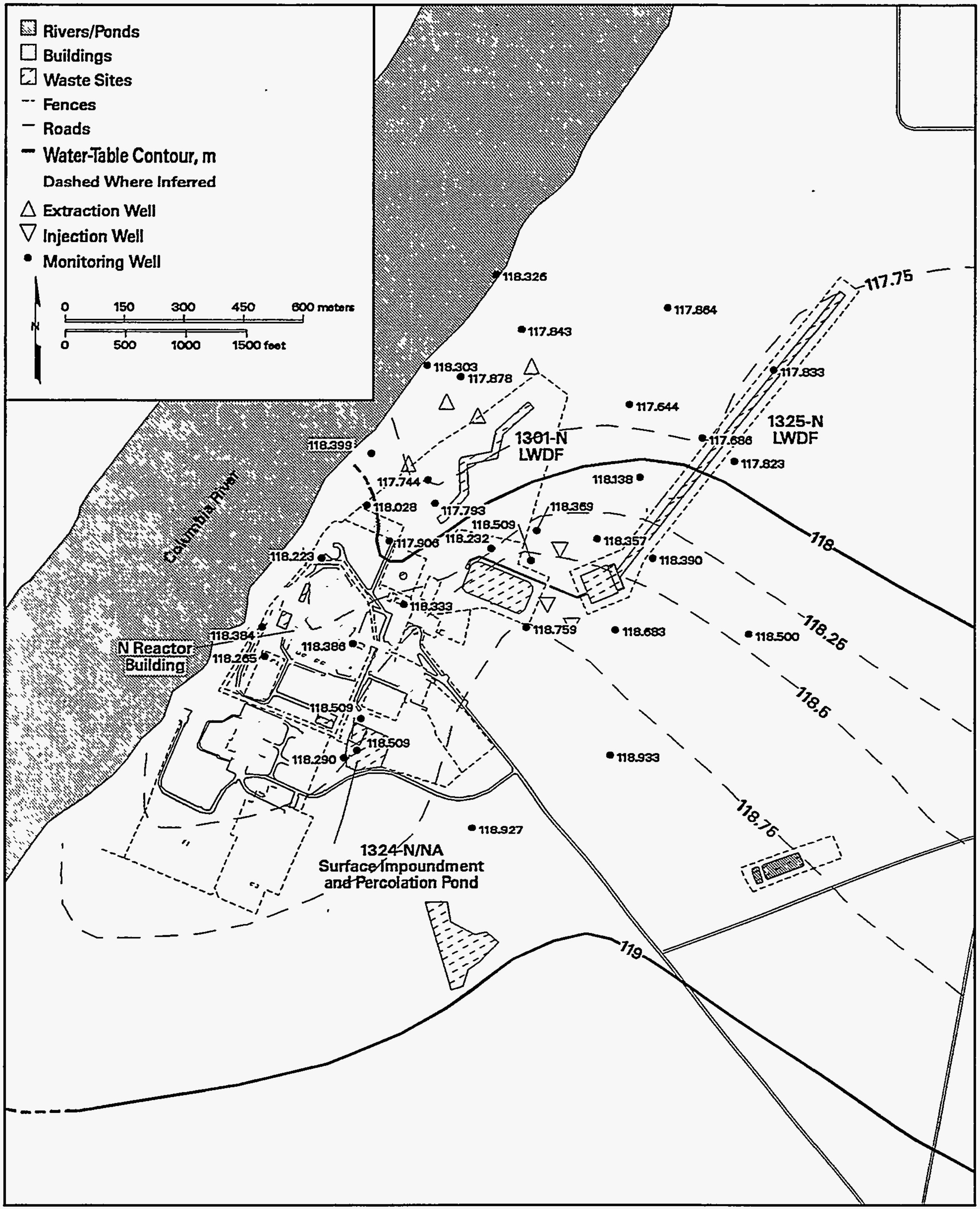

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Figure 3.5-3. Water-Table Map for 100-N Area, January 1997

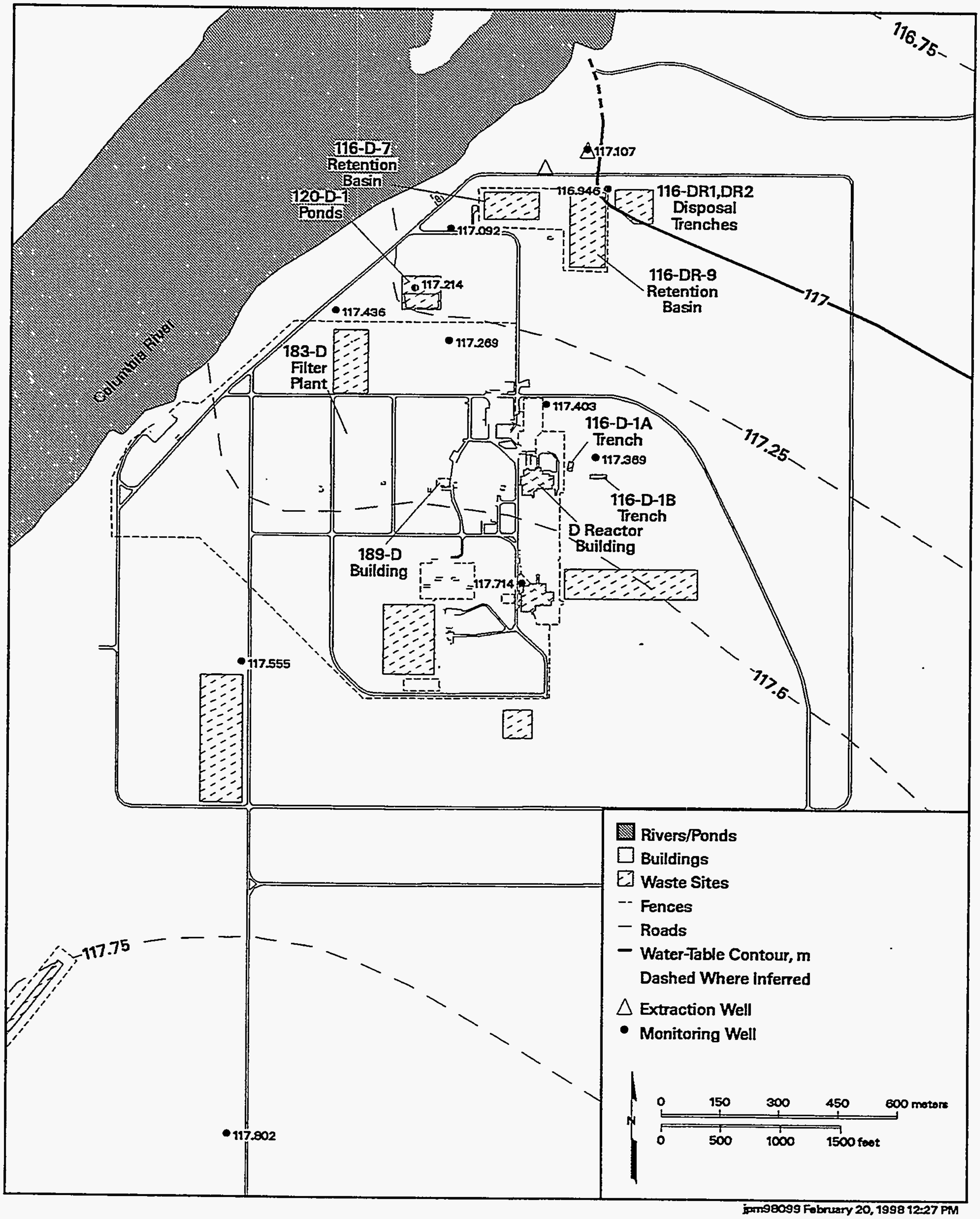

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Figure 3.5-4. Water-Table Map for 100-D Area, January 1997

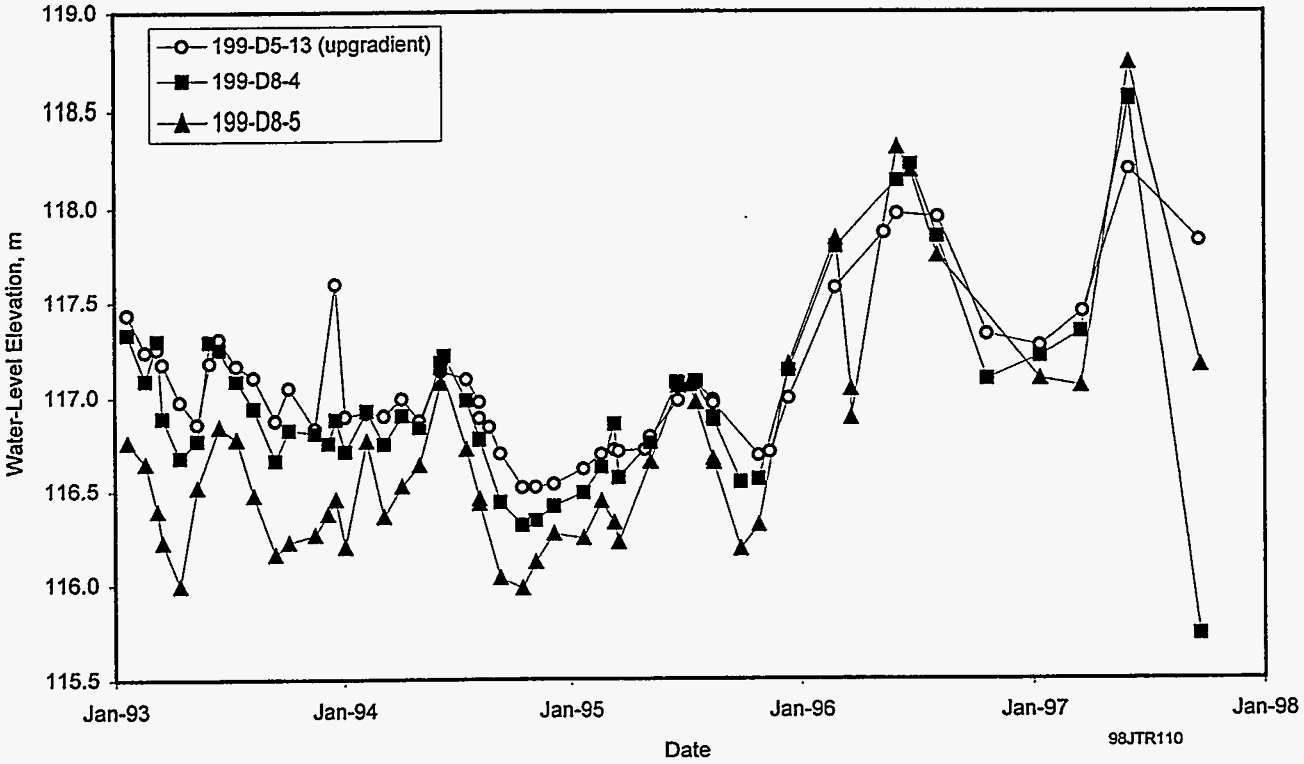

Figure 3.5-5. Water-Table Elevations in Wells Monitoring 120-D-1 Ponds

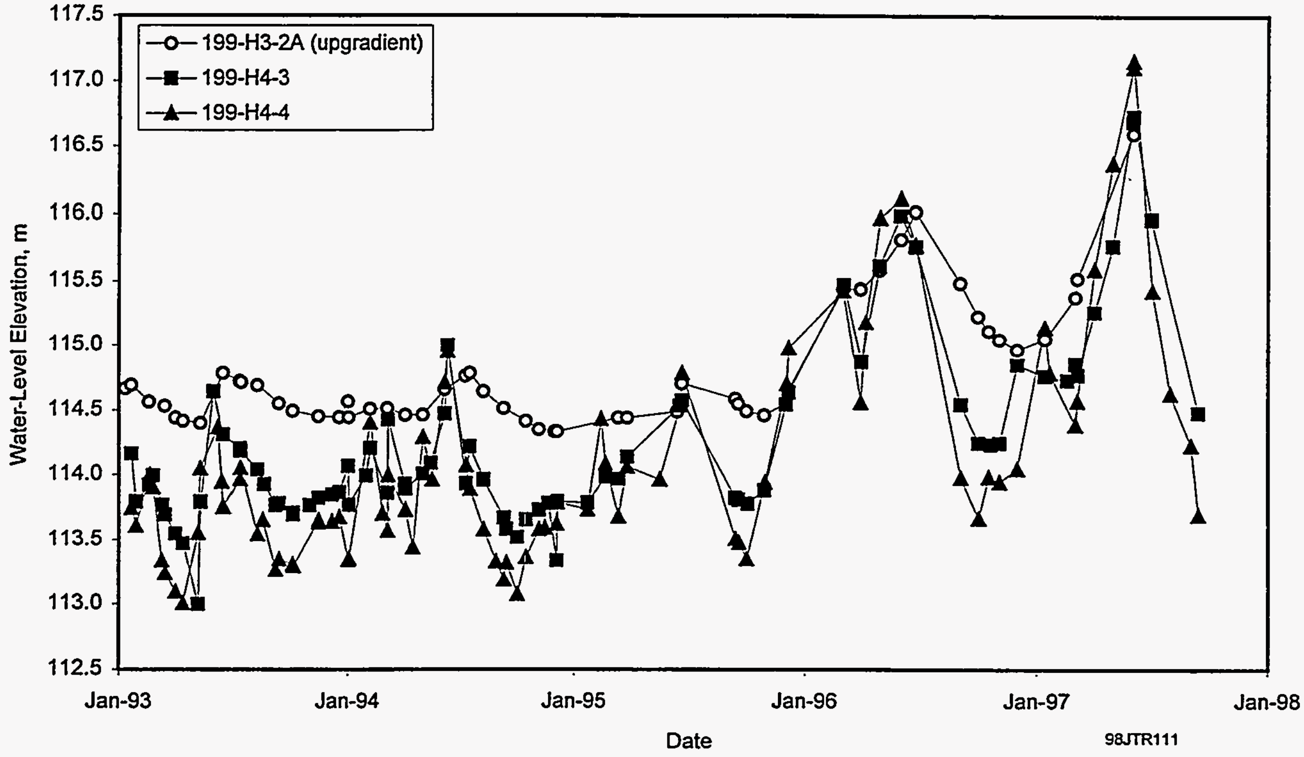

Figure 3.5-6. Water-Table Elevations in Wells Monitoring 183-H Solar Evaporation Basins

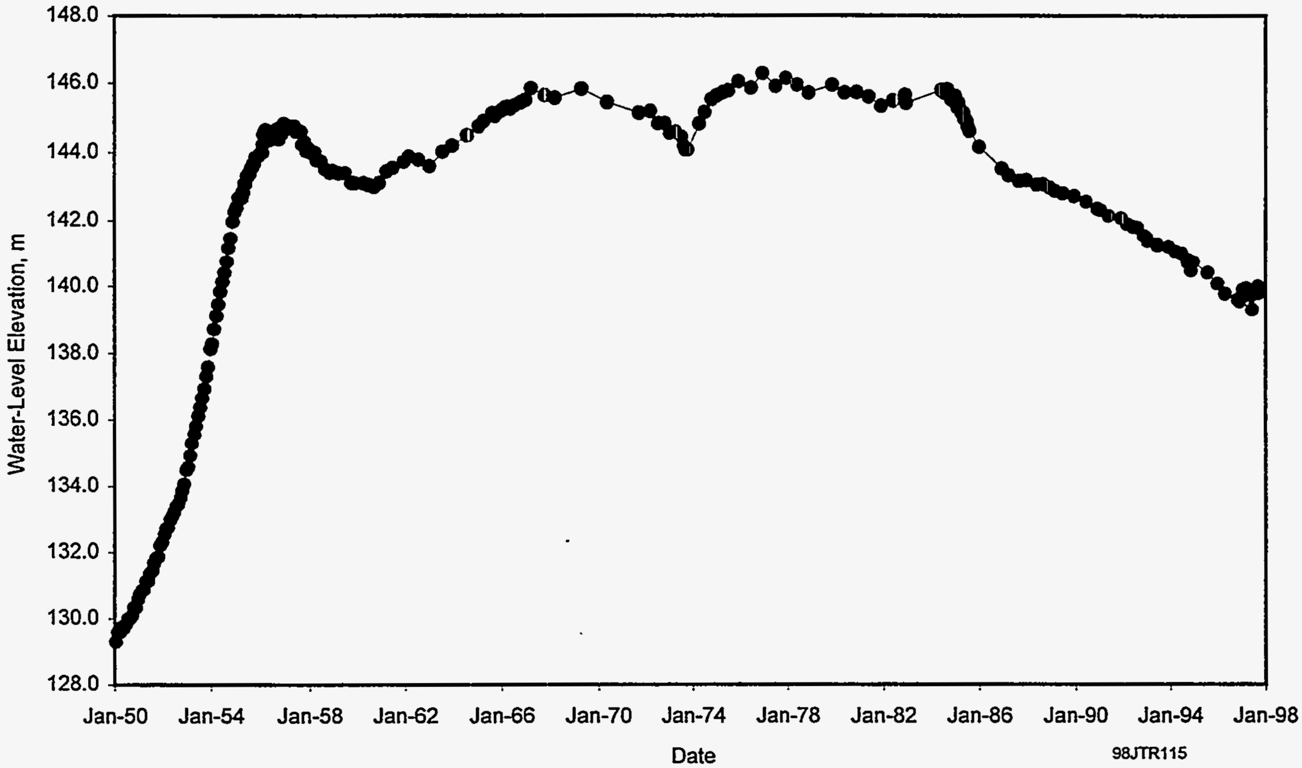

Figure 3.6-1. Water-Table Elevations in Well 699-39-79 Near U Pond

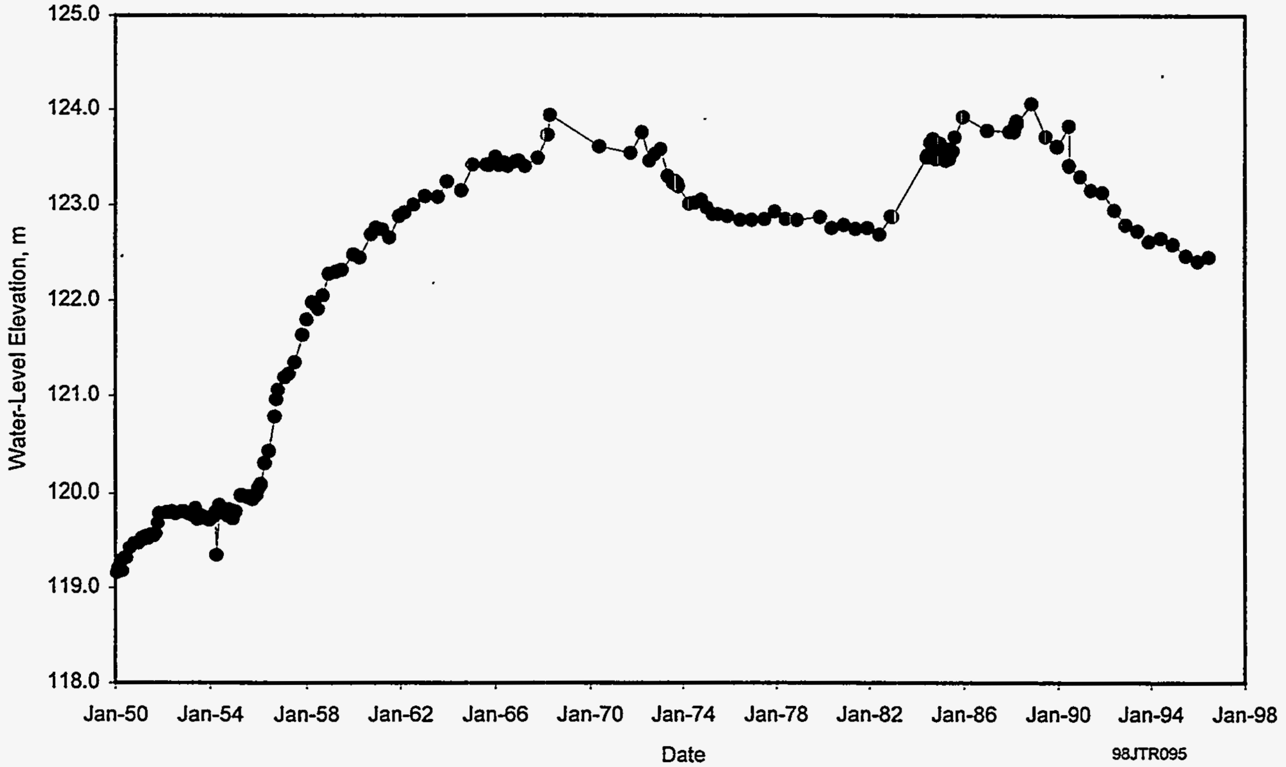

Figure 3.6-2. Water-Table Elevations in Well 299-E26-1

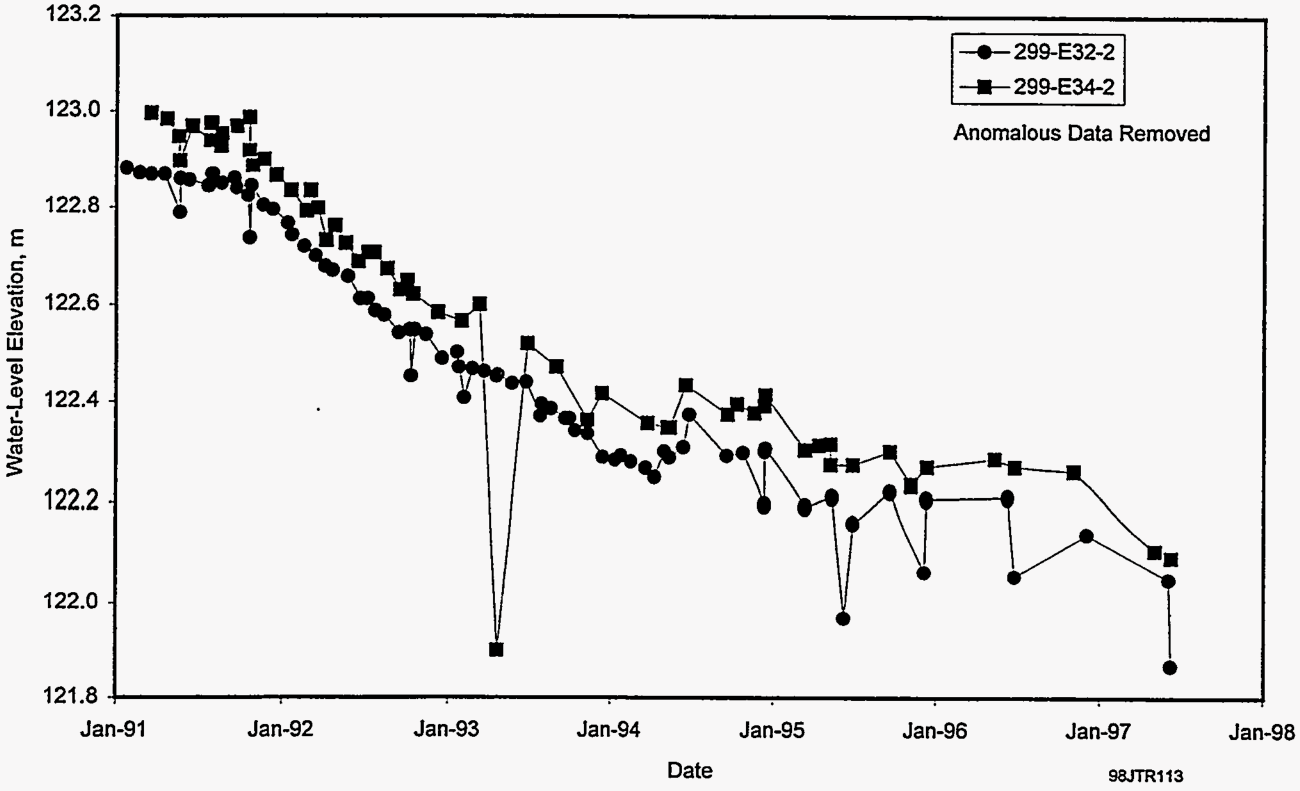

Figure 3.6-3. Water-Table Elevations in Wells 299-E32-2 and 299-E34-2

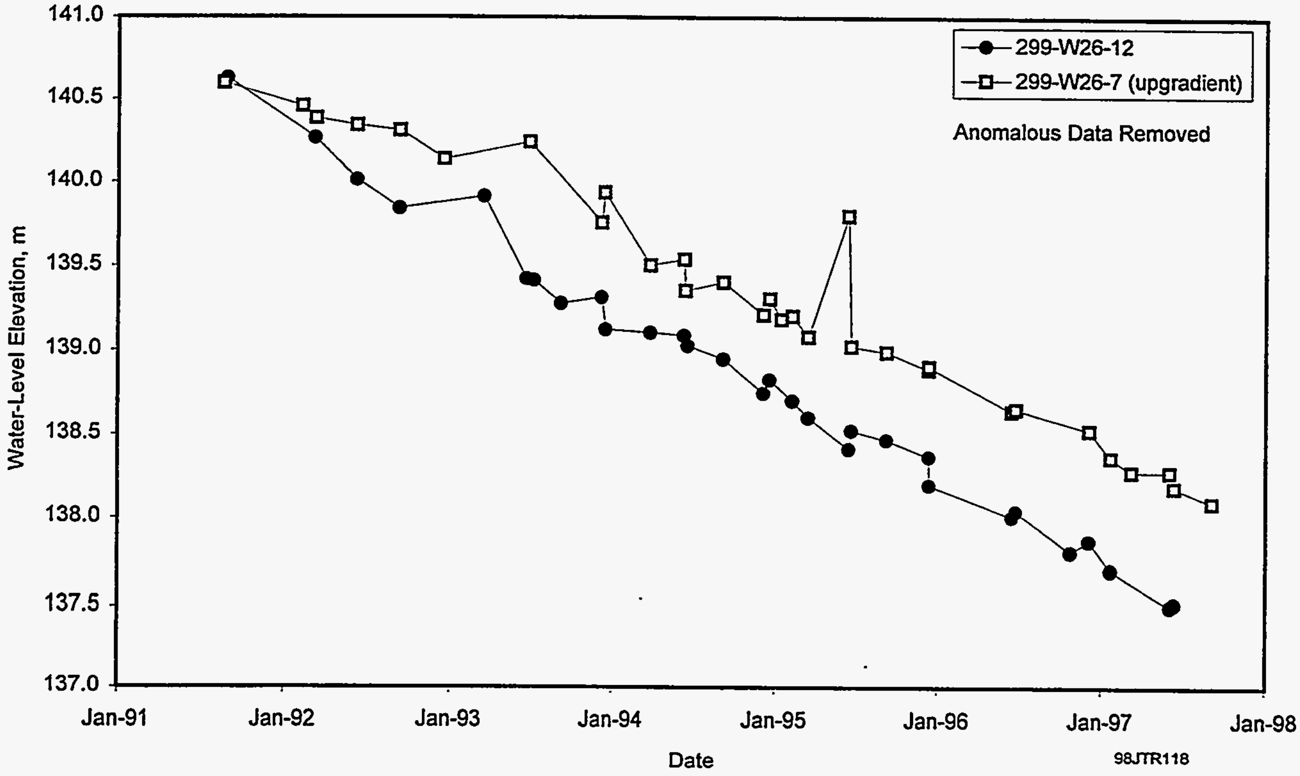

Figure 3.6-4. Water-Table Elevations in Wells Monitoring 216-S-10 Pond and Ditch

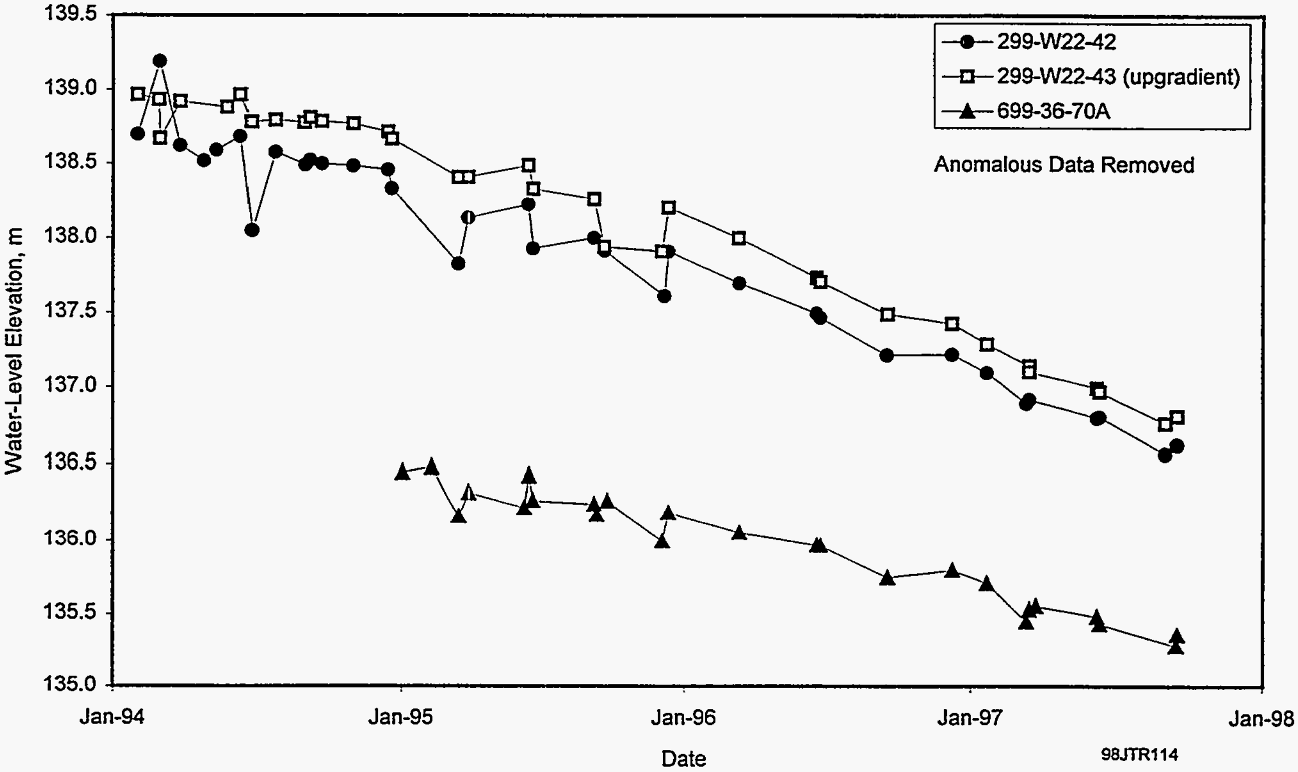

Figure 3.6-5. Water-Table Elevations in Wells Monitoring 216-U-12 Crib

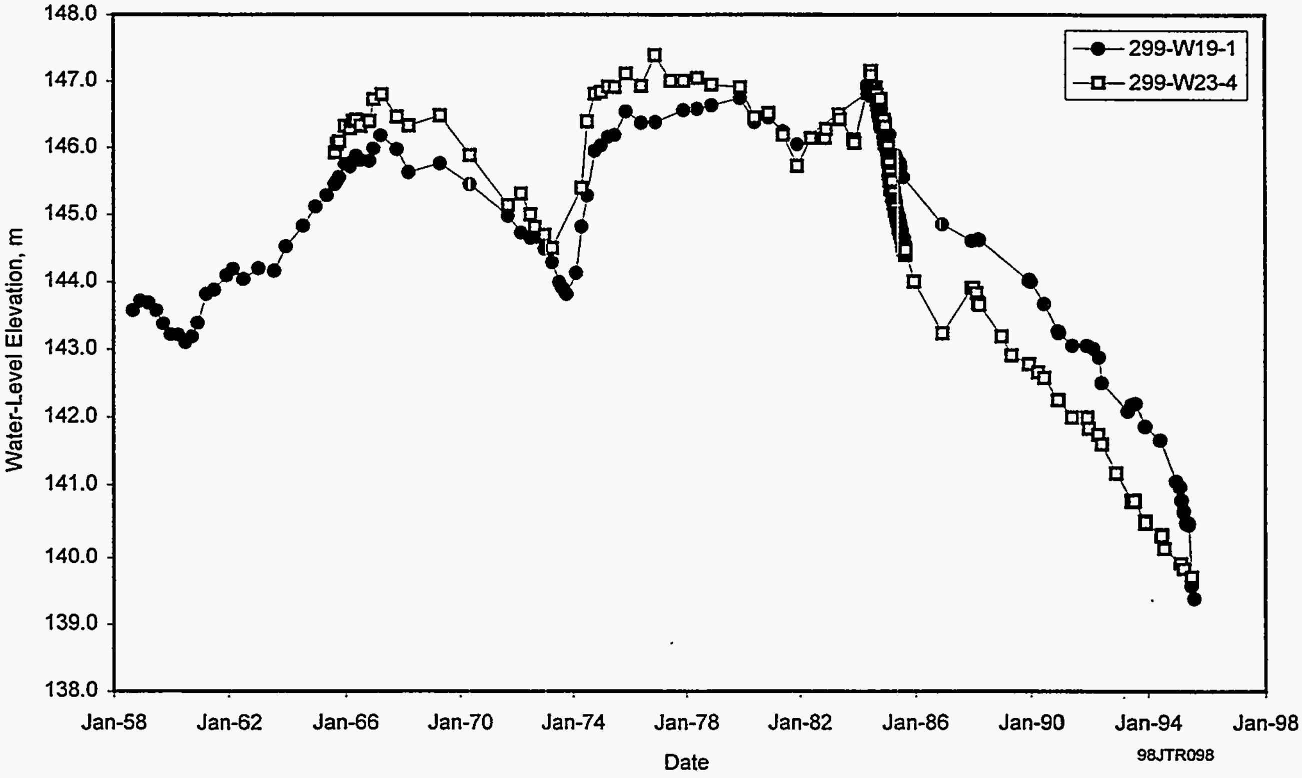

Figure 3.6-6. Water-Table Elevations in Wells 299-W19-1 and 299-W23-4 Near WMAs S-SX and U

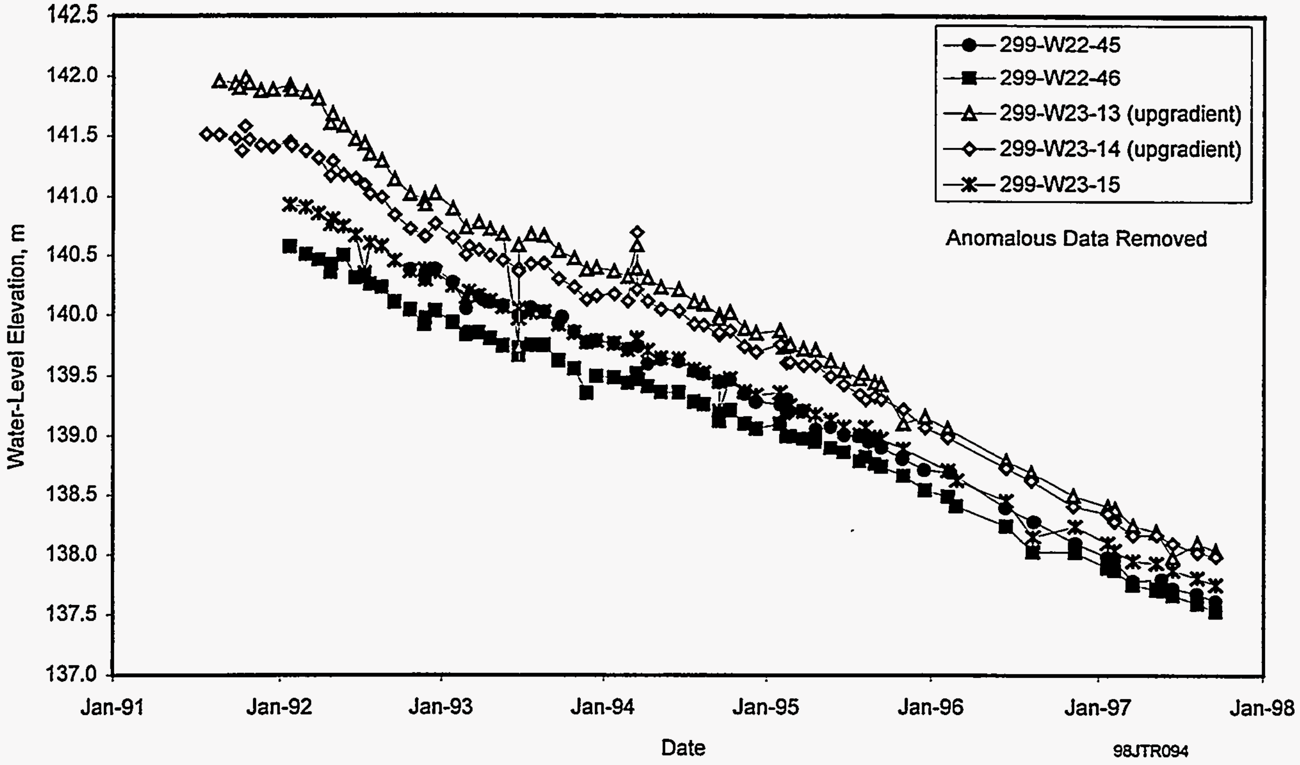

Figure 3.6-7. Water-Table Elevations in Wells Monitoring WMA S-SX

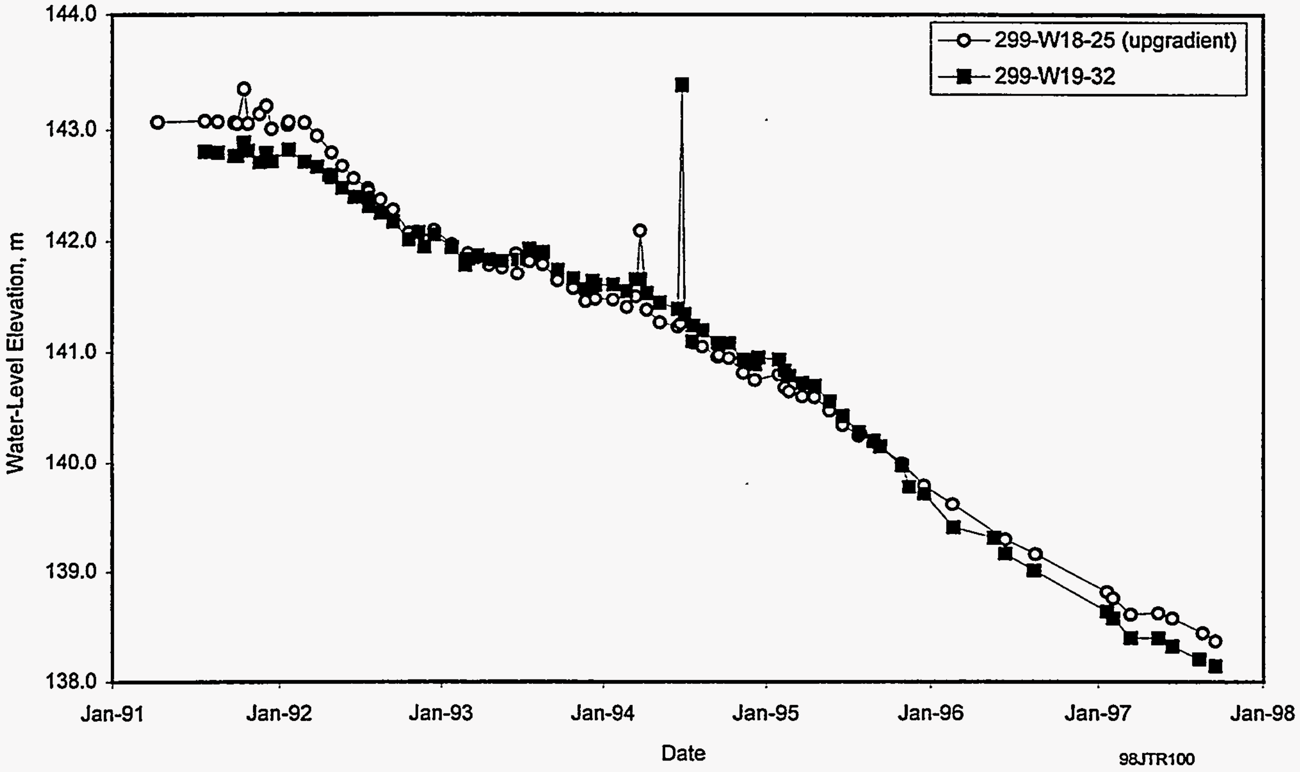

Figure 3.6-8. Water-Table Elevations in Wells Monitoring WMA U

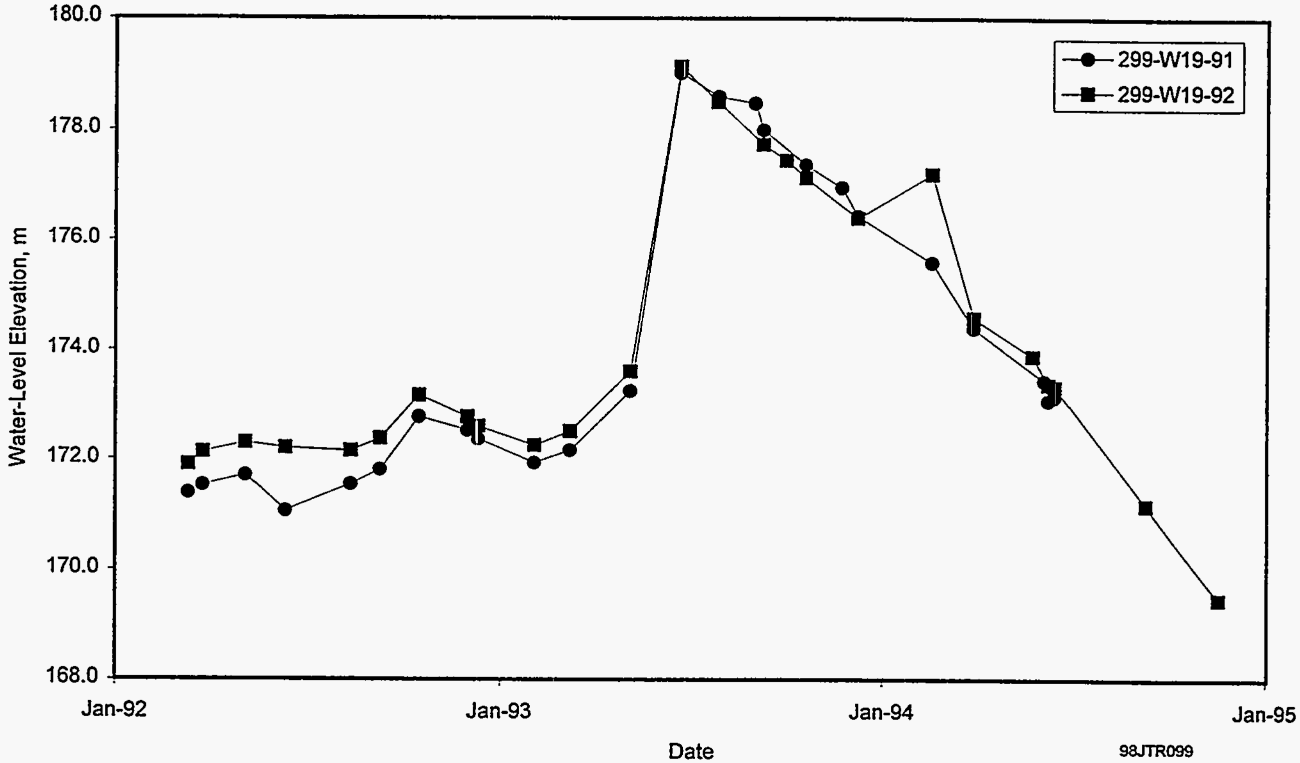

Figure 3.6-9. Water-Table Elevations in Perched Aquifer Wells Monitoring 216-U-14 Ditch

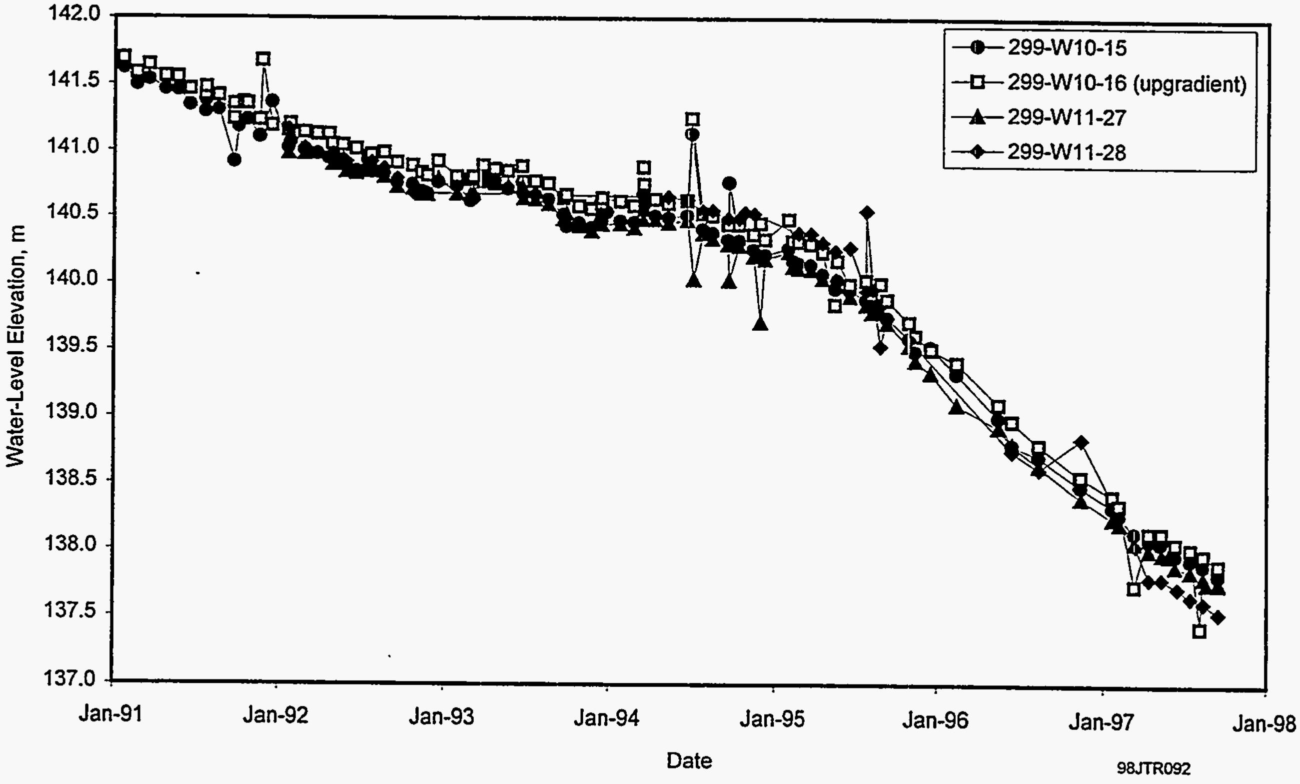

Figure 3.6-10. Water-Table Elevations in Wells Monitoring WMA T

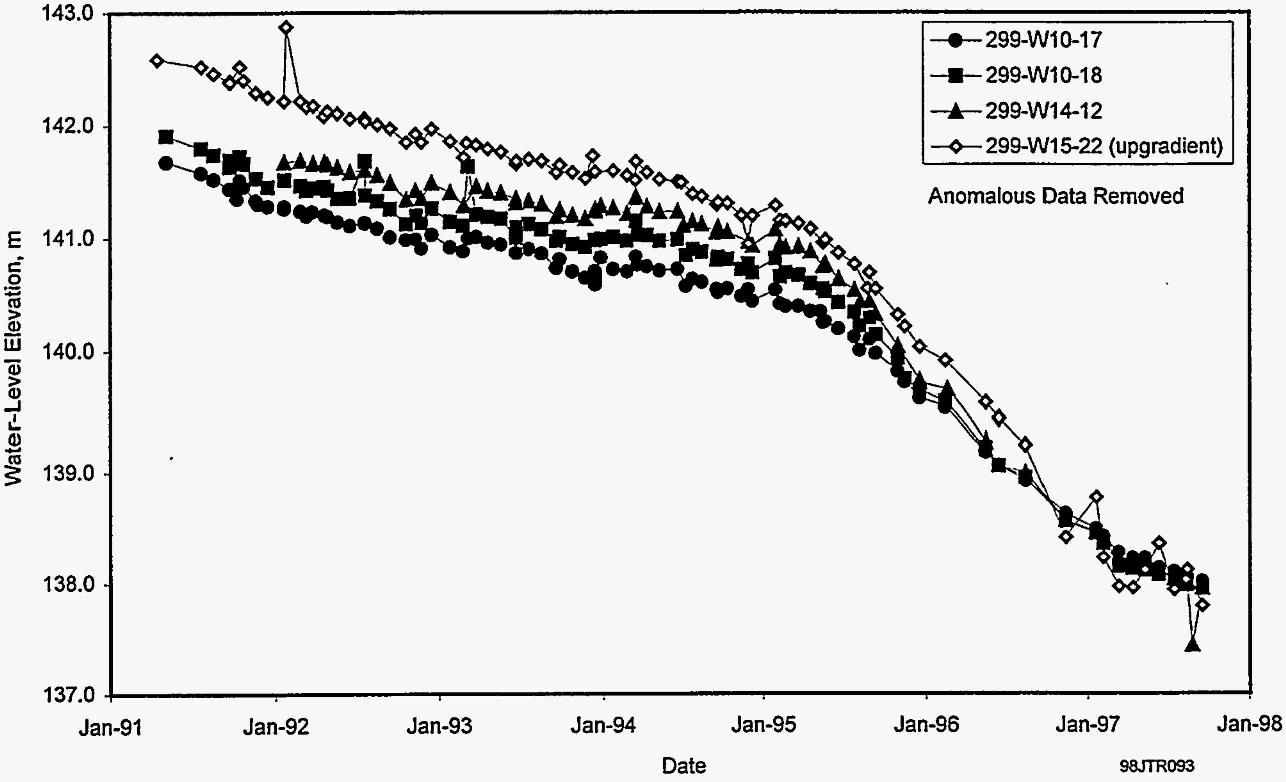

Figure 3.6-11. Water-Table Elevations in Wells Monitoring WMA TX-TY

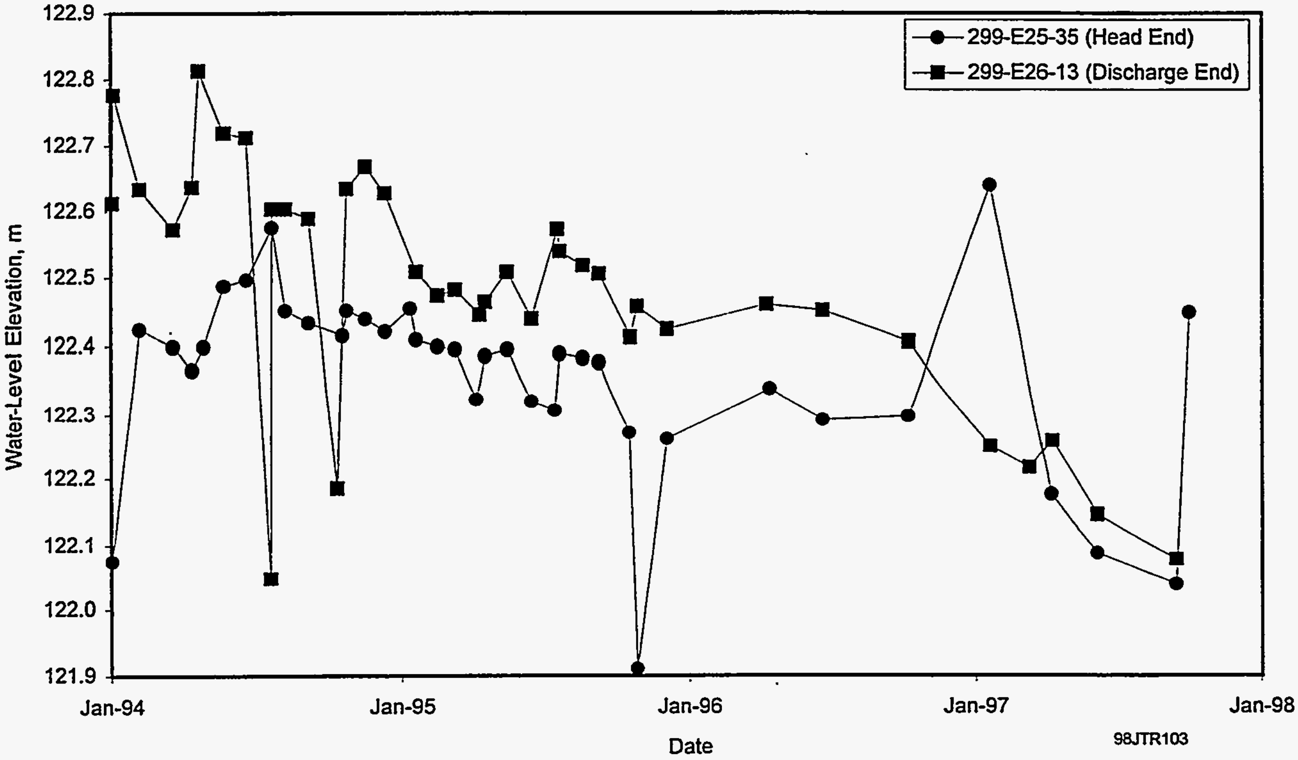

Figure 3.6-12. Water-Table Elevations in Wells Monitoring 216-A-29 Ditch

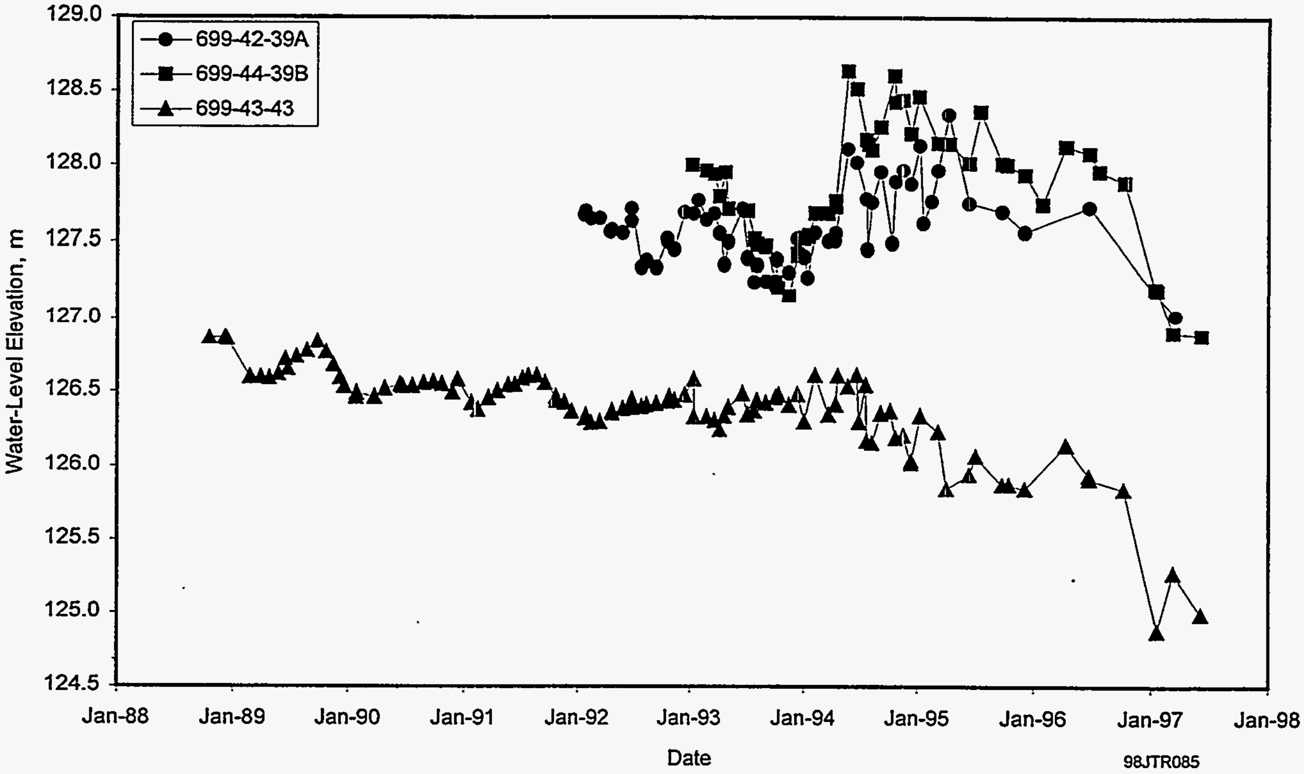

Figure 3.6-13. Water-Table Elevations in Wells Monitoring 216-B-3 Pond

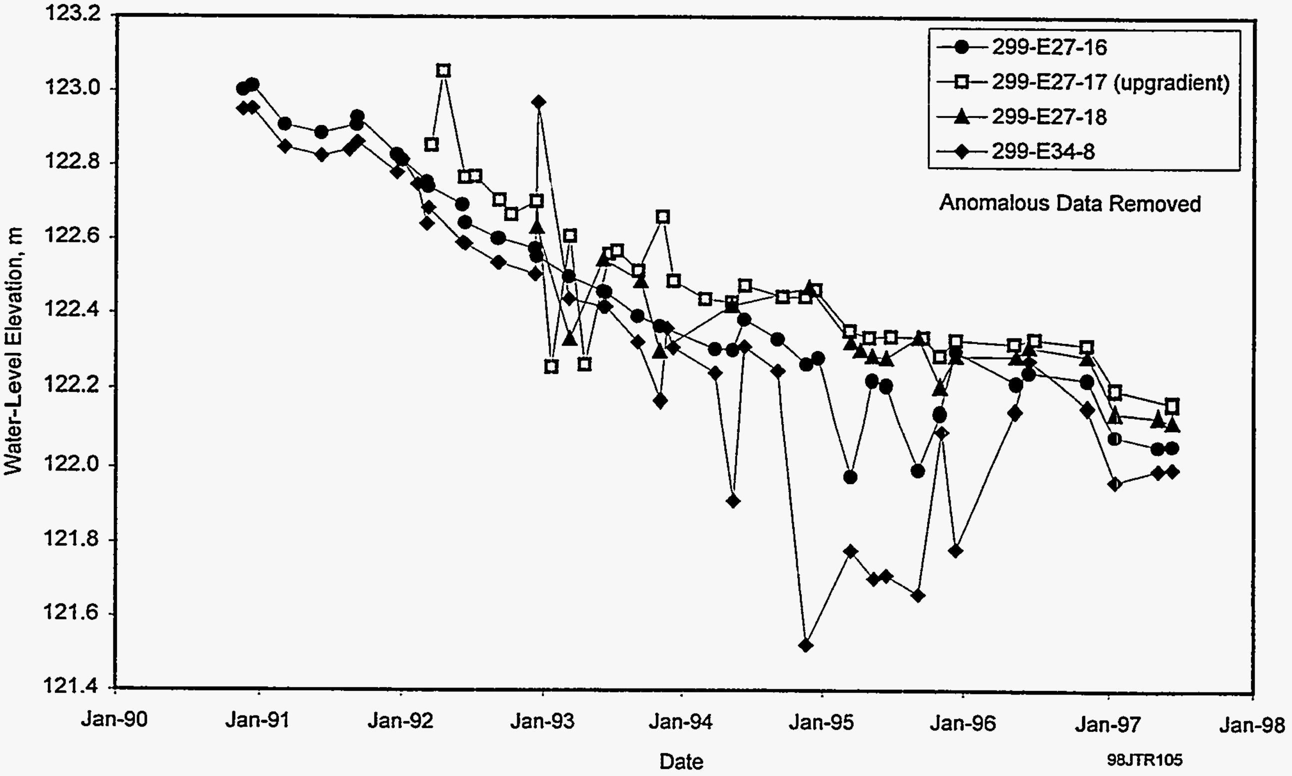

Figure 3.6-14. Water-Table Elevations in Wells Monitoring 216-B-63 Trench

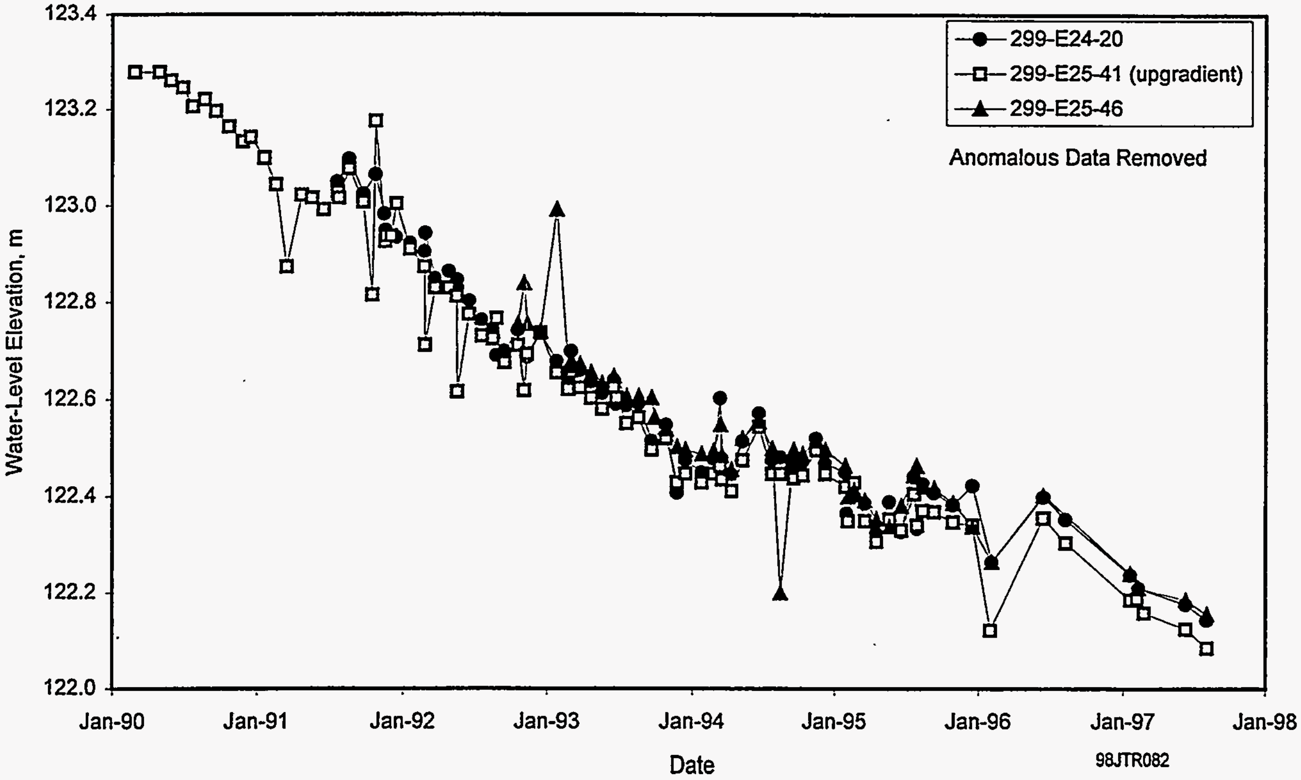

Figure 3.6-15. Water-Table Elevations in Wells Monitoring WMA A-AX

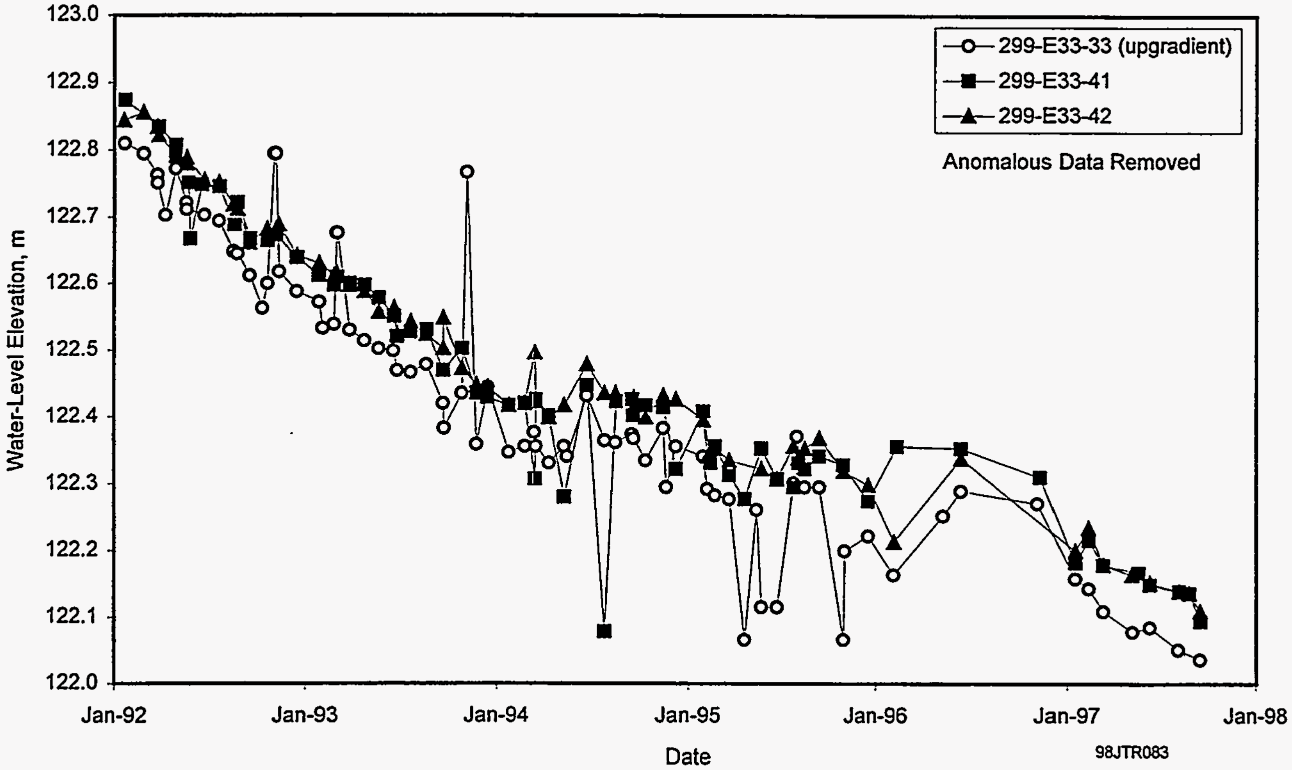

Figure 3.6-16. Water-Table Elevations in Wells Monitoring WMA B-BX-BY

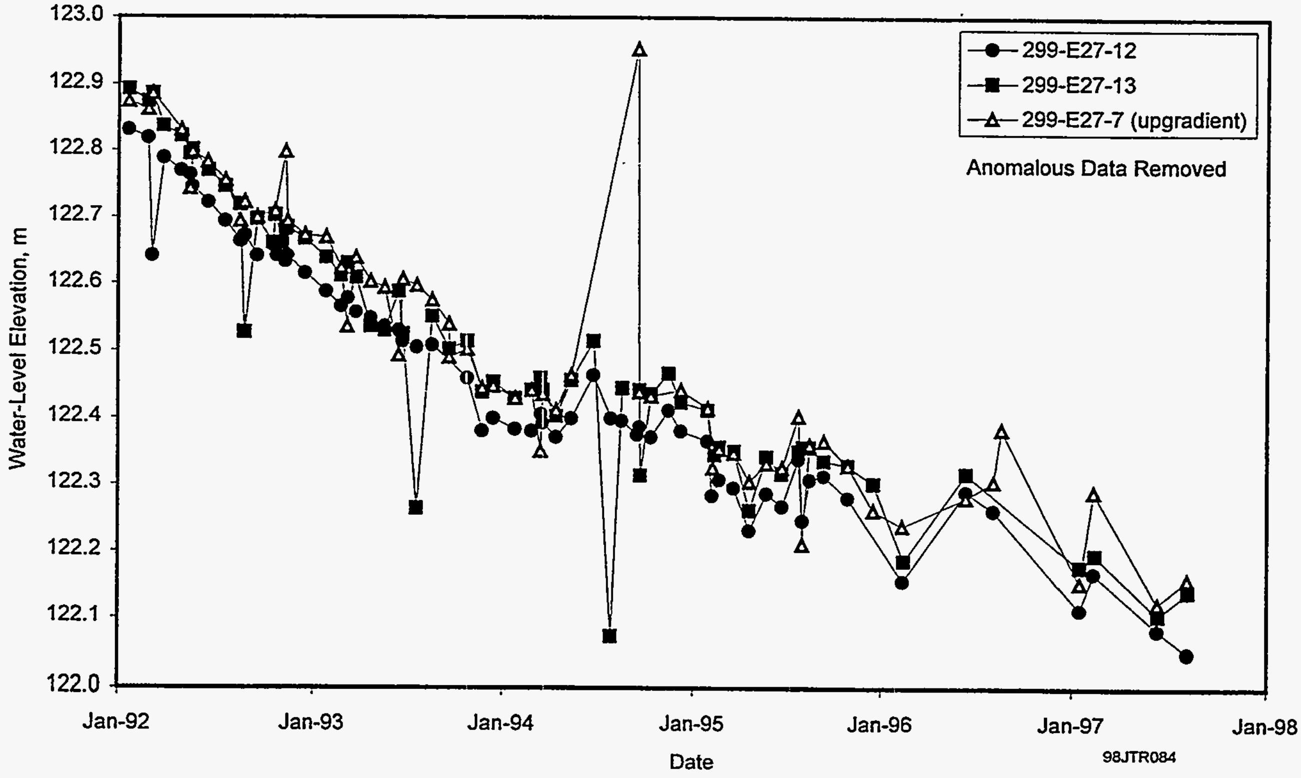

Figure 3.6-17. Water-Table Elevations in Wells Monitoring WMA C

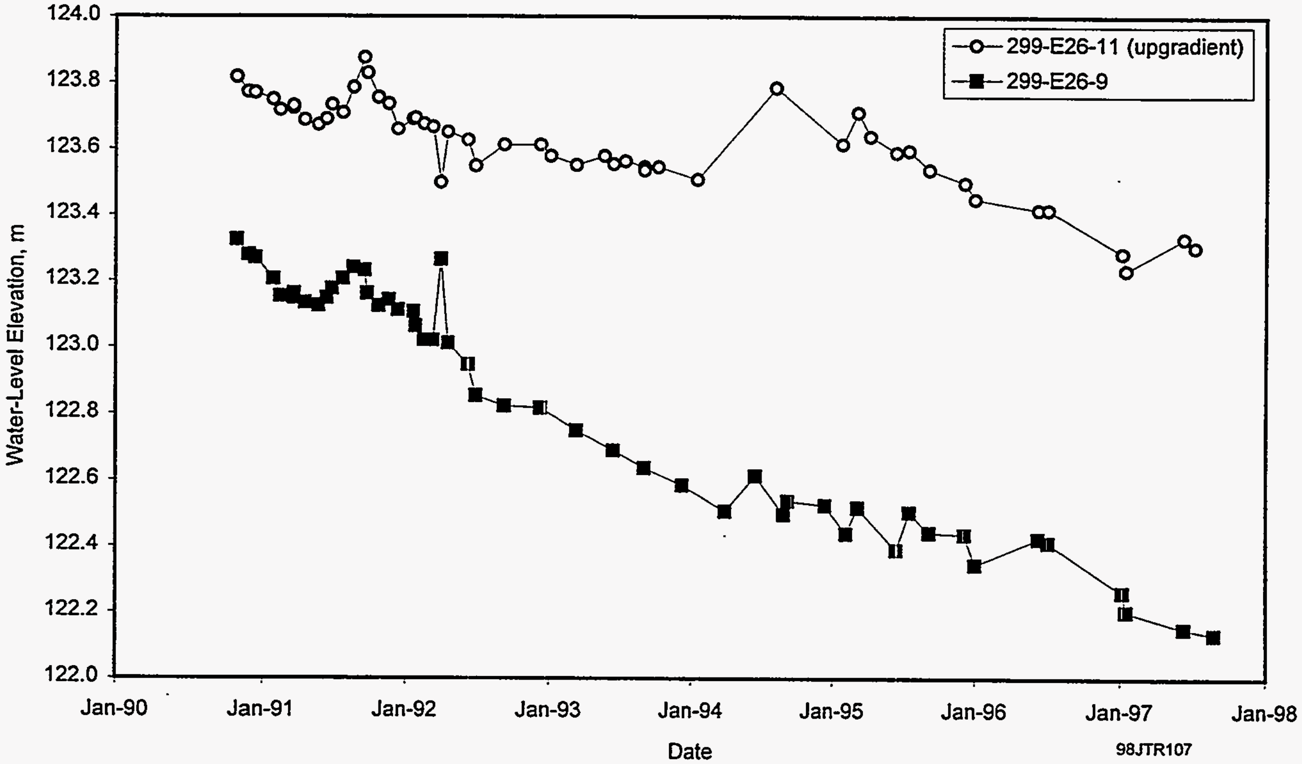

Figure 3.6-18. Water-Table Elevations in Wells Monitoring Liquid Effluent-Retention Facility

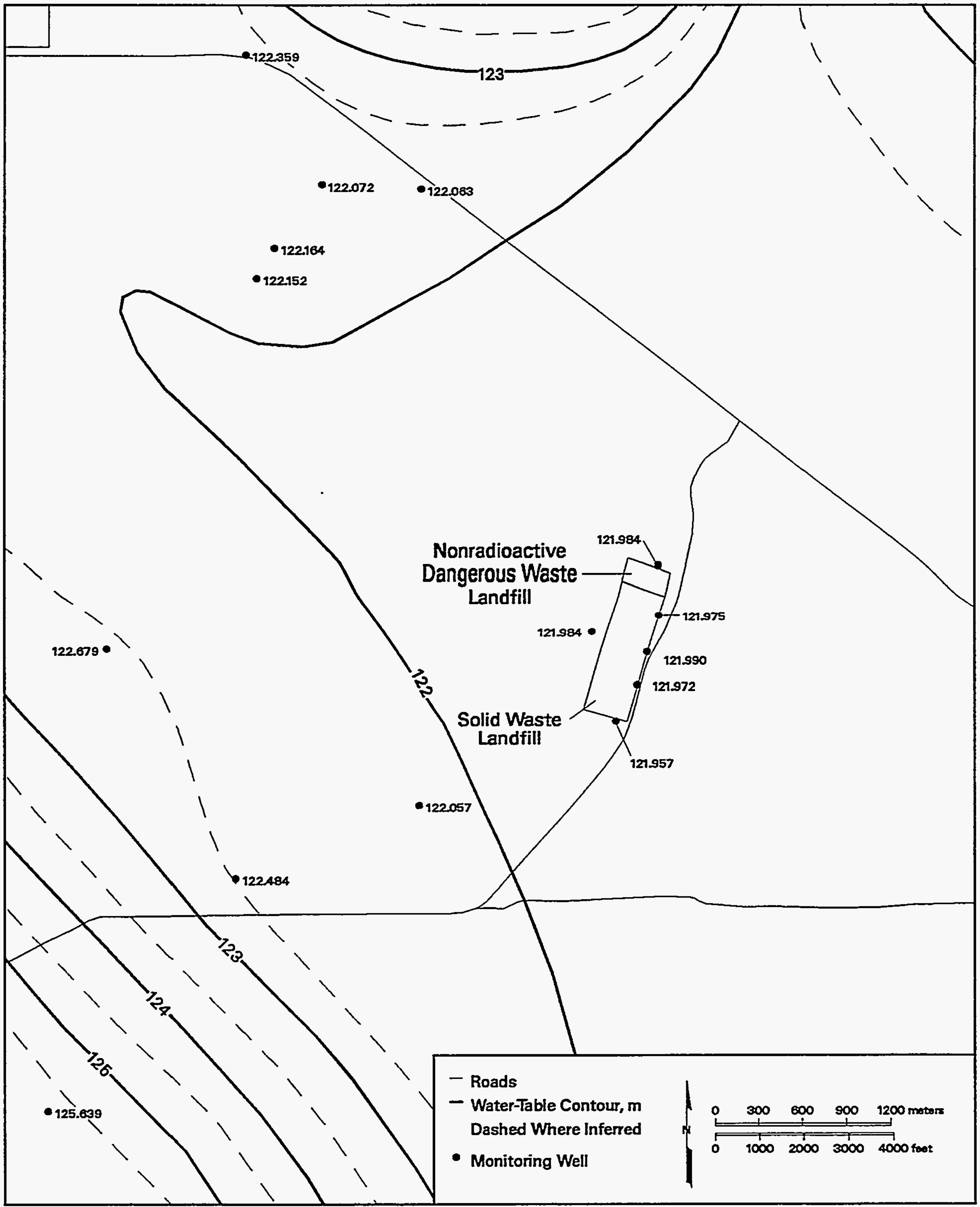

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Figure 3.7-1. Water-Table Map for Nonradioactive Dangerous Waste Landfill/Solid Waste Landfill, June 1997

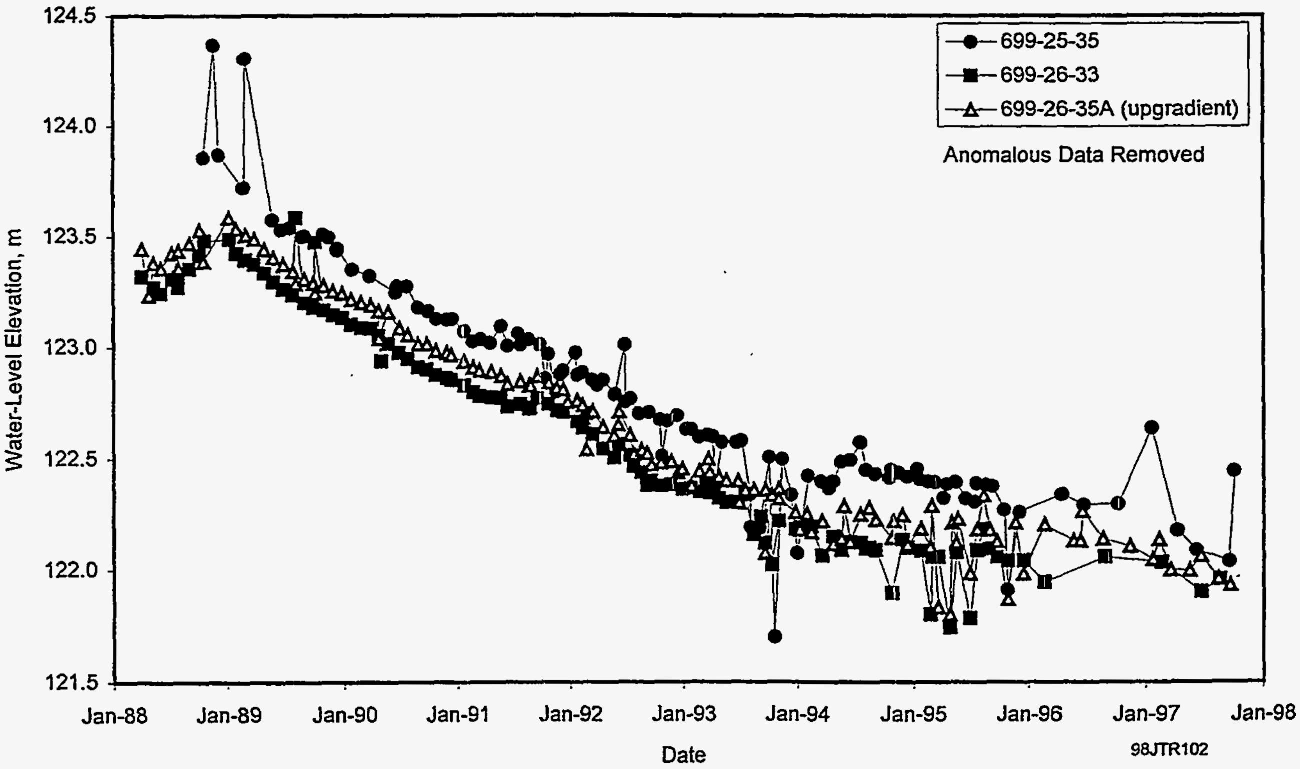

Figure 3.7-2. Water-Table Elevations in Wells Monitoring Nonradioactive Dangerous Waste Landfill

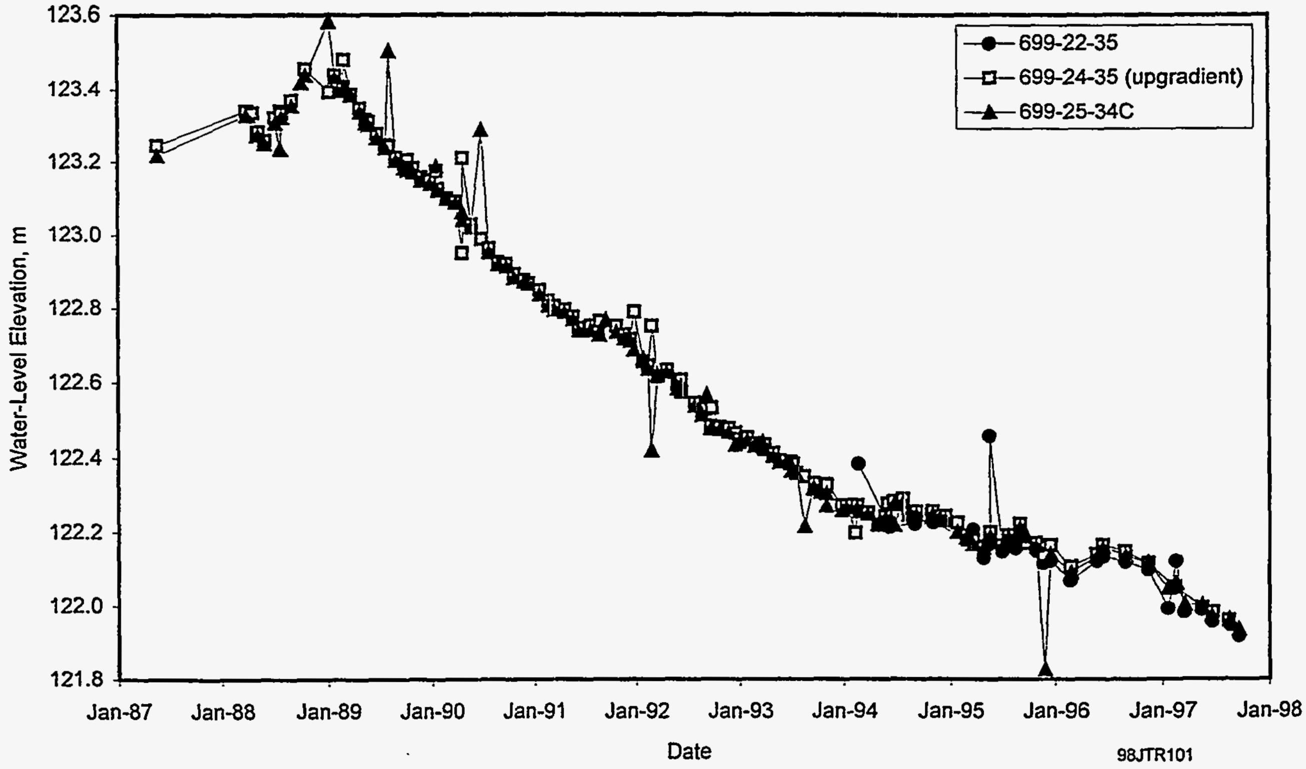

Figure 3.7-3. Water-Table Elevations in Wells Monitoring Solid Waste Landfill

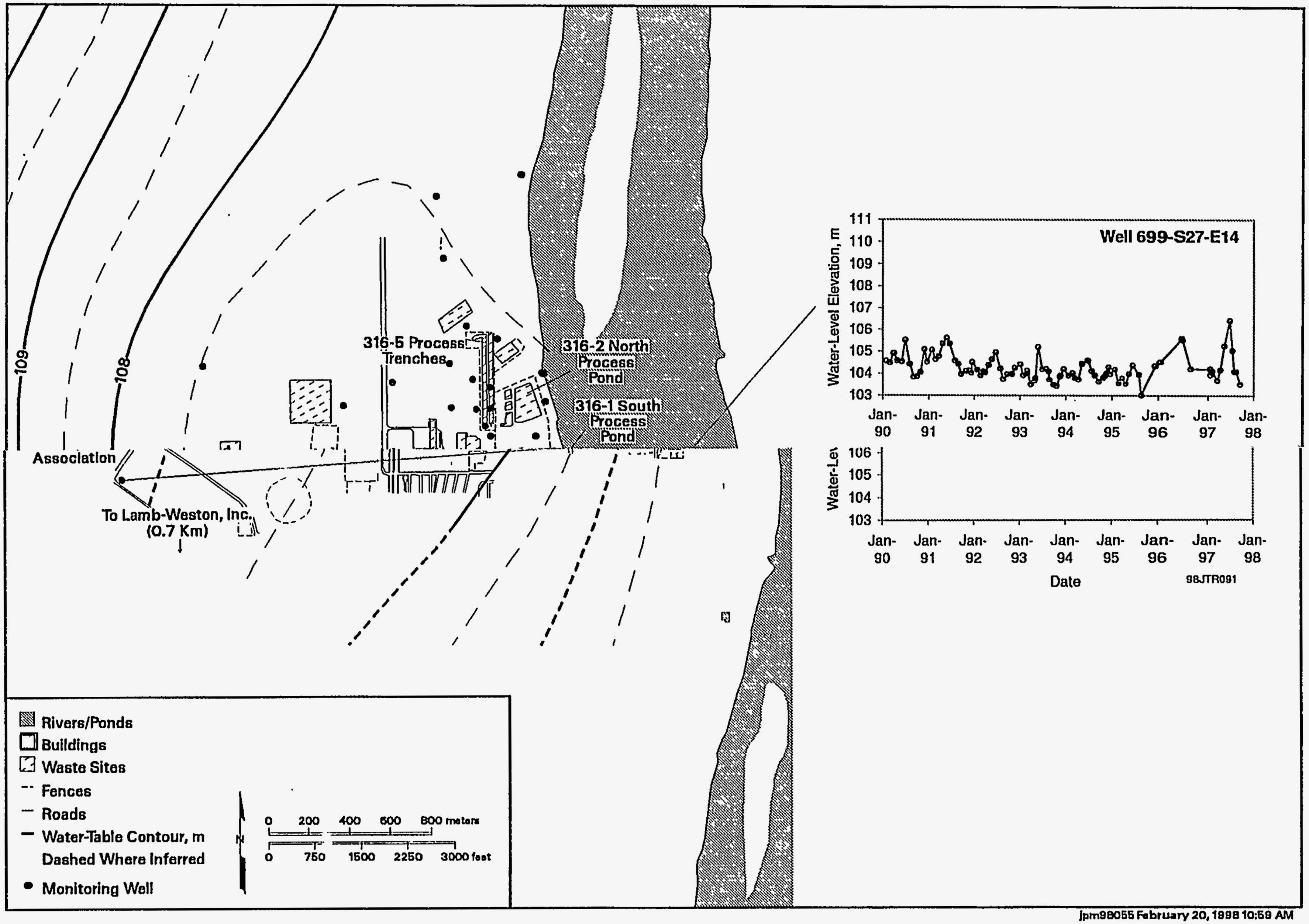

Figure 3.8-1. Water-Table Elevation-Contour Map of 300 and Richland North Areas, June 1997, and Hydrographs of Selected Wells

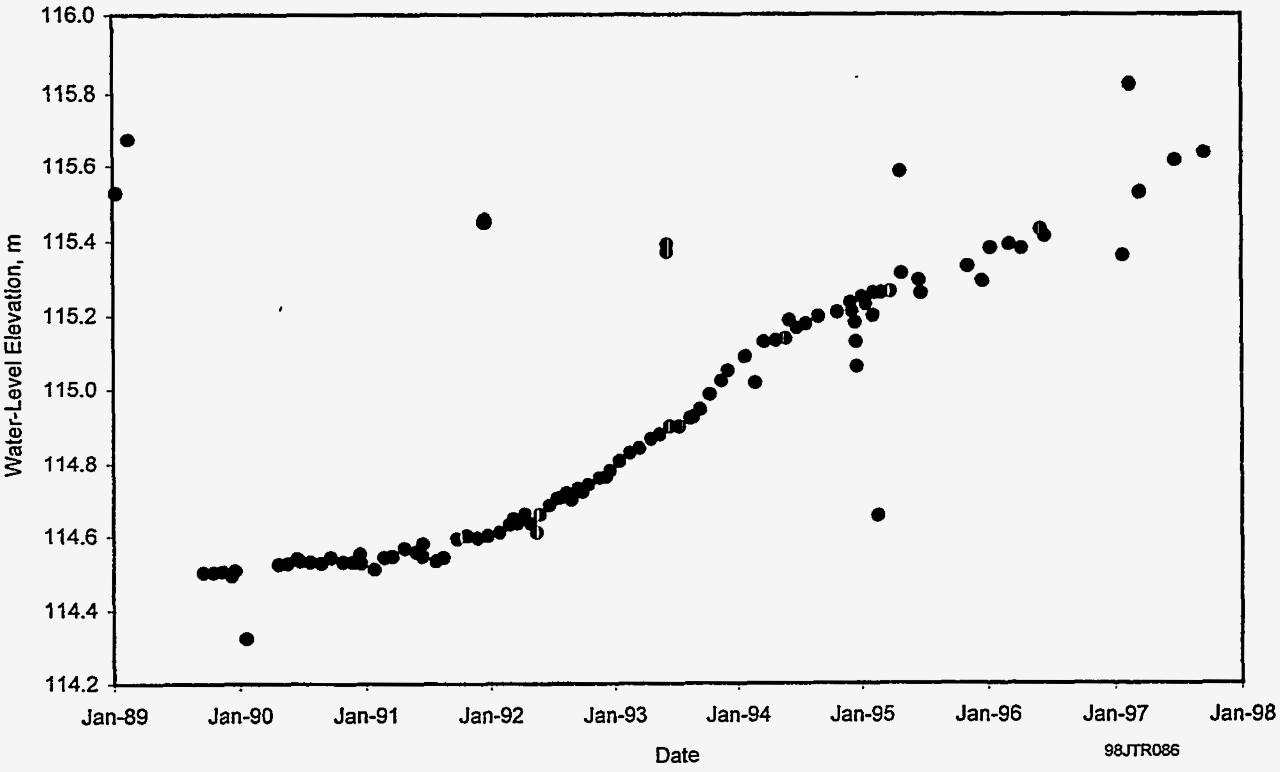

Figure 3.8-2. Water-Table Elevations in Well 699-S31-1 in Richland North Area

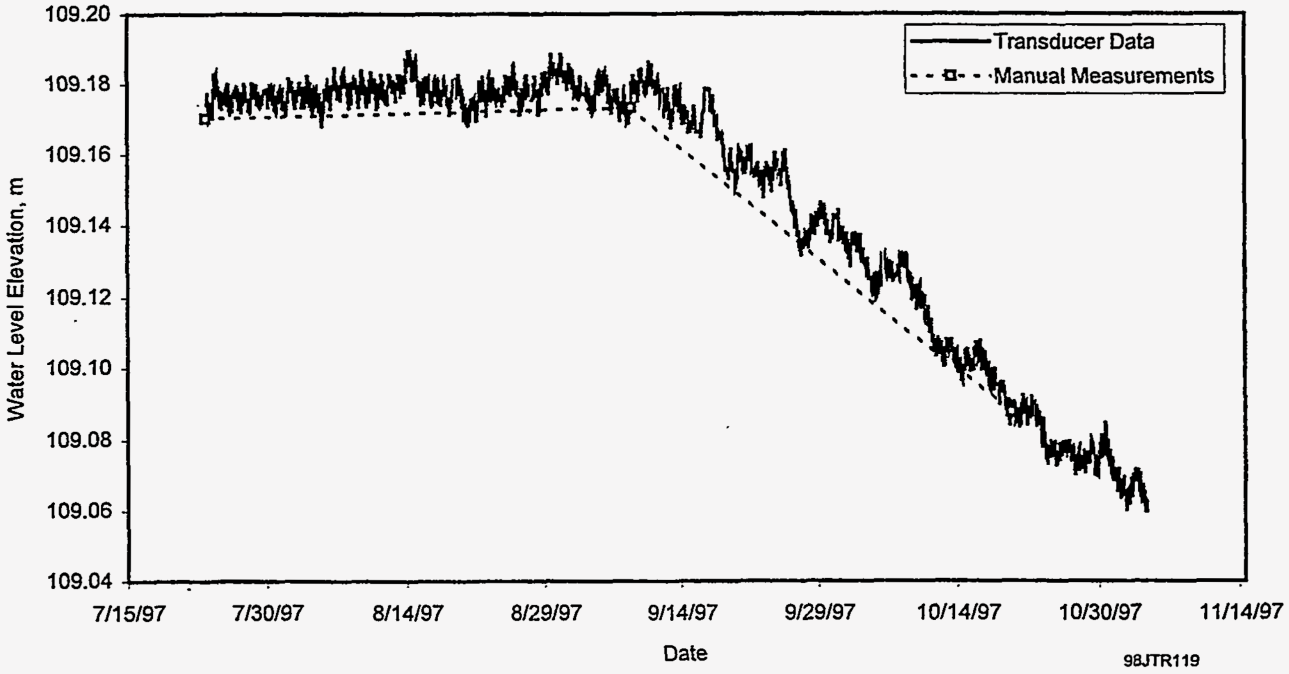

Figure 3.8-3. Water-Table Elevations in Siemens Power Corporation Well GM-2

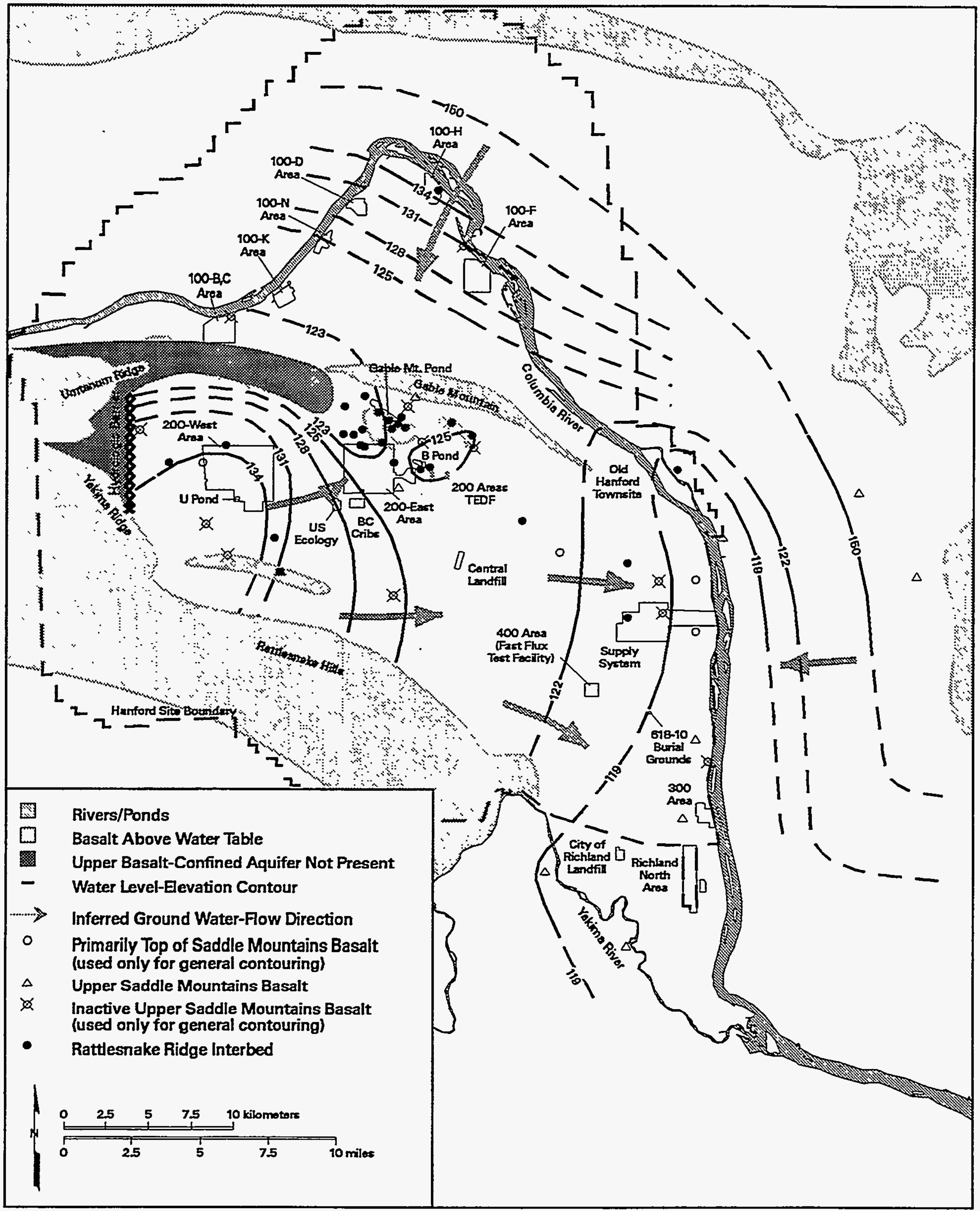

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Figure 3.10-1. Potentiometric Map of Upper Basalt-Confined Aquifer System, June 1996

4.0 Vadose-Zone Contamination

Radioactive and hazardous wastes in the soil column from past intentional liquid waste disposals, unplanned leaks, solid waste burial grounds, and underground tanks at the Hanford Site are potential sources of continuing/future groundwater contamination. Subsurface source characterization and vadose-zone monitoring, using spectral gamma logging, soil-vapor monitoring, and sediment sampling were conducted during fiscal year (FY) 1997. Source-term estimates for strontium-90 in the 100-N Area vadose-zone sediments were calculated using groundwater-monitoring data collected during the recent high-water conditions and knowledge of strontium-90 ion-exchange properties. This chapter summarizes major findings from these efforts. The FY 1997 efforts focused primarily on vadose-zone soil contamination associated with past single-shell tank leaks at several tank farms (i.e., waste management areas [WMAs]), the Plutonium Finishing Plant liquid waste-disposal sites (i.e., the major subsurface sources of carbon tetrachloride and transuranics [TRUs]), the Nonradioactive Dangerous Waste Landfill, and the strontium-90 contamination in the 100-N Area. An overview of the major soil-column sources of groundwater contamination is provided as background for the more detailed description of activities at these specific sites. The interpretation of monitoring and characterization results is presented in the sections that follow.

This section discusses evidence for breakthrough, or transport, of residual soil-column contaminants to groundwater and possible driving forces. Much of the evidence for continuing impacts on groundwater from vadose-zone contamination is discussed in Chapter 5.0. The evaluation depends, to a large degree, on a synthesis of vadose-zone- and groundwater-monitoring data to present a comprehensive picture of contaminant fate and transport. The significant vadose-zone results are summarized here but the bulk of the data synthesis on impacts to groundwater is presented and discussed in Chapter 5.0.

4.1 Major Sources

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The major vadose-zone sediment sources of known or potential groundwater contamination are a result of the treatment, storage, and disposal of liquid wastes produced during 1) once-through cooling water from plutonium-production reactors and cooling water from the now inactive 100-N Reactor; 2) initial, or first-decontamination-cycle, chemical dissolution of irradiated nuclear fuel elements; and 3) subsequent plutonium-refining or -finishing steps. Large volumes of low-activity aqueous waste were intentionally discharged to soil-column-disposal sites from these operations, as well as intermediate processing and waste-handling steps. Also, leaks from fuel-storage-basins in the 100-K Area and from inactive single-shell tanks likely resulted in radioactive waste in the soil column. Subsurface disposal and storage sites with the largest contaminant inventories are found in the 200 Areas and are shown in Figure 4.1-1. Waste characteristics and soil-column-disposal-site conditions for these potential sources of groundwater contamination are discussed below.

4.1.1 Single-Shell Tanks

Liquid waste from the nitric acid dissolution of the irradiated nuclear fuel and initial separation steps typically contained beta-emitting radionuclides at concentrations >100 mCi/L and very high total salt concentrations (>100 g/L). The primary chemical waste components were nitrate, chromate, fluoride, chloride, phosphate, and sodium. The relative amounts varied considerably, depending on the separation process. Detailed descriptions of these complex and variable mixtures are given in LA-UR-94-2657 and LA-UR-96-858.

After the initial plutonium-separation step, the highly acidic first-cycle waste was neutralized with sodium hydroxide and transferred to underground single-shell storage tanks. A high pH was maintained by overaddition of sodium hydroxide, causing many chemical and radioactive constituents to precipitate and settle to the bottom of the tanks. Typically, the tank liquor flowed, or cascaded, through a series of tanks to remove most of the particulate phases. Early in the Hanford Site's production history when the bismuth phosphate process was used, the supernatant from the third tank in the cascade was discharged intentionally to soil-column-disposal sites.

Over 450,000,000 L of liquid waste that cascaded through underground storage tanks were discharged to the vadose zone via cribs, trenches, and french drains (WHC-MR-0227). The estimated total quantity of radioactivity in these cascaded wastes was 65,000 Ci (decayed through December 1989).

Because of the large volumes discharged, the entire soil column beneath many disposal sites in the 200 Areas became saturated and breakthrough of mobile contaminants (e.g., tritium, iodine-129, technetium-99, nitrate, chromate, fluoride) from the soil column to groundwater occurred. Although this disposal practice was terminated over 30 years ago, the residual liquid held in soil-pore spaces following drainage of free liquid at these sites can continue to be a long-term source of groundwater contamination, especially if a source of moisture is available to transport the mobile waste constituents (e.g., enhanced natural infiltration from the coarse gravel coverings present at some inactive disposal facilities, removal of vegetation, leaking water lines).

Leakage from single-shell tanks can also be a source of groundwater contamination under certain conditions (see Sections 5.9.3 and 5.10.3). The estimated total volume of such sources is, however, small (<4,000,000 L) compared to the intentional soil-column-disposal volume (450,000,000 L) of very similar waste. There is growing evidence that downward movement of moisture and associated mobile contaminants from small-volume leaks (~100,000 L) may be greater than previously thought (see Sections 5.9.3 and 5.10.3). Small leak sources can also be mobilized if a driving force and/or a preferential vertical pathway is present to transport the contaminants through the vadose zone to groundwater. The role of ground-cover type or enhanced natural infiltration and preferential pathways is, thus, a crucial issue in the tank farm areas. Corrective action, consisting of a surface covering to limit infiltration, was initiated at the BY cribs a few years ago. Similar remedial actions are being considered for some single-shell tank farms.

4.1.2 Plutonium Finishing Plant

The spent process solutions from the Plutonium Finishing Plant contained carbon tetrachloride, nitric acid, and isotopes of plutonium and americium (TRU waste). Liquid waste discharges to cribs and trenches in the Plutonium Finishing Plant area resulted in the accumulation of an estimated 20,000 Ci of plutonium-239 and americium-241 in the underlying soil column (DOE/RL-91-32, Draft B; WHC-EP-0674). Based on relative hazard (e.g., dividing curie quantities of plutonium-239 and americium-241 by the appropriate health/risk standard), the Plutonium Finishing Plant cribs are some of the most significant sources of radioactive contamination in the vadose zone at the Hanford Site.

The TRU concentrations (>100,000 pCi/g) in the soil were found immediately beneath the 216-Z-1A tile field to a depth of 6 m (estimated volume of soil ~45,000 m^3). There were also isolated volumes of sediment deeper in the profile (extending to depths of 20 to 30 m) that contained TRU concentrations >100,000 pCi/g. An estimate of the volume of this deeper, high-contamination sediment is ~2,000 m^3 but more detailed characterization would be needed to confirm the volume that is based on 16 boreholes near the facility. Details are found in RHO-ST-17. Although TRUs are normally expected to be retained in the first few meters, the combination of high acidity and the presence of complexants apparently allowed the TRUs at these sites to penetrate deeper into the soil column. Because plutonium and americium migrated to a depth of at least 30 m, the absence of TRUs in groundwater in the immediate vicinity of the 216-Z-1A tile field suggests breakthrough beneath this facility has not occurred. Similar conditions exist at the 216-Z-9 trench and 216-Z-18 crib, which received the same waste stream as the 216-Z-1A tile field. An attempt was made to remove much of the TRU-contaminated soil at shallow depths beneath the 216-Z-9 trench (RHO-ST-21). Low (<10 pCi/L) plutonium-239/-240 and americium-241 activities were detected in one groundwater-monitoring well (299-W15-8) adjacent to the trench on two sampling dates (May 7, 1990 and November 13, 1991). The well went dry sometime after January 1992; no water can be sampled now. Whether these analytical results are accurate is not determinable, but future sampling at nearby wells should include careful analyses for these TRUs. If the isotopes were confirmed in the groundwater, it would take more detailed vadose-zone sediment study to determine whether the TRUs traveled through the vadose zone to groundwater or migrated along the outside of the well casing.

In addition to TRUs, the 216-Z-9 trench, 216-Z-18 crib, and 216-Z-1A tile field received 570,000 to 920,000 kg of carbon tetrachloride (as both dissolved and as a separate liquid phase) between 1955 and 1973 (WHC-SD-EN-TI-248). The discharged contaminated liquid wastes were apparently intended to remain in the soil column; however, carbon tetrachloride was discovered in groundwater near the plant in the mid-1980s and was later found to be widespread in the 200-West Area. In December 1990, planning began for an expedited response action that started operation in 1992 to reduce the carbon tetrachloride vadose-zone source in the 200-West Area based on concerns that the carbon tetrachloride was continuing to spread to the groundwater. If left unchecked, the carbon tetrachloride would significantly increase the extent of groundwater contamination because of vapor-phase transport through soil-pore space or by downward migration through the vadose zone as a dense nonaqueous-phase liquid or dissolved in natural recharge water. Once in groundwater, the dense nonaqueous-phase liquid dissolves slowly, and its status in the vadose zone and groundwater is the subject of ongoing remediation and characterization efforts (BHI-00720, Rev. 1).

4.1.3 Other

The Hanford Site has more than 800 past-practice liquid disposal facilities. Radioactive liquid waste was discharged to the vadose zone through reverse wells, french drains, cribs, and tile fields. Along the Columbia River in the vicinity of the nine (now inactive and closed) reactors, once-through cooling waters were routinely disposed into cribs and trenches. The disposed cooling waters contained low levels of fission and neutron activation products and very low levels of some chemicals and actinides. Of biggest concern is the impacts of tritium, strontium-90, nitrate, and chromate to groundwater. Strontium-90 is present in groundwater seeping out of the banks of the river at the 100-N Area. Removal of strontium-90 has been ongoing for several years using pump-and-treat operations (see Section 6.5 in PNNL-11470 and Section 5.5.4 in this report). Chromate is actively being remediated at the 100-K, 100-D/DR and 100-H Areas (see Sections 6.6 and 6.7 in PNNL-11470 and Sections 5.6.4 and 5.7.4 in this report).

Leakage from fuel-storage basins in the 100-K Area also contributes potentially significant inventories of fission products and TRUs to the soil column (WHC-SD-EN-AP-174). Thus, both past-practice sites and fuel-storage-basin leakage are potential vadose-zone sources.

Even though disposal of untreated wastewater to the ground stopped in 1995 (WHC-EP-0573-4), contaminant movement can still occur in the soil column beneath past-practice sites. Vadose-zone monitoring and characterization is one approach to evaluating the status of possible leaks or remobilization of contaminants caused by enhanced natural or artificial infiltration. The objectives of vadose-zone monitoring and characterization are to document the location of the contamination, to determine the moisture and radionuclide movement in the soil column, and to assess the effectiveness of remedial actions. FY 1997 activities involved in situ borehole spectral gamma logging, soil-vapor sampling and analysis, and characterization of sediments obtained through drive-barrel and split-spoon sampling below vadose-zone-monitoring well 41-09-39 at WMA SX. Additional source-term estimates for strontium-90 in 100-N Area vadose-zone sediments were calculated using groundwater-monitoring data collected during the recent high-water conditions and knowledge of strontium-90's ion-exchange properties. Electrical resistivity tomography, another approach for leak detection and moisture-movement tracking, was evaluated at a mock tank leak demonstration site in the 200-East Area in FY 1996 and documented in Section 4.2 of PNNL-11470. The FY 1997 vadose-zone-monitoring activities to assess these possibilities are described in following subsections.

4.2 In Situ Borehole Activities

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The objectives of vadose-zone borehole monitoring are to document the location of the contamination, to determine the moisture, and to determine radionuclide movement in the soil column. Borehole spectral gamma logging is an in situ measurement of subsurface gamma-emitting radionuclides obtained through cased monitoring wells that are completed in the vadose zone or extend into the saturated zone. The detector or sensor is a crystal of sodium iodide or germanium and associated electronics. Photons emitted from radionuclides in the formation interact with the detector material, resulting in electronic pulses transmitted to the surface via electrical cables to a digital data-storage system. By periodically recording detector response at various depths, changes over time can be documented. This general type of logging (in particular gross gamma screening as opposed to spectral gamma) has been conducted at the Hanford Site for over 25 years by slowly raising and lowering the detector inside existing cased monitoring wells in the vicinity of disposal facilities.

4.2.1 Spectral Gamma-Logging Methods

Two organizations performed borehole-logging surveys at the Hanford Site in FY 1997. MACTEC-ERS conducted single-shell tank vadose-zone characterization and Waste Management Federal Services of Hanford, Inc. conducted vadose-zone monitoring at one past-practice liquid waste, soil-column-disposal sites (BY cribs and trenches). The equipment, calibration, and operating procedures were equivalent for the two systems, except for administrative and procedural controls for data acquisition and handling, as indicated in the following subsections.

The logging equipment used at past-practice sites was calibrated at the Hanford Site. The calibration facilities were constructed for long-term stability and designed to represent subsurface conditions (PNL-9958, PNL-10801). The detection systems were calibrated in these facilities, and corrections were established for differences between the calibration facilities and Hanford Site borehole-construction conditions (WHC-SD-EN-TI-292, WHC-SD-EN-TI-306). The subsurface geophysical surveys were acquired in accordance with WHC-CM-7-7.

The MACTEC-ERS spectral gamma-ray borehole-logging measurements in the WMAs (tank farms) were conducted in accordance with P-GJP0-1786. Depth profiles, or logs, of radionuclide concentrations in all boreholes surrounding a tank were produced and stored electronically. The logs were correlated with tank farm gross gamma-ray log data and historical information about each tank, and a tank summary data report was prepared. The individual tank report documented the results of the logging in relation to tank-leak history. An interpretive summary tank farm report was prepared to provide a complete assessment and correlation of all vadose-zone-contamination data at a particular tank farm to identify sources and to determine the nature and extent of the contamination.

The MACTEC-ERS logging systems used in the tank farms were calibrated following GJPO-HAN-1. The base calibration was performed using the calibration facilities in Grand Junction, Colorado, and is reported in GJPO-HAN-1. The field calibrations are published biannually, most recently in GJPO-HAN-3.

Data were recorded by the logging system in accordance with procedures outlined in P-GJPO-1783, Rev. 1 and managed as outlined in P-GJPO-1782, Rev. 1. Details on other aspects of the project are provided in P-GJPO-1778, P-GJPO-1780, P-GJPO-1776, and GJPO-HAN-3.

4.2.2 Monitoring Networks

Two types of monitoring wells were available for logging: 1) older, vadose-zone- and groundwater-monitoring wells in and near past-practice sites and 2) single-shell tank farm vadose-zone networks.

4.2.2.1 Soil-Column-Disposal Sites

Existing groundwater-monitoring wells adjacent to past-practice sites were logged on an as-is basis. Corrections for varying borehole diameters and presence of sealants around the annulus of the casing must be taken into account prior to interpreting the raw counts obtained as a function of depth in these monitoring wells. In addition, a concern with any of the older boreholes is the degree to which contaminants may have migrated down the inside or outside of the borehole casing. Methods to distinguish a distributed source from one at the casing wall were developed in FY 1997 to account for this potential problem. At many past-practice disposal facilities, relatively large numbers of boreholes were installed for earlier characterization purposes (1970s). These older boreholes allow some assessment of downward migration over time by comparing current depth profiles with the previous logs of radionuclide depth distribution. In a few cases, there are data based on actual soil-sample results.

4.2.2.2 Single-Shell Tanks

The tank farm vadose-zone-monitoring networks consist of 5 to 7 steel-cased, 15.2- to 20.3-cm-dia. structures arranged around the perimeter of each tank as illustrated for the SX Tank Farm in Figure 4.2-1 (the horizontal distance from the base of the tanks is ~1.5 m). The depths vary from ~22.8 to 38.1 m below ground surface. Most of the single-shell tank-monitoring networks were installed in the late 1960s and early to mid-1970s. In addition, some tank farms included lateral lines that ran horizontally beneath the tanks to detect leakage from the tanks and to track movement over time.

4.2.3 Borehole Spectral Gamma-Logging Results

4.2.3.1 Soil-Column-Disposal Sites

During FY 1997, Waste Management Federal Services of Hanford, Inc. logged several groundwater-monitoring wells near various inactive liquid-disposal facilities (e.g., 216-B-35 to 216-B-41 trenches; 216-B-43 to 216-B-50 cribs; 216-B-57 crib, 216-B-7, -8, -11 cribs; and 216-B-8 tile field). Sixteen wells were successfully logged in August and September 1997 with a high-purity germanium spectral gamma detector. The casing in one of the wells was bent such that the detector would not fit through the total depth. The preliminary logging data were not available until early FY 1998, and the results will be discussed in next year's annual report.

The logging surveys of the groundwater-monitoring wells will identify gamma-emitting radionuclides and quantify the concentration as a function of depth from the ground surface through the vadose-zone sediments to the water table. These data will serve as the baseline for any further monitoring to protect the groundwater from additional contamination from these facilities.

4.2.3.2 Single-Shell Tank Farms

Spectral gamma logging of vadose-zone-monitoring boreholes were completed in the AX, BY, TX, and U single-shell tank farms in FY 1997. A comprehensive report was published for each of these tank farms in 1997 (GJO-97-14-TAR, GJO-HAN-12; GJO-97-6-TAR, GJO-HAN-8; GJO-97-13-TAR, GJO-HAN-11; GJO-97-1-TAR, GJO-HAN-8, respectively) from which the following summaries are taken. Numerous other individual reports were also prepared in FY 1997 for tanks in the following tank farms: BX, C, S, and TY, but a discussion of the results will await the tank farm summary reports.

AX Single-Shell Tank Farm. In FY 1997, the tank farm summary report on spectral gamma logging of the 32 boreholes surrounding the four 3.8-m^3 tanks was completed (GJO-97-14-TAR, GJO-HAN-12). Figure 4.2-2 shows the tank farm map, borehole positions, and numbering system. Despite two of the tanks being classified as leakers (~41,600 L of liquid are estimated to have leaked from tanks AX-102 and AX-104), the spectral gamma logging shows only shallow depths have significant gamma contamination. The small plumes inferred from connecting adjacent borehole logs appear to be related to surface spills and/or shallow pipeline leaks. Only two boreholes (11-01-10 and 11-03-02) show significant gamma contamination below the 6-m level. Both of these boreholes are on the north side of the two tanks that are assumed to be nonleakers. Figure 4.2-3 shows the gamma logs for these two boreholes. In all the borehole gamma log figures in this section, the notation TD signifies the total depth of the borehole. Borehole 11-01-10 shows ~5,000 pCi/g of cesium-137 and ~200 pCi/g of europium-154 in the shallow sediments down to 5.5 m. Below 6 m, the gamma activities for both the cesium and europium drop below 1 pCi/g. For borehole 11-03-02, cesium-137 activities up to ~1,000 pCi/g are observed from the surface down to 6.7 m. The activity drops erratically to a depth of 10.7 m, then there is a second peak with ~500 pCi/g at the 10- and 12-m depths. Below 12 m, the cesium-137 level is measurable but <2 pCi/g. In the upper 5 m, there is also measurable cobalt-60. In the plume at 10 to 12 m, there are ~10 pCi/g antimony-125.

None of the 32 boreholes showed significant gamma activities below the tank bottoms, which are at ~17 m below ground surface. There has been measurable iodine-129 in *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater-monitoring wells downgradient of the AX tank farm, but there are also many liquid-disposal facilities in the vicinity that seem to be more probable sources than this tank farm. Direct sampling of the vadose-zone sediments under this tank farm would be needed to definitively rule out the tank farm as the source of nongamma-emitting contaminants.

BY Tank Farm. In FY 1997, the tank farm summary report on spectral gamma logging of the 69 boreholes surrounding the 12 single-shell tanks in this tank farm was completed (GJO-96-2-TAR, GJO-HAN-6). Figure 4.2-4 shows the tank configuration and borehole numbering system. The logging supports the designation of tanks BY-103, BY-107, and BY-108 as leakers. The gamma logging is not conclusive in confirming that tanks BY-105 and BY-106 leaked significant amounts of liquid. There is much surface contamination in this tank farm that confounds the simple determination of which tanks actually have leaked substantial volumes of liquid. Figures 4.2-5, 4.2-6, and 4.2-7 show the gamma logs for the boreholes with the most significant levels of contamination that support designation of tank BY-103 as a leaker. The cesium-137 profile in borehole 22-03-05 shows activities of ~1,000 pCi/g at the 18 to 27-m depth interval, whereas borehole 22-03-06 shows cesium-137 activity peaks in a thin zone at 14 m. Both boreholes and others in the vicinity show cobalt-60 at activities up to 10 pCi/g. Borehole 22-03-06 shows antimony-125 activity at ~10 pCi/L at depths between 12.8 and 14 m. Boreholes around tanks BY-107 and BY-108 show cobalt-60 profiles that suggest tank leakage is in the sediments around the sides and below these two tanks (see Figures 4.2-6 and 4.2-7). Cobalt-60 distribution in borehole 22-11-09 suggests that tank BY-111 might not be as sound as currently thought, but the observed activities along the tank side and below the bottom are not above 1 pCi/g.

Vadose-zone spectral gamma logging around tanks in the BY tank farm shows some tank leaks and low activities of cobalt-60 and cesium-137 all the way to the bottom of some of the boreholes, but it is not possible to state whether tank-leak liquids migrated all the way to the groundwater. The groundwater below the BY tank farm contains iodine-29, technetium-99, and cobalt-60, but the activities are below the drinking water standards and the higher activities, or heart, of the contaminant-specific groundwater plumes for technetium-99 and cobalt-60 seem to be under the BY cribs just north of the tank farm and the iodine-129 source is likely the 216-B-63 trench east-southeast of the BY tank farm.

TX Tank Farm. In FY 1997, the tank farm summary report on spectral gamma logging of the 94 boreholes surrounding the 18 tanks in this tank farm was completed (GJO-97-13-TAR, GJO-HAN-11).

Figure 4.2-8 shows the tank farm map, borehole positions, and numbering system. Eight of the 18 tanks have been designated as leakers, and the total tank-farm leakage has been estimated at 216,000 L. The spectral gamma logging corroborates that tanks TX-105, TX-107, and either/or both tanks TX-113 and TX-114 leaked significant amounts of radionuclides into the surrounding vadose-zone sediments. The spectral gamma logging does not show significant amounts of radionuclides in the sediments around other designated leakers (tanks TX-110, TX-115, TX-116, TX-117). There is a very small amount of radionuclides below some of these tanks, but the activity and extent are several orders of magnitude smaller than for the former three or four readily detected leakers. The latter four tanks pose much less risk based on gamma analyses and some of them may not have been leakers. Figures 4.2-9 through 4.2-12 show the logs for TX tank farm boreholes most impacted.

The recent spectral gamma logging (see Figures 4.2-9 and 4.2-10) and past total gamma logging show that tank TX-107 leaked readily measured amounts of cobalt-60, europium-154, and uranium out the south side, and the contaminants migrated largely horizontally with a minor vertical component for up to 9 years (1977 to 1986) before slowing to the point of appearing stagnant. Europium-154 migration was localized between tanks TX-103 and TX-107. The migration route for the cobalt-60, and perhaps uranium, was from the south end of tank TX-107 south toward tank TX-103 and west around tank TX-103 and into the space just east of tank TX-104. Uranium may have migrated to the south-southwest (borehole 51-00-07 in Figure 4.2-10) corner of the tank farm with a vertical migration from the 15.2-m depth down to 21.6 m during the transit from TX-107, past TX-103, and around TX-104. Cobalt-60 and europium-154 activities reach values of nearly 1,000 pCi/g in the sediments 15 to 21 m below ground surface (tank bottoms are at ~15 m below ground surface). Cobalt-60 activities at 1 pCi/g are found to reach the bottom of several boreholes at 30 m. Figure 4.2-9 shows the cobalt-60 and europium-154 plumes but, interestingly, shows no significant cesium-137 contamination under the tanks. Figure 4.2-10 shows that cobalt-60, and perhaps uranium, leaked from tank TX-107 and migrated beyond tank TX-103.

The entire eastern hemisphere around tank TX-105 shows uranium contamination at depths between 15 and 25 m. Figure 4.2-11 shows logs for the boreholes most impacted. The uranium-238 activity ranges from 100 to 300 pCi/g (~30 to 100 ppm) in this depth region. The plume from tank TX-105 migrated ~37 m horizontally and 7.5 m vertically.

Boreholes close to the north and east sides of tank TX-114 show elevated cesium-137 activities between the depths of 12 to 13.7 m. Figure 4.2-12 shows the logs for the boreholes most impacted by the tank TX-113/114 leak. The cesium-137 activity peaks at ~10,000 pCi/g with a small zone in borehole 51-14-04 where the detector was completely saturated. The plume appears to have moved exclusively in the horizontal direction, perhaps along the contact between the backfill and the undisturbed Hanford formation sediments below the tank bottom.

The logging at the TX tank farm showed evidence of much surface contamination from unplanned spills and pipeline leaks. Isotopes observed include cobalt-60, antimony-125, cesium-137, europium-154, uranium-235, and uranium-238. Most of the boreholes are completed in the upper 30 m of sediment but a few reach 45 m. All of the borehole logs that show significant (>100-pCi/g) activity at the bottom are thought to be casing-related contamination, such as contaminated mud attached to the casing, particulate dragdown, or water leakage down the casing's interior or exterior walls. The groundwater is ~62 m below ground surface. The gamma logging does not yield direct evidence that contaminants from the tanks reached the water table, but the logging cannot detect mobile beta emitters such as technetium-99.

Currently, there are groundwater-contaminant plumes underneath the TX tank farm that contain tritium, nitrate, and chromium at concentrations above the maximum contaminant level for drinking water. There are other possible sources for these contaminants surrounding this tank farm (e.g., cribs, trenches, ponds that received millions of liters of liquid wastes). However, direct sampling of the vadose-zone sediments under the tank farm would be needed to definitively rule out the farm as the source of these nongamma-emitting mobile contaminants.

U Tank Farm. In FY 1997, the tank farm summary report on spectral gamma logging of the 59 boreholes surrounding the 12 large tanks in this farm was completed. There are also four small tanks in the farm but they have no monitoring wells (GJO-97-1-TAR, GJO-HAN-8). Figure 4.2-13 shows the tank farm map, borehole positions, and numbering system. The logging data for the six most impacted boreholes are shown in Figures 4.2-14 and 4.2-15. Aside from some surface contamination found in nearly all tank farms, the borehole logging found some cesium-137 contamination localized below the northeastern quadrant of tank U-112 and below the south side of tank U-110. The cesium-137 level below tank U-112 was >10,000 pCi/g over a depth interval from 14.6 to 21.3 m (the tank bottom is at 12.8 m below ground surface). The concentration dropped farther down in the profile but was still elevated at the borehole bottom at 38 m. Below tank U-110, the activity peaked at 500 pCi/g between 15 and 18 m but was below 0.5 pCi/g at deeper depths. There is also a higher-than-natural zone of uranium concentrations in the space between tanks U-104, U-105, U-107, and U-108 in the strata 15 to 30 m below the tanks. These findings agree with the listing of tanks suspected to have been leakers in the past (i.e., tanks U-101, U-104, U-110, and U-112). The data suggest that uranium travels deeper into the soil than does cesium. It does not appear that these isotopes reached the groundwater found at 60 m below ground surface. Elevated gross beta and technetium-99 has been found in RCRA groundwater-monitoring wells surrounding this tank farm, but there are other liquid-disposal facilities nearby that seem to be more probable sources than the U tank farm. Direct sampling of the vadose-zone sediments under this tank farm would be needed to definitively rule out this farm as the source of nongamma-emitting contaminants.

In summary, there are measurable radionuclides and chemical contaminants in the groundwater under or downgradient from several tank farms. For tank farms where cascading was practiced (i.e., B, BX, BY, T, TX, TY), it is especially difficult to ascertain whether contaminants in the groundwater were from the cribs and trenches used for liquid disposal or from leaking tanks. The only method that might differentiate liquid from leaking tanks from cascaded liquid (if both came from the same process waste stream) would be sampling the vadose-zone sediments directly underneath the tank farms. The sampling might require obtaining many samples at depths from the tank bottoms down to the water table. For tank farms where no cascading liquid disposal was practiced, it might be possible to use contaminant ratios in the tanks and the groundwater to determine whether the tanks were the source of the contamination.

4.3 SX Single-Shell Tank Farm Borehole Extension

R. J. Serne

Baseline geophysical logging of dry wells surrounding the tanks of the SX single-shell tank farm (GJPO-HAN-4, DOE/ID/12584-268) discovered that cesium-137 appears to be present in the vadose-zone sediments up to 25 m below the tank bottoms (i.e., depths greater than expected). Identification of this deeper-than-expected cesium-137 resulted in a major reassessment of radionuclide movement through the vadose zone. Field observations at low-level liquid-disposal facilities (i.e., cribs) and laboratory sorption tests were used as input to contaminant-transport models that generally show that the cesium-137 should penetrate the subsurface for only a short distance before being rendered immobile by adsorption processes. The geologic conditions, hydrologic processes, and geochemical interactions that explain how the relatively immobile contaminant penetrated up to 25 m below tank SX-109 are essential parameters for revising the predictive models.

Additionally, if factors other than tank chemistry and/or associated tank-waste-dependent physical parameters are found to be the forces driving cesium-137 to depth, then the findings beneath the SX tank farm may well apply to other environmental restoration activities, such as the immobilized low-activity waste-disposal and low-level waste-burial grounds. Finally, the investigatory techniques and analytical tools to be applied in the SX tank farm investigation will be available, when needed, to apply to subsequent vadose-zone investigations.

4.3.1 Methods

In late FY 1997, it was decided that borehole 41-09-39 would be extended to the groundwater. This borehole was constructed in October 1996 using the pile-driving technique. Cesium-137, a gamma-emitting radionuclide, was detected at a concentration of 2,000 pCi/g at the 40-m completion depth. This concentration, while not extraordinarily high, is indicative that more-mobile, longer-lived contaminants may have migrated even deeper. The borehole-extension activity is designed to sample the sediments from 40 m to the water table and provide objective evidence as to the disposition of radionuclides in the vadose zone beneath an area of known contamination.

Continuous sediment sampling and frequent geophysical logging of the borehole are being conducted. Seven sample intervals are planned for analysis and will be selected as follows: near the base of the existing borehole, directly above the caliche layer (a subunit within the Plio-Pleistocene unit), within the caliche layer, directly below the caliche layer, at the base of the extension (in the capillary zone above the water table) and two samples distributed throughout the ~17 m between the base of the caliche layer and the expected depth of groundwater. Because of the importance of the caliche layer in impeding contaminant migration, a sample will be analyzed from directly above the zone, one from within the zone, and one from directly beneath the zone. Selection and implementation of the method to remove the casing and to close the hole will be done with State of Washington Department of Ecology concurrence after reaching final depth and allowing a short time for groundwater collection.

Laboratory analyses will be made to ascertain the presence and geochemical properties of the following radionuclides in the bulk sediment and in saturation extract liquid: iodine-129, technetium-99, strontium-90, cesium-137, and other gamma-emitting fission products, and uranium isotopes. The porewaters or saturation extracts will also be analyzed for cations and anions (especially sodium and nitrate), using appropriate inductively coupled-plasma spectroscopy and ion chromatography or other approved methods, respectively. A direct comparison of the radiological inventory of the soil and porewater will be used to derive the in situ distribution coefficient value.

Contaminated sediment samples will be leached using several water types that cover the ionic strength and pH from groundwater to tank liquor to determine desorption distribution coefficient values.

Uncontaminated soil samples will be subjected to adsorption analysis for the determination of distribution coefficients for strontium-90 and cesium-137, using several types of water that include the ionic strength and pH range from groundwater up to tank liquor.

Sediment samples will be visually inspected to assess the presence of alterations from normal. Such alterations may include the dissolution of silicate minerals, resulting in the formation of rinds or gels where the minerals were hydrothermally altered. Laboratory analysis of affected minerals, using scanning electron microscopy to quantify the alteration and aid the determination of chemical processes, will occur if warranted. Field logging to obtain gross gamma, gamma spectra, moisture content, and casing air temperature will be performed.

On reaching the water table, a temporary screen will be inserted and several water samples will be taken for complete chemical and radiological analysis and for determining whether colloids are present that contain measurable amounts of radionuclides.

4.3.2 Results

The metal tip on the bottom of borehole 41-09-39 was milled out using a diamond bit and minimal cooling water in mid-September 1997. The borehole had been placed by drive-barrel techniques to a depth of 40 m in early 1996. The casing was 19-cm outside diameter with a closed end to avoid the need to dispose of contaminated sediment. The borehole was used to provide a new conduit to perform spectral gamma analysis close to tank SX-109, which had been confirmed as a leaker. Section 4.4.2 in PNNL-11470 provides a description of the SX tank farm activities performed in FY 1996. Further discussion on the SX tank farm and the anomalous cesium-137 issue can be found in DOE/RL-97-49. After successfully milling and removing the closed casing's tip, continuous core was then taken in ~0.6-m-(~2-ft-) long sections using a 7.6-cm-dia. split-spoon sampler. After each core-sample event, a 14-cm-dia. outer casing was pounded into the formation down to the depth to which the split-spoon sampler had been extended. The 14-cm casing was placed within the original 19-cm casing and extends below the original 40-m depth to maintain an open hole for deeper logging activities. By the end of FY 1997, the borehole extension had reached a depth of 43.2 m, and the core barreling will continue down to the water table (expected depth ~64 m) with the same sequence of continuous sampling and outer 14-cm casing advancement. The borehole reached the water table on December 18, 1997 at a depth of 64.5 m. The borehole was then extended an additional 3.5 m, and water samples were obtained in early January 1998.

The preliminary data for the first 3.4 m of sediment obtained between the depths of 40 and 44 m are shown in Table 4.3-1. The first few samples retrieved below the 40-m depth were very radioactive, with cesium-137 being the dominant isotope. Measurable amounts of technetium-99 and the natural radionuclides, potassium-40, uranium-238, and thorium-232 and their daughters, were also found in the sediments. Very low levels (<5 pCi/g) of strontium-90 may also be present in the sediment, but the measured activity may be lead isotopes from the uranium-238 decay scheme that coelute with the strontium-90 in the wet chemical separation required to isolate the strontium. The chemical nature of the sediments does not show abnormal pH or electrical conductivity. The major cation composition is indistinguishable from natural sediments, but there is evidence of nitrate concentrations above those expected for natural sediments. One would not expect the soluble nitrate constituent to be as sensitive as cesium-137 (a strongly adsorbing constituent) to particle dragdown. The nitrate data from deeper sediments should help identify whether there are signs of tank leaks reaching these depths via natural percolation.

The data available in FY 1997 do not allow a determination of whether the technetium-99, cesium-137, and nitrate represent soluble material from leaks that percolated through the sediments or material that was dragged down during the core-barreling activities. The sediments between 40 and 41.5 m do appear quite fine grained, with much silt, whereas the sediments below 41.5 m appear to be more sandy. This silty sediment may be the farthest extent that the material from the SX tank farm leaks has reached by natural percolation. The cesium-137 data seem to show a clear tapering off below the siltier material, but the nitrate and technetium-99 continue at higher-than-natural background values down as far as samples were available in FY 1997. The preliminary spectral gamma data suggest that the cesium-137 is more associated with the borehole casing than evenly distributed throughout the formation. Our understanding of many of the SX tank farm questions/issues (DOE/RL-97-49) should improve by mid-FY 1998, when the remainder of the borehole extension data will be available.

4.4 Soil-Vapor Monitoring

V. J. Rohay, R. J. Serne

Soil vapor extraction is being used to remove the carbon tetrachloride source from the vadose zone as part of the 200-West Area carbon tetrachloride expedited response action being conducted by Bechtel Hanford, Inc. The primary focus in the following subsections is on FY 1997 activities. For descriptions of past work, see BHI-00720, Rev 1 and Section 4.2.2 in PNNL-11470. In FY 1997, a soil-vapor study (BHI-01115) was also performed at the Nonradioactive Dangerous Waste Landfill and results/observations are included in this subsection.

To track the effectiveness of the remediation effort, measurements of soil-vapor concentrations of chlorinated hydrocarbons were made at individual on-line extraction wells and soil-vapor probes throughout the soil-vapor-extraction sites and at the inlets to the three soil-vapor-extraction systems during FY 1997. The extraction systems were operated in October and November 1996 and in July, August, and September 1997. While the extraction systems were shut down from November 1996 through June 1997, a study was conducted to evaluate the magnitude and rate of chlorinated hydrocarbon concentration rebound by measuring soil-vapor concentrations in samples collected from wells and probes throughout the soil-vapor-extraction sites (BHI-01105).

4.4.1 Methods

To maintain real-time monitoring schedules, constrain costs, and fulfill the requirements for working in a radiologically controlled area, the approach to the carbon tetrachloride remediation maximized the use of field-screening-level data. Since late 1993, contaminant concentrations at the soil-vapor-extraction inlets and vent stacks and at individual wells were monitored using a Type 1302™ infrared photoacoustic spectrometer (Brüel and Kjaer, Naerum, Denmark). The Brüel and Kjaer sensors are calibrated annually by the manufacturer and are periodically checked with calibrated standards in the field. The detection limit for carbon tetrachloride is 1 part per million by volume (ppmv).

Measurements made at the inlet to an extraction system represent the combined soil-vapor concentrations from all on-line wells manifolded to that system. A programmable logic controller samples the incoming concentrations at each inlet every 2 hours; the system technicians use these data to establish daily records of representative concentrations.

To monitor concentrations at individual extraction wells, a sampling apparatus is placed in-line at the wellhead to collect a soil-vapor sample in a Tedlar™ bag (E. I. du Pont de Nemours & Company, Wilmington, Delaware). The sample is analyzed using a Brüel and Kjaer sensor housed in a trailer near the extraction site. Concentrations are typically monitored monthly at individual on-line extraction wells and quarterly at individual off-line monitoring wells. One "snap-shot" sample is collected at each on-line extraction well. Three samples are collected during an hour of continuous extraction at wells that were off-line during the month in which quarterly sampling was conducted.

During the rebound study, a low-flow (0.8-L/min) sampling pump was used to draw soil-vapor samples from wells and probes into a 1-L Tedlar™ bag for analysis using the field Brüel and Kjaer sensor. Two purge volumes were drawn before the sample was collected. For the 12 wells in which the sampling pump was used, a tube was lowered to the target depth where the casing is perforated (i.e., open to the sediment and its pores) to minimize the volume of air to be purged. The tubes were 0.3-cm-inside diameter Teflon-lined Tygon™ (Norton Performance Plastics Corporation, Akron, Ohio). A metal filter attached to the end of the tube also served as a weight. Each sampling tube remained in the well for the duration of the rebound test and was removed at the conclusion of the study. With the exception of sampling tube adjustments at a few wells, each well remained sealed at the surface throughout the rebound study.

The subsurface sampling tubes attached to the deep probes monitored during the rebound study are made of Teflon. The sampling tubes are typically 0.3 cm inside diameter (0.6 cm outside diameter). The subsurface sampling tubes attached to the shallow probes (<2 m deep) monitored during the rebound study are made of polyethylene.

In addition, wells were sampled using a natural barometric pump that uses barometric-pressure fluctuations to control sample collection. On low-barometric pressure days when wells would be venting, the wells selected for sampling using a barometric pump were opened to purge one well volume. The length of time required to vent one well volume was estimated assuming that the average airflow rate was 0.06 m^3/min (BHI-00766). The wells were then resealed, and the sample pump was used to collect samples in 1-L Tedlar™ bags for analysis using the Brüel and Kjaer sensor.

During the first 10 working days of the rebound study, soil-vapor samples were collected from 12 wells and from 38 deep probes at least on alternate days. This sampling frequency was selected to observe potentially rapid concentration changes. Four of the 50 locations were sampled twice per day to evaluate whether diurnal barometric pressure fluctuations affected the observed carbon tetrachloride concentrations. Evaluation of the data collected during this first period of the study indicated that the time interval between sampling could be increased because carbon tetrachloride concentrations did not appear to be changing rapidly. For the next 6 weeks (until January 1997), samples were collected from each well and deep probe once per week; the same four wells continued to be sampled twice per day on sampling days. For the next 7 months (January through July 1997), samples were collected from most wells and deep probes once per month. In addition, the wells and probes (15 total) that had exhibited the greatest concentration fluctuations were sampled twice per month.

The wells identified for barometric pump sampling were sampled during periods of low barometric pressure approximately once per month. Plastic bags were taped to two wells (one open above and one open below the Plio-Pleistocene unit) to indicate the direction of natural airflow. These indicator wells were used to determine favorable times for barometric sampling.

The shallow soil-vapor probes were sampled once per month to evaluate long-term changes.

The soil-vapor-extraction system was used to collect one set of baseline characterization data at every on-line well prior to initiation of the rebound study. When extraction operations resumed in July 1997 following the rebound study, carbon tetrachloride concentrations were monitored at selected wellheads every third day for the first 2 weeks.

Soil-vapor samples were analyzed primarily to monitor for carbon tetrachloride. However, the samples were also analyzed for chloroform, methylene chloride, and methyl ethyl ketone because the Brüel and Kjaer sensors had been configured to analyze for all four contaminants to support routine monitoring during extraction operations.

4.4.2 Networks

There are currently 46 drilled wells available for on-line extraction or monitoring (BHI-00720, Rev. 1; BHI-01105) (Figure 4.4-1). Thirteen of these wells were drilled during 1992 and 1993 and were completed as vapor-extraction wells with stainless-steel casing and screens; one well was drilled at a 45-degree incline. Thirty-three wells, drilled between 1954 and 1978 and completed with carbon-steel casing, were adapted for vapor extraction by perforating the well casing using mechanical or jet perforators. Seventeen of the 46 available wells have 2 screened or perforated open intervals isolated by downhole packers. Each of the soil-vapor-extraction systems extracts simultaneously from multiple wells open either above and/or below the Plio-Pleistocene unit. The mix of on-line wells is adjusted periodically to optimize contaminant removal.

There are 125 subsurface-monitoring probes at >2-m depths as follows. A cone penetrometer was used to install 11 extraction or monitoring wells and 104 subsurface-monitoring points at 33 locations at the carbon tetrachloride site in 1993 and 1994. Up to five monitoring screens were installed per location at various depths. Ten stainless-steel tubes were strapped to the outside of the casing of four wells during installation in 1993 to enable monitoring above and below the screened intervals.

There are 73 shallow soil-vapor probes at depths ranging from 1.2 to 1.8 m below ground surface (Figure 4.4-2). The network was installed between 1991 and 1995.

4.4.3 Results

The carbon tetrachloride soil-vapor-extraction results are discussed in the following subsections based on results before and after shutting the system down to investigate the effects of allowing the vadose zone to reequilibrate, or rebound, after a long period of active vapor extraction.

During FY 1997, the soil-vapor-extraction systems were operated from October 1 through November 3, 1996 and from July 18 through September 30, 1997. From November 4 through July 17, 1997, the extraction systems were shut down and the rebound in carbon tetrachloride concentrations was monitored at 90 wells and soil-vapor probes in the extraction well-field sites.

4.4.3.1 Soil-Vapor Remediation

During the October-November 1996 operating period, carbon tetrachloride concentrations in extracted soil vapor continued to decline, as they have since operation of the extraction systems began in 1992 (BHI-00720, Rev. 1; BHI-01105). This is typical and represents removal of the readily available vapor phase of the contaminant in vadose-zone sediment-pore spaces. The most dramatic vapor-phase decrease was at the 216-Z-9 well field, where carbon tetrachloride concentrations measured at the system inlet declined from ~30,000 ppmv in 1993 to 25 ppmv in early November 1996 (Figure 4.4-3). In comparison, carbon tetrachloride concentrations in soil vapor extracted from the 216-Z-1A well field declined from ~1,500 ppmv in 1992 to 16 ppmv in November 1996 (Figure 4.4-4) and in soil vapor extracted from the 216-Z-18 well field declined from ~ 275 ppmv in 1994 to 10 ppmv in November 1996 (Figure 4.4-5). (Wells in the 216-Z-18 well field were included in the 216-Z-1A well field from 1992 to 1994.)

When the extraction systems were restarted in July 1997 after the 8-month shutdown for the rebound study, carbon tetrachloride concentrations in the extracted soil vapor had increased, as expected, at each of the three extraction systems (BHI-01105). After restart, daily concentrations at the three systems were equivalent to concentrations measured previously (at times ranging from September 1995 to February 1996) as indicated by arrows in Figures 4.4-3, 4.4-4, and 4.4-5. However, the July 1997 concentrations decreased at a faster rate than the equivalent concentrations did in the past.

During the last 3 weeks of extraction operations (October-November 1996), before the 8-month shutdown for the rebound study, the three systems combined were extracting carbon tetrachloride at an average of 102 kg/wk. During the first 3 weeks of operation following the shutdown (July-August 1997), the three systems combined were extracting an average of 178 kg/wk (BHI-01105). With continued operation in 1997, the mass-removal rates at the three systems continued to decline toward the October-November 1996 mass-removal rates.

As of September 1997, ~75,000 kg of carbon tetrachloride had been removed from the subsurface since extraction operations started in 1992 (Table 4.4-1 and see BHI-01105 for additional details). Of this total, 1,824 kg were removed during 15 weeks of operation in FY 1997. Since its initiation in 1992, the extraction systems are estimated to have removed 6% of the residual mass at the 216-Z-1A/216-Z-18 well fields and 21% of the residual mass at the 216-Z-9 well field (BHI-00720, Rev. 1). This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory) or dissolved in groundwater (2% of the original inventory) is still available in the vadose zone as "residual" mass (BHI-00720, Rev. 1; BHI-01105; WHC-SD-EN-TI-101).

Carbon tetrachloride concentrations measured at individual extraction wells are also decreasing with continued vapor-extraction operations (BHI-00720, Rev. 1). At the 216-Z-9 well field, concentrations measured above the Plio-Pleistocene unit before April 1994 were generally an order of magnitude higher than those measured below; by 1995, concentrations measured above and below the Plio-Pleistocene had reached comparable levels (Figure 4.4-6). At the combined 216-Z-1A/216-Z-18 well fields, concentrations measured at intervals open above the Plio-Pleistocene have been the same order of magnitude as those measured below the Plio-Pleistocene throughout extraction operations (Figure 4.4-7).

The concentration of chloroform has been proportional to the carbon tetrachloride concentration (BHI-00720, Rev 1) (Figure 4.4-8). The ratio between carbon tetrachloride and chloroform is relatively constant for carbon tetrachloride concentrations between 25,000 and 1,000 ppmv. The concentration of methylene chloride tends to be higher than that of chloroform. At carbon tetrachloride concentrations <1,000 ppmv, two different linear trends between carbon tetrachloride and chloroform are apparent.

4.4.3.2 Rebound Study

A rebound study was conducted at the 200-ZP-2 Operable Unit carbon tetrachloride soil-vapor-extraction site from November 1996 through July 1997 (BHI-01105). The purpose of the study was to determine the increase in carbon tetrachloride vapor concentrations in vadose-zone pores following shutdown of the extraction systems. During the time when the systems were off-line, carbon tetrachloride concentrations were monitored at 90 subsurface monitoring locations, ranging in depth from 1.5 to 64 m.

A previous bench-scale experimental study (BHI-00861), conducted using pure carbon tetrachloride and clean site-specific soils, concluded that calculation of carbon tetrachloride soil concentrations using measured vapor-phase concentrations and either empirical relationships or adsorption isotherms to estimate the soil-partitioning coefficient can lead to significant error. This conclusion was based on comparisons of calculated and measured soil concentrations using data generated during the experiments. The predictive equations generally assume equilibrium partitioning between phases. However, these relationships do not account for the nonequilibrium partitioning of carbon tetrachloride within the soil particles (the apparent "irreversible" adsorption). Therefore, the mass of carbon tetrachloride remaining in the soil cannot be reliably determined using the rebound study vapor-phase data. However, the magnitude and rate of rebound can be used to indicate the distribution of remaining carbon tetrachloride sources and the transfer of additional carbon tetrachloride to the vapor phase that can be remediated using soil-vapor extraction.

The maximum carbon tetrachloride concentration measured at each sampling location is plotted with depth in Figure 4.4-9 (BHI-01105). This vertical profile indicates that the remaining carbon tetrachloride available for removal using soil-vapor extraction is primarily associated with the lower Hanford formation silt and underlying Plio-Pleistocene unit. The location of remaining carbon tetrachloride sources in the various strata is a result of its initial accumulation in the finer-grained, lower-permeability layers observed during characterization in 1991-1993 (WHC-SD-EN-TI-248) and the relative inability of the extraction system to induce airflow through this lower-permeability zone to effectively remove soil vapor.

The magnitude of the carbon tetrachloride rebound was calculated for the extraction wells by comparing the maximum rebound concentration to the baseline concentration collected 1 week before the extraction systems were shut down. The largest increase in concentration at any well was 725 ppmv at well 299-W15-217, which is screened across the silt and Plio-Pleistocene unit next to the 216-Z-9 trench. Rebound concentrations were an order of magnitude higher than baseline concentrations at five wells (three within or adjacent to the 216-Z-1A tile field and two adjacent to the 216-Z-9 trench); all five wells are open at and above the Plio-Pleistocene.

Additional carbon tetrachloride may be slowly migrating from the micropores of soil particles within the higher-permeability zones also. Although rebound concentrations in these zones appear to be low, the large volume of high-permeability soil represents a potentially significant mass of carbon tetrachloride.

The continuing rebound at many locations indicates that the supply of additional carbon tetrachloride for soil-vapor extraction is limited by diffusion of the contaminant from the micropores and/or the lower-permeability zones. Under these conditions, the removal rate of the additional carbon tetrachloride using soil-vapor extraction is controlled by the desorption and diffusion rates of the contaminant.

Carbon tetrachloride concentrations measured in soil vapor near the water table increased relatively slowly during the rebound study and remained relatively constant during restart in July 1997. These relatively slow changes during the rebound study suggest that the volatilization of dissolved carbon tetrachloride from groundwater into the unsaturated zone, and/or the downward migration of carbon tetrachloride from the lower-permeability zone toward the groundwater, was occurring slowly relative to the 8-month-long rebound study.

The wells that were monitored near the water table have open intervals that together include a 16-m vertical span between the Plio-Pleistocene unit and the groundwater. The concentrations monitored in these wells during the rebound study were similar to those found in other wells open only at shallower intervals below the Plio-Pleistocene. All of these wells had 1) similar baseline carbon tetrachloride concentrations (10 to 15 ppmv), 2) similar relatively slow rebound rates, and 3) similar relatively low maximum rebound magnitudes (10 to 50 ppmv). In addition, because the water-table elevation is declining ~0.8 m/yr, the position of these monitoring points relative to the groundwater is continually changing. The similar concentration behavior observed among these wells, which are located at both the 216-Z-1A and 216-Z-9 well fields, suggests that the sources of the carbon tetrachloride rebound are relatively broad and diffuse.

The carbon tetrachloride vapor concentrations observed between the Plio-Pleistocene unit and the groundwater are similar at the 216-Z-1A and 216-Z-9 well fields despite the underlying groundwater plumes of different concentrations (3,000 μg/L in the water below 216-Z-1A and 6,000 μg/L in the water below 216-Z-9). The measured vapor concentrations are an order of magnitude lower than the equilibrium vapor concentrations predicted for these groundwater concentrations using Henry's Law (450 ppmv predicted at 216-Z-1A and 900 ppmv predicted at 216-Z-9). The rebound vapor concentrations might be less uniform and higher (i.e., more representative of underlying groundwater concentrations) if they had been measured at the capillary fringe/unsaturated zone interface but no vapor samples were collected from that discrete interval. The vapor concentrations are also much lower than saturated vapor concentrations in equilibrium with a carbon tetrachloride nonaqueous-phase liquid (120,000 ppmv), which suggests that the continuous carbon tetrachloride contamination source indicated for the groundwater at the 216-Z-9 well field may be within the aquifer rather than draining from the vadose zone (BHI-01105).

4.4.3.3 Other Results

Carbon tetrachloride (mostly measured as total chlorinated hydrocarbons) was detected using field-screening instruments in wells under construction throughout much of the 200-West Area since January 1987. These wellhead measurements are strongly affected by barometric pressure changes and are used to examine the distribution of carbon tetrachloride vapors, either above or below the Plio-Pleistocene unit. Most of the reported detections have been from below the Plio-Pleistocene, often in the capillary fringe zone just above the water table. Carbon tetrachloride has been detected in wells drilled adjacent to the carbon-tetrachloride-disposal facilities and in some wells drilled west and south of the 216-Z-18 well field. Carbon tetrachloride (as chlorinated hydrocarbons) has been detected both above and below the Plio-Pleistocene in wellheads located outside the maximum extent of the groundwater plume (WHC-SD-EN-TI-248).

4.4.4 Carbon Tetrachloride Migration

Three major pathways for transport of carbon tetrachloride in the vadose zone to groundwater are possible: 1) sinking and lateral spreading of a heavier-than-air vapor phase down to the top of the aquifer; 2) transport of a liquid phase or dense nonaqueous-phase liquid down through the vadose zone over time, which eventually reaches the water column, dissolves, and settles through the saturated zone to an unknown depth; and 3) transportation of carbon tetrachloride dissolved in the aqueous phase either through disposal of aqueous waste or by contact between infiltrating recharge and residual dense nonaqueous-phase liquid (WHC-SD-EN-TI-248). A schematic representation, or conceptual model, of the subsurface behavior of carbon tetrachloride beneath the 216-Z-9 trench is shown in Figure 4.4-10.

A numerical model was developed (BHI-00459) to simulate the primary transport processes shown in Figure 4.4-10 using local stratigraphy and published input parameters for the source-term and soil properties. Results of initial simulations suggested that over two-thirds of the discharged carbon tetrachloride would have been retained in the soil column and that a dense nonaqueous-phase liquid would continue to drain slowly through the vadose zone and be transported into the underlying aquifer for years into the future. The initial modeling results indicated that the dense nonaqueous-phase liquid dissolved in the groundwater and the depth of penetration was dependent on the groundwater-flow rate. Additional modeling is needed to assess the influence of effective porosity and groundwater velocity. Nevertheless, the modeling results support the conceptualization of the liquid-phase transport illustrated in Figure 4.4-10. The vapor-phase results were less definitive but suggested that vapor-phase transport is secondary to dense nonaqueous-phase liquid as a groundwater contamination pathway.

Field measurements of carbon tetrachloride vapor concentrations are not completely consistent with the numerical modeling results. If a major fraction of the carbon tetrachloride originally discharged to the 216-Z-9 site was still present in the soil column as a nonaqueous phase, a relatively high soil-vapor concentration would be expected. For example, a pure, nonaqueous, carbon tetrachloride liquid phase in the soil-pore space should result in a maximum soil-vapor concentration of 120,000 ppmv at 20°C (DOE/RL-91-32, Draft B). As a rule of thumb for soils saturated with an organic contaminant, standard soil-vapor extraction will produce a vapor stream containing one-tenth to one-half the expected concentration (Johnson 1993). Therefore, vapor-extraction concentrations >12,000 ppmv of carbon tetrachloride would indicate that the soil near the extraction well is saturated with nonaqueous carbon tetrachloride liquid.

During initial extraction operations at the 216-Z-9 site, soil-vapor concentrations extracted from wells open above the Plio-Pleistocene unit were in excess of 12,000 ppmv, suggesting the presence of a nonaqueous carbon tetrachloride phase (see Figure 4.4-6). Soil vapor extracted from wells open below the Plio-Pleistocene were an order of magnitude lower and based on the rule of thumb would not suggest the presence of a nonaqueous-phase liquid. However, the depths and locations of the extraction wells below the Plio-Pleistocene may not have been optimal to detect the presence of a nonuniformly distributed contaminant, and the presence of a nonaqueous-phase liquid cannot be ruled out.

During the FY 1997 rebound study, the carbon tetrachloride vapor concentrations monitored deep within the vadose zone at the 216-Z-9 site did not exceed 60 ppmv. These low vapor concentrations do not indicate the presence of a nonaqueous-phase liquid remaining in the vadose zone below the Plio-Pleistocene unit; however, these measurements were not taken directly under the 216-Z-9 crib nor at depth-discrete narrow zones above the water table. Although carbon tetrachloride volatilizing from a residual nonaqueous-phase liquid source may have been diluted by the time the vapor reached the sampling locations, the data suggest that soil-vapor extraction may have removed much of the remaining deep vadose-zone nonaqueous-phase liquid source in the 216-Z-9 area and that the continuing groundwater source may now be within the aquifer (BHI-01105).

The apparent discrepancy between the numerical modeling results and the field measurements may be a result of 1) nonuniform discharge, migration, and distribution of the nonaqueous-phase carbon tetrachloride; 2) nonoptimal locations for monitoring; 3) nonequilibrium partitioning of carbon tetrachloride within the vadose zone; 4) discharge of carbon tetrachloride organic liquid mixtures rather than pure phase liquids; and/or 5) vadose-zone geologic heterogeneities and geostructural dips.

Vertical and areal distribution of dissolved carbon tetrachloride discussed in Section 5.9.3.4 is consistent with a dense nonaqueous-phase liquid-transport mechanism. If the numerical model predictions are correct, for example, slowly dissolving carbon tetrachloride distributed with depth in the aquifer should continue to emanate from the point of origin over time, with the highest concentrations at the source, and should result in dissolved carbon tetrachloride distributed with depth in the aquifer (BHI-00459). If vapor-phase transport were a primary pathway, the top of the aquifer should have the highest concentrations and should decline rapidly with depth over a 1- to 2-m interval.

The carbon tetrachloride plume map and vertical profiles discussed in Section 5.9.3.4 suggest there is a continuing groundwater source that produces somewhat uniform carbon tetrachloride concentrations with depth in the aquifer. A dense nonaqueous-phase liquid that drained from the vadose zone into the aquifer and is slowly dissolving could produce such a pattern. One alternative explanation for the depth-distribution pattern is that a secondary source of water passing near or through an area containing a dense nonaqueous-phase liquid and soil-vapor carbon tetrachloride could absorb this slightly soluble chlorinated hydrocarbon and carry it into the aquifer under saturated flow conditions. This would theoretically drive the contaminated water deep into the aquifer.

The continuing presence, 35 years after termination of disposal operations, of relatively high, dissolved carbon tetrachloride concentrations in groundwater in the immediate vicinity of the 216-Z-9 trench suggests that a dense nonaqueous liquid phase of carbon tetrachloride is slowly dissolving within the aquifer. Although this liquid phase may be slowly draining from the vadose zone to groundwater, the soil-vapor concentrations monitored deep within the vadose zone during FY 1997 suggest that soil-vapor extraction remediation may have removed much of the vadose-zone source and that the continuing groundwater source is now within the aquifer. Carbon tetrachloride concentrations in the soil vapor and underlying groundwater do not appear to be in equilibrium, and the expected direction of carbon tetrachloride migration is from the groundwater to the vadose zone (BHI-01105).

Carbon tetrachloride rebound concentrations indicate that in many areas much of the readily accessible mass has been removed during soil-vapor-extraction operations and that the supply of additional carbon tetrachloride is limited by desorption and/or diffusion from contaminant sources (e.g., lower-permeability zones such as the lower Hanford formation silt and Plio-Pleistocene unit). Under these conditions, the removal rate of the additional carbon tetrachloride using soil-vapor extraction is controlled by the desorption and diffusion rates of the contaminant.

4.4.5 Transuranics Migration

As previously indicated, liquid-waste streams associated with plutonium-process streams contained both carbon tetrachloride and isotopes of americium and plutonium. A complexing agent (tributyl phosphate) was used to extract plutonium from an aqueous phase (nitric acid) into an organic phase (carbon tetrachloride). A subsequent step involved backextracting the plutonium into dilute nitric acid. When the tributyl phosphate became degraded (i.e., converted to dibutyl phosphate), the dibutyl phosphate-bound plutonium remained in the organic phase. When degradation reached this point, the process liquids were discharged to soil-column-disposal sites, primarily the 216-Z-9 trench, 216-Z-1A tile field, and 216-Z-18 crib. The liquid-waste streams thus discharged to these facilities were highly acidic and contained both carbon tetrachloride with plutonium (and americium) as an organometallic complex. In this form, the TRUs may have moved with the carbon tetrachloride phase.

216-Z-1A, 216-Z-9, and 216-Z-18 were designed as specific retention facilities intended to hold or contain the liquid waste in the vadose zone. The general policy for specific retention cribs was to restrict the disposal volume to 10% of the calculated void space in the soil column directly beneath the crib. Although the 216-Z-9 trench received the same waste stream as the 216-Z-18 crib, the volume of liquid waste discharged exceeded the calculated soil-column pore space by ~40% (DOE/RL-91-32, Draft B; WHC-SD-EN-TI-248). Considering the chemistry of the TRUs and the predicted distribution of the dense nonaqueous-phase liquid shown in Figure 4.4-10, it is conceivable that the TRUs could have been transported to groundwater at least beneath the trench.

An extensive soil-column characterization (RHO-ST-17) was conducted at the 216-Z-1A tile field in the mid-1970s and revealed that americium and plutonium were distributed at high concentrations (>100,000 pCi/g) to depths of 20 to 30 m (Figures 4.4-11 and 4.4-12). The current status of the TRUs beneath this crib and the trench is unknown. It is clear, however, that the complexed plutonium and americium were not as mobile as the major cocontaminant (carbon tetrachloride). Detectable TRUs in groundwater, for example, were perhaps found in only one well (299-W15-8) near the Plutonium Finishing Plant waste-disposal facilities at two sampling times. Detectable but relatively low concentrations (<8 pCi/L) of americium-241 and lesser amounts of plutonium-239 were measured in the sediment around this well using spectral gamma logging. The logging data confirmed the presence of TRUs to depths down to 39.6 m such that detection of americium and plutonium in the groundwater for a brief period may be plausible. At shallower depths closer to the crib bottom, the maximum plutonium concentration in soil was 300,000 pCi/g.

One possibility for the apparent low mobility of TRUs in the dense nonaqueous-phase liquid/complexant mixture is that the complexing agents (tri- and dibutyl phosphates) readily degrade in the soil column. If so, then the americium and plutonium would be adsorbed by the soil after degradation. Alternatively, other soil-chemical reactions may have occurred (RHO-ST-17, NUREG/CR-6124). Because these alpha emitters also emit gamma rays, their presence can be detected using high-resolution spectral gamma-logging equipment. Evidence of movement, thus, can be checked over time by periodic borehole logging in the available vadose-zone-monitoring structures. Spectral gamma logs obtained in

1992 demonstrated that the americium and plutonium were detectable by high-resolution spectral gamma-logging methods. More complete, or continuous, spectral gamma profiles, however, are needed for comparison with previous depth-profile data to determine if changes have occurred over time. With this information, some assessment of the mobility status of the americium and plutonium could be made. It should also be noted that a coarse gravel cover was placed over the 216-Z-1A tile field in 1992. Consequently, enhanced infiltration of natural precipitation through the gravel covers could cause some downward movement of residual mobile contaminants. However, continuous soil-vapor-extraction operations at this tile field may have removed much of the subsurface water in the extracted soil vapor.

4.4.6 Nonradioactive Dangerous Waste Landfill

The Nonradioactive Dangerous Waste Landfill (NRDWL) is a RCRA-regulated land-disposal unit, located ~5.6 km southeast of the 200-East Area. The NRDWL was used to dispose of nonradioactive dangerous waste and asbestos waste from 1975 to 1985. Volatile organic compounds were detected primarily within and south of the eastern third of the NRDWL during a 1993 shallow (1.5- to 1.8-m-deep) soil-vapor survey; since 1987, contaminants were detected during groundwater monitoring of nearby wells (WHC-SD-EN-TI-199, Section 5.12 of this report).

A soil-vapor survey was conducted at the NRDWL during FY 1997 to collect deep soil-vapor data to assess the vertical extent of contamination and the potential impacts to groundwater and to resample selected shallow vapor probes to assess changes in contaminant distribution that may indicate contaminant movement. The strategy and methods used to sample and analyze the soil vapor within the subsurface at NRDWL, and a summary of the data quality objectives process, are described in BHI-01073.

The sampling locations focused on the eastern half of the NRDWL based on the results of the 1993 soil-vapor survey (WHC-SD-EN-TI-199). A total of 35 probes, including 33 deep probes, were installed during August 1997 using a Geoprobe Model 5400™ hydraulic probe driver (Geoprobe Systems, Salina, Kansas). Each sample point consists of a dedicated stainless-steel screen implant connected to a length of 0.64-cm outside diameter polyethylene tubing. Soil-vapor samples were collected from six shallow probes (1.5 to 1.8 m deep) and 33 deep probes (8.8 to 29.7 m deep) during September 1997 (BHI-01115).

Six compounds were detected during the 1997 survey: 1,1,1-trichloroethane, 1,1-dichloroethane, tetrachloroethylene, trichloroethylene, carbon tetrachloride, and chloroform (BHI-01115). Of these contaminants, 1,1,1-trichloroethane was the most widespread and was detected in all but one of the samples from the deep probes at concentrations <1 ppmv; however, 1,1,1-trichloroethane was not detected in the samples from the shallow probes. Carbon tetrachloride and chloroform were the only contaminants detected at concentrations exceeding 1 ppmv; in samples from two adjacent locations (one shallow and two deep probes within and beneath the chemical trenches), concentrations ranged from 20 to 46 ppmv. All of the same contaminants, except 1,1-dichloroethane, were detected in the 1993 survey.

Based on the 1997 results, the soil-vapor contaminants tend to be distributed at low concentrations within or south of the NRDWL. The concentrations detected in deep samples suggest that vertical migration of carbon tetrachloride occurred directly beneath the chemical trenches within a narrow zone. Comparison of analytical results for 1993 and 1997 soil-vapor samples collected from shallow probes indicates that the maximum carbon tetrachloride concentrations are still laterally within the chemical trenches at NRDWL, suggesting that the contaminants within NRDWL have not migrated significantly laterally (BHI-01115).

4.5 100 Areas Reactor Sites

R. J. Serne, M. P. Connelly, V. J. Rohay

Remediation continued in the 100-B,C and 100-N Areas and was initiated in the 100-D Area at high-priority liquid waste-disposal sites (see DOE/RL-96-17 for details). Remedial action at the 100-B,C and 100-D Area sites entails excavation, transportation, and disposal of contaminated soil and structures from the upper 4.6 m of the vadose zone. The primary cleanup objective is to meet health-based contaminant levels for direct exposure in the upper vadose zone consistent with residential land use. The secondary objective is to evaluate and determine the potential for groundwater degradation, and impact to the Columbia River, that could result from contaminants being left in place in the lower vadose zone. Site-specific data are being analyzed to determine the nature and extent of possible groundwater impacts under conditions that sustain 76 cm of irrigation per year for 1,000 years.

4.5.1 Calculation of Strontium-90 in Vadose-Zone Sediments

In FY 1997, Bechtel Hanford, Inc. staff took advantage of the high Columbia River stage and its impact on water levels and increased strontium-90 concentrations in existing groundwater-monitoring wells to calculate the amount likely present in the vadose-zone sediments directly above the water table. These calculations can then be used to estimate the future impacts that natural infiltration might have on the overall risk at the 100-N Area and what the future benefit might be for continued pump and treat.

The wells listed in Table 4.5-1 were sampled in July 1997 to help estimate the amount of strontium-90 remaining in the vadose zone under normal river-stage conditions. It is possible to estimate the strontium-90 in the vadose zone, assuming that the current conceptual model is reasonable. The current conceptual model assumes that disposed cooling water, containing the strontium-90, migrates vertically directly under the 1301-N and 1325-N/NA liquid waste-disposal facilities until the water intercepts the artificially mounded water table. During the vertical migration, much of the strontium-90 adsorbed to the vadose-zone sediments under the disposal facilities but some remained in solution. The strontium-90 remaining in the water then traveled mainly horizontally down the upper surface of the artificial mound to the Columbia River. As the liquid discharges to the disposal facilities continued, the mound grew and dissipated, depending on discharge volumes and rates. The sediments that were wetted by the mound adsorbed large quantities of strontium-90, forming a thin lens, or pancake-shaped zone (when viewed in the larger context of the full thickness of alluvial sediments lying over the bedrock) of contaminated sediment. It is this pancake-shaped zone and the sediments directly under the disposal facilities that retains much of strontium-90 today. Directly below the cribs and trench, the mound was several meters thick but thinned out in all directions as the water flowed toward the river. As the disposal of cooling water diminished and finally ceased, the artificial mound subsided until, today, the water table resembles that found during pre-Hanford Site times. The strontium-90 adsorbed on the sediments away from the vertical cross-section directly below the 1301-N and 1325-N/NA facilities resides in this thin layer of vadose sediment and in the upper regions of the current water table. Some of the vadose-zone layer has been rewetted because of the two consecutive high Columbia River flood-stage years. On rewetting, the sediments release (i.e., desorb) some more strontium-90. From knowledge of the distribution coefficient for strontium-90 on the Hanford formation sediment, which has been determined to be ~15 mL/g (PNL-10899), and the strontium-90 groundwater data in Table 4.5-1, one can estimate the amount of strontium-90 remaining in the thin layer within the vadose-zone sediments. The groundwater strontium-90 concentrations for the affected zone in the 100-N Area can be estimated from isoconcentration plots similar to those shown in Chapter 5.0 of this report. The water-level changes between normal river stage (1995) and high river stage (1997) shown in Figure 4.5-1 can be used to estimate the vertical thickness of the pancake shaped lens of sediments that remains contaminated. From the isoconcentration plot and water-level changes, the areas and thickness of the aquifer that exist between the various contours were determined. The volume of water between the contours is equal to the porosity of the sediments (0.28) and by assuming that the water between the contours has the median concentration of strontium-90 throughout, a mass (activity) of strontium-90 dissolved in the groundwater is calculated. The amount adsorbed to the soil in the same volume is equivalent to the water concentration times the distribution coefficient value. The results of this simple calculation are shown in Table 4.5-2.

The calculation suggests that there are 48.5 Ci of strontium-90 within the thin layer directly above the normal water table, and in calendar year 1997, this region was saturated by the high-water conditions. This value is in addition to the PNL-10899 estimate of 89 Ci within the normal water table. The two values should be added together to get the total estimate for strontium-90 in the aquifer and lower vadose zone outside the vertical projection of the two inactive waste-disposal facilities. An estimate of the mass of strontium-90 under the inactive facilities (~1,700 Ci) was estimated in DOE/RL-94-132. The recent limited field investigation (DOE/RL-96-11) could be used to generate a second estimate based on limited sampling through three new boreholes: one placed inside the 1301-N facility and one each placed very near the 1301-N and 1325-N facilities, respectively. Both of these reports include migration calculations that suggest that the strontium-90 in the vadose-zone sediments directly below the inactive facilities will decay to insignificant levels before reaching the Columbia River, assuming current natural infiltration is the driving force to groundwater and that the current groundwater velocities continue for the next 400 years. Although the strontium-90 flux to the river is expected in general to decline with time, in the near future considerable variation may be caused by changing water-level conditions.

4.6 200 Areas Strategy

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In FY 1997, a 200 Areas soil-remediation strategy was developed that redefined and reprioritized operable units into waste-site groups, integrated RCRA and CERCLA (*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*) activities, and defined an integrated assessment process within the U.S. Department of Energy's environmental restoration program (DOE/RL-96-67, DOE/RL-96-81). According to this strategy, the waste-site groups are based on common waste-site types and contaminants of concern rather than on geographic location. The characterization of these waste-site groups will be based on an analogous site approach where a limited number of "representative sites" will be characterized to obtain sufficient information to make remedial action decisions on the entire waste-site group. Characterization activities will begin in FY 1998.

Table 4.3-1. SX Tank Farm Borehole Extension Characterization Task

											1:1 Distilled Water and SX Sediment										
Depth (m)	Sample Identification	Moisture Content, %	^{137}Cs Conc. Wet Wt., pCi/g	^{40}K Conc. Wet Wt. pCi/g	^{238}U Conc. Wet Wt. pCi/g	^{232}Th Conc. Wet Wt. pCi/g	^{99}Tc Conc. Dry Wt. pCi/g	^{90}Sr Conc. Dry Wt. pCi/g	pH	Extract Conduct. μS/cm	NO_3 mg/L	Ca mg/L	K mg/L	Mg mg/L	Na mg/L	Sr mg/L	Al mg/L	B mg/L	Fe mg/L	Mn mg/L	Si mg/L
40.0	1C-light	NM	3.24E+05	<MDA	<MDA	<MDA	NA	NA	8.52	382	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.0	1C-dark	NM	7.96E+04	7.40E+00	5.32E+03	<MDA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.1	1B	13	2.08E+06	<MDA	<MDA	<MDA	NA	NA	8.06	4858	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.1	1B-2	NM	9.29E+02	9.80E+00	2.00E+01	2.40E+00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.1	Clean Out																				
40.6	Clean Out																				
40.6	2D	35.6	4.80E+04	2.20E+00	<MDA	<MDA	2.90E+02	2.00E+00	8.26	865	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.8	2C	18.3	2.66E+04	1.30E+01	<MDA	<MDA			8.28	413	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.8	2C-2	26.7	1.16E+06	<MDA	<MDA	<MDA	NA	NA	NM	NM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
40.9	2B	14.5	2.27E+03	4.40E+00	<MDA	1.20E+00	5.60E+01	1.00E+00	8.36	658	291	49.3	5.38	12.9	31.3	0.22	(<0.05)	1.82	<0.05	<0.05	4.62
41.1	2A	16	5.73E+01	1.15E+01	<MDA	1.20E+00			8.25	611	268	57.4	4.29	13.8	22.5	0.26	(<0.05)	0.45	<0.05	<0.05	6.01
41.1																					
41.2																					
41.2	3B	NM	2.29E+03	3.59E+01	<MDA	<MDA	8.60E+01	3.00E+00	8.25	831	362	57.3	22.36	15	53.6	0.26	(<0.05)	1.86	<0.05	0.06	7.93
41.4	3A	13.1	2.93E+03	<MDA	<MDA	<MDA			8.34	442	165	39.2	(10.73)	8.18	23.4	0.14	(<0.05)	0.77	<0.05	0.06	4.23
41.4	Clean Out																				
41.8	Clean Out																				
41.8	4D	NM	NM	NM	NM	NM	NA	NA	8.29	387	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
41.9	4C	10.9	<MDA	1.05E+01	7.00E-01	6.00E-01	NA	NA	8.78	172	12	19.7	(1.61)	3.13	10.8	0.06	(<0.05)	0.29	<0.05	<0.05	4.98
42.1	4B	11.7	4.31E+01	<MDA	<MDA	<MDA	NA	NA	8.61	223	24	20	(8.12)	3.98	14.8	0.06	(<0.05)	0.37	<0.05	<0.05	5.35
42.8	4A	16.1	5.04E-01	9.00E+00	1.10E+00	6.00E-02	NA	NA	8.63	193	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
42.8	Clean Out																				
42.5	Clean Out																				
42.6	5D	14.1	3.63E+01	7.20E+00	1.20E+00	4.00E-01	NA	NA	NM	NM	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
42.8	5C	14.5	1.54E+01	7.40E+00	1.00E+00	5.00E-01	NA	NA	8.57	230	9.9	16	(3.16)	3.62	19	0.06	(<0.05)	0.5	<0.05	<0.05	6.62
42.9	5B	12.6	6.93E+01	7.00E+00	6.00E-01	4.00E-01	NA	NA	8.92	184	3.7	21.8	(6.62)	3.21	14.2	0.07	(<0.05)	0.41	<0.05	<0.05	4.7
43.1	5A	9.4	3.63E+00	9.00E+00	1.00E+00	6.00E-01	NA	NA	8.97	167	9.8	17.8	2.37	3.24	(13.5)	0.07	(<0.05)	0.34	<0.05	<0.05	6.3
43.3																					

<MDA = Less than minimum detectable activity.
NM = Not measured.
Clean Out = No sample obtained because cleanout step went deeper than it should have.
NA = Not analyzed.

Table 4.4-1. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973,[a] kg	Estimated Mass Lost to Atmosphere 1955 to 1990,[b] kg	Mass Removed Using Soil Vapor Extraction 1992 to 1997,[c] kg
216-Z-1A	270,000	56,700	22,729[d]
216-Z-18	170,000	35,700	
216-Z-9	130,000 to 480,000	27,300 to 100,800	51,984
Total	570,000 to 920,000	119,700 to 196,800	74,713

(a) Based on DOE/RL-91-32, Draft B.
(b) Based on WHC-SD-EN-TI-101.
(c) Based on BHI-01105.
(d) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

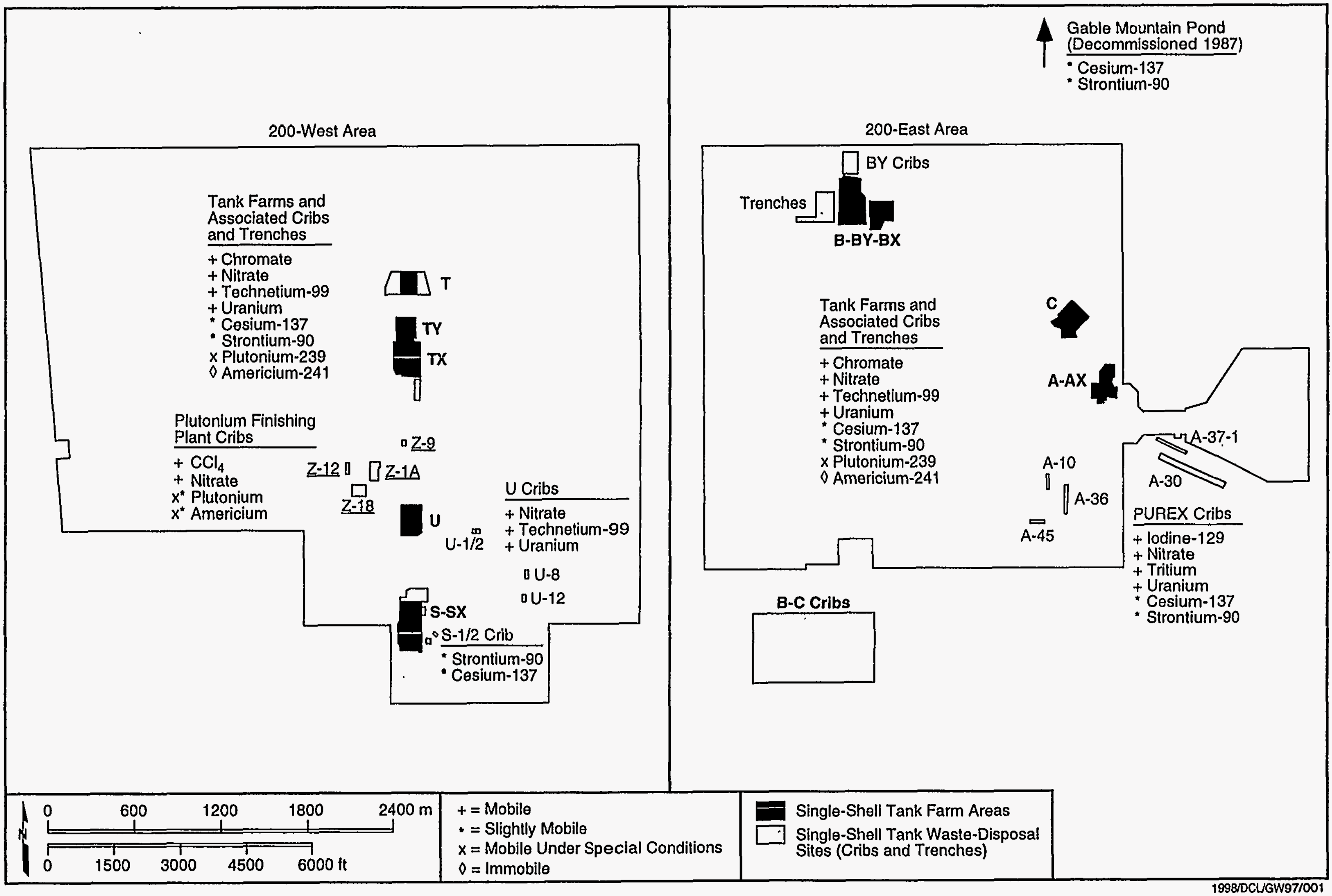
Table 4.5-1. Wells and Strontium-90 Activities in Groundwater Used to Estimate Mass in 100 Areas Vadose Zone

Well Number	1997 Strontium-90, pCi/L	1995 Strontium-90, pCi/L
199-N-21	3	<1
199-N-32	<1	<1
199-N-41	NA	<1
199-N-50	NA	<1
199-N-51	<1	<1
199-N-52	NA	<1
199-N-64	<1	<1
199-N-74	NA	<1
199-N-92A	NA	<1
199-N-96A	NA	9.3
199-N-19	41	44
199-N-31	81	40
199-N-34	NA	52
199-N-14	574	1,065
199-N-27	474	164
199-N-28	124	122
199-N-2	3,900	137
199-N-3	1,400	794
199-N-46	4,830	5,090
199-N-67	12,200	4,247
199-N-76	NA	101
199-N-81	1,260	621
199-N-99A	NA	6,500
199-N-75	1,740	1,304
199-N-103A	2,300	777
199-N-105A	1,880	323
199-N-106A	3,830	3,750

NA = Not analyzed.

Table 4.5-2. Mass Estimate of Strontium-90 in Thin Layer of Vadose-Zone Sediment

Strontium-90 Isopleth Boundaries, pCi/L	Volume Between Isopleths, m^3	Median Value, pCi/L	Mass on Sediments, Ci	Mass in Water, Ci
8< n <42	236,948	25	0.18	0.002
42< n <400	322,594	221	2.14	0.020
400< n <1,000	108,232	700	2.27	0.021
1,000< n <3,000	242,162	2,000	14.53	0.136
3,000< n <4,000	86,730	3,500	9.11	0.085
4,000< n <7,500	69,020	5,750	11.91	0.111
7,500< n <10,000	9,981	8,750	2.62	0.024
>10,000	11,627	15,000	5.23	0.049
	Total		47.98	0.448



1998/DCL/GW97/001

Figure 4.1-1. Major Vadose-Zone-Contamination Sites

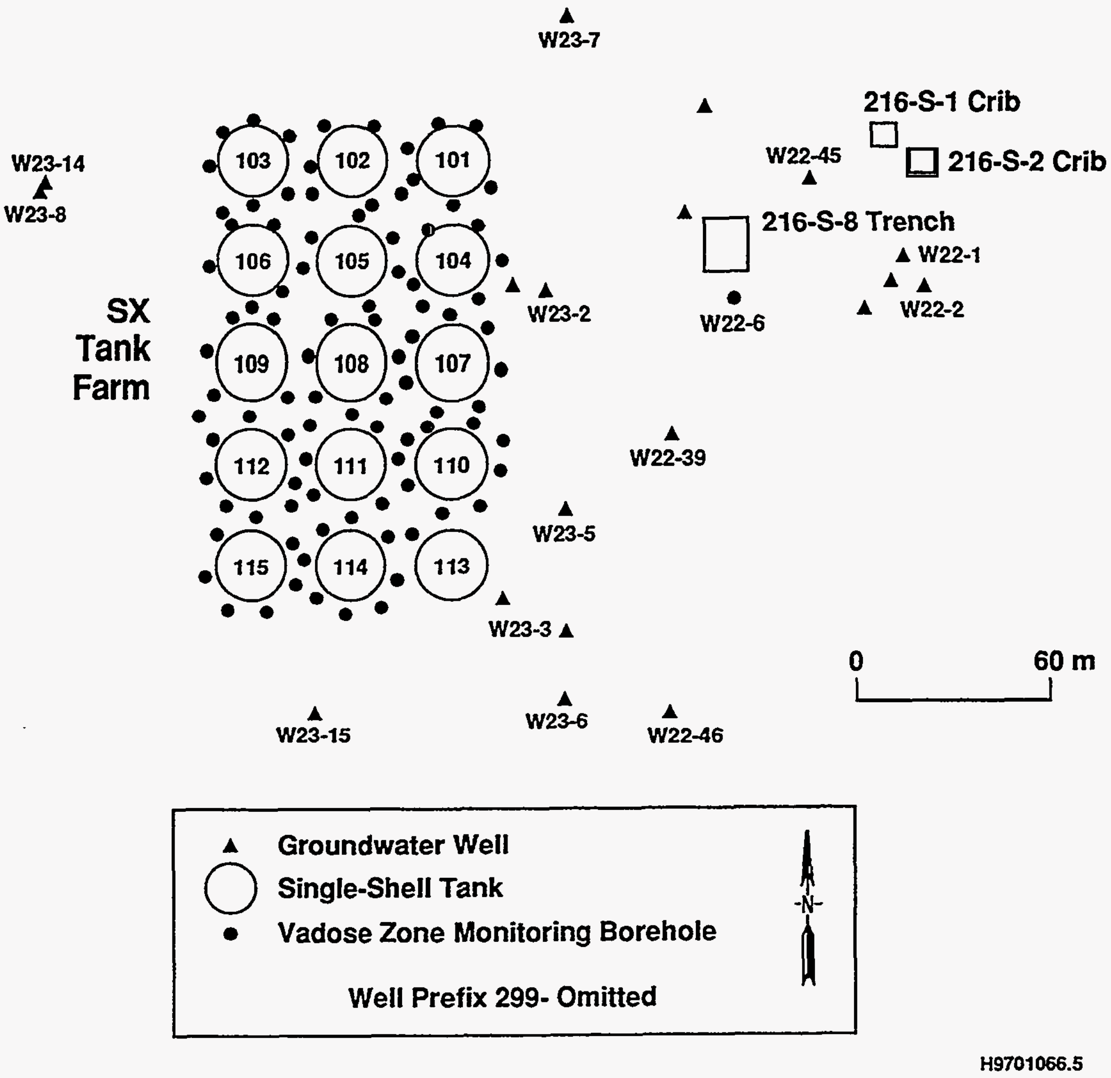


Figure 4.2-1. Example of Vadose-Zone-Monitoring Array

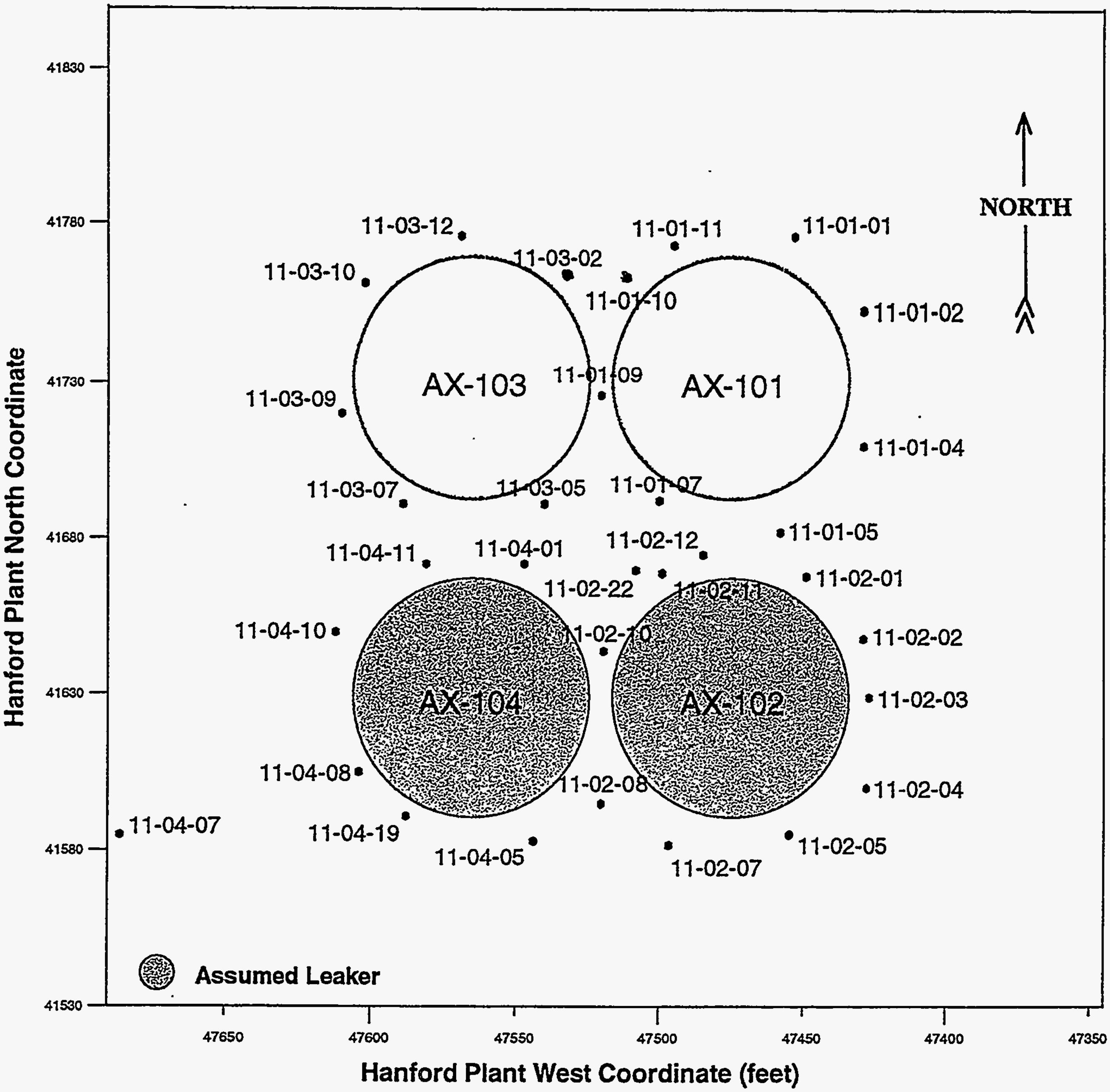


Figure 4.2-2. AX Tank Farm Configuration and Monitoring Boreholes (from GJO-97-14-TAR, GJO-HAN-12) (NOTE: To convert feet to meters, multiply by 0.3048.)

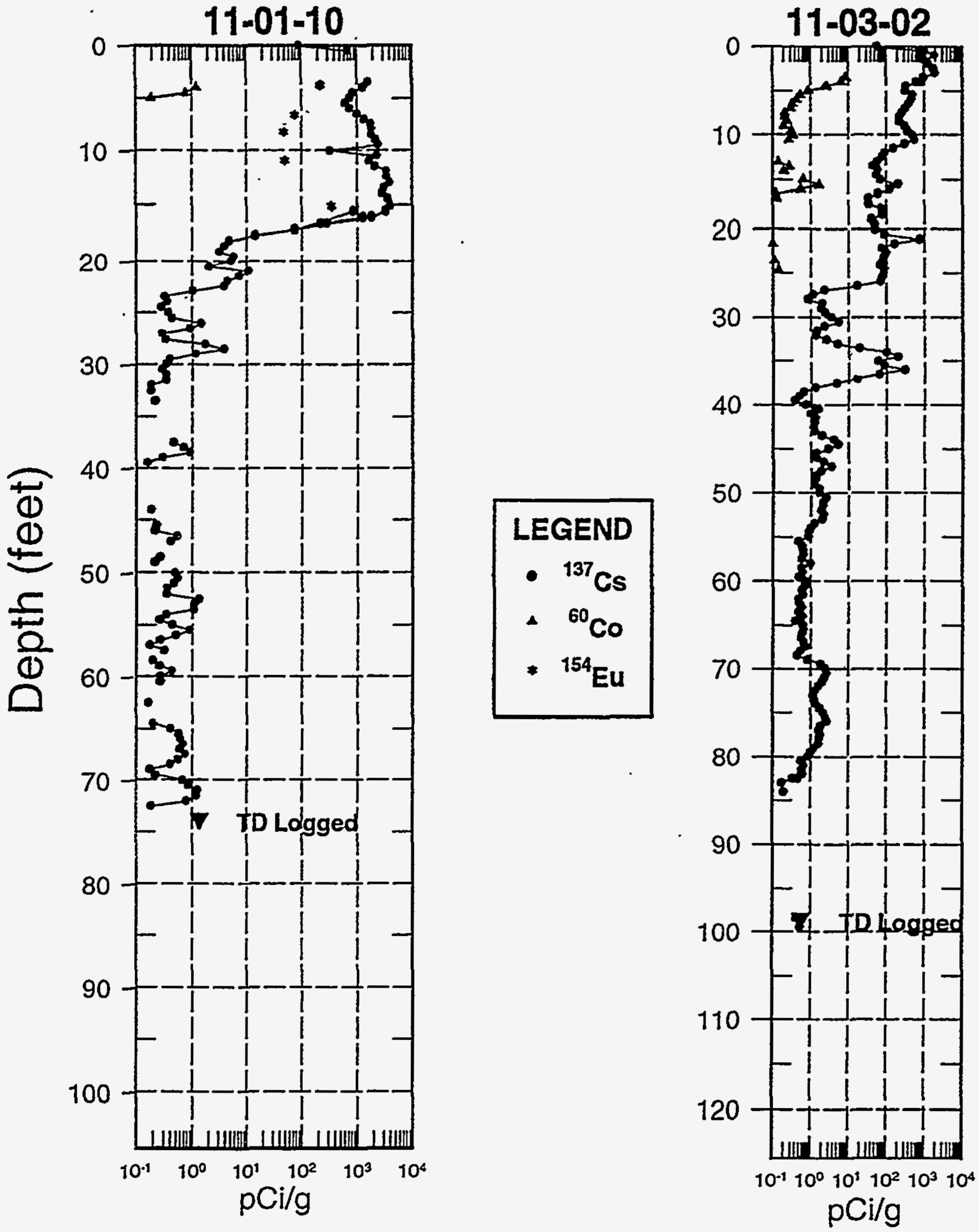


Figure 4.2-3. Correlation Plots of Cobalt-60 and Cesium-137 Concentrations in WMA A-AX Boreholes (after GJO-97-14-TAR, GJO-HAN-12) (NOTE: To convert feet to meters, multiply by 0.3048.)

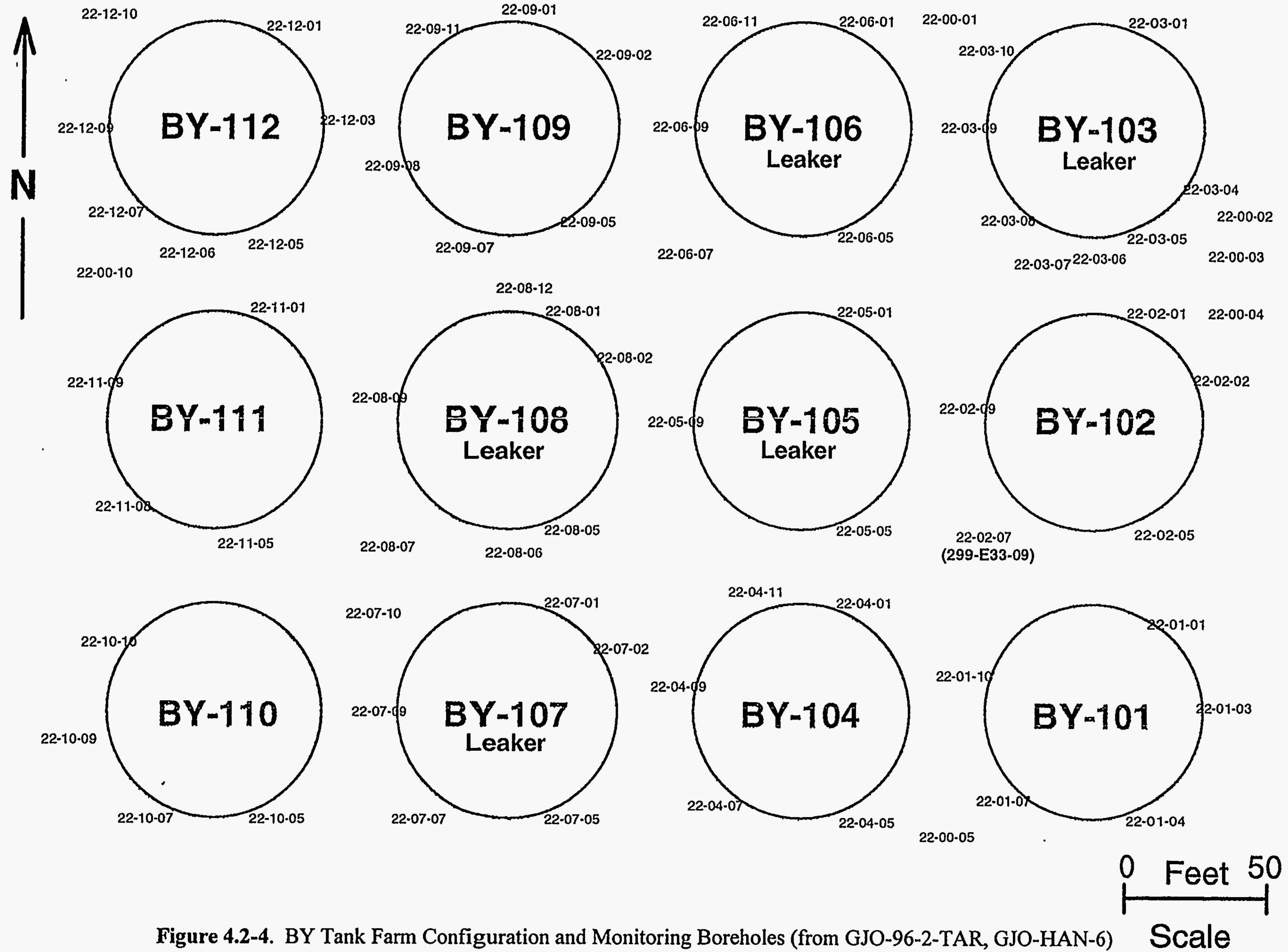


Figure 4.2-4. BY Tank Farm Configuration and Monitoring Boreholes (from GJO-96-2-TAR, GJO-HAN-6)
(NOTE: To convert feet to meters, multiply by 0.3048.)

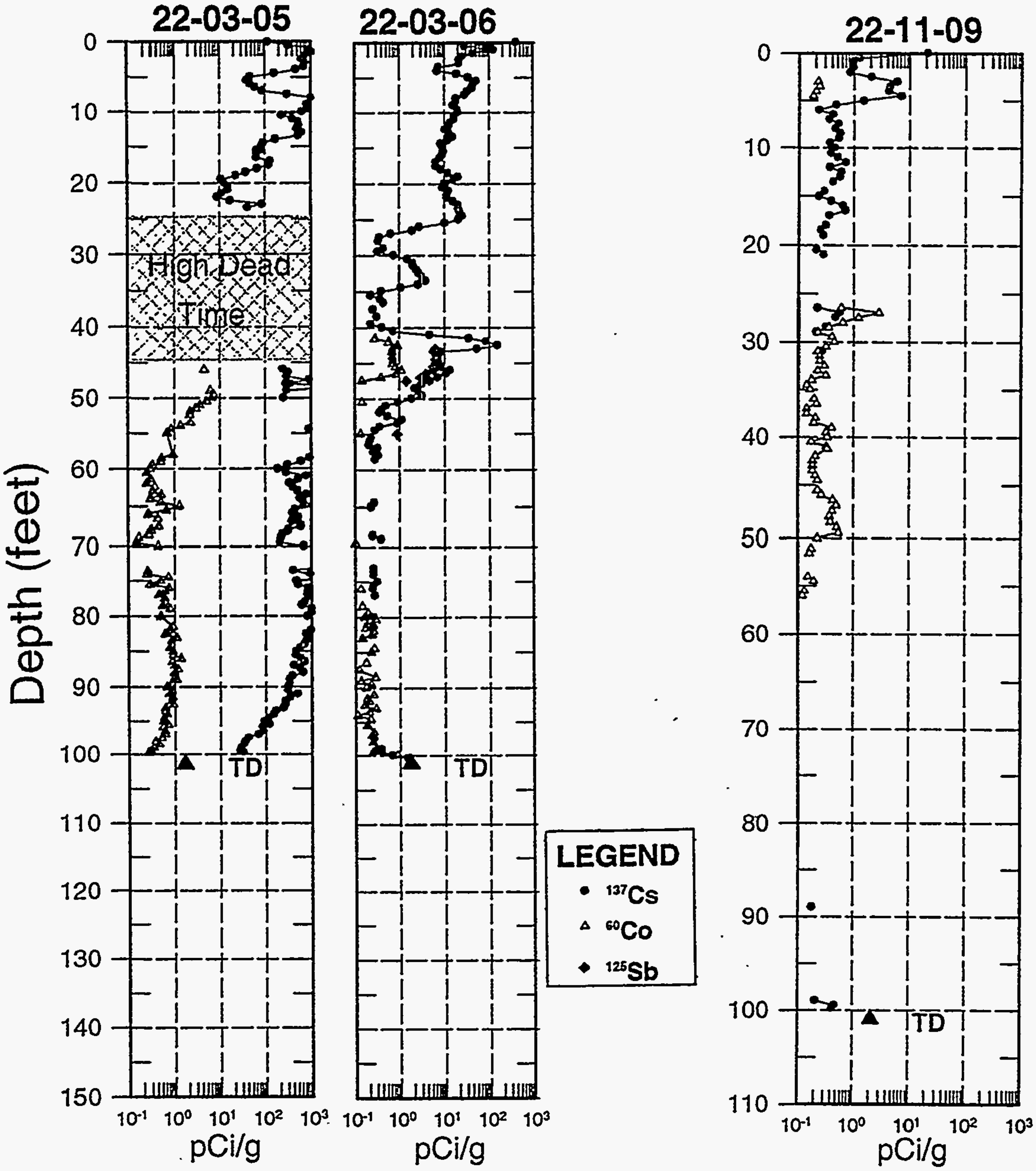


Figure 4.2-5. Correlation Plots of Antimony-125, Cobalt-60, and Cesium-137 Concentrations in Boreholes Surrounding Tanks BY-103 and BY-111 (after GJO-96-2-TAR, GJO-HAN-6) (NOTE: To convert feet to meters, multiply by 0.3048.)

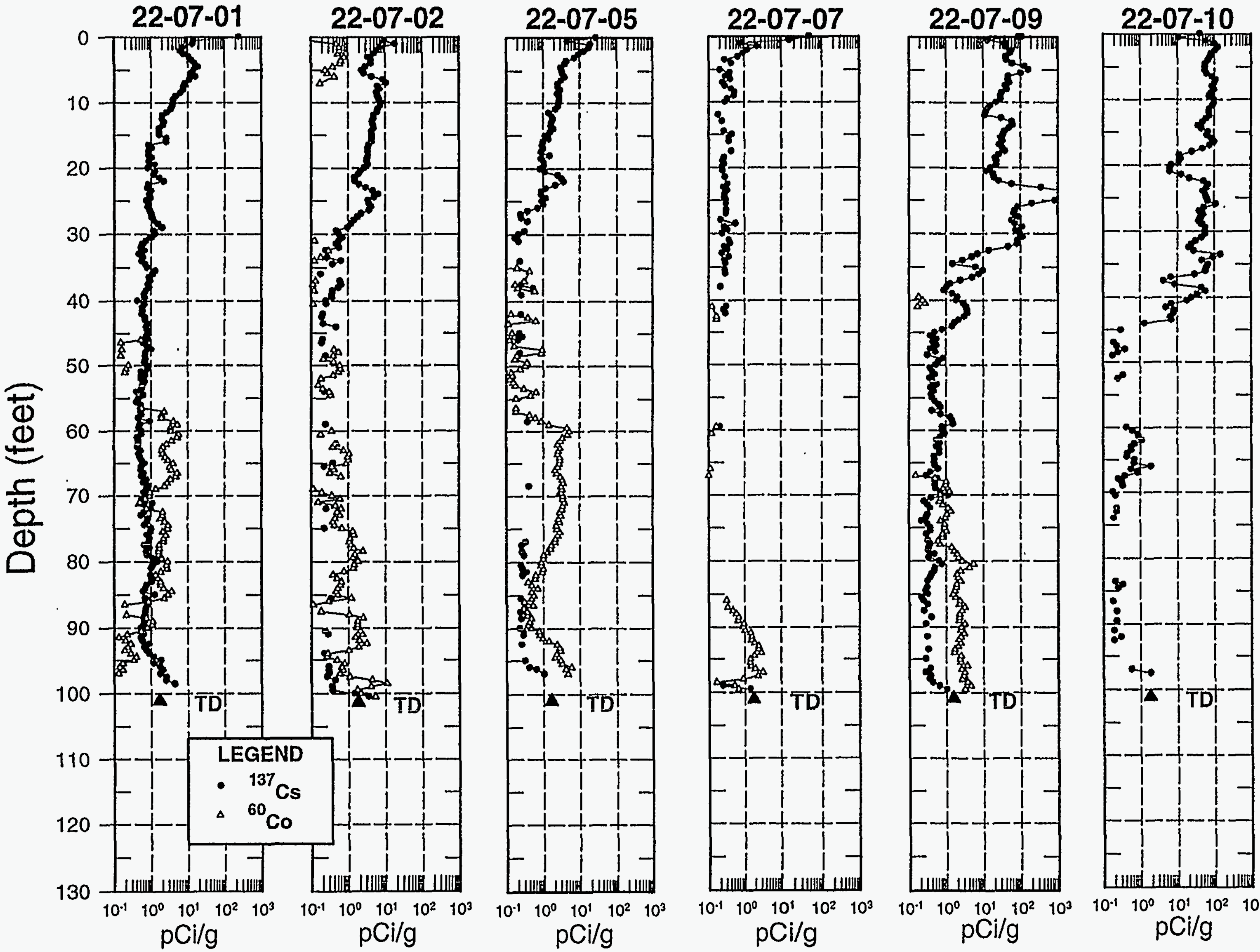


Figure 4.2-6. Correlation Plots of Cobalt-60 and Cesium-137 Concentrations in Boreholes Surrounding Tank BY-107 (after GJO-96-2-TAR, GJO-HAN-6) (NOTE: To convert feet to meters, multiply by 0.3048.)

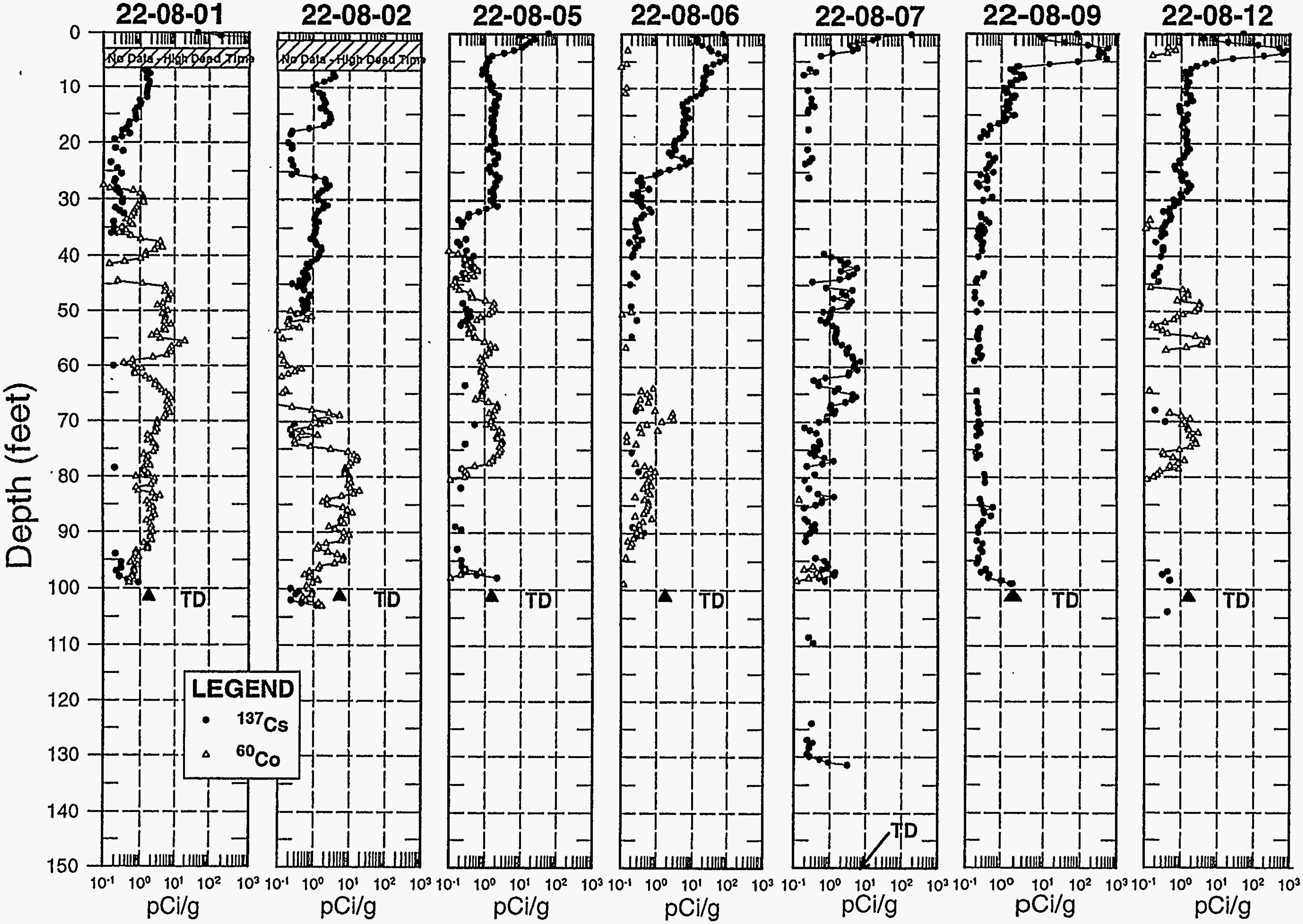


Figure 4.2-7. Correlation Plots of Cobalt-60 and Cesium-137 Concentrations in Boreholes Surrounding Tank BY-108 (after GJO-96-2-TAR, GJO-HAN-6) (NOTE: To convert feet to meters, multiply by 0.3048.)

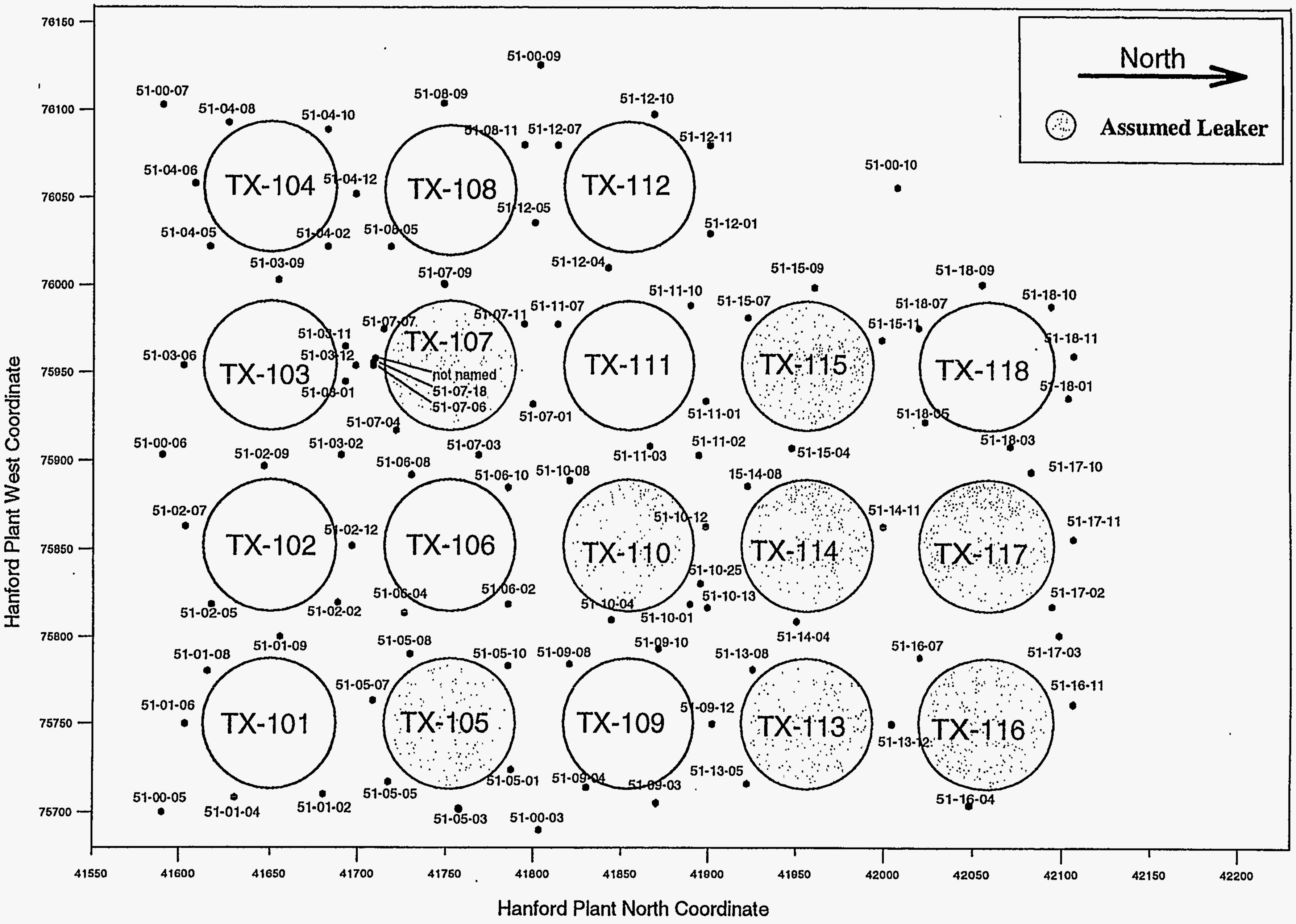


Figure 4.2-8. TX Tank Farm Configuration and Monitoring Boreholes (from GJO-97-13-TAR, GJO-HAN-11) (NOTE: To convert feet to meters, multiply by 0.3048.)

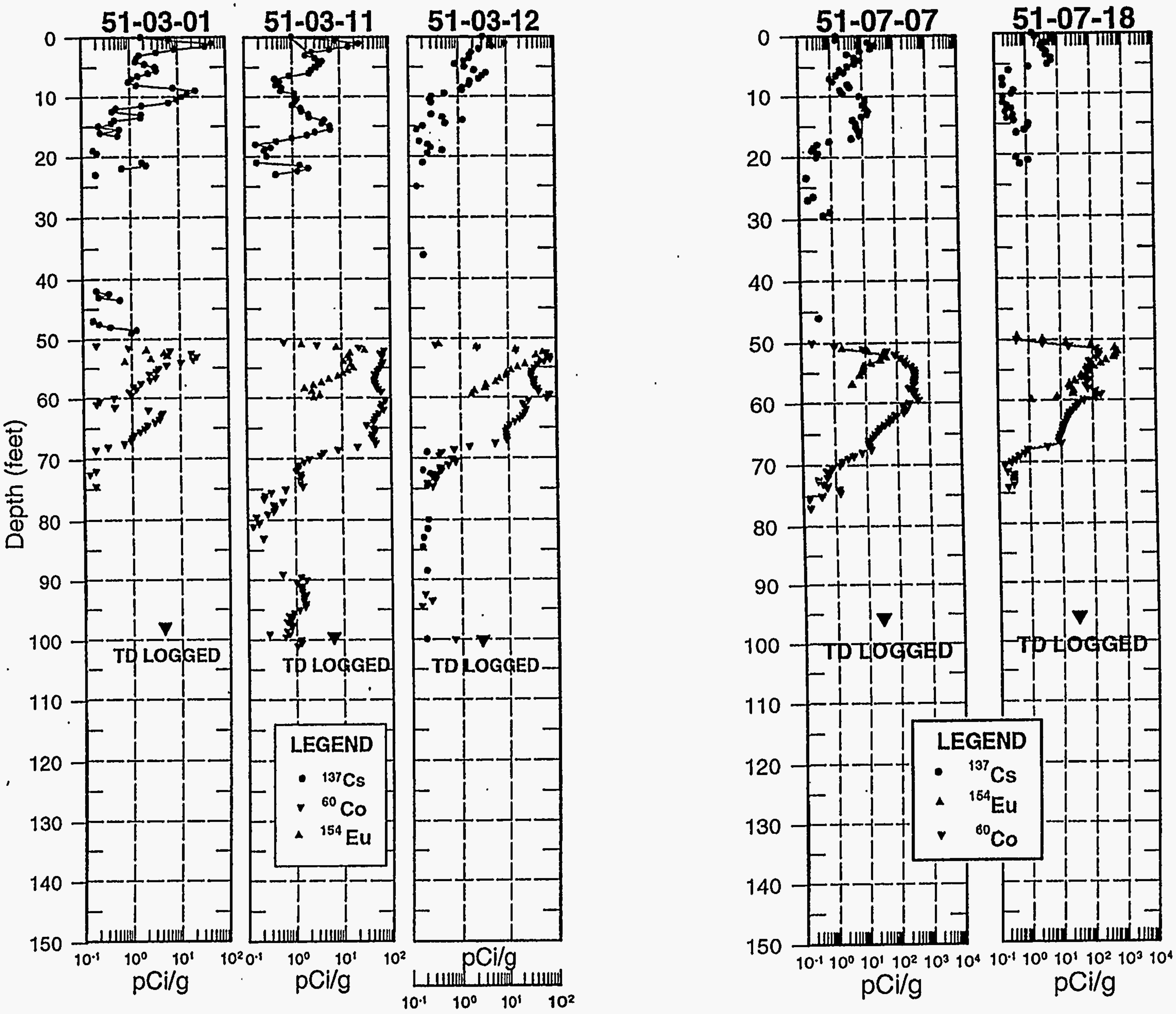


Figure 4.2-9. Correlation Plots of Cobalt-60, Cesium-137, and Europium-154 Concentrations in Boreholes Surrounding Tank TX-107 (after GJO-97-13-TAR, GJO-HAN-11) (NOTE: To convert feet to meters, multiply by 0.3048.)

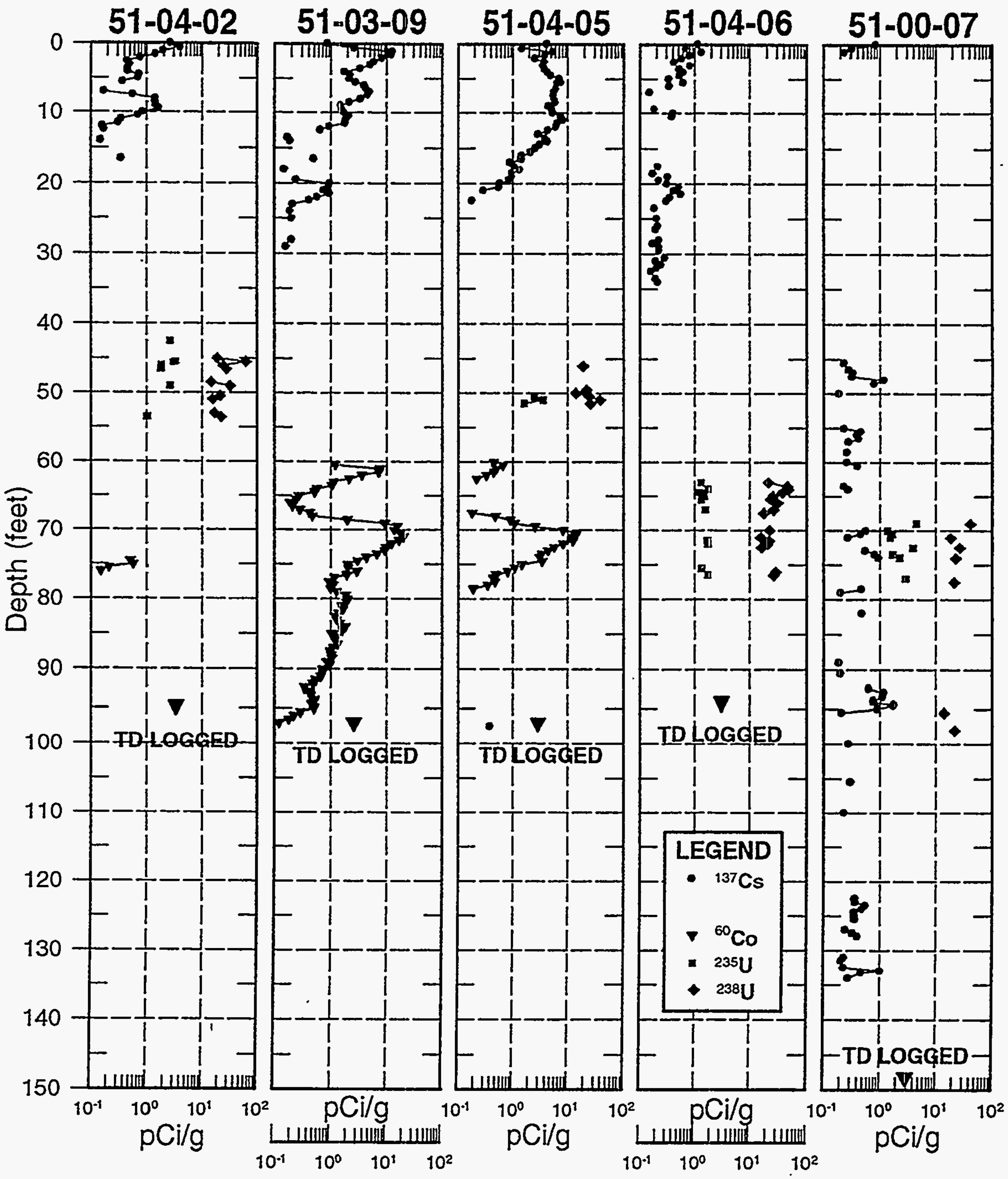


Figure 4.2-10. Correlation Plots of Cesium-137, Cobalt-60, Uranium-235, and Uranium-238 Concentrations in Boreholes South of Tank TX-104 and Southwest of Leaking Tank TX-107 (after GJO-97-13-TAR, GJO-HAN-11) (NOTE: To convert feet to meters, multiply by 0.3048.)

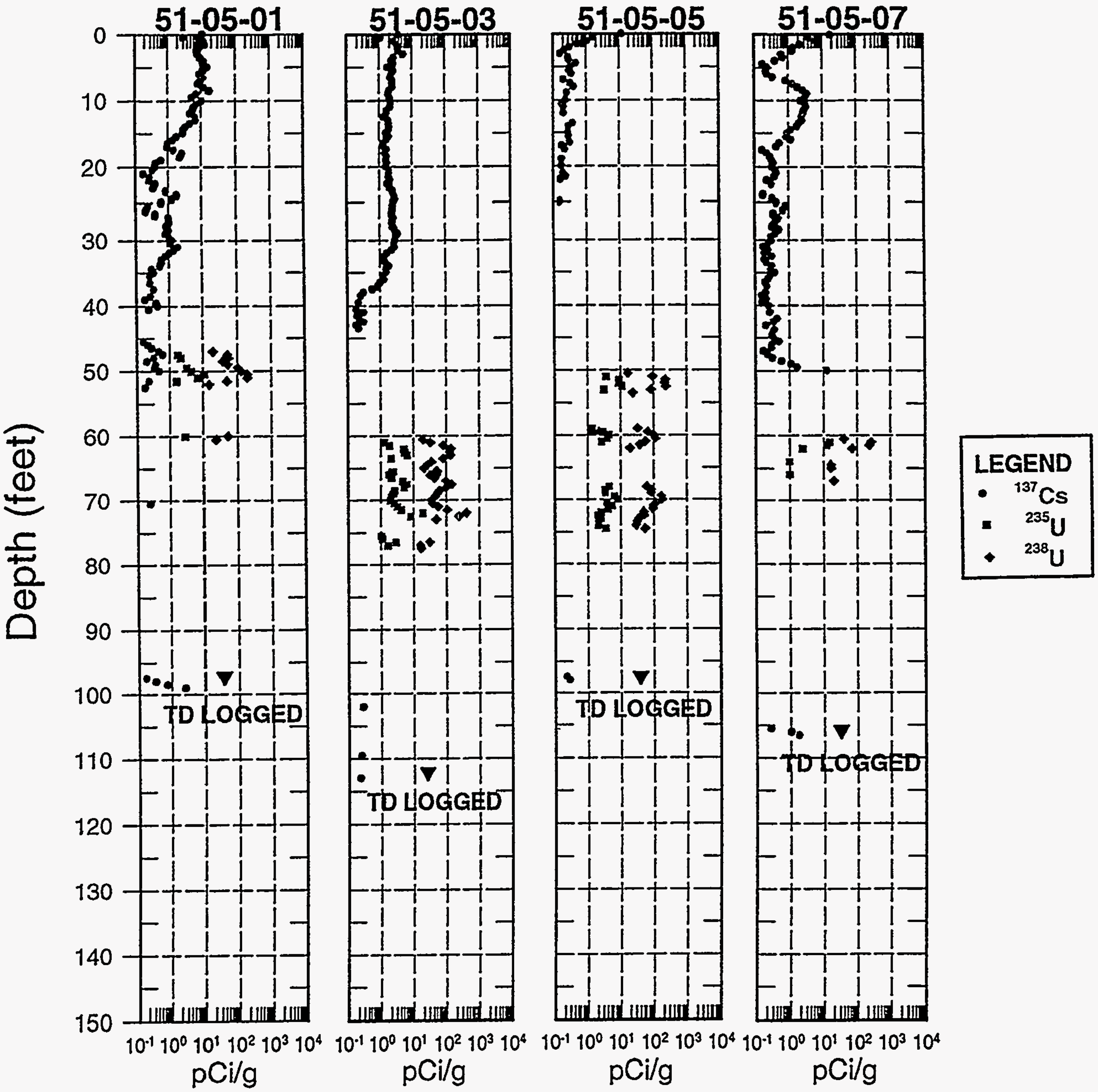


Figure 4.2-11. Correlation Plots of Cesium-137, Uranium-235, and Uranium-238 Concentrations in Boreholes Surrounding Tank TX-105 (after GJO-97-13-TAR, GJO-HAN-11) (NOTE: To convert feet to meters, multiply by 0.3048.)

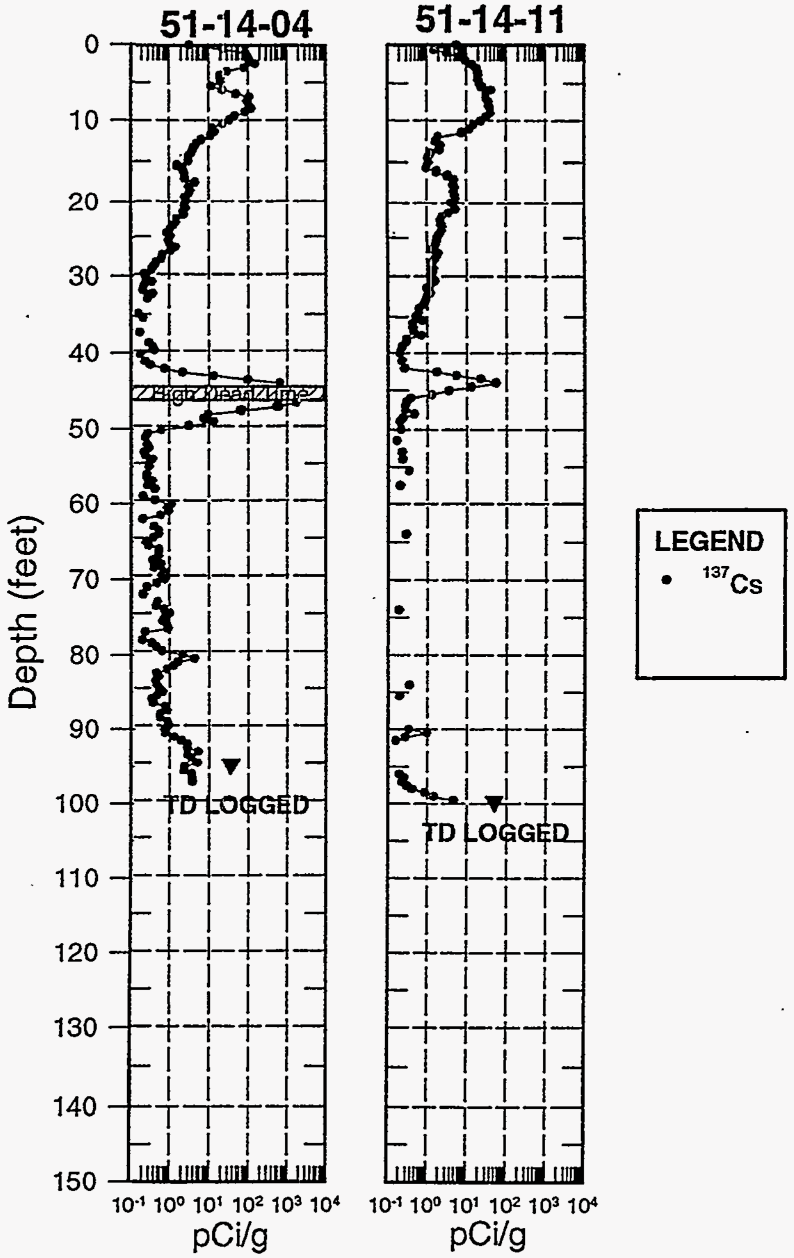


Figure 4.2-12. Correlation Plots of Cesium-137 Concentrations in Boreholes Surrounding Tank TX-105 (after GJO-97-13-TAR, GJO-HAN-11) (NOTE: To convert feet to meters, multiply by 0.3048.)

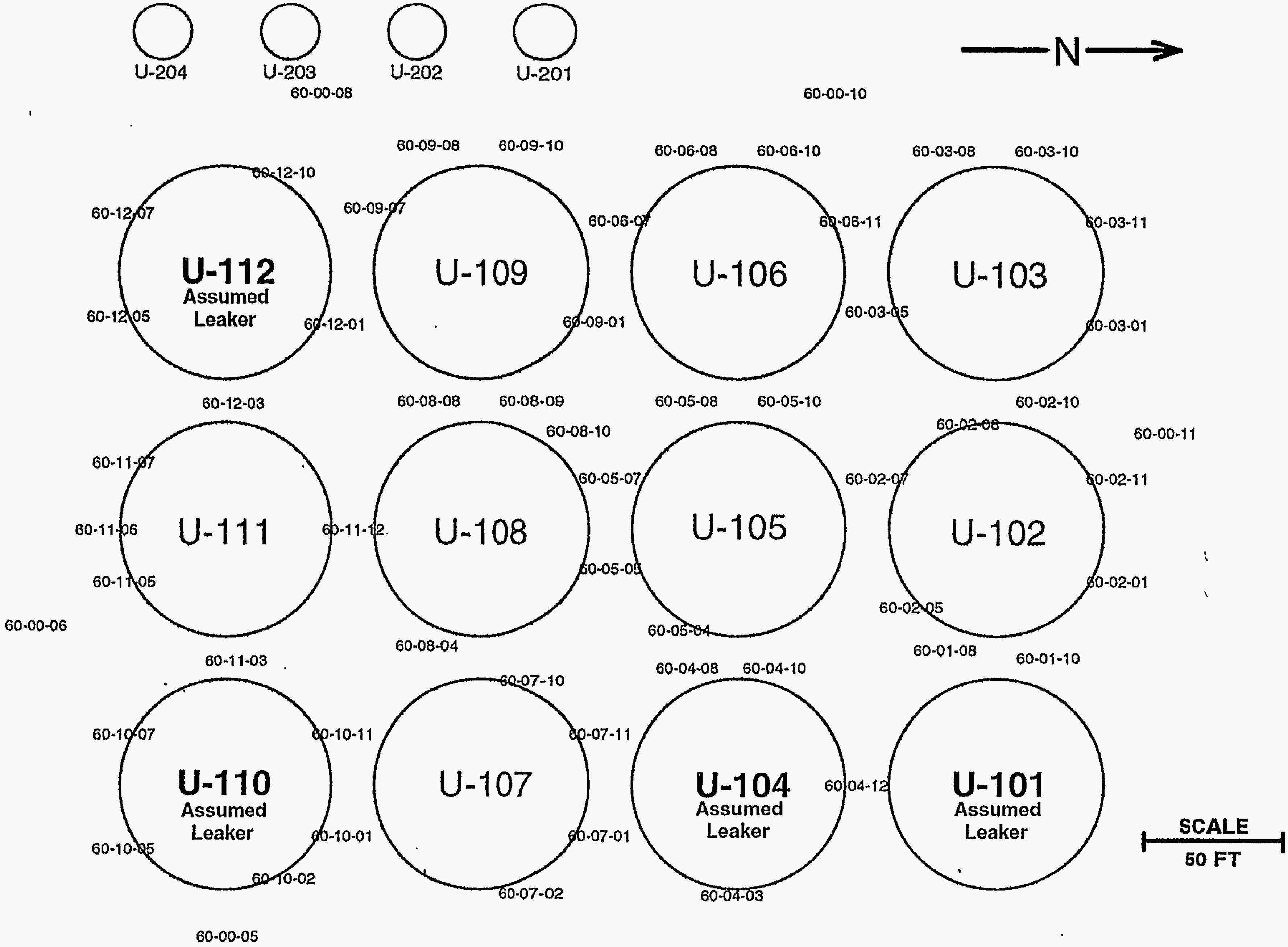


Figure 4.2-13. U Tank Farm Configuration and Monitoring Boreholes (from GJO-97-1-TAR, GJO-HAN-8) (NOTE: To convert feet to meters, multiply by 0.3048.)

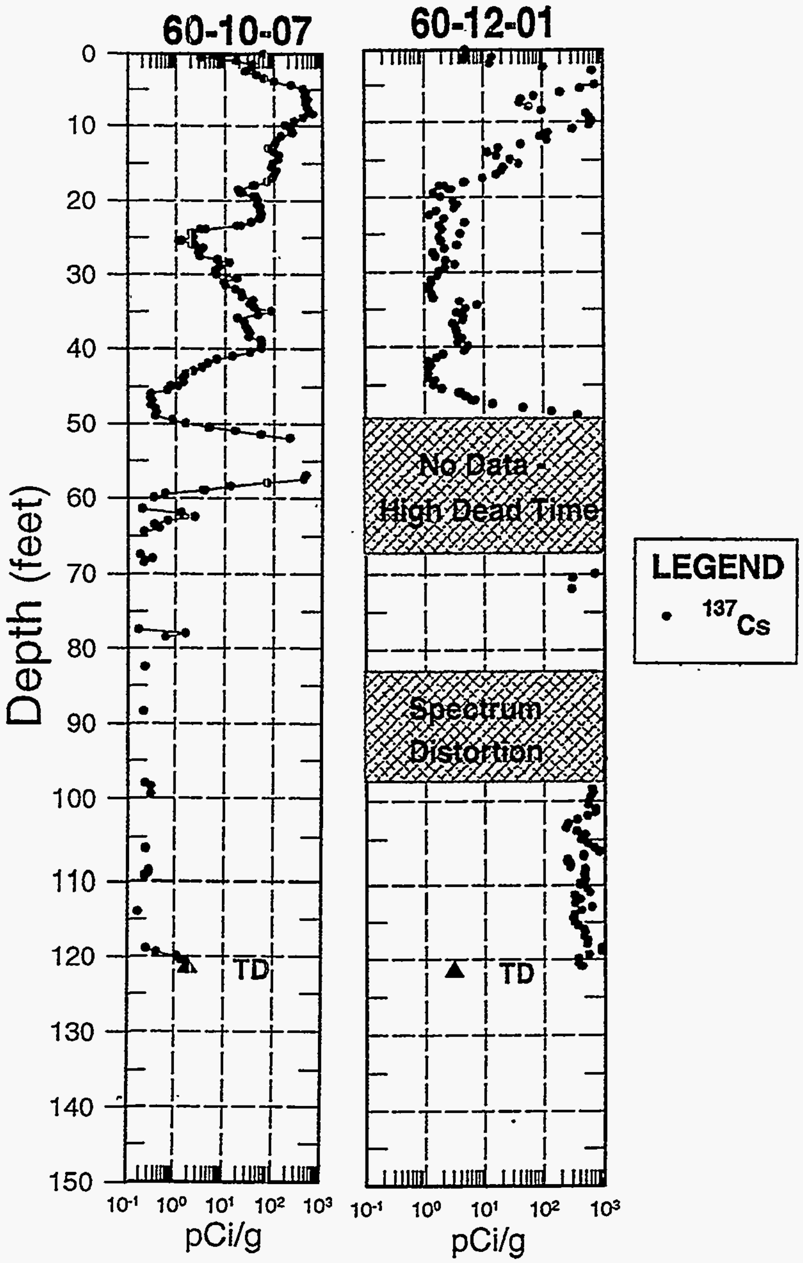


Figure 4.2-14. Correlation Plots of Cesium-137 Concentrations in Boreholes Surrounding Tanks U-110 and U-112 (after GJO-97-1-TAR, GJO-HAN-8) (NOTE: To convert feet to meters, multiply by 0.3048.)

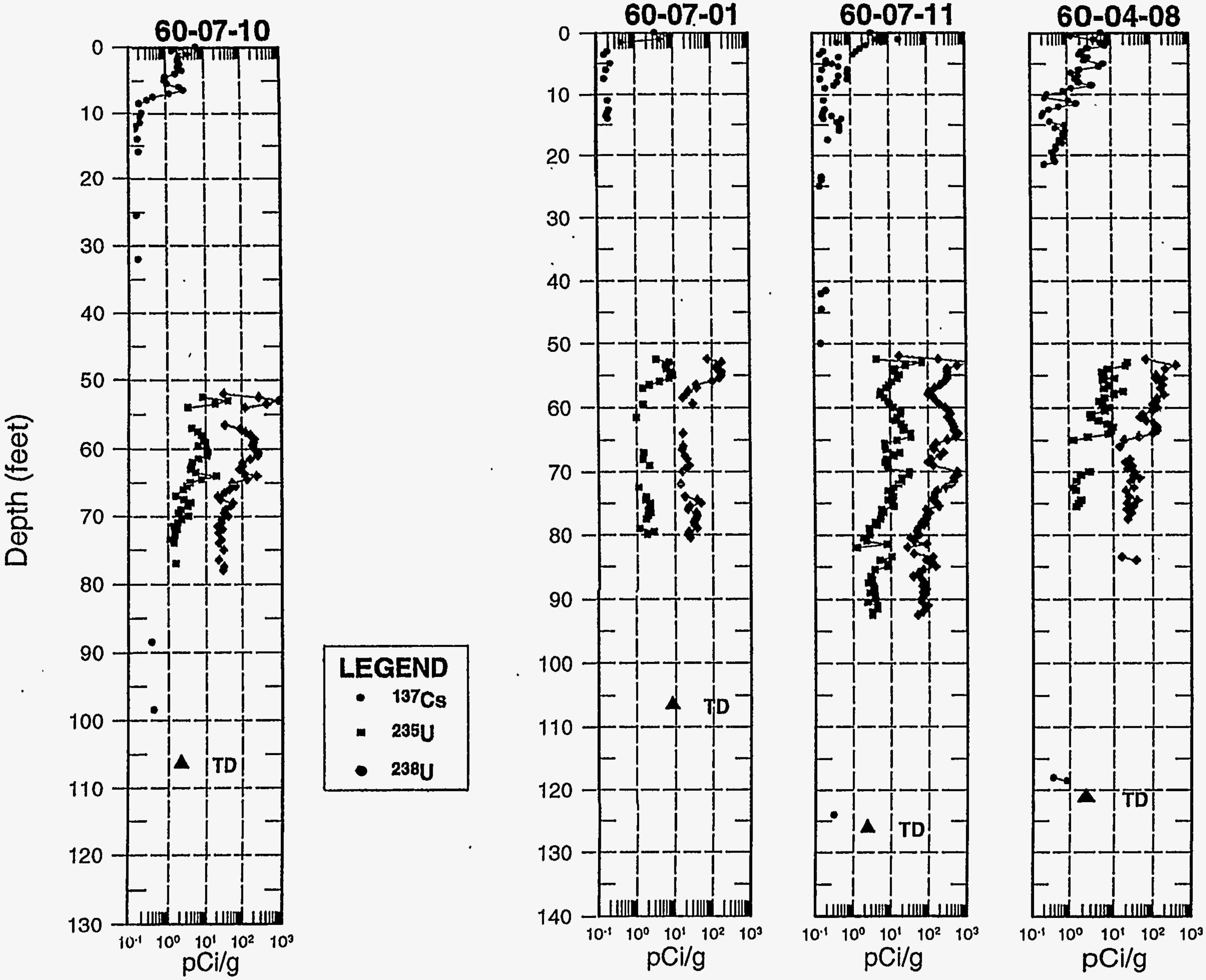
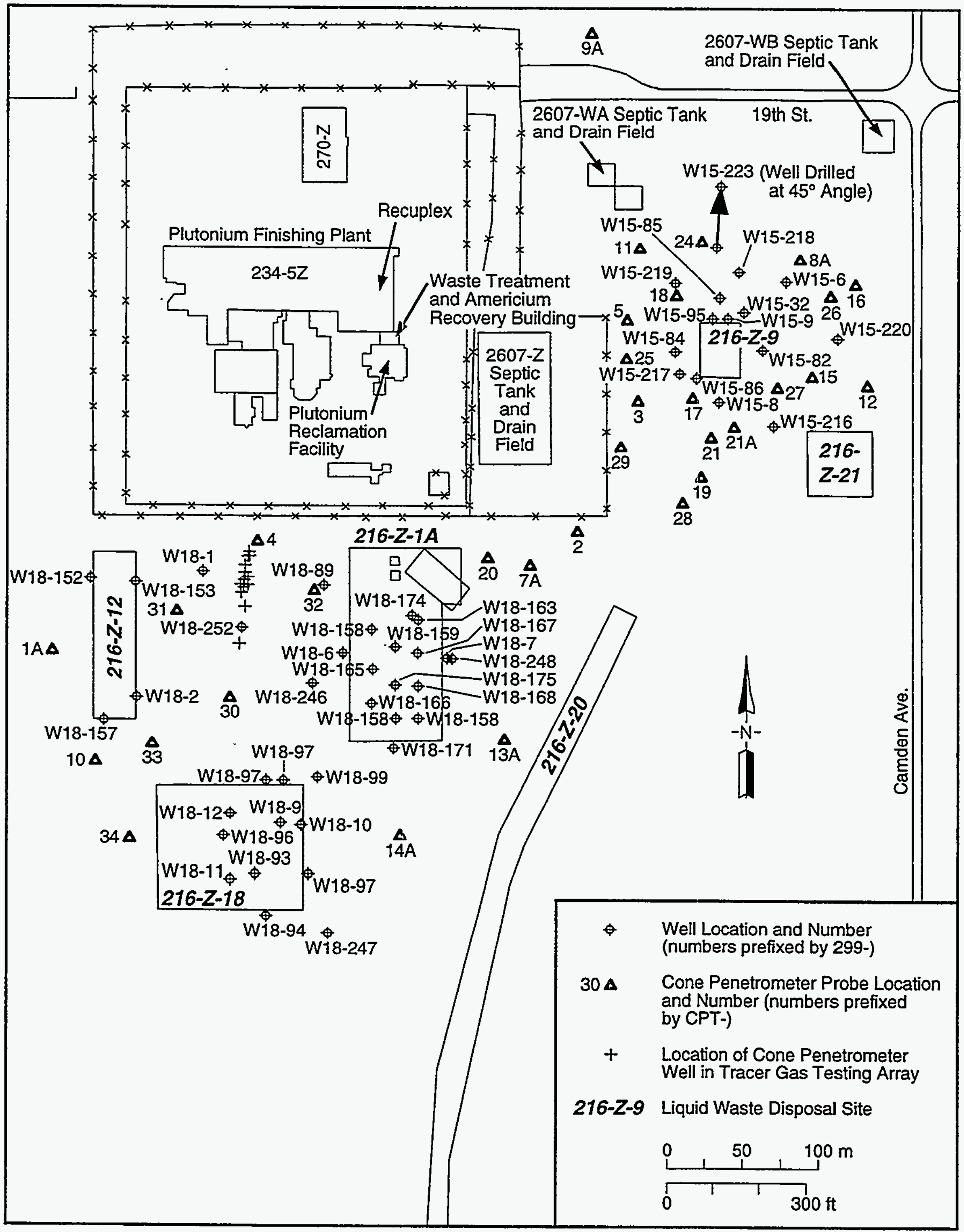
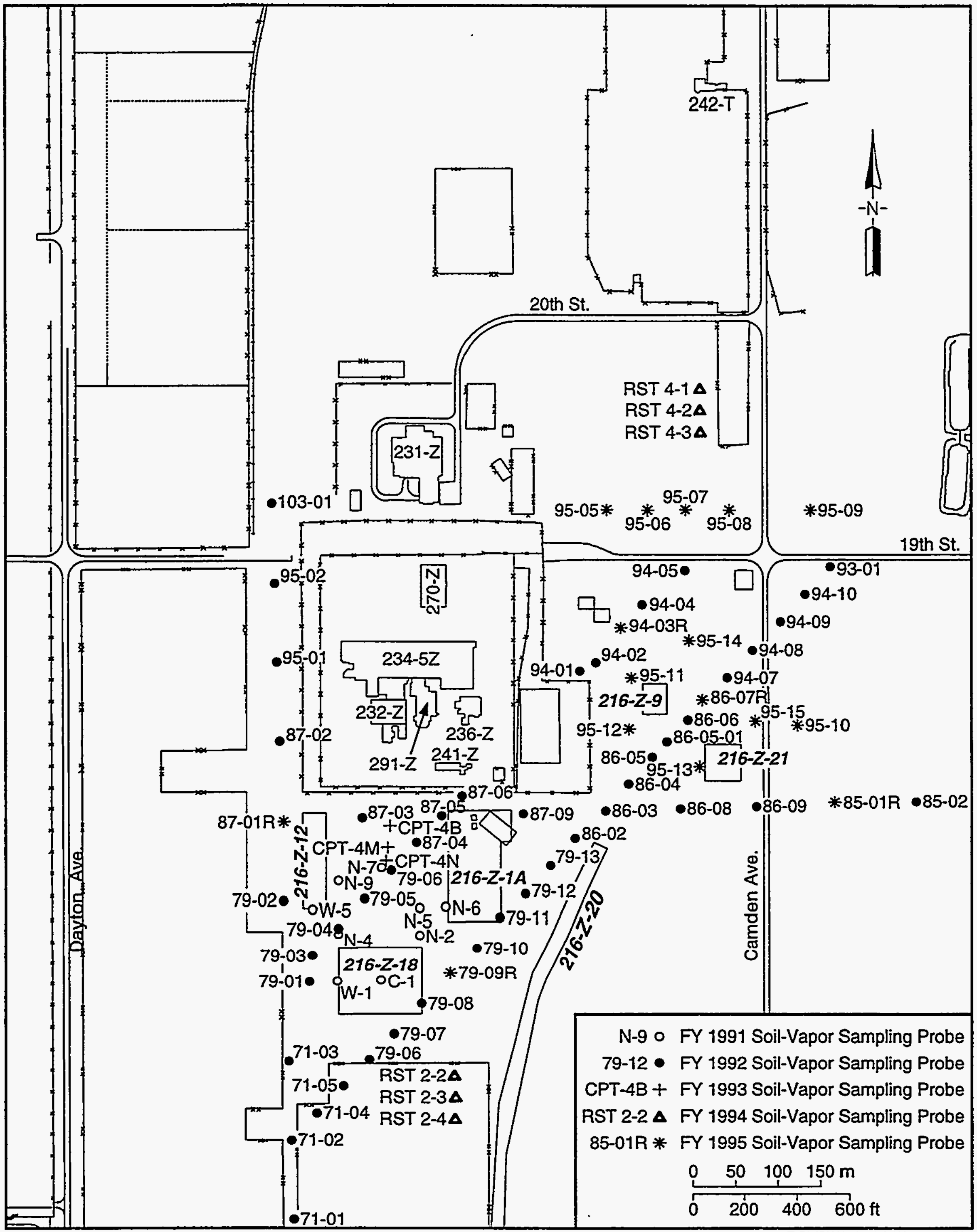


Figure 4.2-15. Correlation Plots of Cesium-137, Uranium-235, and Uranium-238 Concentrations in Boreholes Surrounding Tanks U-104 and U-107 (after GJO-97-1-TAR, GJO-HAN-8) (NOTE: To convert feet to meters, multiply by 0.3048.)



1998/DCL/GW97/002 (2W:072996A)

Figure 4.4-1. Location of Wells and Deep-Monitoring Probes at the Carbon Tetrachloride Vapor-Extraction Site



1998/DCL/GW97/003 (2W092795D)

Figure 4.4-2. Location Map of Shallow Soil-Vapor-Monitoring Probes at the Carbon Tetrachloride Vapor-Extraction Site

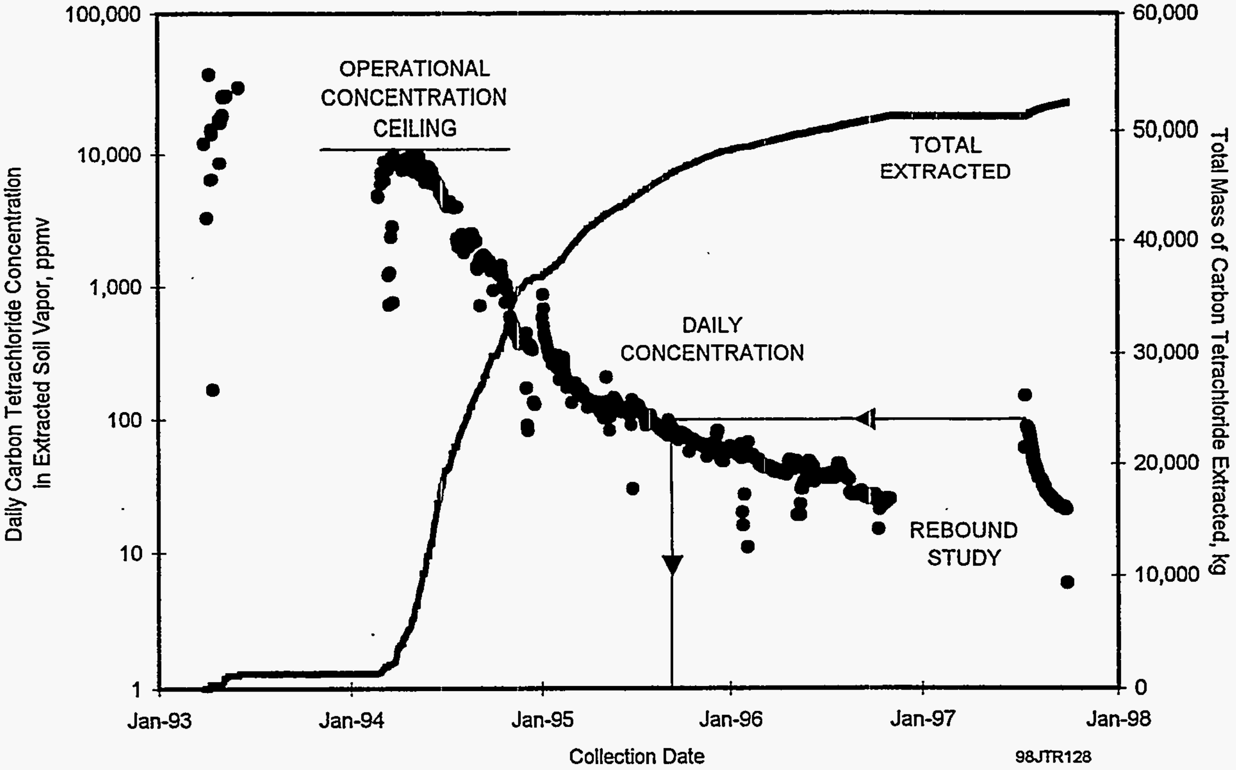


Figure 4.4-3. Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-9 Site (after BHI-00720, Rev. 1)

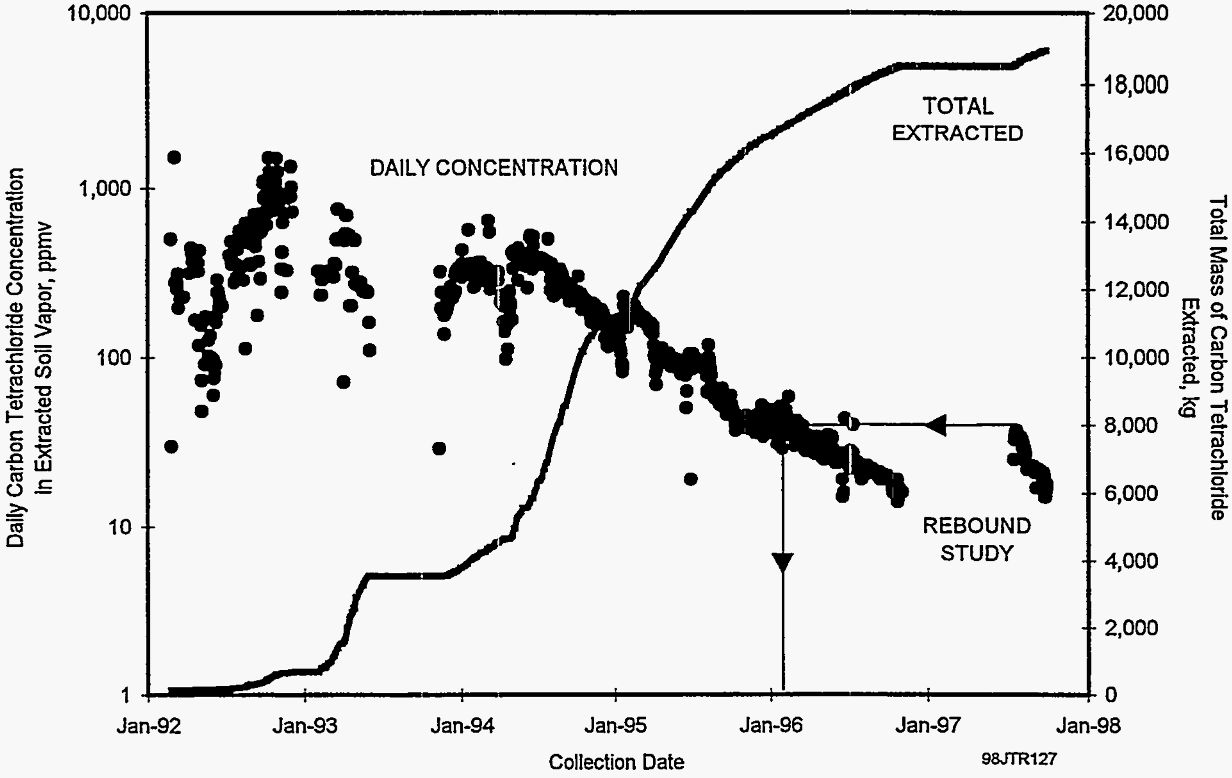


Figure 4.4-4. Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-1A Site (after BHI-00720, Rev. 1)

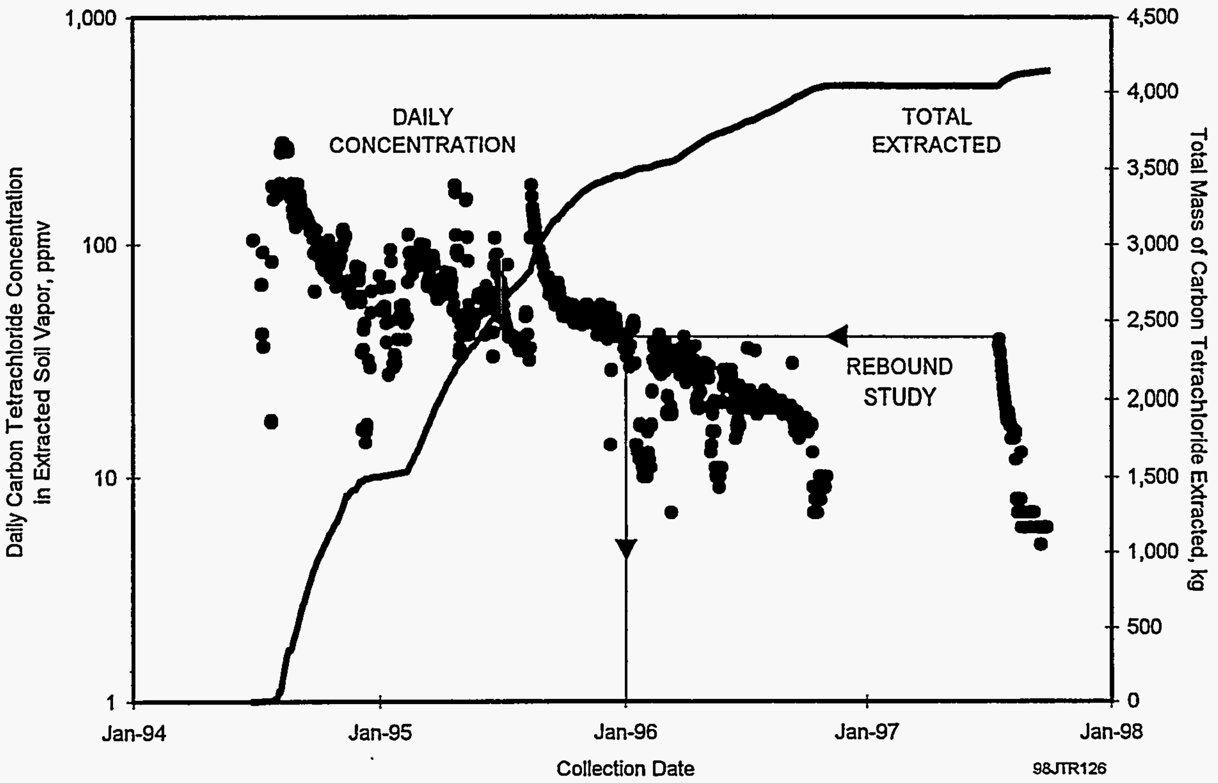


Figure 4.4-5. Daily Carbon Tetrachloride Concentrations in Soil Vapor Extracted from 216-Z-18 Site (after BHI-00720, Rev. 1)

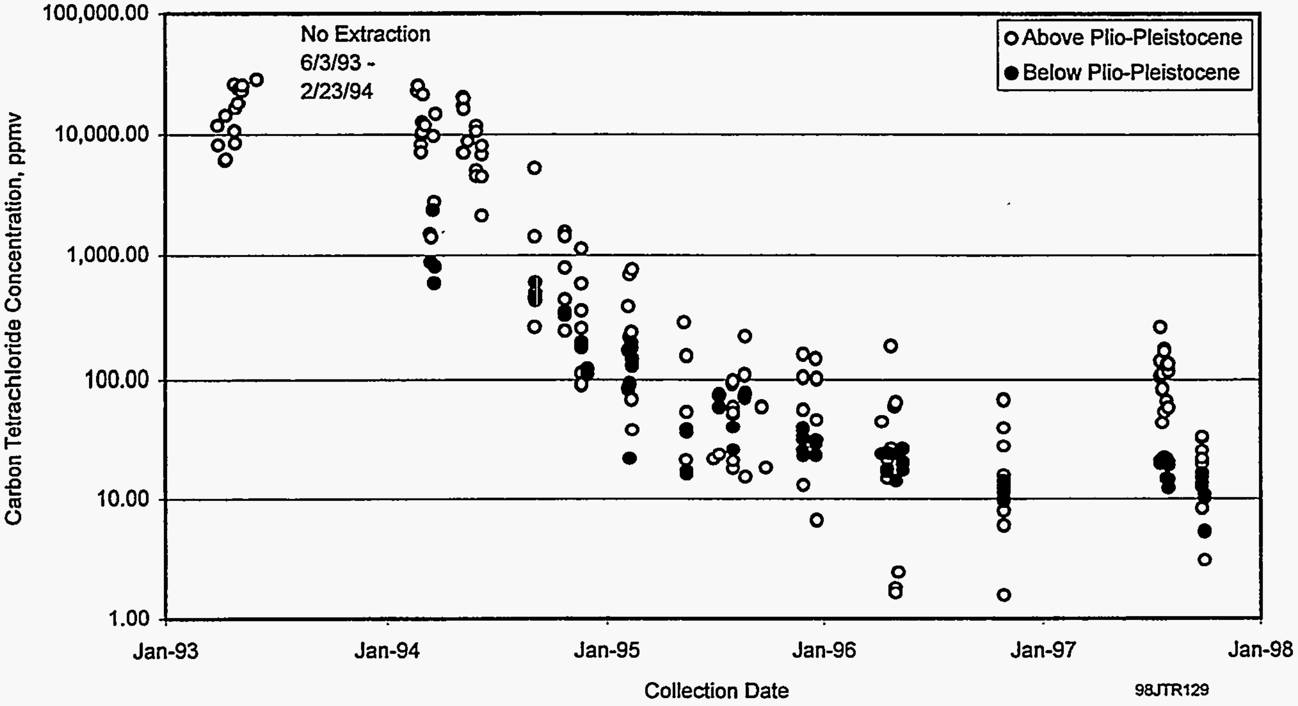


Figure 4.4-6. Carbon Tetrachloride Concentrations in Extraction Wells in 216-Z-9 Well Field as a Function of Time (after BHI-00720, Rev. 1)

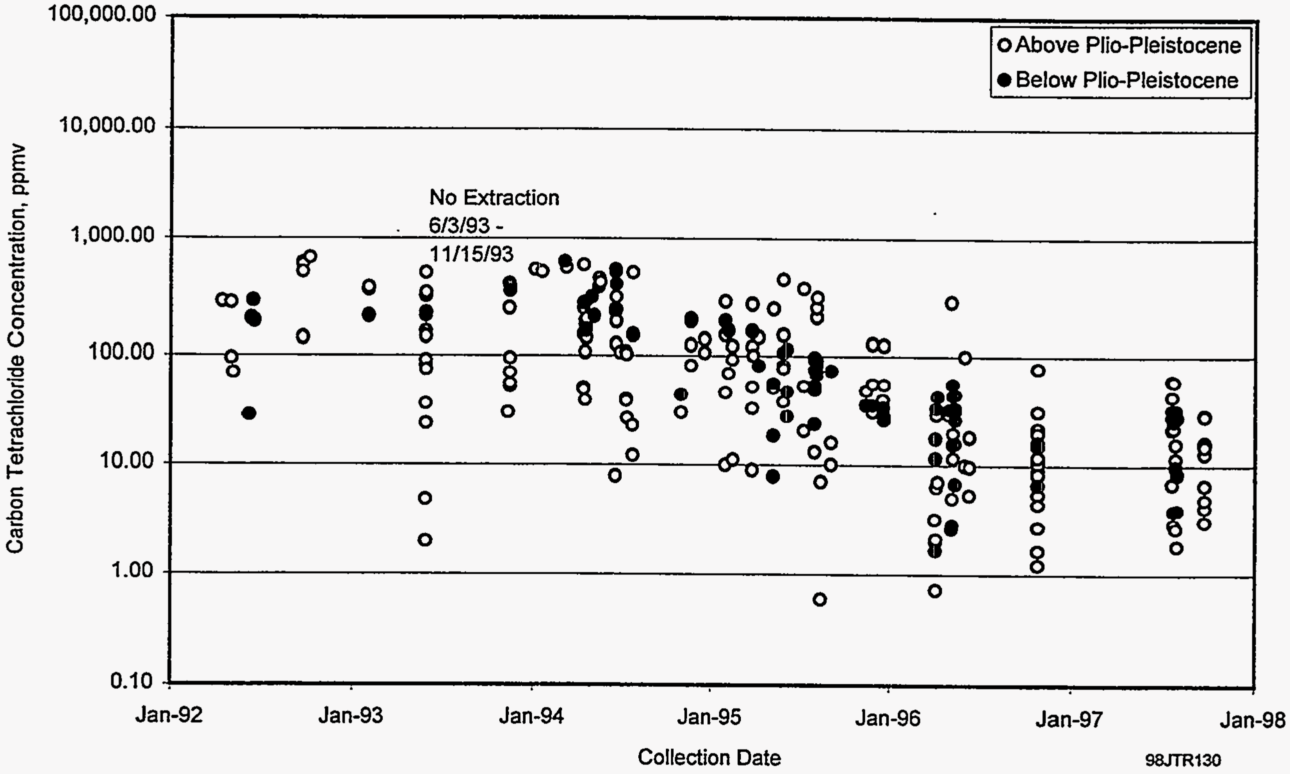


Figure 4.4-7. Carbon Tetrachloride Concentrations in Extraction Wells in Combined 216-Z-1A/216-Z-12/216-Z-18 Sites as a Function of Time (after BHI-00720, Rev. 1)

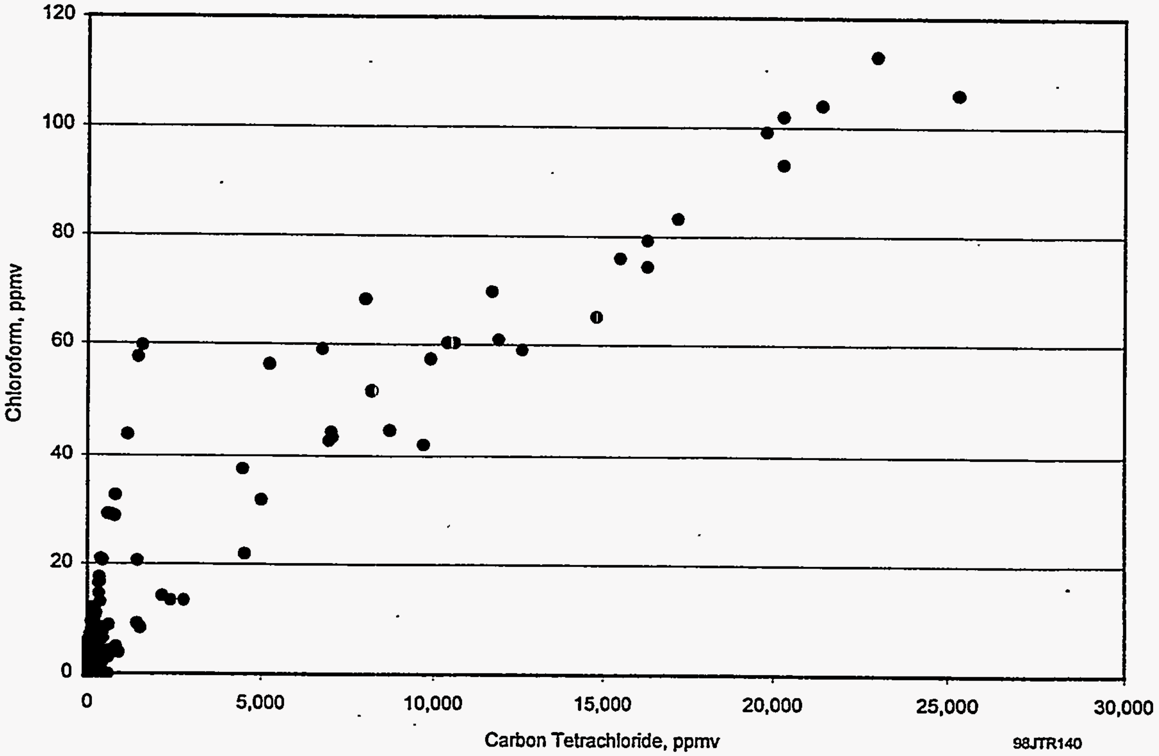


Figure 4.4-8. Relationship Between Concentrations of Carbon Tetrachloride and Chloroform at all Extraction Wells

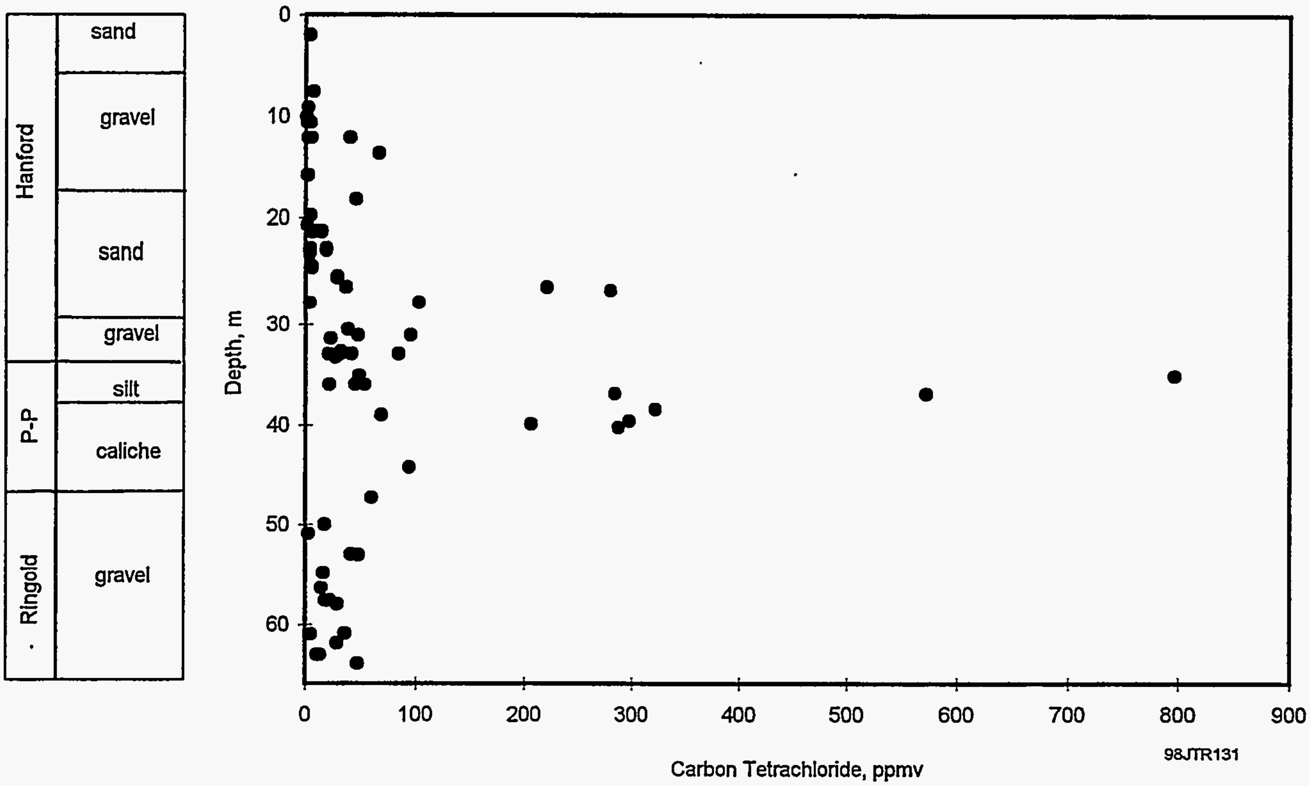


Figure 4.4-9. Vertical Profile of Maximum Carbon Tetrachloride Rebound Concentrations (after BHI-01105)

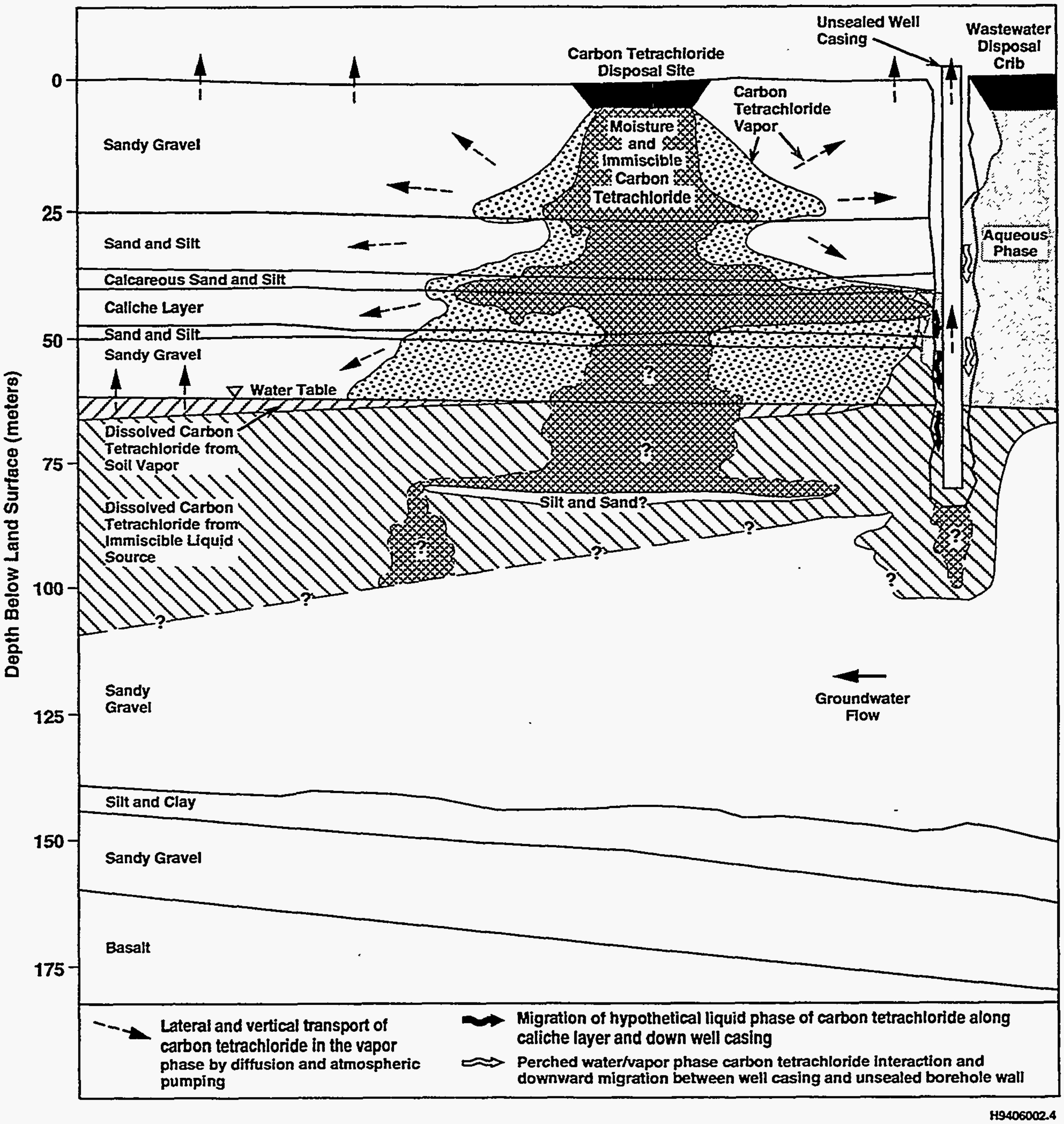


Figure 4.4-10. Conceptual Model of Carbon Tetrachloride and Wastewater Migration Beneath 216-Z-9 Trench

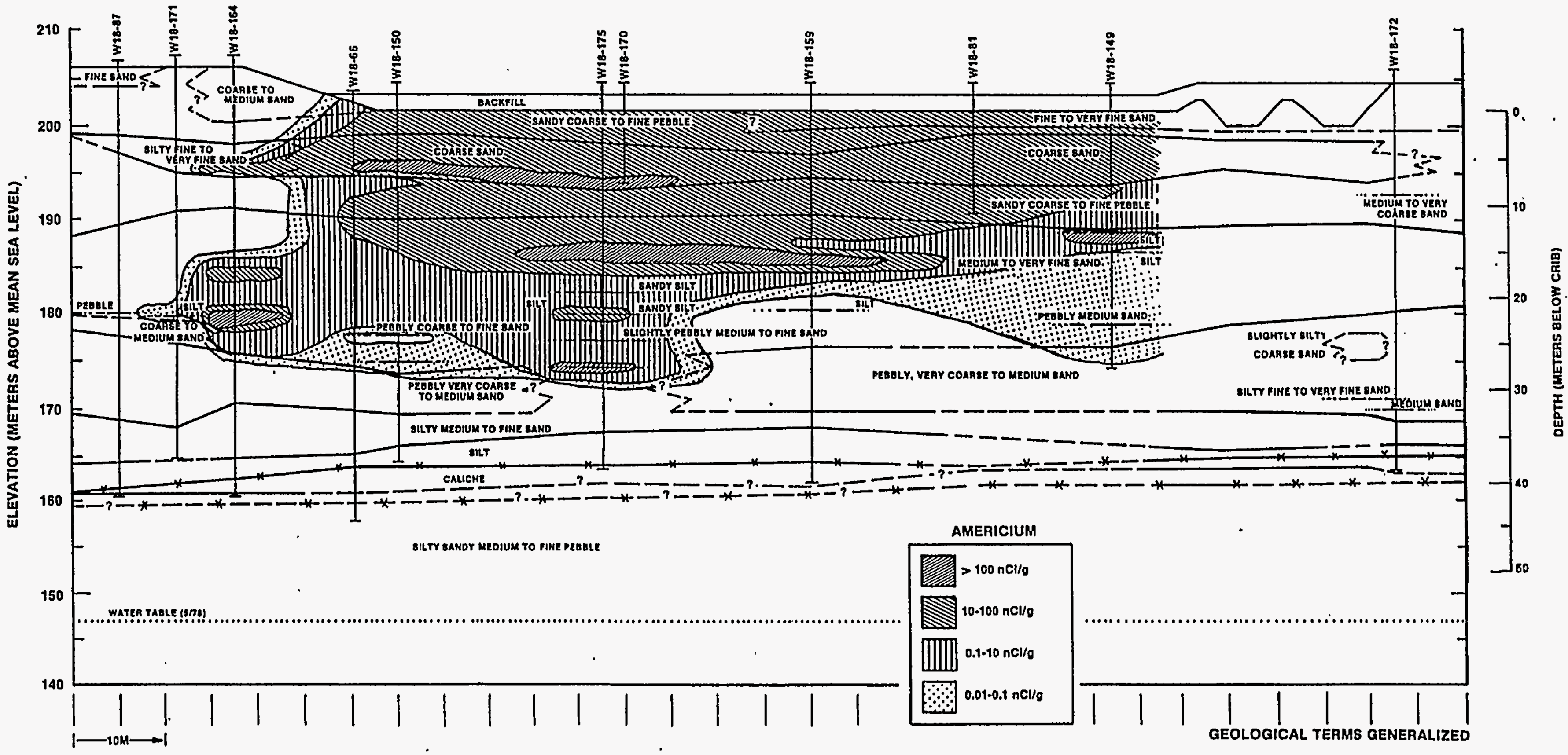


Figure 4.4-11. Cross-Section of Americium-241 Concentrations Beneath 216-Z-1A Tile Field (from RHO-ST-17). The cross-section is centered along the north-south, or long, axis of the tile field. Plutonium contours are based on soil-sample results from core locations shown as vertical lines. Horizontal lines and texture labels indicate stratigraphic and grain-size variations.

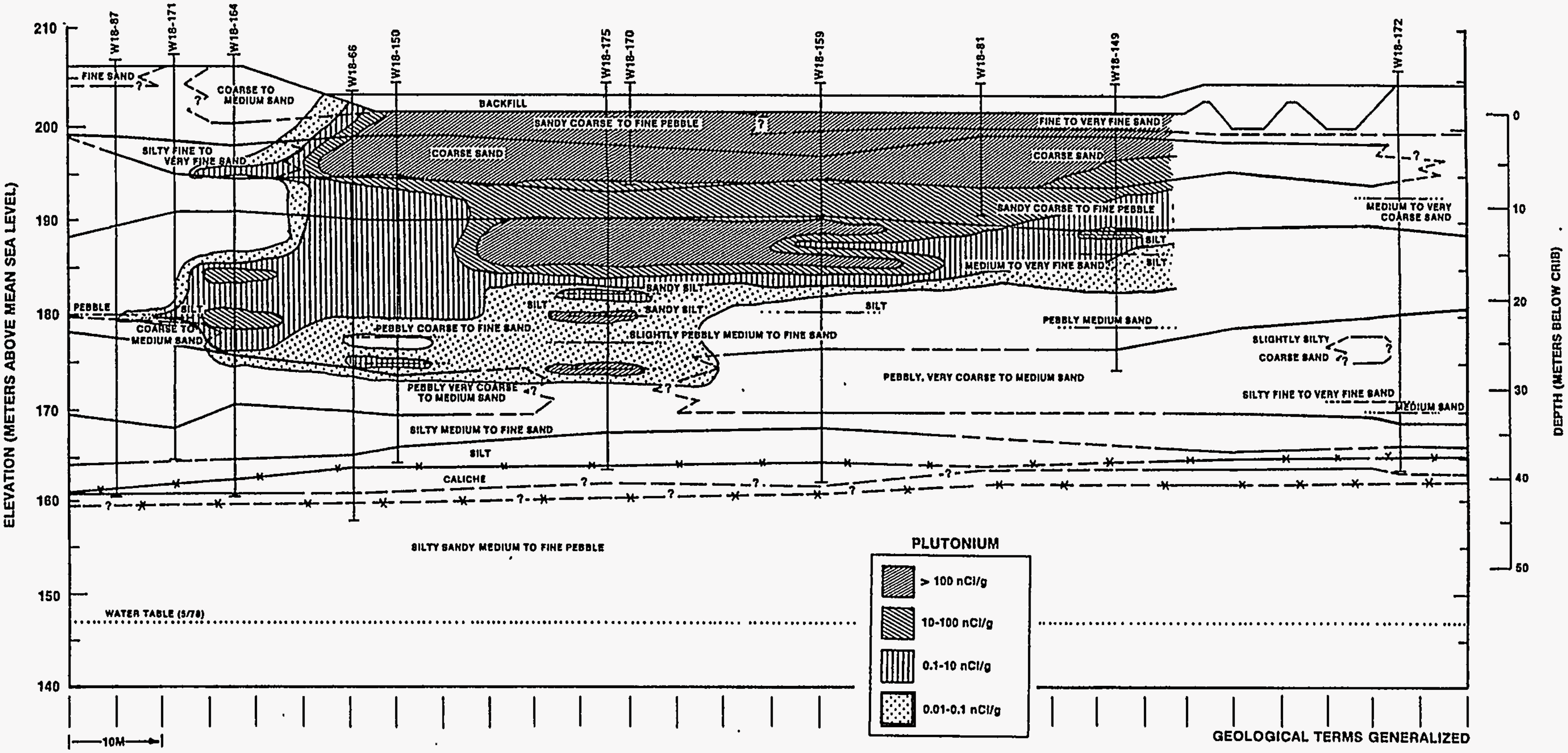


Figure 4.4-12. Cross-Section of Plutonium-239/-240 Concentrations Beneath 216-Z-1A Tile Field (from RHO-ST-17). The cross-section is centered along the north-south, or long, axis of the tile field. Plutonium contours are based on soil-sample results from core locations shown as vertical lines. Horizontal lines and texture labels indicate stratigraphic and grain-size variations.

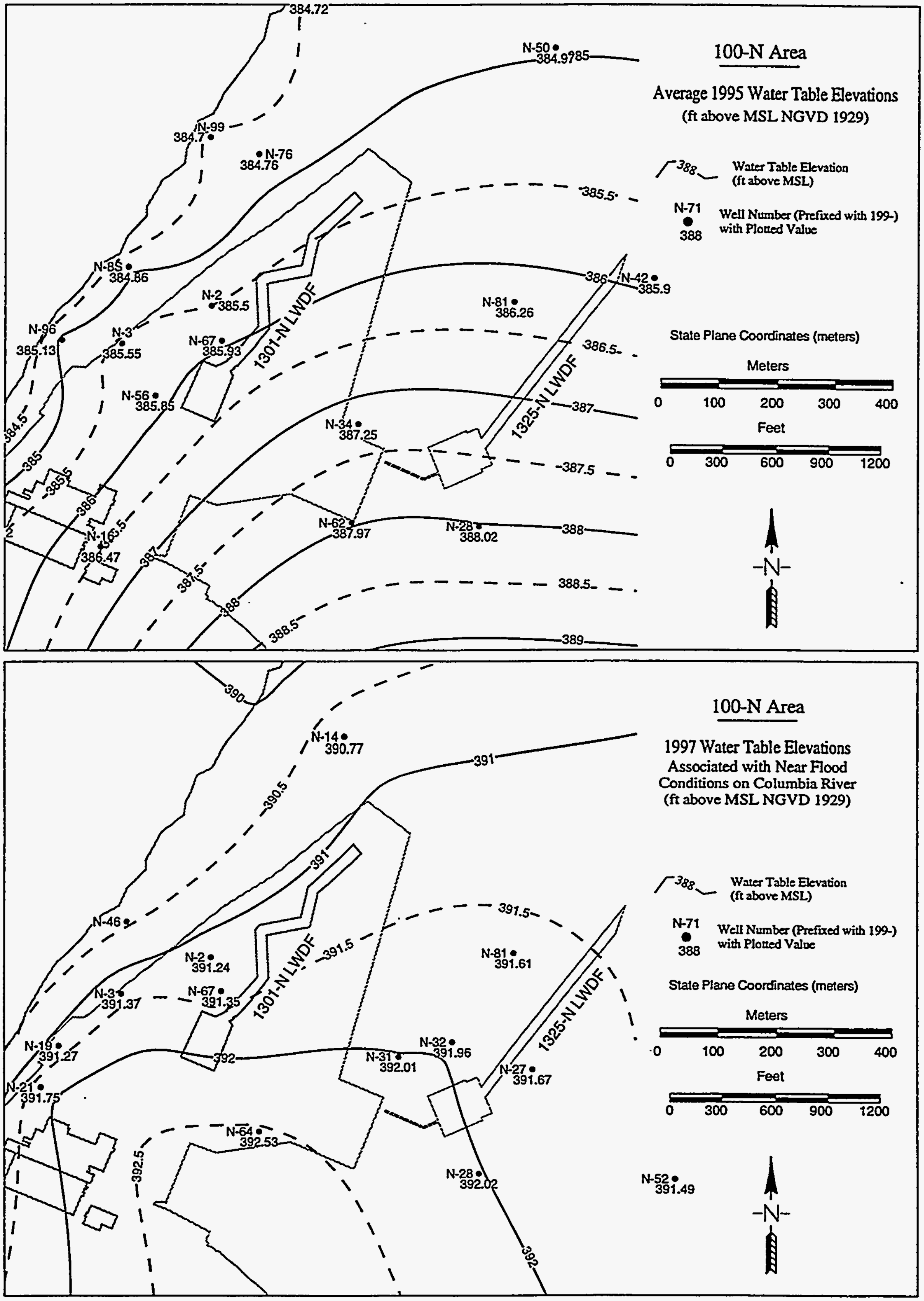


Figure 4.5-1. Water-Table Elevations for 1995 (normal) and 1997 (high) Columbia River Stages (NOTE: To convert feet to meters, multiply by 0.3048.)

5.0 Contaminant Evaluation and Compliance

Groundwater contamination at the Hanford Site is associated with a number of sources within its past and present operational areas. This chapter groups sources and potential sources of groundwater contamination by operational area in geographic (west to east) order. The results of the monitoring program and the evaluation of current contamination 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 *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal 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. Additional discussions are included for the potential receptors in the Richland North and 400 Areas and for the uppermost basalt-confined aquifer system.

5.1 Monitoring Program Description

P. E. Dresel, M. J. Hartman, B. M. Gillespie

Groundwater monitoring at the Hanford Site during fiscal year (FY) 1997 was to track changes in the extent of existing contamination, to identify any new impacts of contamination on groundwater, to provide data needed to support groundwater remediation, and to evaluate the effectiveness of remedial activities. The selections of wells, constituents, and sampling frequencies are based on knowledge of waste-disposal practices and inventories (PNL-6456), regulatory requirements (RCRA/CERCLA), proximity to disposal areas, contaminant mobility, and site hydrogeology.

5.1.1 Monitoring Network

During FY 1997, ~700 wells were sampled for radiological and chemical constituents as part of the various Hanford Site groundwater investigations (Figure 5.1-1). Of the wells sampled, ~330 were sampled once, ~170 were sampled twice, ~40 were sampled three times, ~70 were sampled four times, and ~90 were sampled more frequently. Well locations for the Hanford Site are shown in Plate 1. A number of wells are sampled to meet RCRA- or CERCLA-specific requirements. More detailed maps of well locations are included in this chapter where necessary and in Appendix A for RCRA units and other sites regulated under the Washington Administrative Code (WAC).

A groundwater-monitoring plan for each RCRA unit describes the site hydrogeology, well networks, constituents, sampling and analytical methods, and sampling frequency. Well networks and constituents analyzed for each RCRA unit and for the Solid Waste Landfill are listed in Appendix A. References to groundwater-monitoring plans or assessment plans are also included in Appendix A.

Most of the monitoring wells on the Hanford Site are completed near the top of the unconfined aquifer system. Most of the wells monitored in the operational areas are constructed to meet WAC 173-160 (e.g., stainless steel casing and screen, sand pack, and full annular seal). Many of the wells in other areas were constructed before the adoption of WAC requirements. These older wells were usually constructed of carbon steel casing, often with perforated casing rather than well screens, and may have no annular seal.

5.1.2 Methods

Methods for chemical analysis of groundwater samples conform to the U.S. Environmental Protection Agency's (EPA's) *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods* (SW-846); *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-82-055), or other EPA methods; *Annual Book of ASTM Standards* (American Society for Testing and Materials 1986); and *Standard Methods for the Examination of Water and Wastewater, 17th Edition* (American Public Health Association 1989). The methods used for analysis of radiochemical constituents were developed by the analyzing laboratory and are recognized as acceptable within the technical radiochemical industry. Analytical methods used by the laboratories are described in Appendix C.

Groundwater was sampled by employees and subcontractors of Pacific Northwest National Laboratory and Bechtel Hanford, Inc. during FY 1997. Samplers followed their company's documented procedures for sampling, recordkeeping, field measurements, and sample shipment. The procedures were equivalent in most aspects. Most samples for metals are filtered in the field, and most other samples were unfiltered.

5.1.3 Data Quality

The chemical composition of groundwater at any location fluctuates with time because of differences in the contaminant source, recharge, and/or flow field. The range of this fluctuation can be estimated by taking many samples but there is a practical limit to the number that can be taken. Comparison of results through time and location helps in interpreting the natural variability.

Sampling techniques are designed to provide a sample that is reasonably representative of the aquifer concentration when the sample is taken. However, there are limitations to the ability to collect representative samples or even to define precisely the volume of aquifer that is represented in the sample. Proper well construction, well purging, sample preservation, and, in some instances, filtering are used to help ensure that samples are consistent and representative. Careful sample-labeling protocols, chain-of-custody control and documentation, and bottle preparation prevent many gross errors in sample results. Duplicate samples and field blanks help in assessing the sampling procedure. The majority of the analytical results have been found to be suitable for the intended purposes. Appendix D gives more specific discussions on quality assurance/quality control.

Uncertainties are also inherent in laboratory analysis of samples. Gross errors can be introduced in the laboratory as well as during sampling, including transcription errors, calculation errors, mislabeling of results, instrument malfunction, and other errors that result from failing to follow established procedures. Often, these gross errors can be recognized because unreasonably high or unreasonably low values result. Data-review procedures are used to identify and correct gross errors.

Random errors are unavoidably introduced in the analytical procedures. Usually, there are too few replicate analyses to assess the overall random error. Instruments for analyzing radioactive constituents count the amount of ionizing radiation at a detector, and background counts are subtracted. The nature of radioactive decay and the instrument design result in a random counting error, which is reported with the analytical result. Generally, sample results that are less than the counting error are an indication that the constituent was not detected. The counting methods may also result in the reporting of results that are less than zero. Although they are physically impossible, the negative values are useful for some statistical analyses.

Systematic errors may result from inaccurate instrument calibration, improper standard or sample preparation, chemical interferences in analytical techniques, or faulty sampling methodology and sample handling. Sample and laboratory protocols, therefore, were designed to minimize systematic errors. The laboratories participate in interlaboratory comparisons, including analysis of blind samples prepared by the EPA. The contracted laboratories compared favorably with other laboratories, indicating that the level of systematic error from many sources is small enough to be acceptable.

The RCRA groundwater data undergo a validation/verification process according to a documented procedure. In addition to the quality assurance/quality control checks mentioned above, data are screened by scientists familiar with the hydrogeology of the unit, compared to historical trends or spatial patterns, and flagged if they are not representative.

Several potentially significant data quality issues were identified in FY 1997 related to total organic carbon, technetium-99, and gross beta analyses. Total organic carbon is one of the contamination indicator parameters monitored by most of the RCRA projects on the Hanford Site. Apparent high bias and poor precision in total organic carbon data were observed during the first two quarters of FY 1997. In July 1997, the laboratory adjusted their calibration procedure to address concerns about bias and precision. The high bias appeared to have been reduced in the data from samples analyzed after the laboratory procedure changed. Data from blind samples submitted to the laboratory in August 1997 also showed an improvement in precision and accuracy.

Unexpected technetium-99:gross beta ratios were observed in data from two wells in FY 1997. Blind samples were submitted to the laboratory in November 1997 to help evaluate the problem. Results from blind samples submitted earlier in FY 1997 are discussed in Appendix D. The suspect data are flagged in the database while investigations continue.

5.1.4 Data Management

Results of groundwater sampling and analysis are made accessible in the Hanford Environmental Information System (HEIS) database. This database currently resides on a Sun Sparc 20 UNIX-based multiprocessor computer. The database software is ORACLE® (Oracle Corporation, Redwood Shores, California). Analytical results from all groundwater-monitoring programs are stored in this common database, with the exception of some data collected for limited special projects that may not be directly comparable to standard data. The data are made available to federal and state regulators for retrieval.

The HEIS programmers and HEIS data owners, including the groundwater projects, ensure database integrity and data consistency through membership in the onsite HEIS configuration control board and other ad hoc groups. The majority of data are loaded into the database from electronic files provided by the analytical laboratories. This minimizes data-entry errors and reduces the cost of data management.

5.1.5 Interpretive Techniques

Overall sample uncertainty may be factored into data evaluation by considering the concentration trend in a given well over time. This often helps identify gross errors, and long-term trends can be distinguished from short-term variability. The interpretation of concentration trends depends on an understanding of chemical properties as well as site hydrogeology. The trend analysis, in turn, aids in refining the conceptual model of the chemical transport.

Trend plots in this report generally include all the available data, including those points flagged as suspect, unless the suspect points are beyond the scale of the plot. For specific conductance and pH, only field measurements are plotted. Replicate values are averaged by sample date, with outliers removed.

The plume maps presented in this report are diagrams of the interpretation of the groundwater chemistry at the Hanford Site based on data from all sampling programs. Although analytical data are available only for specific points where wells were sampled, contours are drawn to join the approximate locations of equal chemical concentration or radionuclide activity. The contour maps are, necessarily, simplified representations of plume geometry given the map scale, lack of detailed information, variations in well completion, and the fact that plume depth and vertical extent cannot be fully represented in a two-dimensional map. Thus, the contours shown do not honor all data values at individual wells. The contours show the extent of contamination at levels of regulatory concern, such as maximum contaminant levels (MCLs), interim drinking water standards (DWSs), or derived concentration guides (DCGs). Additional contours are shown at levels that illustrate additional features of the contaminant distribution, such as zones of high concentration or areas impacted at levels less than the interim DWSs or MCLs. Figures meeting these requirements are best prepared by using irregular contour intervals. In addition, groundwater contaminants are often found at values ranging over several orders of magnitude – often over short distances. In these cases, logarithmically increasing contour intervals or irregular intervals must be used to preserve the information about the distribution at both low and high concentrations.

Plume maps in this report were prepared using averages of FY 1997 samples from each well. Average values for radionuclides were calculated using reported values, including the negative values that may be reported when the sample measurement is less than the instrument background correction. Values for chemical constituents below detection limits were considered to be zero in calculating averages. In a few instances, data believed to represent gross errors in sample collection or analysis were removed from the data set before averaging. In addition, results that were reported as less than detection but at higher than normal detection levels were removed from the data set. This occurred when samples were diluted to bring another constituent into range and when certain samples were analyzed to meet specific needs of individual programs that did not require the same reporting levels. The average values are posted in the contour plots, allowing comparison of the contour interpretation to the input data set. As discussed above, not all posted values are in agreement with the contours presented. In some locations, contours are shown around areas having no supporting sample data from FY 1997. These contours are based on data from past monitoring. The wells may have been dropped from sampling as a result of changing sampling programs and budgets or other sampling problems.

Particular onsite situations lead to difficulties in using plume contour maps to display the extent of contamination. Rapid increases or highly variable concentrations of technetium-99 and other constituents have been observed near several of the RCRA single-shell tank waste management areas. The average values do not reflect the trends in these wells. In areas of pump-and-treat remediation, particularly where injection wells are used, the contour maps do not completely reflect the dynamics of the flow field. Average values tend to smooth out the trends induced by remediation activities.

Nitrate data are reported most commonly as nitrate or as nitrogen. The latter have been converted to nitrate for trend plots, maps, and text discussion, but are reported in their original units on the data diskette included with this report.

Total chromium in filtered samples is assumed to be hexavalent, the most soluble state. In some cases, analyses were performed specifically for hexavalent chromium; both types of data are included in plots and maps in this report.

Some of the strontium-90 data discussed in the text and plotted in the figures are actually combined strontium-89 and strontium-90. All of the strontium detected is assumed to be strontium-90 because strontium-89 has a much shorter half-life (50.5 days, compared to 29 years for strontium-90), and has decayed to undetectable levels since reactor operations ceased.

Monitoring at sites regulated under RCRA interim-status regulations requires a comparison between upgradient and downgradient levels of selected indicator parameters to determine if the facility has potentially impacted groundwater quality. Initial background monitoring was completed at all RCRA facilities having groundwater-monitoring requirements. The statistical methods applied in RCRA interim-status monitoring are discussed in Appendix B. The results of the statistical analyses are presented in Appendix B but conclusions with regard to specific facilities are summarized in this chapter.

Two facilities on the Hanford Site were monitored under RCRA final-status regulations in FY 1997 (the 183-H solar evaporation basins and the 316-5 process trenches). The statistical methods used for the final-status monitoring are also discussed in Appendix B and the conclusions from the statistical interpretations are included in this chapter.

One CERCLA operable unit (1100-EM-1) was subject to groundwater monitoring under a final record of decision (ROD 1993) during FY 1997. This record of decision requires monitoring of trichloroethylene at point-of-compliance wells. The comparison to standards at the point of compliance is discussed in Section 5.14.2.

5.1.6 Regulatory Standards

Contaminant concentrations in this report are compared to various regulatory standards that may apply under different programs. These standards include the following:

- MCLs are federally or state-enforceable standards for drinking water supplies. Although MCLs only apply at the point of consumption of the water, they provide a useful indicator of the potential impact of groundwater contamination if water usage were to change. In addition to primary MCLs, secondary MCLs are set on aesthetic criteria, such as taste, rather than on health criteria. Under the Model Toxics Control Act – Cleanup regulations (WAC 173-340), the State of Washington claims the right to require corrective actions in some instances where water supplies exceed secondary standards. Selected MCLs are shown in Table 5.1-1.

- interim DWS – Specific MCLs have not been set for most radionuclides; however, the MCL for gross alpha measurements, excluding uranium and radium, is 15 pCi/L. For beta particles and photon activity, the MCL is set at a 4-mrem/yr effective dose. The method of calculating the 4-mrem/yr effective dose equivalent for individual radionuclides that is used in the interim DWSs generally results in lower activities producing higher doses than result from calculations used in the proposed final standards. The interim DWS will serve the purpose of providing a measure of potential impacts from groundwater contamination until the final rule is promulgated. Interim DWSs for selected radionuclides are shown in Table 5.1-1.

- DCGs are standards set for protection of the public from radionuclides resulting from U.S. Department of Energy (DOE) activities. The DCG is based on a 100-mrem/yr exposure standard and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios. Because the effective dose equivalent calculations for the DCG use more current methodology, the results are not completely consistent with the interim DWSs. Selected DCGs and the 4-mrem/yr effective dose equivalent are shown in Table 5.1-2.

- standards for groundwater quality (WAC 173-200) were established to provide for the protection of the environment, human health, and existing and future beneficial uses of groundwater. These standards apply to the Solid Waste Landfill, which is regulated under WAC 173-304.

- regulations in the Model Toxics Control Act (WAC 173-340) may be applicable for sites undergoing remediation. In many cases, these levels are more stringent than MCLs or DWSs.

Also, concentration limits may be set in a facility's operating permit or record of decision. These limits are listed in the remainder of this chapter where they are applicable.

5.2 Hanford Site Groundwater Contamination Overview

P. E. Dresel

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their concentrations in wells and plume contours for the upper part of the unconfined aquifer system are shown in Plates 3, 4, and 5, respectively. Available data indicate that the vast majority of the onsite contamination remains near the water table, but information on the depth of the contaminant plumes is lacking for much of the site. The distributions of tritium, nitrate, and iodine-129 are generalized in Figures 5.2-1, 5.2-2, and 5.2-3. Figures for other constituent distributions are presented for specific areas as needed. Chromium contamination is widespread in several of the 100 Areas and extends into the surrounding 600 Area, as discussed below. Strontium-90 plumes in the 100 Areas exhibit very high concentrations in some cases but are of relatively smaller extent. Other extensive contaminant plumes include chromium in the 600 Area south of the 200 Areas, technetium-99 and uranium extending eastward from the 200-West Area, and technetium-99 with minor amounts of cyanide and cobalt-60 northeast 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 will be discussed with the source areas. A few smaller sources within the 600 Area are discussed in Section 5.12.

Contamination in the upper basalt-confined aquifer is discussed in Section 5.15. All analytical results for FY 1997 are included on the data diskette included with this report.

Waste sites are grouped into source operable units, and the groundwater beneath the sites are divided into groundwater operable units. Operable unit boundaries are illustrated in Figure 5.2-4.

A number of onsite facilities have specific RCRA-monitoring requirements. The results of monitoring at these facilities are integrated into the following discussions, and specific RCRA-reporting requirements for the facilities monitored, such as indicator parameter evaluations, are included as needed. Appendix A summarizes analytical results for wells monitoring RCRA and state-permitted facilities that exceeded MCLs or interim DWSs. Statistical evaluations for RCRA-monitoring requirements are discussed in Appendix B.

5.3 100-B,C Area

M. D. Sweeney, R. E. Peterson

The 100-B,C Area is the farthest upstream reactor area 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).

5.3.1 Facilities and Operable Units

There are no active facilities or waste-disposal sites in the 100-B,C Area. The facilities noted below that are associated with former reactor operations that involved hazardous materials are to be decommissioned and remediated under CERCLA. A description of reactor operations and associated hazardous waste sites is presented in a report prepared to support environmental restoration (WHC-SD-EN-TI-220).

For environmental restoration activities under CERCLA, the 100-B,C Area is divided into two source operable units that contain hazardous waste sites at or near the surface (100-BC-1 and 100-BC-2). A single groundwater operable unit (100-BC-5) addresses contamination at and below the water table and extends from beneath the source operable units laterally to adjacent areas where contamination may pose a risk to human and ecological receptors. For the 100 Areas, the lateral boundary is generally considered to be where Hanford Site groundwater meets Columbia River water. This interface occurs along the riverbanks and within the riverbed substrate.

High-priority waste sites in the 100-BC-1 Operable Unit include reactor-coolant-water-retention basins, liquid waste-disposal trenches, and associated effluent pipelines. High-priority sites in the 100-BC-2 Operable Unit include liquid waste-disposal sites near the reactor buildings and solid waste-burial grounds. Descriptions of high-priority waste sites are presented in the proposed plans for remediation activities in each of these source operable units (DOE/RL-94-99, DOE/RL-95-66, Draft A).

The 100-BC-5 Operable Unit encompasses the groundwater underlying the 100-B,C Area (see Figure 5.2-4). The groundwater was contaminated by liquid effluent disposal associated with past reactor operations. Most of the waste site sources for this contamination ceased operating by the late 1960s.

A significant amount of contamination carried by the groundwater discharged into the Columbia River. A conceptual site model for groundwater contamination at this operable unit is included in BHI-00917.

The 116-B-11 and 116-C-5 retention basins are located in the northern part of the 100-B,C Area. They received enormous volumes of reactor-coolant effluent that contained radionuclides and metals. They held the effluent for a short time to allow thermal cooling and radionuclide decay before the effluent was discharged to the Columbia River. The basins developed significant leaks, creating a mound on the underlying water table that enhanced the spread of contamination.

The 116-B-1 and 116-C-1 liquid waste-disposal trenches received highly radioactive coolant effluent that resulted when a reactor fuel element failed. The effluent was held briefly in the retention basins and was then diverted to the nearby liquid waste-disposal trenches instead of to the river. The trenches were unlined and intended as soil-column-disposal sites because the natural soils were known to retain several radionuclides of concern.

Relatively small soil-column-disposal facilities such as cribs, trenches, and french drains were located near the reactor buildings. Contaminated water and sludges from fuel-storage basins at each reactor were disposed to trenches.

Solid wastes from reactors, including piping and equipment, were disposed in unlined trenches, buried metal culverts, or buried concrete pipes.

5.3.2 Compliance Issues

The 100-B,C Area is monitored under both CERCLA and DOE Order 5400.1. Both programs have been combined under a sitewide monitoring program managed by the Pacific Northwest National Laboratory. Each of the individual program requirements is maintained, but sampling schedules and analyte selection are coordinated.

The groundwater-monitoring network in the 100-B,C Area includes a total of 20 groundwater wells and 2 seeps at the Columbia River shoreline. Most of the wells were sampled annually for the reporting period; however, quarterly sampling was performed on eight of the monitoring wells. Constituents of concern include tritium, technetium-99, strontium-90, and chromium. Tritium and strontium-90 exceeded their interim DWSs locally. Chromium exceeded its MCL in one sample. Nitrate exceeded its MCL in one well, but the data are believed to be erroneous. Although technetium-99 was detected, levels are far below the interim DWS. No radiological contaminants were detected at levels above the DCGs.

5.3.3 Extent of Contamination

The most notable contaminants in the 100-B,C Area are tritium and strontium-90; however, nitrate is slightly elevated. Groundwater is also contaminated locally with chromium at levels above the drinking water MCL. These contaminants were introduced from leaking retention basins, cribs, and trenches and, in some cases, from sources upgradient of the area.

5.3.3.1 Tritium

Tritium was produced in B and C Reactors (DOE/RL-90-08, WHC-MR-0425). Separation of tritium produced between 1949 and 1952 in the 100-B,C and other reactor areas was performed in the 108-B building. Liquid wastes from the tritium-recovery process were discharged to the 116-B-5 crib. Also, high-level liquid tritium wastes were disposed to the 118-B-6 burial ground (DOE/RL-90-08).

Tritium results for the 100-B,C Area in FY 1997 exceeded the interim DWS in two wells (199-B5-2 and 199-B3-47) (Figure 5.3-1). The two data points for well 199-B5-2 in FY 1997 were one to two orders of magnitude higher than concentrations measured in 1992 through 1995. The single data point from well 199-B3-47 in FY 1997 was higher than in the last 3 years but was comparable to tritium concentrations measured in 1992 after the well was installed. These wells are located downgradient of waste-disposal cribs associated with B Reactor.

Wells east and southeast of the 100-B,C Area continue to show elevated tritium levels (see Plate 3). It is believed that this contamination is moving from the 200 Areas through the gap between Gable Mountain and Gable Butte and merges with tritium plumes in the 100-B,C and 100-K Areas. Another possible explanation for the elevated tritium is groundwater mounding from past disposal practices in the 100-B,C Area.

5.3.3.2 Strontium-90

The highest activities of strontium-90 in the 100-B,C Area in the unconfined aquifer system continue to be found in wells near the 116-B-1 and 116-C-1 liquid waste-disposal trenches. The 116-B-11 and 116-C-5 retention basins and liquid waste-disposal sites near the B Reactor building also appear to have contributed strontium to groundwater. Groundwater with strontium-90 activity greater than the 8-pCi/L interim DWS extends from the B Reactor building downgradient to the retention basins, liquid waste-disposal trenches, and the Columbia River (Figure 5.3-2).

A sample from well 199-B3-2P, which is completed in the confined aquifer, had 63 pCi/L of strontium-90 in FY 1997, up from 7 pCi/L in FY 1996. However, the value is not believed to be representative of aquifer conditions, and the well has been decommissioned (see Section 3.10).

5.3.3.3 Chromium

Chromium was introduced to the soil column and groundwater from cooling water that leaked from retention basins and pipes or was disposed in trenches and cribs. Chromium in filtered samples was elevated in two very small areas. The first is near the river, downgradient of the retention basins, where well 199-B3-47 had 54 µg/L of chromium in the March 1997 sample. Chromium concentrations are increasing in this well (Figure 5.3-3). The second area of elevated chromium is downgradient of former water-treatment facilities, where sodium dichromate may have leaked from storage tanks and transfer facilities. The single monitoring well in this area (199-B5-1) had an average concentration of 37 µg/L of chromium in FY 1997. The maximum concentration of hexavalent chromium in this well (110 µg/L) exceeded the 100-µg/L MCL. Chromium concentrations fluctuate widely in this well, perhaps seasonally (see Figure 5.3-3). The low values were observed in the winter or spring of the year; the high values in the fall. However, well 199-B3-47 is much closer to the river than 199-B5-1 and does not exhibit similar fluctuations.

5.3.3.4 Nitrate

There is a plume of slightly elevated nitrate in the eastern part of the 100-B,C Area (see Plate 4). All concentrations were below the 45-mg/L MCL, except for 2 apparently erroneous values from well 199-B3-1. Excluding these data, the maximum average nitrate concentration in FY 1997 was 43 mg/L in well 199-B3-47. That value was more than seven times higher than the single previous data point from that well.

5.3.3.5 Water Quality at Shoreline-Monitoring Locations

Riverbank seepage is sampled annually during the late fall along the 100-B,C Area shoreline under the CERCLA remedial investigation for the 100-BC-5 Operable Unit. Samples are collected from two seepage sites per reactor area, depending on availability. Water and fine-grained sediments are analyzed for metals, anions, and radioactivity. At the 100-B,C Area, the sampling is conducted in accordance with Federal Facility Agreement and Consent Order Change Control Form No. M-15-96-07, dated July 31, 1996.

The results for sampling the two 100-B,C Area seeps showed relatively low concentrations of contamination indicators. Chromium was barely detectable and was well below the 100-µg/L MCL. The maximum gross beta activity was 28 pCi/L, which is below the 50-pCi/L standard. If all of the beta activity (28 pCi/L) is assumed to be strontium-90, it would correspond to a strontium-90 activity of ~14 pCi/L, which exceeds the 8-pCi/L interim DWS. Nitrate was also below the 45-mg/L MCL. Analyses for tritium were not performed. The riverbank-seepage data are consistent with contamination patterns indicated by data from monitoring wells. The specific conductance found in the fall 1996 riverbank seepage samples suggests that the samples represent primarily groundwater, with some dilution of riverwater. The new data are consistent with previous results for 100-B,C Area riverbank seepage, which had shown the presence of chromium, strontium-90 at relatively low concentrations, and tritium (DOE/RL-92-12, Rev. 1; WHC-EP-0609).

Aquifer-sampling tubes were installed at ~300-m intervals along the 100-B,C Area shoreline during the fall of 1997 (BHI-01090). These polyethylene tubes are driven into the aquifer at locations near the low-water shoreline. At each location, multiple tubes monitor several depths in the aquifer. Analyses of the water from these tubes included screening for tritium, gross beta, nitrate, and hexavalent chromium. Analytical results for initial samples from the tubes are presented in BHI-01153. The highest results were tritium (47,100 pCi/L), gross beta (42 pCi/L), nitrate (32,000 µg/L), and hexavalent chromium (41 µg/L). All of these samples came from a location opposite the former reactor-coolant-water-retention basins and liquid waste-disposal trenches. These results were generally consistent with contamination inferred from monitoring wells.

5.4 100-K Area

R. E. Peterson, V. G. Johnson

The 100-K Area contains two former plutonium-production reactors. The K-East Reactor operated between 1955 and 1971; the K-West Reactor operated between 1955 and 1970. Prior to construction of N Reactor, K-East and K-West were the largest of the production reactors. A description of operations and associated hazardous waste sites for the 100-K Area is presented in a report prepared to support environmental restoration (WHC-SD-EN-TI-239). A pump-and-treat system to remove chromium from groundwater between the 116-K-2 liquid waste-disposal trench (i.e., 100-K mile-long trench) is currently in operation.

5.4.1 Facilities and Operable Units

Existing facilities, hazardous waste sites, monitoring wells, and other general features for the 100-K Area are shown in Plate 1. Principal facilities that remain are the reactor complexes and the former water-treatment plant basins, one of which (183-KE) is currently used for a fish-rearing project. Decontamination and decommissioning of the facilities are under way, with removal of the circular, steel, coolant-water-retention basins being a significant recent project.

The K-East and K-West fuel-storage basins are functioning facilities that hold irradiated fuel rods from the last production run of N Reactor. They represent one of the most significant cleanup challenges on the Hanford Site. Leakage of large amounts of radiologically contaminated water occurred in the past from the K-East basin, and the underlying soil column contains a significant inventory of radionuclides.

Each reactor had a liquid waste-disposal facility that is a potential source for currently observed groundwater contamination. The 116-KE-3 and 116-KW-2 french drains/reverse wells were used to receive storage-basin effluent from the sub-basin drainage collection systems (WHC-SD-EN-TI-239). The french drains actually consist of drain fields containing perforated well casing that extends to below the water table. Strontium-90 and other radionuclides accumulated on the soil column beneath these drain fields and contamination was probably introduced directly to groundwater via the well casings.

Two other important contaminant sources near the reactor buildings are the 116-KE-1 and 116-KW-1 cribs, which received condensate from processing of various inert gases in the reactors. Irradiation of helium and nitrogen in the reactor atmosphere resulted in tritium and carbon-14, respectively, in the condensate that was disposed to the cribs. Approximately 200 Ci of tritium and 200 Ci of carbon-14 were discharged to these cribs during reactor operations.

The 116-K-2 liquid waste-disposal trench is located to the northeast of the K-East Reactor facilities and was designed as a soil-column liquid effluent-disposal facility and operated between 1955 and 1971. 116-K-2 is the largest radioactive liquid waste trench in the 100 Areas and received significant quantities of chemical wastes. Solutions containing chromium that were discharged to the trench were primarily decontamination solutions and leakage of routine coolant water from the 107-K retention basin and floor drains in the K-East and K-West Reactor buildings. Solutions contributing the greatest amount of radionuclides were decontamination solutions, shielding water from the fuel-storage basins, and coolant water containing debris from fuel-element failures.

Coolant for these reactors was piped to the 116-KW-3 and 116-KE-4 water-retention basins, which were steel tanks located near the Columbia River. Thermal cooling and decay of short-lived radionuclides occurred in these tanks. The coolant was then discharged into the river via large-diameter outfall pipes. Significant leakage of coolant water occurred from the retention basins to the ground, as well as to the 116-K-2 liquid waste-disposal trench via faulty valves and associated piping.

The area immediately south of the 183-KE water-treatment plant was the receiving facility for makeup chemicals. Tank-car loads of sodium dichromate and other chemicals were transferred to other locations from this point. During transfers, spillage of highly concentrated solutions occurred and drained into the soil. A similar chemical-receiving area existed behind the 183-KW water-treatment plant.

For CERCLA environmental restoration purposes, the 100-K Area is divided into several operable units. The 100-KR-1 and 100-KR-2 Operable Units address waste sites, spill/leakage locations, and facilities that may act as hazardous materials sources. The 100-KR-1 Operable Unit addresses source sites nearest the river and includes the former reactor-coolant-water-retention basins and liquid waste-disposal trenches. The 100-KR-2 Operable Unit addresses source sites farther inland and includes the reactor complexes and water-treatment plants.

The 100-KR-4 Operable Unit addresses groundwater that underlies the 100-K Area. This operable unit also addresses adjacent groundwater and surfacewater (i.e., the river) that may be impacted by contaminated groundwater from 100-K Area operations. Riverbank seepage, riverbed sediment porewater, and sediments contacted by contaminated groundwater from the 100-K Area are included in the operable unit.

5.4.2 Compliance Issues

Regulatory compliance issues related to groundwater in the 100-K Area include operational monitoring associated with the fuel-storage basins and CERCLA environmental restoration activities.

5.4.2.1 Monitoring at KE and KW Fuel-Storage Basins

Groundwater monitoring is being conducted around these facilities to ensure compliance with requirements for nuclear fuel- and waste-storage facilities (DOE Order 5400.1 [IV]9b). The regulatory basis for monitoring these facilities is further described in the Hanford Site environmental monitoring plan (DOE/RL-91-50, Rev. 2). The implementation of these monitoring and reporting requirements is contained in WHC-SD-EN-AP-174.

5.4.2.2 CERCLA Interim Action

In April 1996, a decision was made to proceed with accelerated groundwater remediation activities in the 100-K Area (ROD 1996b). Hexavalent chromium in groundwater that discharges into the Columbia River was viewed to pose significant risk to aquatic organisms. A groundwater-extraction-well network was designed that would intercept a chromium plume that is located between the 116-K-2 liquid waste-disposal trench and the river (DOE/RL-96-84). The extracted groundwater is passed through ion-exchange columns where hexavalent chromium is removed. The treated effluent is then returned to the aquifer.

In addition to reducing the amount of hexavalent chromium that is entering the river along the 100-K Area shoreline, the interim pump-and-treat system is intended to produce data on the efficiency of the method and effectiveness for aquifer restoration. These data are being collected under a performance- and compliance-monitoring plan (DOE/RL-96-90, Draft A). The first performance-evaluation report for the system is planned for April 1998.

5.4.2.3 100-KR-4 Operable Unit Remedial Investigation

Characterization of groundwater contamination is being conducted as the CERCLA interim action proceeds. The groundwater-monitoring schedule consists of predominantly annual sampling of wells, with analyses for anions, metals, and radiological indicators (BHI-00916). The list of wells, frequency of sampling, and analyses to be performed are described in National Priorities List Agreement/Change Control Form No. 108, dated November 20, 1996.

5.4.2.4 Drinking Water Standards and Derived Concentration Guides

Wells downgradient of the K-East and K-West Reactors exceeded the DWSs for tritium, strontium-90, carbon-14, and nitrate. Chromium exceeded the 100-µg/L MCL near the K-East Reactor and the 116-K-2 liquid waste-disposal trench. Trichloroethylene exceeded the 5-µg/L MCL near the K-West Reactor. Strontium-90 exceeded the 1,000-pCi/L DCG near the K-East Reactor.

5.4.3 Extent of Contamination

The geographic distribution of the groundwater contaminants found in the 100-K Area is described in this section. The description is organized by facilities and/or waste sites that are potential sources for contaminants that have reached the groundwater. Contaminants of concern for the 100-KR-4 Operable Unit are described in a conceptual site model report (BHI-00778). Contamination indicators adopted for operational monitoring associated with the fuel-storage basins include gross beta and tritium (WHC-SD-EN-AP-174).

5.4.3.1 K-East and K-West Reactors

Various liquid waste-disposal facilities associated with each reactor complex have contributed various radionuclides and chemical contaminants to groundwater. Also, leakage from the fuel-storage basins has been a significant source of groundwater contamination. The principal contaminants of concern from these sources are described below.

Tritium. Concentration contours from the reactor complexes to the river are shown in Plate 4. Groundwater-flow patterns near the river are complicated by daily and seasonal fluctuations in river stage (DOE/RL-92-64). Although the principal movement is toward the river, a second component parallels the shoreline in a downstream direction. This could account for the apparent northeastern occurrence of the high tritium concentrations near the river in well 199-K-120A (a new well recently installed for the chromium pump-and-treat campaign). Tritium concentrations of 85,100 and 55,000 pCi/L were observed in the November 1996 and May 1997 samples, respectively. The source of this tritium is attributed to the reactors and is discussed as follows.

As indicated in Plate 4, the highest tritium concentrations occur in the vicinity of the 116-KW-1 and 116-KE-1 cribs, located along the east side of the K-East and K-West Reactor buildings. These disposal sites are monitored by well 199-K-30 (K-East) and well 199-K-106A (K-West). The time variations in tritium and carbon-14 concentrations at these two sites are shown in Figure 5.4-1. In general, the two monitoring wells show similar concentration-time-response patterns.

The lower tritium concentrations in FY 1996 and FY 1997 may be in part related to increases in groundwater elevation, causing the plume to shift to the northeast and away from the monitoring wells. If this hypothesis is correct, and continued drainage of residual contaminants from these facilities occurs, higher tritium concentrations should be observed as water levels return to long-term average conditions.

Well 199-K-27, which monitors potential leakage from the construction joint in the K-East fuel-storage basin, continues to exhibit a decreasing concentration trend, as shown in Figure 5.4-2. Apparently, corrective action in 1994 eliminated or reduced leakage from the basin.

The most dramatic change in tritium concentrations in FY 1997 and October 1997 was the abrupt increase in well 199-K-109A, located at the northwestern corner of the K-East Reactor building (Figure 5.4-3). Basin leak-rate calculations and other operational data suggest that a new leak in the fuel-storage basin is unlikely. Additional investigation is planned during FY 1998 to assess the cause of the increase.

Carbon-14. This long-lived, low-energy, beta emitter is widely distributed in the 100-K Area at relatively low concentrations, as shown in Figure 5.4-4. The highest concentrations occur in the two wells (199-K-30 and 199-K-106A) that monitor the 116-KW-1 and 116-KE-1 cribs (see Figure 5.4-1). Carbon-14 concentrations appear to have increased significantly in FY 1997, whereas tritium remained lower than previous years. The latter may reflect a slower migration rate for carbon-14 than for tritium because of the chemical interaction or exchange of carbon-14 (as HCO_3^-) with stable carbon in carbonate minerals in vadose-zone and aquifer sediments.

Strontium-90. Localized strontium-90 plumes (Figure 5.4-5) occur near the reactor buildings and are attributed to past-practice discharges of fuel-storage basin water. Sorption and/or chemical exchange with aquifer mineral phases account for the more limited areal distribution than observed for tritium.

The fuel-storage-basin water (overflow and sub-basin leakage) was discharged to the 116-KW-2 and 116-KE-3 french drain/reverse well disposal sites located at the northwestern corner of the reactor buildings. The highest concentrations occur in well 199-K-109A, located at the K-East Reactor building. This well was drilled through the edge of the vadose-zone plume associated with the 116-KE-3 disposal site. Concentrations fluctuated by an order of magnitude, with the maximum exceeding 18,000 pCi/L (Figure 5.4-6). One explanation is that infiltration of water from natural or artificial sources through the contaminated vadose-zone sediments near well 199-K-109A accounts for the short-term increases. Possible water sources include surface runoff or fire hydrant testing near the well. These discharges are now directed away from this well and the adjacent waste-disposal site.

Nitrate. Waste sources near the reactor complexes have contaminated groundwater with nitrate at levels above the 45-mg/L MCL (see Plate 4). The plumes are assumed to reach the river, but there are few wells in that region. The nitrate plume extends south of the 183-KE water-treatment plant and beneath most of the 116-K-2 liquid waste-disposal trench, but levels there are below the MCL.

Chromium. Well 199-K-36 is located at the southeastern end of the former 183-KE water-treatment plant basins, which are now in use for raising fish. In the past, this well showed wide variations in chromium concentrations, ranging from several hundred to several thousand parts per billion, with the most recent results suggesting much lower concentrations (Figure 5.4-7). The suspected source for the chromium is leakage/spillage of sodium dichromate stock solutions that were stored and transferred in the area near the well. The mechanism causing relatively high concentrations and widely varying concentrations remains unknown but is believed to be related to infiltration of water from the surface, with remobilization of contamination held in the vadose zone. Leakage of water from the 183-KE basins is a potential source of recharge.

The speculation in last year's annual report (Section 6.4.3 of PNNL-11470) that chromium may be migrating downgradient from the hot spot at well 199-K-36 cannot be solidly confirmed by FY 1997 data from downgradient wells 199-K-23 and 199-K-110A (Figure 5.4-8). Well 199-K-23 seems to show a slight increasing trend since 1994, however.

Trichloroethylene. Trichloroethylene has been observed at concentrations above the 5-µg/L MCL in two 100-K Area wells (199-K-33 and 199-K-106A) located near the K-West Reactor complex. Concentration trends for these wells are shown in Figure 5.4-9. Trichloroethylene is not a widespread contaminant of concern in the 100-K Area.

5.4.3.2 116-K-2 Liquid Waste-Disposal Trench

This trench received liquid effluent from a variety of reactor operations. During a fuel-element rupture, the reactor coolant was diverted from the normal retention-basin path to the trench. This effluent contained significant quantities of radionuclides. Although not originally designed for reactor-coolant effluent, the trench also received a significant proportion of routine coolant because of faulty valves in the retention basins. Because the trench was unlined, disposal of huge volumes of coolant, which contained chromium, caused mounding of the water table beneath the facility. The mounding created a radial dispersal pattern, thus resulting in a widespread chromium plume that extended up to 1.6 km inland.

Chromium. The FY 1997 distribution of chromium (filtered samples) in the 100-K Area was shown in Figure 5.4-8. The southeast extent of the plume was defined from unfiltered samples that were collected from wells 199-K-121A, 199-K-122A, 199-K-123A, and 199-K-124A before their use as injection wells.

Chromium (38 µg/L in FY 1996) observed in well 699-78-62, located ~1,600 m inland and southeast of this trench, may have been moved inland under the influence of water-table mounding that existed during the reactor-operating period, as described in last year's annual report (Section 6.4.3 of PNNL-11470). Historical water-level data for the well confirm that a higher water table existed. Considering the results from the new injection wells, the explanation for the chromium observed today in the well has gained greater credibility.

Strontium-90. Strontium-90 is present along the northern portion of the trench (see Figure 5.4-5). Average concentrations in some wells exceeded the 8-pCi/L interim DWS in FY 1997, though the distribution is somewhat spotty and ill-defined.

5.4.3.3 Water Quality at Shoreline-Monitoring Locations

Riverbank seepage is sampled annually during the late fall from two sites along the 100-K Area shoreline as part of CERCLA remedial investigations. Seepage and fine-grained sedimentary materials associated with the seepage are analyzed for metals, anions, and radioactivity. At the 100-K Area, the sampling is conducted in accordance with National Priorities List Agreement/Change Control Form No. 108, dated November 20, 1996.

Results for sampling two 100-K Area seeps showed relatively low concentrations of chromium and gross beta that are consistent with contamination patterns indicated by data from monitoring wells. Specific conductance of the seepage suggested that the sample represented approximately equal parts riverwater and groundwater. Previous sampling of 100-K Area riverbank seepage also showed the presence of chromium and strontium-90 at relatively low concentrations (DOE/RL-92-12, Rev. 1; WHC-EP-0609).

Aquifer-sampling tubes were installed at ~300-m intervals along the 100-K Area shoreline during the fall of 1997 (BHI-01090). These polyethylene tubes are driven into the aquifer at locations near the low-water shoreline. At each location, multiple tubes monitor several depths in the aquifer. Analyses of the water from these tubes included screening for tritium, gross beta, nitrate, and hexavalent chromium. Analytical results for initial samples from the tubes are presented in BHI-01153. The highest results were tritium (5,620 pCi/L), gross beta (41 pCi/L), nitrate (25,000 µg/L), and hexavalent chromium (81 µg/L). These results were generally consistent with contamination inferred from monitoring wells.

Several analyses for strontium-90 were also performed on samples from certain locations, and results were consistent with gross beta results. The highest strontium-90 concentration observed was 17.9 pCi/L in the sample that also showed the highest gross beta (41 pCi/L). Where gross beta is primarily caused by strontium-90, gross beta activity is approximately twice strontium-90. Two analyses for carbon-14 were performed on tube samples from locations adjacent to monitoring wells that show carbon-14 in the 10,000-pCi/L range. The maximum tube sample result was 348 pCi/L.

5.4.4 Groundwater Remediation

Groundwater remediation activities currently under way in the 100-K Area consist of an interim action to address chromium contamination in the area between the 116-K-2 liquid waste-disposal trench and the river. The 100-KR-4 Operable Unit pump-and-treat system consists of two modular 426-L/min treatment trains containing ion-exchange columns filled with Dowex 21K™ resin to remove chromium from the influent (Dow Chemical Company, Midland, Michigan). The well network consists of six extraction wells (199-K-113A, 199-K-115A, 199-K-116A, 199-K-118A, 199-K-119A, and 199-K-120A; see Plate 1). The treated effluent is injected back into the aquifer at a location upgradient of the trench, using injection wells 199-K-121A, 199-K-122A, 199-K-123A, and 199-K-124A.

The current pumping rate from the extraction wells is ~570 L/min. Both treatment trains are being used. This system went into full operation (October 1997), which satisfied Milestone M-16-11 (Ecology et al. 1989). A performance-evaluation report for the 100-KR-4 Operable Unit will be issued in April 1998 (Milestone M-16-06C; Ecology et al. 1989).

5.5 100-N Area

R. E. Peterson, M. J. Hartman, J. V. Borghese

The N Reactor is no longer in service and is being decommissioned and decontaminated. A major project currently under way involves cleanout of the reactor's fuel-storage basin. The Hanford Generating Plant, which used steam from N Reactor to generate electrical power for the Washington Public Power Supply System, is also no longer in operation. Environmental restoration efforts have begun with the construction of a pump-and-treat system to remove strontium-90 from groundwater. Plans for additional remedial actions to address contaminated soils and groundwater have been proposed and are undergoing the public review process (DOE/RL-96-102, Draft B).

5.5.1 Facilities and Operable Units

Existing facilities, hazardous waste sites, monitoring wells, and other general features of the 100-N Area are shown in Plate 1. A detailed description of the operational history of the 100-N Area and its associated waste sites is presented in a report prepared to support the environmental restoration program (WHC-SD-EN-TI-251). The most recent summary of progress made by the pump-and-treat system is contained in the FY 1997 annual report for the 100-NR-2 Operable Unit (BHI-01126).

For CERCLA environmental restoration purposes, the 100-N Area is divided into two operable units (100-NR-1 and 100-NR-2). The 100-NR-1 Operable Unit is a source operable unit that includes liquid, sludge, and solid waste-disposal sites associated with operation of N Reactor. The 100-NR-2 Operable Unit (see Figure 5.2-4) addresses the groundwater that lies beneath the waste sites and includes groundwater in adjacent areas, Columbia River water, and river sediments that might be impacted by contaminated groundwater from 100-N Area operations.

Four RCRA units are located in the 100-N Area: 1301-N liquid waste-disposal facility, 1324-N surface impoundment, 1324-NA percolation pond, and 1325-N liquid waste-disposal facility. The 1301-N facility was the primary liquid waste-disposal facility for N Reactor from 1963 until 1985. Discharge to this facility was primarily cooling water containing radioactive fission and activation products. Minor amounts of dangerous waste also were discharged, including hydrazine, ammonium hydroxide, diethylthiourea, sodium dichromate, morpholine, phosphoric acid, lead, and cadmium. The 1301-N facility consists of a concrete basin with an unlined, zigzagging extension trench, covered with concrete panels.

The 1325-N facility was constructed in 1983, and N Reactor effluent was discharged to it and to the 1301-N facility. In 1985, discharge to 1301-N ceased, and all effluent was sent to 1325-N. All discharge to 1325-N ceased in late 1991. The facility consists of a concrete basin with an unlined extension trench, covered with concrete panels.

The 1324-N impoundment was a treatment facility that was in service from May 1986 to November 1988. This facility is a double-lined pond that was used to neutralize high- and low-pH waste from a demineralization plant. There is no indication that the facility leaked during its period of use.

The 1324-NA pond is an unlined pond that was used to treat waste from August 1977 to May 1986 and to dispose treated waste from May 1986 to August 1990. The effluent to both facilities contained sulfuric acid and sodium hydroxide, whose pH was occasionally high or low enough to be classified as a dangerous waste.

5.5.2 Compliance Issues

This section summarizes how groundwater was monitored to comply with applicable regulations in FY 1997, including RCRA monitoring, CERCLA environmental restoration activities, and a National Pollutant Discharge Elimination System (NPDES) permit under the *Federal Water Pollution Control Act*. The results are interpreted in more detail in Section 5.5.3.

5.5.2.1 1301-N and 1325-N Liquid Waste-Disposal Facilities

These facilities are monitored under RCRA interim-status, indicator evaluation programs (40 CFR 265, WAC 173-303-400). During FY 1997, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (see Appendix A).

Indicator parameter data from upgradient wells were statistically evaluated and values from downgradient wells were compared to values established from the upgradient wells (see Appendix B). Indicator parameters in downgradient wells remained below the comparison values. Of the dangerous waste constituents discharged to these facilities, only nitrate was observed at levels greater than the MCL (Section 5.5.3.3). The 1301-N and 1325-N facilities have contaminated the groundwater with tritium and strontium-90, but radionuclides are not monitored as part of the RCRA program at these facilities. Tritium and strontium-90 are discussed in Section 5.5.3.1.

High-river stage temporarily changed the groundwater gradient and flow direction beneath the 1301-N and 1325-N facilities (see Section 3.5.3). However, the current well network adequately monitors the site for long-term average conditions, and there are no plans to modify the networks in FY 1998.

5.5.2.2 1324-N Surface Impoundment/1324-NA Percolation Pond

These two facilities are monitored jointly under a RCRA interim-status, indicator evaluation program. During FY 1997, one upgradient and four downgradient wells were sampled twice for contamination indicator parameters and once for groundwater quality and site-specific parameters (see Appendix A). Indicator parameter data from the upgradient well were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient well (see Appendix B). Specific conductance values in downgradient wells were above the comparison value. A groundwater quality assessment program (1989-1992) concluded that the 1324-NA pond introduced nondangerous constituents (e.g., sulfate, sodium) to the groundwater, raising the specific conductance (WHC-SD-EN-EV-003, Rev. 1). Recent concentrations of these constituents and specific conductance are continuing previous trends, so no additional groundwater assessment is warranted.

Total organic carbon in downgradient well 199-N-59 was above the comparison value in FY 1997. Results of verification sampling were not available when this report was compiled. Total organic halide and pH limits were not exceeded in FY 1997.

The current well network adequately monitors the 1324-N/NA facilities, and there are no plans to modify the network in FY 1998.

5.5.2.3 N Springs Expedited Response Action

In 1994, the State of Washington Department of Ecology (Ecology) and the EPA directed DOE to immediately initiate groundwater remedial actions at the 100-N Area (Ecology and EPA 1994). The remedial actions requested were a groundwater pump-and-treat system and a sheet pile barrier wall. A construction test indicated that the sheet pile barrier wall could not be installed as specified. Ecology and EPA subsequently directed DOE to proceed with installing a pump-and-treat system for strontium-90 removal, and the system was in full operation by September 1995.

The goals of the expedited response action are to:

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

In July 1996, an evaluation of the initial operation of the pump-and-treat system was presented in DOE/RL-95-110. The report recommended pumping from wells 199-N-75, 199-N-103A, and 199-N-106A and increasing the combined pumping rate from 189 to 227 L/min. A fourth well (199-N-105A) was originally intended as a pumping well but was shown to be less effective at creating a capture zone and was placed in standby.

Between November and December 1996, the system was upgraded. For the rest of FY 1997, the system operated at ~227 L/min. The current performance-monitoring schedule, which reflects an optimization study (DOE/RL-97-34), is described in National Priorities List 100 Agreement/Change Control Form No. 113, dated March 25, 1997.

5.5.2.4 100-NR-2 Operable Unit Remedial Investigation

Groundwater is monitored for contamination other than strontium-90 as part of the remedial investigation for the 100-NR-2 Operable Unit. Groundwater characterization results, along with information gained by operating the pump-and-treat system, will be used to support selection of a final remediation alternative for the operable unit.

A consolidated groundwater-monitoring schedule was developed in 1995 to provide for efficient collection of groundwater data in support of several requirements (BHI-00725). Based on this proposed consolidation and RCRA groundwater-monitoring plans, Ecology, DOE, and EPA entered into Federal

Facility Agreement and Consent Order Change Control Form No. M-15-96-08, dated October 9, 1996. This agreement lists the wells to be sampled and analyses to be performed to satisfy groundwater-monitoring requirements for the 100-NR-2 Operable Unit under CERCLA and the 1301-N, 1324-N/NA, and 1325-N facilities under RCRA. Monitoring wells were sampled during FY 1997 for the 100-NR-2 Operable Unit for constituents of concern (tritium, strontium-90, nitrate, hexavalent chromium, manganese, petroleum hydrocarbons, and sulfate).

Under Bechtel Hanford, Inc.'s 100 Areas groundwater project, riverbank-seepage samples are collected annually during the fall months within each 100 Area groundwater operable unit (BHI-00916). Also during the fall of 1997, a project to install aquifer-sampling tubes along the 100 Areas shoreline was implemented (BHI-01090). These data will support characterization and performance-monitoring objectives for remediation activities within the 100 Areas groundwater operable units, including 100-NR-2.

5.5.2.5 Drinking Water Standards and Derived Concentration Guides

Tritium, strontium-90, nitrate, and sulfate continued to exceed MCLs or DWSs in the 100-N Area. Filtered manganese continued to exceed its MCL in one well. Filtered chromium consistently exceeded its MCL in the past in one well completed in a locally confined unit, but the well was not sampled in FY 1997. Strontium-90 was detected at up to 25 times the 1,000-pCi/L DCG.

5.5.2.6 Pollution Permit

The NPDES permit requires that 100-N Area well 199-N-8T be sampled quarterly for ammonium, chromium, grease, iron, oil, and temperature. The original purpose of this sampling was to monitor the effects of effluent discharge that was associated with the 1301-N and 1325-N facilities at a near-river location. Because neither facility has been in operation since 1991, a request to remove well 199-N-8T from the permit has been submitted to the EPA; the well continues to be sampled awaiting concurrence.

5.5.3 Extent of Contamination

This section describes the geographic distribution of groundwater contamination indicators for the 100-N Area. Contaminants of concern that have been identified for both groundwater and river protection are described in DOE/RL-95-111, Draft A. Contaminants of concern for groundwater protection are tritium, strontium-90, nitrate, hexavalent chromium, petroleum hydrocarbons (dissolved and free-product phases), manganese, and sulfate. Contaminants of concern for river protection are tritium, strontium-90, and hexavalent chromium.

5.5.3.1 1301-N and 1325-N Liquid Waste-Disposal Facilities

The principal groundwater contaminants associated with these two facilities are tritium, strontium-90, and chromium.

Tritium. A tritium plume map is shown in Plate 3. Concentrations at near-river wells are lower than those shown on the FY 1995 or FY 1996 plates and there appears to be a decreasing trend in tritium concentrations in this area. The highest average concentration of tritium was 76,000 pCi/L at well 199-N-32, near the 1325-N facility. The areal extent of this plume has been fairly constant for the last 3 years.

Strontium-90. Figure 5.5-1 shows the 100-N Area strontium-90 plume for FY 1997. Average concentrations are generally higher than shown in earlier plume maps because of the anomalously high water table that was present during 1997. The concentration of strontium-90 in groundwater varies at some locations as a result of the rise and fall of the water table. This is caused by the desorption of strontium-90 from soils in the vadose zone that become temporarily saturated during high water levels (BHI-01126). The highest concentrations (i.e., >5,000 pCi/L) are centered under and to the river side of the 1301-N facility and within the rivershore area between wells 199-N-46 and 199-N-99A. The highest concentrations are found in well 199-N-67, which exhibited a concentration of 25,000 pCi/L in early 1997 and had a yearly average of 14,000 pCi/L (Figure 5.5-2).

Strontium-90 exceeded 1,000 pCi/L in well 199-N-81, downgradient of the 1325-N facility, in FY 1997. These were the highest concentrations measured in any well monitoring the facility, but concentrations over 1,000 pCi/L were observed in other wells near the facility in the 1980s when it was in use. The increase in strontium-90 in well 199-N-81 may represent movement of this contaminated water downgradient, or movement of the 1301-N plume inland during periods of reversed hydraulic gradient.

Chromium. Chromium concentrations higher than the 100-µg/L MCL have been consistently observed in two wells: 199-N-74, located to the southwest of the 1325-N facility, and 199-N-80, located northwest of the 1301-N facility (Figures 5.5-3 and 5.5-4). The concentrations for filtered samples, which are considered to be representative of dissolved hexavalent chromium, consistently are below the MCL in well 199-N-74; the higher concentrations for the unfiltered samples are probably caused by trivalent chromium associated with particulate matter. Well 199-N-80, completed in a thin, confined aquifer in the Ringold Formation, has contained chromium above the MCL in filtered and unfiltered samples in the past (178 µg/L in FY 1996). Well 199-N-80 was not sampled in FY 1997. Nearby wells do not show similarly high concentrations of chromium. Well 199-N-33, which had elevated chromium in FY 1996 (430 µg/L) contained only 7 µg/L in a March 1997 filtered sample; thus, the FY 1996 value appears to be erroneous.

RCRA Parameters. Specific conductance of ambient groundwater near the 1301-N facility is relatively low (200 to 300 µS/cm) compared to typical site groundwater because the site is close to the river. Upgradient well 199-N-57 and downgradient well 199-N-3 show elevated specific conductance (700 to 1,000 µS/cm; Figure 5.5-5). The position of these wells and the chemical composition of the water indicate that the source of the elevated specific conductance is the 1324-N/NA facilities (WHC-SD-EN-EV-003, Rev. 1).

Specific conductance near the 1325-N facility was ~300 to 400 µS/cm during the past year (Figure 5.5-6). When 1325-N was in use, specific conductance of groundwater was lower because of artificial recharge with low-conductivity water. After discharge to the facility ceased, specific conductance gradually increased. Specific conductance in the upgradient well (199-N-74) was elevated in the past, possibly because of the upgradient influence of the 1324-NA percolation pond.

Groundwater pH beneath the 1301-N and 1325-N facilities averaged between 7.2 and 8.4 in the past year. There are no clear upward or downward trends and no significant differences between upgradient and downgradient wells. Total organic halides ranged from less than the detection limit to 17 µg/L; total organic carbon ranged from below detection to 1,670 µg/L, with no significant differences between upgradient and downgradient wells.

Groundwater at 1301-N and 1325-N is also analyzed for other constituents that were discharged to these facilities during their use. These analytes include nitrate, cadmium, chromium (discussed above), and phosphate (see Appendix A). Cadmium (in filtered samples) and phosphate were not detected in 1301-N or 1325-N groundwater. Nitrate was elevated in some of the downgradient wells, as discussed in Section 5.5.3.3, but the sources are unclear.

5.5.3.2 1324-N Surface Impoundment/1324-NA Percolation Pond

Groundwater beneath these facilities is characterized by high specific conductance (>1,000 µS/cm), primarily because of high levels of nondangerous constituents such as sodium and sulfate (Figure 5.5-7).

Field pH in 1324-N/NA wells was between 7.9 and 8.3 during FY 1997. Total organic halides ranged from below the detection limit to 17.9 µg/L, with no significant differences between upgradient and downgradient wells. Total organic carbon concentrations ranged from less than the detection limit to 2,600 µg/L in well 199-N-59. Total organic carbon in this well trends higher than in the other wells and appears to be increasing (Figure 5.5-8). The only organic constituent observed in 1324-N/NA groundwater in the past was chloroform, which is believed to have come from nondangerous water disposed in a nearby french drain (WHC-SD-EN-EV-003, Rev. 1). The well is no longer sampled for specific organic constituents. Well 199-N-59 contains very little water and cannot be sampled unless the water table is high.

Sulfate. A plume of high-sulfate groundwater emanates from the 1324-NA pond toward the Columbia River (Figure 5.5-9). The highest concentrations of sulfate in recent years have been observed in wells between the N Reactor building and the river. In FY 1997, sulfate concentrations in this area decreased because of dilution from inflow of riverwater. Wells 199-N-2 and 199-N-3, located near the 1301-N facility, both show an increasing sulfate trend, with the most recent sample results from 199-N-3 slightly exceeding the 250-mg/L secondary MCL (Figure 5.5-10). The 1324-N/NA plume has apparently reached these wells.

5.5.3.3 Other Groundwater Contamination Indicators

Petroleum Hydrocarbons. Petroleum hydrocarbons are present as dissolved and free-product phases at several locations in the 100-N Area. During the fall of 1996, well 199-N-8T, which is used to support the NPDES permit, had consistent detections of grease and oil, as indicated by analysis for total petroleum hydrocarbons. However, no floating product was observed by the samplers at the time of sampling. To ensure that the N Springs pump-and-treat system was not being exposed to hydrocarbons, which would have a detrimental effect on performance, wells 199-N-103A (an extraction well), 199-N-96A, and 199-N-3 were also sampled. All results for these samples were below the detection limit. Well 199-N-96A, located at the river shoreline, was also checked for the presence of floating product by field observation and interface probe measurement; none was detected.

Floating petroleum product (i.e., diesel) has been observed in wells 199-N-17 and 199-N-18. The thickness of the layer observed during FY 1996 and FY 1997 varied from a trace to a maximum of 0.5 m. The thickness of the free-product layer is believed to be related to the elevation of the water table that, in turn, is influenced by river stage.

Nitrate. Nitrate continues to be elevated in scattered monitoring wells throughout the 100-N Area, with some concentrations exceeding the 45-mg/L MCL (see Plate 4). The highest values in FY 1997 were in wells 199-N-19 (150 mg/L) and 199-N-105A (110 mg/L), but neither of these wells have enough historical data to define trends. Well 199-N-19 is located near the Columbia River, approximately downgradient of the 1324-N/NA facilities, and well 199-N-105A monitors the 1301-N facility. Nitrate was also greater than the MCL at fairly stable levels in wells 199-N-3, 199-N-26, and 199-N-32 (Figure 5.5-11). Well 199-N-3 monitors the 1301-N facility, well 199-N-26 is located near the N Reactor building, and well 199-N-32 monitors the 1325-N facility. The sources of nitrate are unknown.

Manganese. Manganese is present at concentrations greater than the 50-µg/L MCL in samples from well 199-N-16. The most recent results (805 µg/L in the September 1996 sample) showed an increase compared to previously reported results. Results from a September 1997 sampling had not been received when this report was compiled. The source of manganese is unknown, though it is a common, naturally occurring constituent in Hanford Site sediments.

5.5.3.4 Water Quality at Shoreline-Monitoring Locations

Shoreline-monitoring locations for the 100-N Area are concentrated in the area directly downgradient from the 1301-N facility. Carbon-steel casings were installed in the riverbank to collect samples of these springs. The seep points are measured annually (HNF-EP-0573-5). Only a few of the sample points were accessible during the September 1996 sampling event because of high-river stage. The samples collected from these wells were analyzed for radioactive constituents. Seep point NS-3 contained the highest strontium-90 concentration (5,800 pCi/L) and the highest tritium concentration (16,000 pCi/L). Sampling results for FY 1997 were not available in time for this report.

The wells located near the river (199-N-92A, 199-N-94A, 199-N-96A, 199-N-46, and 199-N-8T) also offer locations to monitor groundwater quality very close to the river. FY 1997 data available from these wells are incorporated in the contaminant distribution maps presented in this report.

Because of the monitoring coverage offered by the seep points and near-river wells, new aquifer-sampling tubes were not installed in the 100-N Area during the fall 1997 installation project (BHI-01153). The ability to install aquifer-sampling tubes along the 100-N Area shoreline was also questionable because of the coarse gravels in this area.

5.5.4 Groundwater Remediation

The expedited response action in the 100-N Area is intended to 1) reduce the strontium-90 contamination flux from the groundwater to the river, 2) evaluate commercially available treatment options for strontium-90, and 3) provide data necessary to set demonstrable strontium-90 groundwater-cleanup standards (Ecology and EPA 1994). These objectives are being addressed by a pump-and-treat system.

The 100-NR-2 Operable Unit pump-and-treat system began operating in September 1995 (BHI-01126). The system consists of four extraction wells, a treatment facility, and two injection wells. The extraction wells are all located between the 1301-N liquid waste-disposal facility and the Columbia River (Figure 5.5-12). Pumping from these wells creates a hydraulic barrier between the river and the 1301-N facility, thus reducing the rate at which groundwater discharges into the river. High-river stage also contributes to this hydraulic barrier. Because groundwater is the mechanism by which strontium-90 is transported to the river, the flux of strontium-90 contamination is also reduced.

The ion-exchange system used to remove strontium-90 from the extracted groundwater has performed as planned. The system uses clinoptilolite, a zeolite mineral, to remove the strontium-90 with an average efficiency of 90%, as measured by comparing treated effluent concentrations to influent concentrations (DOE/RL-97-34). During FY 1997, the pump-and-treat system removed ~0.17 Ci of strontium-90 (BHI-01126).

A performance-evaluation report was prepared to describe the results of the initial operation of the pump-and-treat system and also to report on some additional characterization and evaluation work (DOE/RL-95-110). The evaluation's conclusions relative to the three objectives are as follows:

- The pumping well network is reducing the flux of strontium-90 to the river by means of hydraulic control.

- Clinoptilolite (zeolite) is an effective ion-exchange medium for reducing strontium-90 in extracted groundwater.

- Strontium-90 concentrations in groundwater will not be changed significantly by pumping operations because of the equilibrium being maintained between groundwater concentrations and the much larger inventory of strontium-90 held on sediment particles.

  Subsequent to completing the performance evaluation, the Columbia River experienced unusually high discharge, especially during 1996 and 1997. This caused a significantly elevated water table in the aquifer along shoreline areas, including the 100-N Area. The elevated water table allowed groundwater to come in contact with strontium-90 stored on normally unsaturated sediments in the vadose zone and resulted in significant increases in strontium-90 concentrations in groundwater at some locations (BHI-01126). Concentrations are expected to decrease again, as the water table returns to more typical long-term average elevations.

5.6 100-D/DR Area

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The 100-D/DR Area contains two former plutonium-production reactors. D Reactor operated between 1944 and 1967 and DR Reactor between 1950 and 1964. A description of operations and associated hazardous waste sites is presented in a report prepared to support environmental restoration (WHC-SD-EN-TI-181).

Extensive environmental restoration activities are under way that include the removal of radiologically contaminated soil associated with reactor-coolant-water-retention basins, liquid waste-disposal trenches, and associated underground piping. These remediation activities help to reduce the risk of future groundwater contamination. A pump-and-treat system to remove chromium from groundwater is currently operating.

5.6.1 Facilities and Operable Units

Existing facilities, hazardous waste sites, monitoring wells, and other general features of the 100-D/DR Area are shown in Plate 1. For CERCLA environmental restoration purposes, the 100-D/DR Area is divided into two operable units (100-DR-1 and 100-DR-2), which address hazardous waste sites located at or near the ground surface. The 100-DR-1 Operable Unit contains a former liquid waste-disposal facility (the 120-D-1 ponds) that is regulated under RCRA. These ponds were constructed in 1977 for disposal of nonradioactive effluent derived from operating facilities in the 100-D/DR Area. Some past discharges contained hydrochloric acid, sodium hydroxide, and sulfuric acid. Before 1986, the effluent may have had a >12.5 or <2.0 pH and, thus, may have been dangerous waste, and there was also a potential for up to 2.3 kg of mercury to have been discharged to the ponds. Effluent discharge ceased in 1994 and contaminated sediments were removed.

The following summaries describe principal past-practice waste sites that may have contributed to groundwater contamination.

- The 116-D-7 and 116-DR-9 retention basins are located in the northern part of the 100-D/DR Area. They received enormous volumes of reactor-coolant effluent that contained radionuclides and chromium. They held the effluent for a short time to allow thermal cooling and radionuclide decay prior to discharging the effluent to the Columbia River via outfall pipes. The basins developed significant leaks, creating a mound on the underlying water table. Mounding enhanced the spread of contamination over a broad area that potentially exceeded the reactor area boundaries.

- The 116-D-1 and 116-DR-2 liquid waste-disposal trenches received highly radioactive coolant effluent that resulted when a reactor fuel element failed. The effluent would be held briefly in the retention basins and then diverted to the nearby trenches instead of the normal discharge via river-outfall pipes. The trenches were unlined and intended as soil-column-disposal sites.

- Relatively small soil-column-disposal facilities, such as cribs and french drains, were located near the reactor buildings. Contaminated water and sludges from fuel-storage basins at each reactor were disposed to trenches and percolation ponds. Decontamination solutions, consisting of various acid solutions that picked up radionuclides and metals were also disposed to the ground near the reactors. Condensate from the inert gas system that was part of the reactor may be the source for carbon-14 contamination that is found in the area.

- Sodium dichromate, which was added to coolant water as a corrosion inhibitor, was typically transferred from railcars to storage tanks and then piped to the facilities where it was added to coolant water. Leakage and spillage of stock solution occurred at storage tanks located on the north side of the D Reactor building and from piping that transferred the materials to the 190-D building located immediately west of the reactor. During the later period of operations, a sodium dichromate transfer station was established ~300 m west of D and DR Reactors. Significant spillage of sodium dichromate solution and washdown waste is assumed to have occurred at this location.

Groundwater underlying the 100-D/DR Area is part of the 100-HR-3 Operable Unit, which includes groundwater beneath the 100-H Area as well (see Figure 5.2-4). Groundwater operable units address groundwater beneath the reactor areas and also groundwater in adjacent areas, Columbia River water, and river sediments that might be adversely impacted by contaminated groundwater from the reactor area.

5.6.2 Compliance Issues

Regulatory compliance issues related to groundwater in the 100-D/DR Area include RCRA monitoring and CERCLA environmental restoration activities.

5.6.2.1 120-D-1 Ponds

This RCRA facility is monitored under an interim-status, indicator evaluation program (40 CFR 265, WAC 173-303-400). During FY 1997, one upgradient well and three downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (see Appendix A). Indicator parameter data from the upgradient well were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient well (see Appendix B). Specific conductance, pH, total organic carbon, and total organic halides in downgradient wells remained below the comparison values. Mercury is the only listed waste that may have been discharged to these ponds, and it has not been detected in any of the downgradient monitoring wells to date.

Abnormally high-river stage during FY 1997 temporarily reversed the flow direction beneath these ponds. However, the monitoring network is still adequate to monitor the site under average conditions. A pump-and-treat system (Section 5.6.4) located northeast of the ponds has not yet affected groundwater flow beneath the ponds. No changes are planned for FY 1998.

The RCRA closure plan for the ponds is currently being revised, and the site is scheduled to be incorporated into the Hanford Site permit in FY 1998.

5.6.2.2 CERCLA Interim Action

In April 1996, a decision was made to proceed with accelerated groundwater remediation activities in the 100-D/DR Area (ROD 1995b). Hexavalent chromium in groundwater that discharges into the Columbia River was viewed to pose significant risk to aquatic organisms. A groundwater extraction well network was designed that would intercept the chromium plume near the river (DOE/RL-96-84). The system began operating in July 1997. Groundwater is extracted from two 100-D/DR Area wells (199-D8-53 and 199-D8-54A) and piped to the 100-H Area, where chromium is removed using ion-exchange technology. The treated effluent is returned to the aquifer in the 100-H Area.

In addition to reducing the amount of hexavalent chromium that is entering the river along the 100-D Area shoreline, the interim pump-and-treat system is intended to produce data on the efficiency of the methodology and effectiveness of aquifer restoration. These data are being collected under a performance- and compliance-monitoring plan (DOE/RL-96-90, Draft A). The first performance-evaluation report for the system is planned for April 1998.

5.6.2.3 100-D Area Chromium Hot Spot

At the time that decisions involving accelerated remediation activities were taking place, characterization sampling was being conducted that produced new information on the extent of chromium contamination in groundwater. During a project to sample riverbed sediment porewater in October 1995, chromium was discovered along the segment of 100-D Area shoreline upstream of the water-intake structure (BHI-00778). Concentrations of hexavalent chromium in the range of 600 to 800 µg/L were observed in porewater samples and in samples from the aquifer at the shoreline.

In response to this discovery, a new well (199-D4-1) was constructed in early FY 1997 to help define the extent of this contamination. Initial sampling confirmed the presence of chromium in the 1,000-µg/L range but did not show evidence of other chemical or radiological contamination (BHI-01131). Four additional wells (199-D3-2, 199-D4-13, 199-D4-14, and 199-D4-15) were constructed in August 1997 to help define the boundaries of this plume. Numerous wells were also installed near well 199-D4-1 as part of the in situ redox manipulation technology demonstration project (Section 5.6.4.3).

Monitoring data from the new wells, along with new data from aquifer-sampling tubes along the shoreline, will be interpreted to provide a comprehensive description of the contaminant plume. This information will be used to guide near-future environmental restoration decisions.

5.6.2.4 100-HR-3 (D Area) Operable Unit Remedial Investigation

Characterization of groundwater contamination in the 100-D Area is being conducted as the interim action proceeds. The groundwater-monitoring schedule consists of predominantly annual sampling of wells, with analyses for anions, metals, and radiological indicators (BHI-00916). The list of wells, frequency of sampling, and analyses to be performed are included in National Priorities List Agreement/ Change Control Form No. 107, dated November 20, 1996.

5.6.2.5 Drinking Water Standards and Derived Concentration Guides

Nitrate and chromium exceeded MCLs or DWSs during FY 1997 in a fairly broad area. Tritium and strontium-90 exceeded their interim DWSs locally. No radiological constituents exceeded the DCGs.

5.6.3 Extent of Contamination

In this section, the geographic distribution of groundwater contamination is described in relation to facilities and/or waste sites that are sources for the contaminants. The predominant contaminants in groundwater are tritium, strontium-90, nitrate, and chromium.

5.6.3.1 D and DR Reactors

Numerous facilities, waste sites, and spillage/leakage sites are located in the vicinity of the D and DR Reactors. Chemical and radiological contamination was introduced to the groundwater via these reactor complexes. The most prevalent contaminant remaining today is chromium, a primary source for which was probably disposal or spillage of sodium dichromate stock solution. Sodium dichromate was used in reactor coolant as a corrosion inhibitor.

In the past, chromium concentrations in 100-D Area groundwater were highest in the area around D Reactor. The area was used to test pump-and-treat technology for groundwater restoration (DOE/RL-95-83). The source for the elevated chromium concentrations was apparently leakage/spillage from sodium dichromate stock solutions storage tanks and/or underground transfer-line leakage (BHI-00967, Rev. 1; WHC-SD-EN-TI-181). The pilot-scale pump-and-treat test operated between August 1994 and August 1996 and removed ~50 kg of chromium from groundwater.

Tritium. Tritium is elevated beneath much of the 100-D Area but is low in the area surrounding the 120-D-1 ponds and near the river (see Plate 3). Tritium exceeded the 20,000-pCi/L interim DWS in one well (199-D5-16) near the reactor buildings and in two wells (199-D3-2 and 199-D2-6) in the southwestern corner of the area. The two tritium values measured in well 199-D2-6 in FY 1997 were an order of magnitude higher than the previous 4 years. The single value measured in well 199-D3-2 was the first data point from this new well. The contamination may have originated in the 100-N Area.

Strontium-90. The strontium-90 distribution remained essentially the same as in previous years, with a single well containing concentrations above the 8-pCi/L interim DWS. Well 199-D5-12, located near the D Reactor's fuel-storage basin trench, contains strontium-90 concentrations of ~40 pCi/L, which represents the highest concentrations observed in the 100-D/DR Area.

Nitrate. Nitrate is elevated beneath most of the 100-D Area (see Plate 4), and is above the 45-mg/L MCL near the disposal trenches and retention basins, near the reactor buildings, and in the western 100-D Area. A lack of wells between these areas makes it unclear whether these are separate plumes, as indicated in Plate 4, or a single plume.

Chromium. The FY 1997 distribution pattern for chromium in the 100-D/DR Area is shown in Figure 5.6-1. The northern portion of the plume is the target of an interim action (DOE/RL-96-84) discussed Section 5.6.4.2. The southwestern portion is referred to as the 100-D Area chromium hot spot and is discussed in Section 5.6.3.3.

One change in the distribution of chromium in the 100-D/DR Area that is becoming more apparent is the decrease of the effect of noncontaminated water being discharged to the 120-D-1 ponds (discharges ceased in June 1994). The last discharges consisted of effluent from backwashing the 183-D water-treatment plant filters. When this effluent reached groundwater, it apparently diluted any contamination the groundwater might have contained.

Chromium contamination, the source for which is probably located in the vicinity of the former D Reactor coolant makeup facility and D Reactor building, migrates northwestward toward the 120-D-1 ponds. Well 199-D5-13 is located immediately upgradient of the ponds. An increase in chromium concentrations in this well in recent years illustrates the reduction in dilution formerly caused by discharges to the 120-D-1 ponds (Figure 5.6-2).

5.6.3.2 120-D-1 Ponds

RCRA Parameters. Groundwater chemistry in the vicinity of the 120-D-1 ponds is characterized by low concentrations of anions and metals and no detectable radionuclides, apparently because of dilution from pond discharge. The dilution effect appears to have influenced groundwater chemistry even in upgradient well 199-D5-13. After discharges to the pond ceased in 1994, higher-conductivity groundwater from upgradient sources flowed past the well and specific conductance increased. This parameter also is trending upward in the downgradient wells but remains lower than in the upgradient well (Figure 5.6-3).

Groundwater pH is higher in the wells immediately adjacent to the ponds than in the other wells, up to 9.3 in well 199-D8-6 (Figure 5.6-4). The elevated pH is caused by pond discharge reacting with materials in the ash underlying the ponds (WHC-EP-0666, WHC-SD-EN-EV-033). Total organic carbon ranged from less than the detection limit to 1,550 µg/L, with the highest concentrations in the upgradient well. Total organic halides ranged from less than the detection limit to 18.8 µg/L. The highest value was from well 199-D8-6; however, quadruplicate analyses yielded poor precision.

5.6.3.3 100-D Area Chromium Hot Spot

Data from five new wells (199-D3-2, 199-D4-1, 199-D4-13, 199-D4-14, and 199-D4-15) have confirmed the presence of a significant chromium plume in this area (see Figure 5.6-1). The extent and concentration of the plume inland from the river have been better characterized by data from the new wells (BHI-0967, Rev. 1; BHI-01131).

Analyses of groundwater- and shoreline-monitoring data, along with historical information on potential sources for chromium and the water-table configuration during operating years, have been used to explain the occurrence of chromium in this area (BHI-01131). Sodium dichromate was introduced to the soil column via spillage or leakage at a variety of potential locations near the 190-D water-treatment plant and D Reactor, as well as at a sodium dichromate transfer station. A groundwater mound existed in the northern part of the 100-D/DR Area beneath the reactor-coolant-water-retention basins. The mounding created a radial flow pattern that included pathlines to the south and southwest. These pathlines crossed potential source locations for chromium. When mounding dissipated following shutdown of reactor operations in the late 1960s, flow direction shifted to the west and followed the natural groundwater gradient toward the river.

5.6.3.4 Water Quality at Shoreline-Monitoring Locations

The 100-D/DR Area shoreline has been sampled more comprehensively than other reactor area shorelines. Water quality data are available from aquifer-sampling tubes installed at the low-water shoreline and from riverbed sediment porewater. These data came about as the result of a project in October/November 1995 to characterize the influx of hexavalent chromium to the river, along a river segment that is heavily used by fall chinook salmon for spawning (BHI-00778). Data are also available from riverbank-seepage sites.

Fall 1995 Project Update. The highest hexavalent chromium concentrations observed at shoreline-sampling sites during the fall 1995 project were ~900 µg/L. Preliminary results for resampling some of these sites during FY 1997 indicate that high concentrations are still present. These concentrations are well above the EPA's ambient water quality criterion for protection of aquatic organisms (11 µg/L; EPA/440/5-86-001). In response to this discovery in 1995, five new monitoring wells were installed during FY 1997 to better define the extent of the chromium plume that is impinging on the river. The wells have confirmed the presence of a significant plume that has concentrations up to ~2,000 µg/L (BHI-01131).

Remedial investigations being conducted within the 100-HR-3 Operable Unit have used data from aquifer-sampling tubes and riverbed porewater-sampling tubes to help define the areal limits of the riverbed where contaminated groundwater might be exposed. Cross-sections have been drawn that show the vertical relationship between the contaminated aquifer and the river channel. It is apparent, given the relative thinness of the contaminated layer and the channel topography, that the area of exposure is small relative to the total area of river bottom. A cross-section through the 100-D/DR Area hot spot is shown in Figure 5.6-5. The cross-section includes the fall 1995 concentrations for hexavalent chromium that were obtained from wells, aquifer-sampling tubes at the shoreline, and riverbed sediments.

A second aspect of groundwater/river interaction being studied along this segment of shoreline is how water quality at shoreline-monitoring locations varies in response to seasonal river-discharge cycles. During 1996 and 1997, considerably more water flowed through the Hanford Reach than in the previous several years. This resulted in an increase in the infiltration of riverwater into the banks and, possibly, the riverbed sediments. Repeated sampling between October 1995 and November 1996 of aquifer-sampling tubes installed at multiple depths along the shoreline provide evidence for the extent to which infiltration of riverwater influences groundwater quality near the shoreline (Peterson 1997). The data also provide insight on how quickly riverbank water quality conditions return to more normal (typical) conditions after the seasonal high discharge passes.

Additional aquifer-sampling tubes were installed at ~150-m intervals along the 100-D/DR Area shoreline during the fall of 1997 (BHI-01090). Analyses of water from these tubes included screening for tritium, gross beta, nitrate, and hexavalent chromium. Analytical results for initial samples from the tubes were presented in BHI-01153. The newly installed tubes produced samples that were primarily riverwater held in bank storage. Concentrations were much higher in the older tubes (installed in October 1995): tritium (20,000 pCi/L), gross beta (6 pCi/L, which is near background), nitrate (38,000 µg/L), and hexavalent chromium (603 µg/L). These results are generally consistent with contamination inferred from monitoring wells.

FY 1997 Riverbank-Seepage Results. Sampling of riverbank seeps is conducted annually during the late fall along the 100-D/DR Area shoreline as part of the CERCLA remedial investigation of the 100-HR-3 Operable Unit. Samples are collected from approximately four seepage sites, depending on availability. Water and fine-grained sediments are analyzed for anions, metals, and radioactivity. At the 100-D/DR Area, the sampling is conducted in accordance with National Priorities List Agreement/ Change Control Form No. 107, dated November 20, 1996.

Results from sampling four 100-D/DR Area seeps showed concentrations of contamination indicators that are consistent with concentrations suggested by monitoring well data. Most seepage results show some evidence of dilution by riverwater (i.e., the concentrations are lower than might be expected based on nearby monitoring well data and specific conductance is lower than undiluted groundwater).

Chromium is the main contaminant of concern in the seepage samples, and the maximum observed value was 182 µg/L in the 100-D Area chromium hot spot.

5.6.4 Groundwater Remediation

Groundwater remediation activities in the 100-D/DR Area include a pilot-scale test of a pump-and-treat system to address chromium contamination in the vicinity of the D Reactor, an interim action to address a chromium plume that is approaching the river at the northern boundary of the 100-D/DR Area, and an in situ redox manipulation technology demonstration in the 100-D Area chromium hot spot.

5.6.4.1 Effects of Pilot-Scale Pump-and-Treat System

The pilot-scale system for extracting groundwater and treating it to remove chromium operated between August 1994 and August 1996 (DOE/RL-95-83). The groundwater-extraction-well network was located immediately north of the D Reactor building. The system removed ~50 kg of hexavalent chromium using Dowex 21K™ ion-exchange resin, the same resin used in the interim action for chromium in the 100-KR-4 and 100-HR-3 Operable Units (DOE/RL-96-84).

Concentration trend plots for the three wells used for groundwater extraction during the pilot-scale test are shown in Figure 5.6-6. All three wells show decreases in chromium concentrations that correlate with the operating period of the pumping system, which started in August 1994. (Note: The very low chromium concentration from well 199-D5-15 in late 1996 was not representative of aquifer conditions. At the time of sampling, groundwater had been diluted by clean water from the surface, which had infiltrated from a major water utility line leak). Wells 199-D5-18 and 199-D5-19 were used as injection wells for the effluent from the treatment system. FY 1997 chromium results from well 199-D5-18 reveal a decreasing trend from ~60 µg/L in 1994 to 20 µg/L in late 1996, possibly indicating the dilution caused by the injection of treated, clean effluent from the treatment system. There are no FY 1997 data for well 199-D5-19.

5.6.4.2 CERCLA Interim Action

The chromium plume being intercepted by a groundwater-extraction-well network was shown in Figure 5.6-1. Wells 199-D8-53 and 199-D8-54A are being used to extract groundwater, which is then piped across the 600 Area to the chromium-treatment facility in the 100-H Area.

The 100-HR-3 Operable Unit pump-and-treat system, which includes treating groundwater extracted from the 100-D/DR and 100-H Areas, was designed to meet the objectives stated in the record of decision (ROD 1995b, DOE/RL-96-84). The treatment system is located in the 100-H Area and consists of four 380-L/min treatment trains, each containing 4 ion-exchange columns filled with Dowex 21K™ resin that removes chromium from the influent. The treated effluent is injected back into the aquifer in the 100-H Area via wells 199-H3-3, 199-H3-4, and 199-H3-5. This system went into full operation by July 1, 1997, thus meeting Milestone M-16-06B (Ecology et al. 1989). A performance-evaluation report for the 100-HR-3 and 100-KR-4 Operable Units will be issued in April 1998 (Milestone M-16-06C; Ecology et al. 1989).

5.6.4.3 In Situ Redox Manipulation Technology Demonstration

A technology demonstration project is currently under way at the 100-D/DR Area (hot spot) as part of CERCLA environmental restoration activities. The demonstration is intended to determine the feasibility of using this technology to address hexavalent chromium contamination in groundwater. Concentrations of hexavalent chromium in this area exceed 1,000 µg/L. Also, elevated concentrations have been detected in samples of porewater collected from the riverbed sediments in the adjacent Columbia River (BHI-00778).

The goal of the project is to create a permeable treatment zone in the subsurface to remediate redox-sensitive contaminants in the groundwater. The permeable treatment zone is created by reducing the ferric iron to ferrous iron within the minerals of the aquifer sediments. This reduction is accomplished by introducing chemical reducing agents, such as sodium dithionite. After the aquifer sediments are reduced, any reagent or reaction products introduced into the subsurface are removed.

Redox-sensitive contaminants that can be treated by this technology include hexavalent chromium, technetium, uranium, and some chlorinated solvents (e.g., trichloroethylene). Hexavalent chromium is immobilized by reduction of the soluble chromate ion to highly insoluble chromium hydroxide or iron chromium hydroxide solid solution. This transformation is particularly advantageous because chromium is not easily reoxidized under ambient environmental conditions. Technetium and uranium can also be reduced to less-soluble forms, and chlorinated solvents can be destroyed by reductive dechlorination.

A successful proof-of-principle test of the process was conducted in 1995. The project has been monitored since its emplacement (PNL-11372). Hexavalent chromium concentrations within the reduced zone at the 100-H Area test site have been below the 8-µg/L detection limit of the measurement equipment since the test. Prior to the test, hexavalent chromium concentrations ranged up to 65 µg/L in this zone. Estimates of the lifetime of the reduced zone at the 100-H Area site range from 9 to 12 years based on analysis of core samples collected from the reduced zone. The successful completion of this field experiment led to the 100-D Area technology demonstration project.

A small-scale test section will be installed as part of this project to assess the performance and cost of the technology as a remediation alternative. The test section is located around well 199-D4-1 and is ~150 m inland from the Columbia River (see Plate 1). The test section has overall dimensions of 46 m long and 15 m wide, and will be created by overlapping five cylindrical reduced zones. The site contains five injection/withdrawal wells, along with one upgradient and five downgradient monitoring wells that are both fully screened and partially screened to provide monitoring for depth-discrete samples. Additional monitoring wells are also located within the reduced zone to monitor the injection and withdrawal process.

The reduced zones will be created by sequentially injecting and withdrawing a chemical reagent, consisting of sodium dithionite along with potassium carbonate and potassium bicarbonate pH buffers, in each of the five injection/withdrawal wells. The reagent is injected into the aquifer, given time to react with the aquifer sediments, and then the unreacted reagent and reaction products are removed from the aquifer by pumping from the same well used for injection. Approximately five times the injection volume is removed from the aquifer to recover a majority of the reagent. The withdrawn water will then be disposed of at the 616-A crib (also known as the State-Approved Land-Disposal Site) near the 200-West Area.

The first injection/withdrawal activity was conducted in September 1997. The remaining emplacements will be made in the spring and summer of 1998. The operation will be refined based on the analysis of the results from the September 1997 emplacement. Monitoring of the site will be ongoing after emplacement.

Baseline hydrologic and geochemical characterization has been conducted at the test site (e.g., constant-rate discharge tests, conservative tracer tests, slug interference tests, aqueous samples for major ions and trace metals, and sediment analyses). Baseline data will be compared with postemplacement measurements to evaluate the performance and to determine any side effects from this process.

5.7 100-H Area

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The 100-H Area contains one plutonium-production reactor, which operated between 1949 and 1965. A description of reactor operations and associated hazardous waste sites is presented in a report prepared to support environmental restoration (BHI-00127).

Remediation activities completed or currently under way include demolition and removal of a former waste-storage facility and associated contaminated soils and pumping and treating of groundwater to remove chromium.

5.7.1 Facilities and Operable Units

Existing facilities, hazardous waste sites, monitoring wells, and other general features of the 100-H Area are shown in Plate 1. For CERCLA environmental restoration purposes, the 100-H Area is divided into two source operable units (100-HR-1 and 100-HR-2) that address hazardous waste sites located at or near the ground surface. The 100-HR-1 Operable Unit contains a former treatment, storage, or disposal facility that is RCRA regulated: the 183-H solar evaporation basins. The waste discharged to the basins originated in the 300 Area fuel-fabrication facility and was predominantly acid-etch solution that had been neutralized with sodium hydroxide. The acid solutions included chromic, hydrofluoric, nitric, and sulfuric acids. The waste solutions, described as supersaturated, contained various metallic and radioactive constituents (e.g., chromium, technetium, uranium). All wastes have been removed, the facility has been demolished, and the underlying contaminated soils have been removed and replaced with clean fill. Because residual amounts of nitrate and fluoride remain in the soil, and these constituents are attributable to 183-H wastes, groundwater monitoring continues.

The principal past-practice waste sites that may have contributed to groundwater contamination are described as follows.

- The 107-H retention basin is located in the eastern part of the 100-H Area adjacent to the Columbia River. The basin received enormous volumes of reactor-coolant effluent that contained radionuclides and chromium and held the effluent for a short time to allow thermal cooling and radionuclide decay prior to discharging the effluent to the river via outfall pipes. The basin leaked at rates sufficient to create a mound on the underlying water table. Mounding enhanced the spread of contamination over a broad area that potentially exceeded the reactor area boundaries.

- The 107-H liquid waste-disposal trench received highly radioactive coolant effluent that resulted when a reactor fuel element failed. The effluent would be held briefly in the retention basin and then diverted to the nearby liquid waste-disposal trench instead of the normal discharge via river-outfall pipes. The trench was unlined and intended as a soil-column-disposal site.

- Relatively small soil-column-disposal facilities, such as cribs and french drains, were located near the H Reactor building. Contaminated water and sludges from the fuel-storage basin, located within the reactor building, were typically disposed to nearby trenches, though the fate of the fuel-storage-basin effluents is not well-documented. Fuel-storage-basin water typically contained high concentrations of tritium. Decontamination solutions, consisting of various acid solutions that picked up radionuclides and metals, were also disposed to the ground near the reactor. Decontamination solutions also contained large amounts of chromate.

Groundwater underlying the 100-H Area is part of the 100-HR-3 Operable Unit, which includes groundwater beneath the 100-D/DR Area as well (see Figure 5.2-4). Groundwater operable units address groundwater beneath the reactor areas and also groundwater in adjacent areas, Columbia River water, and river sediments that might be adversely impacted by contaminated groundwater from the reactor area.

5.7.2 Compliance Issues

Regulatory compliance issues related to groundwater in the 100-H Area include RCRA monitoring and CERCLA environmental restoration activities.

5.7.2.1 183-H Solar Evaporation Basins

This RCRA unit was monitored under a final-status compliance program during FY 1997 (WAC 173-303-645). Eight wells were sampled in the fall of 1996 and the spring of 1997, with four independent samples collected from each well. Contaminants of concern are technetium-99, uranium, nitrate, and chromium (see Appendix A). Downgradient concentrations were compared to concentration limits defined in the monitoring plan (WHC-SD-EN-AP-180).

Results of the September through December 1996 and March through June 1997 sampling events indicated that concentration limits for technetium-99, uranium, nitrate, and chromium were exceeded in one or more downgradient wells. These concentrations continued previously observed trends, and Ecology was notified in 1996 that concentration limits had been exceeded. In May 1997, a corrective action groundwater-monitoring plan was released (PNNL-11573). The corrective action will be implemented when modification C to the Hanford Site RCRA permit (Ecology 1994) becomes effective. The new plan calls for four wells to be sampled annually during a CERCLA pump-and-treat activity (PNNL-11573).

5.7.2.2 CERCLA Interim Action

In April 1996, a decision was made to proceed with accelerated groundwater remediation activities in the 100-H Area (ROD 1996b). Hexavalent chromium in groundwater that discharges into the Columbia River was viewed to pose a significant risk to aquatic organisms. A groundwater-extraction-well network was designed that would intercept the chromium plume near the river (DOE/RL-96-84). The system began operating in July 1997. Groundwater is extracted from five 100-H Area wells: 199-H3-2A, 199-H4-7, 199-H4-11, 199-H4-12A, and 199-H4-15A. The extracted groundwater is piped to the 1713-H building where an ion-exchange treatment system has been constructed. The treated effluent is returned to the aquifer via wells 199-H3-3, 199-H3-4, and 199-H3-5, located in the southwestern portion of the 100-H Area.

In addition to reducing the amount of hexavalent chromium that is entering the river along the 100-H Area shoreline, the interim pump-and-treat system is intended to produce data on the efficiency of the methodology and effectiveness of aquifer restoration. These data are being collected under a performance- and compliance-monitoring plan (DOE/RL-96-90, Draft A). The performance-evaluation report for the system is planned for April 1998.

5.7.2.3 100-HR-3 (H Area) Operable Unit Remedial Investigation

Concurrent characterization of groundwater contamination is being conducted as the interim action proceeds. The groundwater-monitoring schedule consists of predominantly annual sampling of wells and analyses for anions, metals, and radiological indicators (BHI-00916). The list of wells, frequency of sampling, and analyses to be performed are included in National Priorities List Agreement/Change Control Form No. 107, dated November 20, 1996.

5.7.2.4 Drinking Water Standards and Derived Concentration Guides

Technetium-99 and uranium continued to exceed standards in the area immediately downgradient of the 183-H solar evaporation basins. Chromium was elevated beneath the entire 100-H Area but only exceeded the 100-µg/L MCL near the basins and in one upgradient well. Chromium also exceeded the MCL in a well completed in the middle of the unconfined aquifer system. Nitrate continued to be elevated beneath most of the 100-H Area but only exceeded the 45-mg/L MCL downgradient of the basins and near the 107-H liquid waste-disposal trench. Strontium-90 was found at levels above the 8-pCi/L interim DWS near the 107-H retention basin and 107-H trench. No constituents exceeded the DCGs.

5.7.3 Extent of Contamination

In this section, the geographic distribution of groundwater contamination is described in relation to facilities and/or waste sites that are sources for the contaminants. Major groundwater contaminants are technetium-99, uranium, strontium-90, nitrate, and chromium. Water quality monitoring at the 100-H Area shoreline is also discussed.

5.7.3.1 183-H Solar Evaporation Basins

Groundwater chemistry near these basins is characterized by elevated levels of technetium-99, uranium, nitrate, chromium, sodium, and sulfate. All of these constituents were present in waste discharged to the basins when they were in use.

The concentrations of the waste indicators typically are highest in well 199-H4-3, located immediately downgradient of the basins. Although the concentrations have decreased several orders of magnitude in this well since the basins ceased operation, they remained above maximum contaminant levels for drinking water for most of the past year, as discussed below.

Technetium-99 and Uranium. The concentrations of these radionuclides are elevated in groundwater downgradient from the basins (Figures 5.7-1 and 5.7-2). As in previous years, the plumes extend from the basins toward the Columbia River. Contaminant levels have increased in well 199-H4-7, which was an extraction well for the interim action and is located at the northwestern corner of the basins. This well previously had very low or undetectable concentrations of technetium-99 and uranium. The increased concentrations observed in the most recent data from this well may be caused by pumping the well and capturing contaminated groundwater from beneath the basins. Alternatively, the unusually high water table and significantly modified groundwater-flow patterns during 1996 and 1997 may have displaced contaminated groundwater toward this well.

The highest concentration of technetium-99 in FY 1997 was 2,080 pCi/L in the April 1997 sample from well 199-H4-3. This well also contained the maximum uranium concentration (225 µg/L in October 1996). Concentrations vary widely in wells 199-H4-3 and 199-H4-4 because of changes in the elevation of the water table (Figures 5.7-3 and 5.7-4). Concentrations of waste indicators are highest in well 199-H4-4 during times of lowest water level; concentrations are lowest when the water table is high. This inverse relationship was also observed in well 199-H4-3 until the fall of 1996. Technetium-99 decreased sharply between September and October 1996 and remained relatively low in November and December 1996, though the water table also remained low during these months. A small peak in technetium-99 and uranium concentrations was seen in April 1997 as the water table was increasing, which was opposite the usual inverse relationship.

High-river-discharge conditions affect the groundwater-flow pattern in the 100-H Area by causing a change in predominant flow direction from east-northeast to southeast, particularly in areas near the river. The unusually high-river discharge during 1996 and 1997 caused the plume associated with the basins to be displaced to the south. FY 1997 data for well 199-H4-18, located at the northwestern corner of the 107-H retention basins and at the normal southern boundary for the plume, showed an increase and subsequent decrease in contaminant indicators during calendar year 1996, as illustrated for uranium in Figure 5.7-5. In FY 1997, concentrations remained relatively stable but were higher than historical levels. Water-table conditions may have caused a temporary shift in the contaminant-migration pattern. An alternative explanation is that the unusually high water table remobilized contamination on the normally unsaturated soils in the vicinity of well 199-H4-18. Nearby well 199-H4-11 showed a small increase in waste indicators in late 1996, though the true height of the peak may have been undetected because this well was sampled less frequently than well 199-H4-18.

Nitrate. The basins contributed to a more widespread plume of nitrate (see Plate 4). Nitrate exceeds the MCL immediately downgradient of the basins. Figure 5.7-6 illustrates nitrate concentrations in wells 199-H4-3 and 199-H4-4 for the past 5 years. Nitrate concentrations show the same patterns and apparent relationships to water level as do technetium-99 and uranium, including the recent anomaly in well 199-H4-3.

Chromium. The basins also contributed to a more widespread plume of chromium (see Figure 5.6-1). Concentrations in filtered samples exceeded the MCL downgradient of the basins in wells 199-H4-3 and 199-H4-4 during FY 1997 (Figure 5.7-7). Chromium contamination is discussed in more detail in Section 5.7.3.2.

Fluoride. Fluoride was detected in the vadose zone beneath the basins, making it a constituent of interest for RCRA postclosure care (DOE/RL-97-48, Draft A; PNNL-11573). Fluoride has been higher in downgradient well 199-H4-3 than in upgradient wells in the past, but during FY 1997, fluoride declined in this well. Recent and historical values are all below the 4-mg/L MCL.

5.7.3.2 Other Sources of Contamination

The 107-H retention basins, 107-H trench, and disposal facilities near H Reactor contributed to groundwater contamination in the 100-H Area. The most significant contaminants are tritium, strontium-90, nitrate, and chromium.

Tritium. Tritium levels remained below the 20,000-pCi/L interim DWS but were somewhat elevated beneath the 100-H Area (see Plate 3). Tritium concentrations are lowest in wells near the Columbia River.

Strontium-90. Additional results are available this year to describe strontium-90 in the area between the 107-H retention basins and the river, where concentrations were slightly above the 8-pCi/L interim DWS in FY 1997 (Figure 5.7-8).

Nitrate. A small, poorly defined plume exceeded the 45-mg/L MCL near the 107-H liquid waste-disposal trench for the first time in FY 1997 (see Plate 4). Nitrate concentrations throughout the 100-H Area increased in FY 1997, with a larger area encompassed by the 20-mg/L contour than in FY 1996 (Plate 4 in PNNL-11470).

Chromium. The chromium distribution pattern for FY 1997 at the 100-H Area (see Figure 5.6-1) remains essentially the same as presented in FY 1996 (BHI-00917; Section 6.7.3 of PNNL-11470). Concentrations of chromium near or over 100 µg/L were detected in wells 199-H4-48 and 199-H4-14 and are attributed to decontamination solutions disposed of near the H Reactor building. Concentrations in the three new injection wells (199-H3-3, 199-H3-4, and 199-H3-5), located in the western (inland) portion of the 100-H Area and immediately north of the solid waste-burial ground, help confirm the arrival of chromium-bearing groundwater from upgradient sources (i.e., past disposal at the 100-D/DR Area). These values are not included in Figure 5.6-1 because they are for unfiltered samples. The arrival of this contamination is also indicated by the presence of chromium in riverbank seepage and aquifer-sampling tubes at locations upgradient of 100-H Area sources.

5.7.3.3 Water Quality at Shoreline-Monitoring Locations

The 100-H Area was the first location where riverbed sediment porewater was collected by divers. Seventeen transects of two stations each were sampled in March/April 1995 (BHI-00345, Rev. 1). Hexavalent chromium was detected at two locations, both adjacent to the 107-H retention basins, at concentrations of ~100 µg/L.

Aquifer-sampling tubes were installed at ~300-m intervals along the 100-H Area shoreline during the fall of 1997 (BHI-01090). These polyethylene tubes were driven into the aquifer at locations near the low-water shoreline. At each location, multiple tubes monitor several depths in the aquifer. Analyses of the water from these tubes included screening for tritium, gross beta, nitrate, and hexavalent chromium. Analytical results for initial samples from the tubes were presented in BHI-01153. The highest results were tritium (3,060 pCi/L), gross beta (54 pCi/L), nitrate (44,000 µg/L), and hexavalent chromium (29 µg/L). These results are generally consistent with contamination inferred from monitoring wells.

Riverbank seepage was sampled in the fall of 1996 and again in the fall of 1997 (results for the latter event were not available when this report was compiled). Analyses of water and sediment samples collected included anions, gross alpha, gross beta, and metals, along with field measurements for pH, specific conductance, and temperature. Samples were only collected if the specific conductance of the seepage indicated that groundwater was present (i.e., that riverwater stored in the bank since the last high-river stage had drained back to the river).

For the fall 1996 sampling event, chromium in filtered samples along the 100-H Area was present in the 20- to 40-µg/L concentration range. Gross beta is somewhat elevated in riverbank seepage near the 107-H retention basins, with an activity of 85 pCi/L.

5.7.4 Groundwater Remediation

Groundwater remediation activities in the 100-H Area consist of an interim action to pump and treat groundwater contaminated by chromium. The objective is to reduce the amount of hexavalent chromium that is entering the river via groundwater discharge from the aquifer. The interim action extracts groundwater from wells in the 100-D/DR and 100-H Areas, removes chromium at a treatment facility in the 100-H Area, and reinjects the treated effluent into wells in the 100-H Area. The system was designed to meet objectives stated in the record of decision (ROD 1996b, DOE/RL-96-84).

The treatment system at the 100-H Area consists of four, modular, 380-L/min treatment trains containing ion-exchange columns filled with Dowex 21K™ resin to remove chromium from the influent. The extraction system consists of a total of 7 extraction wells, 2 at the 100-D/DR Area (199-D8-53 and 199-D8-54A) and 5 at the 100-H Area (199-H3-2A, 199-H4-7, 199-H4-11, 199-H4-12A, and 199-H4-15A). The total pumping rate from the extraction wells is ~640 L/min. During FY 1997, screening detected a slight radiological buildup on the resins. The radionuclide responsible was determined to be technetium-99 and the source to be well 199-H4-7. A resin changeout was completed, and pumping from well 199-H4-7 was stopped.

Two of the four treatment trains are currently in use. The treated effluent is injected at wells 199-H3-3, 199-H3-4, and 199-H3-5. This system went into full operation prior to July 1, 1997, a requirement of

Milestone M-16-06B (Ecology et al. 1989). A performance evaluation report for the 100-HR-3 and 100-KR-4 Operable Units interim action will be issued in April 1998.

5.8 100-F Area

M. D. Sweeney

The 100-F Area is located the farthest east and downstream of the other reactor areas. F Reactor operated from 1945 to 1965. Like all of the other Hanford Site reactors, except for N Reactor, it was cooled by a single-pass system (i.e., cooling water passed through the reactor and was discharged directly to the Columbia River).

5.8.1 Facilities and Operable Units

For CERCLA environmental restoration activities, the 100-F Area is divided into two source operable units (100-FR-l and 100-FR-2), which contain hazardous waste sites at or near the surface. A single groundwater operable unit (100-FR-3) addresses contamination at and below the water table, which extends from beneath the source operable units laterally to adjacent areas where contamination may pose a risk to human and ecological receptors (see Figure 5.2-4). For the 100 Areas, the lateral boundary is generally considered to be where Hanford Site groundwater meets Columbia River water. This interface occurs along the riverbanks and within the riverbed substrate.

High-priority waste sites in the 100-FR-1 Operable Unit include reactor-coolant-water-retention basins, liquid waste-disposal trenches, associated effluent pipelines, and french drains near the F Reactor building. High-priority sites in the 100-FR-2 Operable Unit are primarily burial grounds that received radioactive and mixed wastes. Descriptions of high-priority waste sites are presented in the proposed plans for remediation activities in each of these source operable units (DOE/RL-95-54, Draft B; DOE/RL-95-92, Decisional Draft).

Contamination of groundwater occurred as the result of liquid effluent disposal associated with past reactor operations and from solid wastes disposed in burial grounds. A conceptual site model for groundwater contamination in this operable unit is included in BHI-00917.

There are no active facilities or waste-disposal sites in the 100-F Area. The facilities associated with former reactor operations that may have affected groundwater (summarized below) are being decommissioned and remediated under CERCLA. A description of reactor operations and associated hazardous waste sites is presented in a report prepared to support environmental restoration (WHC-SD-EN-TI-169).

The greatest volumes of liquid wastes in the 100-F Area were associated with the 116-F-14 retention basin and pipelines that lead to the basin from the F Reactor building. The retention basin is located near the Columbia River in the eastern part of the 100-F Area and received enormous volumes of reactor-coolant-water effluent that contained radionuclides and sodium dichromate. The basin held the effluent for a short time to allow thermal cooling and radionuclide decay before being discharged to the Columbia River. The basin developed significant leaks, creating a mound on the underlying water table that enhanced the spread of contamination.

The 116-F-2 overflow trench, located near the 116-F-14 retention basin, received highly radioactive effluent from the basin and F Reactor. A second trench (116-F-9) is also located near the retention basin and received liquid wastes from cleaning the experimental animal laboratories. The trenches were unlined and intended as soil-column-disposal sites because the natural soils were known to retain many radionuclides.

Other prominent liquid waste-disposal sites include cribs and french drains near the F Reactor building. The 116-F-6 and 116-F-3 trenches received cooling water and sludge from F Reactor. The 116-F-1 trench received liquid waste from F Reactor and associated buildings. Effluent discharged to these facilities contained radionuclides and metals.

Solid waste-burial grounds are located in the southwestern part of the 100-F Area. They were used to dispose of contaminated equipment, animal wastes from the experimental animal laboratories, or coal ash and soil.

5.8.2 Compliance Issues

The 100-F Area is monitored under both CERCLA and DOE Order 5400.1. Both programs have been combined under a sitewide monitoring program managed by Pacific Northwest National Laboratory. Each of the individual program requirements is maintained, but sampling schedules and analyte selection are coordinated.

The groundwater-monitoring network in the 100-F Area includes a total of 22 groundwater wells and 4 seeps at the Columbia River shoreline. Most of the wells were sampled annually for the reporting period; however, quarterly sampling was also performed at three of the monitoring wells and semiannual sampling occurred at five wells.

Constituents of concern include tritium, strontium-90, nitrate, and trichloroethylene. No concentrations of tritium exceeded the 20,000-pCi/L interim DWS in FY 1997; however, the well that exceeded the interim DWS in FY 1996 was not sampled this fiscal year. Strontium-90 exceeded the 8-pCi/L interim DWS in three wells. Uranium exceeded its proposed MCL in one well. Nitrate exceeded the 45-mg/L MCL in most of the 100-F Area monitoring wells in FY 1997. Trichloroethylene continued to exceed the MCL in the southwestern 100-F Area. No radiological constituents exceeded the DCGs.

5.8.3 Extent of Contamination

Primary groundwater contaminants in the 100-F Area are tritium, strontium-90, and nitrate. Chromium, trichloroethylene, and uranium concentrations are also elevated locally. Contaminants are organized below by their general source areas.

5.8.3.1 118-F-1 and 118-F-6 Burial Grounds

Tritium was elevated in most of the wells in the southeastern 100-F Area in FY 1997 (see Plate 3). In FY 1996, well 199-F8-3 near the 118-F-1 burial ground averaged 110,000 pCi/L. This well is sampled every other year and was not sampled in FY 1997, but the plume is assumed to remain. It is unusual to observe tritium concentrations this high near a solid waste-burial ground where there is no obvious liquid waste disposal nearby.

Tritium concentrations were well below the 20,000-pCi/L interim DWS in other parts of the 100-F Area. Concentrations generally tended to be declining, but well 199-F5-47 reported an increase from ~3,700 pCi/L in FY 1995 to an average of ~5,700 pCi/L in FY 1997.

5.8.3.2 116-F-14 Retention Basin and 116-F-2 Liquid Waste-Disposal Trench

Strontium-90. Strontium-90 exceeded the 8-pCi/L interim DWS in several wells in the eastern part of the 100-F Area near the 116-F-14 basin and the 116-F-2 trench (Figure 5.8-1). The highest activity of strontium-90 was 282 pCi/L in well 199-F5-3 in the October 1996 sampling event, an increase from previous years. The September 1996 result from nearby well 199-F5-1 was 63 pCi/L, declining to 10.3 pCi/L in September 1997. Well 199-F5-46 also exceeded the DWS in September 1997 (10.1 pCi/L).

Chromium. Chromium in filtered samples was detected in most of the wells in the northeastern 100-F Area, but did not exceed the 100-µg/L MCL in FY 1997. Well 199-F5-46, which exceeded the MCL from FY 1993 through FY 1995, had the highest filtered chromium concentration in the 100-F Area in FY 1997 (at 83 µg/L in September 1997). Well 199-F5-6 had the next highest concentration (33 µg/L), a decline from FY 1996. Some of the other nearby wells were not sampled until October 1997; chromium in those wells was <20 µg/L.

5.8.3.3 Vicinity of F Reactor

Uranium. Only one well exceeded the 20-µg/L proposed MCL during FY 1997. Well 199-F8-1 reported an increase from 28 µg/L in FY 1996 to 48 µg/L in FY 1997. Both of these values are much lower than the FY 1995 value of 257 µg/L. Well 199-F8-1 is located south of the F Reactor building near several solid and liquid waste-disposal facilities. Uranium in nearby wells ranged from 10 to 16 µg/L, which is fairly consistent with trends when historical data exist.

Strontium-90. Strontium-90 concentrations exceeded the 8-pCi/L interim DWS in a small area near the F Reactor building in FY 1996 (wells 199-F5-47 and 199-F5-48). Concentrations declined below the interim DWS in these wells in FY 1997.

Nitrate. Elevated throughout most of the 100-F Area (see Plate 4), nitrate exceeded the 45-mg/L MCL in most of the monitoring wells near the reactor building and solid waste-burial grounds, reaching the 100-mg/L level. Nitrate provides a good indication of contaminant movement through preferential pathways created by buried former river channels. Movement of nitrate is generally to the south and southeast from sources near the F Reactor building and the 116-F-1 trench.

5.8.3.4 Other Contamination

Trichloroethylene was detected in the southwestern corner of the 100-F Area and in the adjacent 600 Area. The maximum concentration in FY 1997 in well 199-F7-1 was 18 µg/L, which exceeds the 5-µg/L MCL. Trend plots for this well and a nearby well in the 600 Area (699-77-36) illustrate a gradual decline (Figure 5.8-2). A trichloroethylene field screening investigation in soil-vapor and groundwater was performed in 1995 (DOE/RL-95-99). The extent of contamination was delineated but no specific sources were identified.

5.8.3.5 Water Quality at Shoreline-Monitoring Locations

Aquifer-sampling tubes were installed at ~300-m intervals along the 100-F Area shoreline during the fall of 1997 (BHI-01090). These polyethylene tubes were driven into the aquifer at locations near the low-water shoreline. At each location, multiple tubes monitor several depths in the aquifer. Analyses of the water from these tubes included screening for tritium, gross beta, nitrate, and hexavalent chromium.

Analytical results for initial samples from the tubes were presented in BHI-01153. The highest results were tritium (1,040 pCi/L), gross beta (12.3 pCi/L), nitrate (30,000 µg/L), and hexavalent chromium (14 µg/L). These concentrations are very low relative to typical water quality standards. Part of the reason for the low values is that many of the samples showed evidence of significant dilution by riverwater (i.e., bank storage).

Riverbank seepage was sampled during the fall of 1997 at a single site under the CERCLA remedial investigation for the 100-FR-3 Operable Unit, in accordance with Federal Facility Agreement and Consent Order Change Control Form No. M-15-96-06, dated July 31, 1996. The specific conductance of the sample (382 µS/cm) indicates that the sample was primarily groundwater, with minimal or no dilution by riverwater.

Typical reactor area contaminant indicators were detected at relatively low concentrations, with the highest detected values as follows: tritium (1,240 pCi/L), gross beta (16 pCi/L), gross alpha (12 pCi/L), nitrate (54,892 µg/L), and chromium (23.6 µg/L). Analyses for strontium-90, carbon-14, and organic compounds produced nondetections.

5.9 200-West Area

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The 200-West Area was used historically for chemical separation and purification of plutonium and associated waste management. For reasons of safety and security, the area was established with a significant spatial separation from the 200-East Area and with some redundancy of function. Differing hydrogeology between the two sites resulted in significant dissimilarities in the degree of the spread of contaminants. Four key source areas in the environs of the 200-West Area will be discussed: T Plant, Reduction-Oxidation (REDOX) Plant, U Plant, and Plutonium Finishing Plant (formerly known as Z Plant).

Numerous waste-disposal and -storage facilities, including cribs, trenches, tile fields, surface impoundments, tank farms, and landfills, are located in the 200-West Area. Specific facilities that may have contributed to groundwater contamination will be discussed, as appropriate, in Section 5.9.3. However, because of the complexity of past waste-disposal operations in the 200 Areas, as well as the close spacing of the facilities, it is often difficult to determine the exact source of contamination. Groundwater remediation activities are grouped into groundwater operable units. These units are distinct from the numerous source area operable units for facility and vadose-zone remediation.

5.9.1 Facilities and Operable Units

5.9.1.1 T Plant

T Plant used the bismuth phosphate process from December 1944 through August 1956 to separate plutonium from irradiated fuel (WHC-MR-0132). More recently, T Plant has been used as an equipment-decontamination facility. The waste facilities for T Plant are located generally southwest of the plant and include cribs and Tank Farms T and TX-TY (also known as waste management areas [WMAs]. Waste management techniques changed during the period of operations, reducing the volume of waste produced for a given amount of fuel processed. Waste-disposal practices were complex and changed, depending on available storage capacity and treatment technology. Between 1948 and 1956, the tanks were used for settling of solids from second-decontamination-cycle wastes in a cascading system. The supernatant from the last tank in the cascade was discharged to nearby cribs or specific retention trenches (WHC-MR-0227). From 1951 to 1956, cell drainage waste was discharged through the cascade with the second-cycle waste. From 1951, the 242-T evaporator was used to reduce the volume of first-decontamination-cycle wastes, though in 1953-1954, some first-cycle waste was discharged to specific retention trenches. In 1954, scavenging operations to reduce the radioactivity of first-cycle waste began (WHC-MR-0132). The scavenged supernatant was disposed to the 216-T-26 crib (WHC-MR-0132, WHC-MR-0227). Waste from the original plutonium concentration facility in the 224-T building was settled in 208,000-L, 200-series, single-shell tanks before being discharged to cribs. In addition, WHC-MR-0227 indicated that, in 1954, evaporator bottoms (concentrated waste) from the 242-T evaporator were discharged to the 216-T-25 trench. Thus, some of the most radioactive liquid waste was discharged to the ground rather than being stored in tanks. The wastes discharged were closely related to tank wastes; the tanks, however, apparently retained much of the solid fraction in the waste streams. At WMA T, 6 of 12 tanks are known or suspected to have leaked; at WMA TX-TY, 13 of 24 tanks are known or suspected to have leaked.

There are a number of significant waste-discharge sites in the T Plant area. Of particular interest is the 216-T-26 crib that received diverse chemical and radiological waste, including first-cycle-scavenged waste via the 101-TY, 103-TY, and 104-TY tanks (PNL-6456). The adjacent 216-T-28 crib received large amounts of water, as well as some decontamination wastes. The large volumes of water discharged to the 216-T-28 crib may have enhanced migration of contaminants from nearby sources. The 216-T-19 crib and tile field are located south of WMA TX-TY and received a variety of waste streams, including condensate from the 242-T evaporator and second-cycle supernatant waste. As discussed above, the 216-T-25 trench, located west of WMA TX-TY, received evaporator bottom waste.

Contaminants found in the groundwater near T Plant include tritium, iodine-129, technetium-99, nitrate, chromium, carbon tetrachloride, chloroform, trichloroethylene, and fluoride.

5.9.1.2 REDOX Plant

Operation of the REDOX Plant began in 1951 and continued through 1967, with its primary mission to separate plutonium from uranium and fission products using countercurrent solvent extraction, eventually replacing the bismuth phosphate process used in T and B Plants. The solvent-extraction process used an organic solvent (hexone) to separate plutonium from uranium fuel that had been dissolved in nitric acid. Chemical contaminants found in the groundwater near the REDOX Plant include nitrate and minor amounts of trichloroethylene. The carbon tetrachloride plume prevalent in most of the rest of the 200-West Area is largely absent near the REDOX Plant, apparently as a consequence of the low-permeability sediment in that area and the lack of any local discharges of carbon tetrachloride. The main radiological contaminants are tritium, iodine-129, technetium-99, and uranium.

Disposal facilities associated with the REDOX Plant are generally located to the west of the plant. A number of disposal facilities, including several ponds that received large amounts of water, are located outside the 200-West Area perimeter fence. Waste from the redox process is stored in WMA S-SX (single-shell tanks) and WMA SY (double-shell tanks). Of the 27 single-shell tanks, 11 are known or assumed to have leaked. A number of disposal facilities located around WMA S-SX received waste from REDOX Plant operations, including condensate from the self-boiling waste tanks. Leakage of piping and transfer boxes during tank farm operations may also have released contaminants in this area. WHC-MR-0227 indicated that tank wastes were not discharged directly to ground via pumping or cascade overflow from WMA S-SX.

5.9.1.3 U Plant

U Plant was originally designed as a plutonium-separation facility but was never used for that purpose. The plant was converted in 1952 to recover uranium from "metal waste" generated by the bismuth phosphate process that had been stored in tanks up to that time. The uranium-recovery process used tributyl phosphate solvent extraction; however, the process generated a large amount of waste to be stored in the single-shell tanks. In 1954, ferrocyanide and nickel scavenging of the waste from the uranium recovery began. Supernatant from the scavenged waste then was discharged to ground after settling in 200-East Area single-shell tanks. Discharge was primarily to the BY cribs in the northern 200-East Area between 1954 and 1955; subsequent discharge in 1956-1958 was to the BC cribs and specific retention trenches located south of the 200-East Area (WHC-MR-0227). Other process waste was discharged to cribs generally south and west of U Plant. Groundwater contaminants in the U Plant area include iodine-129, technetium-99, uranium, nitrate, and trichloroethylene. In contrast to many parts of the fuel-processing areas, tritium contamination near U Plant is only minor.

5.9.1.4 Plutonium Finishing Plant

Z Plant was constructed in 1949 to purify plutonium and reduce it to a metallic state. In the early 1980s, the plant was modernized and renamed the Plutonium Finishing Plant. The mission of the plant remained essentially unchanged but liquid discharges were significantly reduced. Primary wastes associated with the plant include transuranics (primarily plutonium and americium), nitrate, carbon tetrachloride, tributyl phosphate, dibutyl phosphate, dibutylbutylphosphonate, aluminum fluoride nitrate, and lard oil. Transuranic contaminants typically remain bound in the soil column at relatively shallow depths, though there are exceptions particularly where complexants for plutonium were present in the waste stream (see Section 4.1.2). Alkyl phosphates were not observed in the groundwater and their fate is still relatively obscure. Lard oil is expected to remain at shallow depth in the soil because of its high viscosity. Nitrate, carbon tetrachloride, chloroform, and trichloroethylene associated with the plant's cribs produced plumes in the groundwater. Wastes were disposed to a number of nearby facilities. The 216-Z-1A crib and 216-Z-9 trench are considered to be major sources of groundwater contamination.

5.9.1.5 RCRA Facilities

A number of facilities in the 200-West Area are being monitored under RCRA. Additional detail on those facilities is warranted by the RCRA-monitoring and -reporting requirements.

Single-Shell Tank Farms. The single-shell tanks that are currently storing hazardous, radioactive wastes in the 200-West Area are located in WMAs S-SX, T, TX-TY, and U (see Plate 1 and Appendix A). These WMAs have been designated as RCRA facilities since 1989.

Currently, the single-shell tanks are used to store mixed waste received from various chemical-processing facilities. These tanks were constructed between 1943 and 1964 and, depending on dimensions, each held between 1,892,500 and 3,785,000 L. WMAs T and U contain four, smaller, 200-series tanks that hold 208,175 L each. The waste in the tanks was generated by chemical processing of spent fuel rods using the tributyl phosphate, bismuth phosphate, REDOX, or plutonium-uranium-extraction (PUREX) processes.

The single-shell tanks received mixtures of organic and inorganic liquids containing radionuclides, solvents, and metals that were originally discharged to the tanks as alkaline slurries. Waste management operations mixed various waste streams from numerous activities generated in the processing of spent fuel rods. Thus, the original contents within each tank are difficult to determine. The situation is further complicated by subsequent chemical reactions, degradation, and decay of radionuclides. However, much recent work has been done to characterize the tank waste (e.g., LA-UR-94-2657, Rev. 2; LA-UR-96-858). The radionuclide and chemical inventories of the single-shell tanks are summarized in WHC-SD-WM-TI-565, Rev. 1; waste types and historical operations at the tank farms are summarized in WHC-MR-0132. Tank wastes were, in some instances, discharged to nearby cribs, unlined specific retention trenches, unlined ditches, french drains, and ponds.

Tank wastes exist in the form of salt cake and sludge, which is left after the liquids were removed. However, there are small quantities of supernatant and interstitial liquids that could not be removed by pumping. The wastes consist predominantly of sodium hydroxide and sodium salts of nitrate, nitrite, carbonate, aluminate, and phosphate. Some hydrous oxides of iron and manganese also are present. Fission-product radionuclides, such as technetium-99, strontium-90, and cesium-137, and actinide elements, such as neptunium, plutonium, thorium, and uranium, constitute the principal radioactive components. Some of the tanks also contain ferrocyanide or organic salts.

216-U-12 Crib. This crib is located ~610 m south of U Plant (see Plate 1). This crib is an unlined, gravel-bottomed, percolation crib that has bottom dimensions of 3.05 m wide, 30.5 m long, and 4.3 m deep. The crib has a plastic barrier cover and is backfilled with the original excavated soil. A vitrified clay distributor pipe buried in gravel dispersed the effluent across the bottom of the crib.

The crib received U Plant wastewater from April 1960 until February 1988, when the crib was permanently retired and replaced by the 216-U-17 crib. The wastewater disposed to the 216-U-12 crib contained dangerous waste and radioactive materials. Specifically, the waste was composed of effluent from U Plant and included 291-U-1 stack drainage and highly acidic process condensate from the 224-U building. The 216-U-12 crib received this waste stream from April 1960 until 1972, when it was deactivated. The crib was reactivated in November 1981 and received U Plant waste until it was permanently retired in February 1988. An average of >133,000,000 L/yr of effluent were disposed to this crib during its active life. Also, the crib received small amounts of radioactive waste that is known to have included nitric acid in addition to plutonium, ruthenium-106, strontium-89/-90, and uranium. In 1985, physical controls and operating procedures were modified to avoid inadvertent discharge of hazardous chemicals to the wastewater stream.

216-S-10 Pond and Ditch. This facility is located south-southwest of the 200-West Area outside the perimeter fence (see Plate 1). Initially, the facility consisted of an open, unlined ditch ~1.8 m deep, 1.2 m wide, and 686 m long. An open, unlined percolation pond, constructed at the southwest end of the 216-S-10 ditch and ~2.0 ha in size, was also active during part of the time that the ditch was receiving waste.

The ditch began receiving waste from the REDOX Plant in August 1951. The pond was excavated and placed in service in February 1954. In October 1985, the pond and portions of the ditch were decommissioned and backfilled. The remaining portion of the ditch received nondangerous, nonregulated waste from the 202-S building chemical sewer. The waste stream included cooling water, steam condensate, water tower overflow, and drain effluent. From 1985 to October 1991, physical controls and operating procedures were modified to avoid inadvertent discharge of hazardous chemicals to the wastewater stream. The effluent stream to the 216-S-10 facility was permanently deactivated in October 1991. The facility will not receive additional dangerous substances and will be closed in final status pursuant to WAC 173-303-610.

Releases of dangerous constituents to the 216-S-10 facility are poorly documented. Radioactive waste was reportedly disposed to the facility as a result of contaminated floor and sewer drains at the REDOX Plant. Hazardous chemical releases were documented in 1954 and 1983 and included aluminum nitrate, sodium nitrate, sodium phosphate, sodium hydroxide, sodium fluoride, sodium chloride, and potassium dichromate.

Low-Level (LL) Waste Management Areas. LLWMAs 3 and 4 are monitored under RCRA interim-status regulations and include a number of burial grounds within each area.

Burial grounds 218-W-3A, 218-W-3AE, and 218-W-5 make up LLWMA 3, located in the north-central portion of the 200-West Area (see Plate 1 and Appendix A). These facilities cover 74.3 ha. Burial ground 218-W-3A began accepting waste in 1970 and received primarily ion-exchange resins and failed equipment (e.g., tanks, pumps, ovens, agitators, heaters, hoods, jumpers, vehicles, and accessories). Burial ground 218-W-3AE began operation in 1981 and contains low-level and mixed waste, including rags, paper, rubber gloves, broken tools, and industrial waste. Burial ground 218-W-5 first received waste in 1986, and contains low-level and low-level-mixed waste, including lead bricks and shielding.

LLWMA 4 covers 24.4 ha in the south-central portion of the 200-West Area. Burial grounds 218-W-4B and 218-W-4C make up LLWMA 4 (see Plate 1 and Appendix A). Burial ground 218-W-4B first received waste in 1968 and contains mixed and retrievable transuranic waste in trenches and 12 caissons. One caisson is believed to contain mixed waste. Waste was first deposited in burial ground 218-W-4C in

1978. Transuranic, mixed, and low-level waste placed in burial ground 218-W-4C included contaminated soil, decommissioned equipment, and remote-handled transuranic waste.

LLWMA 5, located in the north-central portion of the 200-West Area, has been eliminated from further groundwater monitoring because no waste has been disposed to this facility and there are no plans for its use (see Plate 1 and Appendix A).

5.9.1.6 Other Facilities

State-Approved Land-Disposal Site. This site, the 616A crib (also known as the State-Approved Land-Disposal Site) is located ~500 m north of the 200-West Area northern boundary (see Plate 1). The site consists of a drain field that receives treated effluent from the 200 Areas Effluent-Treatment Facility, located near the northeastern boundary of the 200-East Area. That facility receives liquid wastes from various Hanford Site cleanup activities. Those wastes are stored temporarily in the Liquid Effluent-Retention Facility (Section 5.10.1.10). The treated effluent, containing nominally high levels of tritium (~1.0E+08 pCi/L), is transported by pipeline across the 200 Areas plateau to the State-Approved Land-Disposal Site for disposal. This site is regulated by a state waste discharge permit (Section 5.9.2.8), and began receiving effluent in 1995.

Environmental Restoration Disposal Facility. This facility receives waste material generated by the environmental restoration program during remediation of the Hanford Site and is located southeast of the 200-West Area. The facility contains two cells and will expand on an as-needed basis to accommodate excavated soil and debris generated from remediation activities. This waste material may have elevated levels of radionuclides and/or hazardous materials. The site covers 4.1 km^2, but ~67 ha were used for the initial waste cells. An additional 23 ha will be utilized during the first expansion, which is currently under way. The facility is constructed as a single, 21.3-m deep trench, consisting of a series of two side-by-side cells each measuring 152.4 x 152.4 m at the base, with a finished wall slope of 3 horizontal to 1 vertical. Current dimensions are 432.8 m long (north-south) by 219.5 m wide (east-west) at the top of the trench. The trench design includes a double liner and leachate-collection system compliant with RCRA minimum technology requirements.

5.9.1.7 Operable Units

Only two CERCLA groundwater operable units (200-UP-1 and 200-ZP-1) relate to 200-West Area contamination (see Figure 5.2-4). These operable units are defined mainly on the basis of the contaminant plumes, rather than on precisely defined geographic regions. The 200-UP-1 Operable Unit generally covers the groundwater in the southeastern part of the 200-West Area. Currently technetium-99 and uranium contamination in the vicinity of U Plant are being addressed by the 200-UP-1 interim action. The 200-ZP-1 Operable Unit generally covers groundwater contamination in the northwestern part of the 200-West Area, though 200-ZP-1 interim actions for carbon tetrachloride that extend to other parts of the area are considered part of the operable unit.

5.9.2 Compliance Issues

5.9.2.1 WMAs T and TX-TY Single-Shell Tank Farms

In November 1992, WMAs T and TX-TY were triggered into groundwater quality assessment monitoring because of specific conductance exceedances in downgradient wells. An assessment plan covering both WMAs was prepared (WHC-SD-EN-DP-042) and a Phase I assessment report based mainly on data from FY 1997 and earlier was released in January 1998 (PNNL-11809).

WMA T was triggered into assessment monitoring because of specific conductance exceedances in downgradient well 299-W10-15 (see Appendix A for well locations). Subsequently, in late 1995, specific conductance increased rapidly in well 299-W11-27, exceeding the critical mean for the WMA in the August 1996 sample. The increase in specific conductance was accompanied by increases in technetium-99 and other cocontaminants (Section 5.9.3.1). Assessment findings indicate that contaminants in well 299-W10-15 are a result of sources external to the WMA. There is strong evidence, however, that contaminants observed in well 299-W11-27 are a result of sources within the WMA, so a Phase II assessment will be performed.

WMA TX-TY was triggered into assessment because of specific conductance exceedances in wells 299-W10-17 and 299-W14-12. The exceedance in well 299-W14-12 was accompanied by elevated tritium, iodine-129, technetium-99, and cobalt-60. Assessment results indicate that contaminants in well 299-W10-17 are a result of sources external to the WMA. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the WMA; however, upgradient sources remain a possibility. Because there is no direct evidence for upgradient sources, a Phase II assessment will be performed.

If the current rate of water-level decline continues, all wells in the RCRA-monitoring networks for WMAs T and TX-TY will be dry by the end of 1998. A precursor to this trend, WMA T downgradient well 299-W10-15 could not be sampled in August 1997 because of insufficient water within the screened interval. The loss of these wells is taking place much sooner than originally expected because of the rapid drop in water levels in the area following the cessation of effluent discharges in 1995. This is clearly shown by the inflection in the hydrographs presented in Figure 3.6-10 Non-RCRA well 299-W10-18 will be used, at least temporarily, as a replacement for well 299-W10-15. Plans are in place for two new monitoring wells at WMA T and four new monitoring wells at WMA TX-TY, which along with several older wells will be used to maintain the assessment-monitoring networks for these WMAs.

5.9.2.2 WMA S-SX Single-Shell Tank Farms

A detection-level groundwater-monitoring program for WMA S-SX was initiated in 1990. This unit was placed in assessment-level monitoring status in May 1996 in response to a directive from Ecology (WHC-SD-EN-AP-191). The directive cited anomalous trends in technetium-99 and elevated specific conductance in vicinity groundwater as primary reasons for the assessment. A Phase I (or first determination) groundwater quality assessment plan was written in response to Ecology's directive and was submitted in August 1996 (WHC-SD-EN-AP-191). A report on the findings of the first determination was submitted to Ecology in 1998 (PNNL-11810). The report concluded this WMA has contributed to groundwater contamination. Accordingly, investigation of the nature and extent of the contamination is required.

The DWS exceedances in RCRA-compliant monitoring wells are currently limited to one well (299-W22-46) at the southeastern corner of the SX tank farm. Technetium-99, the constituent with the highest concentration relative to a standard, is currently four to five times the 900-pCi/L interim DWS. Hexavalent chromium and nitrate (cocontaminants) are at or below their 100-µg/L and 45-mg/L MCLs, respectively.

In addition to groundwater quality issues, declining water levels will eventually require replacement of wells at this WMA. However, the rate of decline is slower at this WMA than at other 200-West Area RCRA sites (e.g., WMAs T and TX-TY). Based on the current rates of decline, no replacement wells are forecast for FY 1998. Replacement wells will be needed, however, beginning in FY 1999 or FY 2000. Changes in well locations may also be needed as the flow direction gradually shifts in response to elimination of wastewater discharges to adjacent facilities. (Monitoring well network compliance issues for WMA S-SX are being addressed in an overall RCRA well-drilling strategy.)

5.9.2.3 WMA U Single-Shell Tank Farm

The RCRA-monitoring network completed in 1993 was designed on the basis of a west-to-east groundwater-flow direction. The flow reversal between mid-1993 and late-1995 resulted in flow toward the northwest (see Section 3.6.3.1), rendering both upgradient and downgradient coverage inadequate. However, by the time this reversal was recognized, groundwater flow had returned toward the southeast. Under current flow conditions, some downgradient wells may be impacted by the carbon tetrachloride plume emanating from the vicinity of the Plutonium Finishing Plant (Section 5.9.3.4) prior to its being detected in the upgradient wells.

This WMA is currently under an interim-status detection-level monitoring program. There were several critical mean exceedances for total organic halides during FY 1997. The exceedances are a result of an upgradient source near the Plutonium Finishing Plant and are not related to the WMA. The critical means are discussed in Appendix B.

If water-table declines continue at the current rate, wells 299-W18-25, 299-W19-31, and 299-W19-32 will be dry by the end of 1999. The loss of these wells is taking place much sooner than originally expected because of the rapid drop in water levels in the area following the cessation of effluent discharges in 1995. This is clearly shown by the inflection in the hydrographs presented in Figure 3.6-8. To maintain the monitoring network, non-RCRA well 299-W19-12 is being added to the network and two new wells are being drilled. One will replace well 299-W19-32 and one will be drilled along the southern boundary of the site where there is presently no coverage. The new well along the southern boundary is particularly important because a spectral gamma survey of vadose-zone wells in WMA U (GJO-97-1-TAR, GJO-HAN-8) revealed the deepest penetration of cesium-137 and uranium along its southern edge. Well 299-W18-30, which is currently neither up- nor downgradient, will be removed, at least temporarily, from the monitoring network.

5.9.2.4 216-U-12 Crib

RCRA groundwater monitoring began at this crib in 1991. In the January 1993 sample, specific conductance in two downgradient wells (WHC-SD-LEF-EV-001) significantly exceeded upgradient concentrations, promoting the initiation of an interim-status groundwater quality assessment program to determine if the crib has affected the quality of the groundwater in the uppermost aquifer beneath it. In FY 1997, monitoring wells were sampled quarterly for constituents of interest (see Appendix A).

The results and findings of Phases I and II of the assessment-monitoring program, as required by 40 CFR 265.93, are presented in PNNL-11574. The elevated levels of specific conductance in the downgradient "triggering" wells are attributed to nitrate (the mobile anion released when nitric acid is diluted in water) and calcium (released from the sediments as acid is neutralized). Technetium-99 has also been elevated in the trigger wells since monitoring began. The source of these constituents is the crib.

Based on the results of the investigation (PNNL-11574), the site must remain in interim-status assessment monitoring because of continued elevated levels of nitrate and technetium-99. However, the objective of the groundwater monitoring, rather than delineating the existing plumes, will be focused on 1) determining whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; 2) monitoring the known constituents until a near-term interim corrective action is defined; and 3) monitoring until a final-status monitoring plan is implemented for the crib.

The crib will not receive additional effluents and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final-status regulations in 2003.

Because the groundwater-flow direction is unchanged, the wells are appropriately located for RCRA assessment monitoring to monitor releases from this crib. Declining water levels at this crib will impact the ability to sample the network wells in FY 1998. Two wells will go dry in the next year. One new replacement well is planned to be installed during FY 1998 to maintain the RCRA assessment network.

5.9.2.5 216-S-10 Pond and Ditch

During FY 1997, this facility was monitored semiannually for interim-status contaminant indicator parameters and site-specific constituents (see Appendix A). Statistical comparisons of contaminant indicators to critical mean values are shown in Appendix B.

One of four quadruplicate samples for total organic carbon at downgradient well 299-W26-10 was above the critical mean (quadruplicate measurements averaged 1,210 µg/L). However, this value is not consistent with the historical trend where all total organic carbon results have been nondetections. A laboratory corrective action has been implemented for their total organic carbon procedure (see Appendix D). Fourth quarter results for total organic carbon at well 299-W26-10 were back on trend; verification sampling is not needed.

Previously, total organic halides were not detected in upgradient wells, and the limit of quantitation was used for the critical mean. However, in FY 1996 and FY 1997, total organic halides were detected in the upgradient wells, which then required quarterly sampling for 1 year to establish a critical mean. Four quarters of upgradient well samples were completed during the fourth quarter of FY 1997. The cause of the upgradient total organic halides is probably the upgradient carbon tetrachloride plume.

The current monitoring network is adequate for the monitoring objectives at this facility; however, the water table in the vicinity is dropping at an average rate of 0.43 m/yr. Assuming this rate continues, within 1 year, well 299-W26-8 will not contain enough water to be sampled with the installed pump. Well 299-W26-8 is currently one of the two upgradient wells for this facility; when it goes dry, it is planned to use only one upgradient well for this facility.

Two of the downgradient wells (299-W26-10 and 299-W26-12) produced increasingly turbid samples, potentially affecting some analytical results. Turbidity increased to over 180 nephelometric units (NTUs) during FY 1996. Several measures were undertaken to try to collect less-turbid samples, including comprehensive maintenance, development, and lowering the pump. The turbidity during FY 1997 ranged from 11 to 5 NTUs for well 299-W26-10 and 8 NTUs for well 299-W26-12.

5.9.2.6 Low-Level Waste Management Area 3

Groundwater-monitoring wells at this LLWMA are sampled semiannually (March and September) under RCRA interim-status regulations. See Appendix A for a list of monitoring wells and a constituent list. There were no exceedances of the upgradient/downgradient comparison values for any of the indicator parameters.

The water level in monitoring well 299-W7-2 has dropped to the point were sampling is no longer possible. The overall monitoring well network continues to be adequate, and no additional wells are planned.

5.9.2.7 Low-Level Waste Management Area 4

Samples are taken semiannually for contamination indicator parameters under RCRA interim-status regulations. See Appendix A for a list of monitoring wells and a constituents list.

The groundwater-flow direction reversed under LLWMA 4 in the past year. The predominant flow direction is now from west to east. The continuing decline in the groundwater mound created by past disposal practices and, possibly, the effects of the 200-ZP-1 Operable Unit pump-and-treat program (discussed in Section 5.9.4.2) were the causes of the flow reversal. The required statistics were calculated, and critical means were established for the indicator parameters. The critical means were established using the wells to the east of LLWMA 4 as the upgradient wells. Although these wells became the downgradient monitoring wells in FY 1997, it was deemed appropriate to continue using the same upgradient/downgradient designations for statistical purposes because the source of the groundwater beneath LLWMA 4 was from the east. There was an exceedance of the critical mean for total organic carbon at well 299-W15-23 in the January 21, 1997 sample. The water level in this well was known to be too low for pumping, and in an attempt to collect samples, a bailer was used. The purge volume was also reduced. The quadruplicate samples had a wide variability. Resampling to confirm the elevated total organic carbon failed because the water level had declined to the point that the well could not be sampled. Because of the wide variability in the four results and the fact that the samples had been bailed, it was assumed that the high total organic carbon was a result of poor sample quality and analytical difficulties.

Other wells in the area did not indicate a similar increase. One other monitoring well (299-W15-24) can no longer be sampled because of the decline in water level; however, the monitoring well network is still adequate.

5.9.2.8 State-Approved Land-Disposal Site

Liquid effluent (essentially deionized water with tritium) from the 200 Areas Effluent-Treatment Facility is discharged to the State-Approved Land-Disposal Site (see Plate 1). These facilities are regulated by a state waste discharge permit, promulgated by WAC 173-216 and administered by Ecology. The permit was granted in June 1995; effluent receipt started in December 1995. The permit stipulates requirements for groundwater monitoring and criteria for allowable concentrations of several constituents (WHC-SD-C018H-PLN-004). Groundwater-monitoring requirements are specified in the discharge permit and are discussed in detail in PNNL-11665. During FY 1997, high levels of tritium emanating from this site were detected in downgradient wells 699-48-77A (2,000,000 pCi/L) and 699-48-77D (80,000 pCi/L). This occurrence was predicted and is within the performance criteria of the waste discharge permit. Elevated levels of sulfate, calcium, and related properties (e.g., specific conductance) have also recently appeared in these wells, but these constituents have been derived from natural salts in the vadose zone beneath the facility (PNNL-11633, PNNL-11665). No other constituents have exceeded permit criteria.

5.9.2.9 Environmental Restoration Disposal Facility

This facility is a landfill authorized by CERCLA that is designated to meet RCRA minimum technology requirements under 40 CFR 264, Subpart N. The groundwater-monitoring network consists of one upgradient and three downgradient wells that were sampled in September 1996 and March 1997. In addition, the facility has a leachate-collection and -removal system that helps evaluate whether the liner system is performing within design standards.

No impact to groundwater is expected to occur from this facility. Groundwater data collected from the monitoring work indicates that the facility is not impacting groundwater. However, there are 10 existing plumes near or extending into the area of the facility: nitrate, carbon tetrachloride, chloroform, trichloroethylene, tritium, gross beta, technetium-99, iodine-129, gross alpha, and uranium. The source facilities of all the contaminant plumes are located upgradient of the facility and are inside the 200-West Area.

5.9.2.10 Drinking Water Standards and Derived Concentration Guides

No radiological contaminants were found at levels above the DCGs in the 200-West Area, except for total uranium analyses of samples from wells near U Plant that indicate the DCGs for uranium-234 and uranium-238 were exceeded. Tritium, iodine-129, and technetium-99 were found at levels above the interim DWSs in the 200-West Area. Uranium was found at levels above its proposed MCL. Carbon tetrachloride, chloroform, trichloroethylene, nitrate, fluoride, and chromium were detected at levels above the MCLs.

5.9.3 Extent of Contamination

The groundwater contamination in the 200-West Area may generally be related to the four major production locations: T, REDOX, U, and Plutonium Finishing Plants. The discussion below divides the monitoring activities according to these four major areas. LLWMA 3 and LLWMA 4 are discussed separately because RCRA detection monitoring indicates that they have not contributed to the existing contamination. The State-Approved Land-Disposal Site, a relatively new disposal facility north of the 200-West Area, is also discussed.

5.9.3.1 T Plant

Groundwater plumes originating from the T Plant area include tritium, iodine-129, technetium-99, uranium, nitrate, and chromium. A fluoride plume is also present in the area. Carbon tetrachloride and trichloroethylene plumes, originating near the Plutonium Finishing Plant, appear to extend throughout the T Plant area. Aqueous discharges to the 216-T-19 crib may be responsible for part of the carbon tetrachloride and trichloroethylene plumes in that area (WHC-SD-EN-TI-248).

Tritium. A tritium plume covers much of the northern half of the 200-West Area (see Plate 3). The maximum average tritium detected in this plume in FY 1997 was 120,000 pCi/L in well 299-W11-30, located west of T Plant. The plume extends northeast, beyond the 200-West Area boundary. Concentrations of tritium in wells 299-W15-22 and 299-W15-4, located west and south of WMA TX, declined sharply in FY 1997. An area north of WMA T consistently shows tritium at levels much lower than the surroundings, which may be related to discharge of relatively clean water to the 216-T-4-2 ditch (WHC-EP-0815). Concentrations of tritium and other contaminants, including nitrate and technetium-99, are increasing rapidly in well 299-W11-27 in the northeastern corner of WMA T.

Iodine-129. The extent of iodine-129 above the interim DWS in the T Plant area coincides generally with the tritium (see Plate 3) and technetium-99 plumes. The maximum concentration of iodine-129 detected in this vicinity in FY 1997 was 5.0 pCi/L in well 299-W11-30.

Technetium-99. A technetium-99 plume in the T Plant area (Figure 5.9-1) has dimensions similar to the tritium plume (see Plate 3). This contrasts with the U Plant technetium-99 plume (discussed in Section 5.9.3.3) that has lower tritium levels. Technetium-99 with FY 1997 average values above the interim DWS were restricted to one well (299-W14-12) in the vicinity of WMA TX-TY and associated disposal facilities and another well (299-W11-27) in the northeastern corner of WMA T. The maximum technetium-99 detected in the T Plant area in FY 1997 was 21,700 pCi/L in well 299-W11-27, which reflects the continuation of the rapid increase seen in this well in FY 1996 to a peak in early FY 1997 (Figure 5.9-2). The FY 1997 average for this well was 18,000 pCi/L. There are no corresponding increases in nearby or upgradient wells for WMA T. As discussed in Section 5.9.2.1 and with regard to the rest of the RCRA assessment parameters, the assessment concluded that WMAs T and TX-TY were probably the sources of this technetium-99.

Uranium. Few analyses for uranium were performed in the vicinity of T Plant in FY 1997 because most wells showed insignificant levels in previous monitoring. Wells monitored near the single-shell tank farms for RCRA compliance are sampled for gross alpha measurements, which would show an increase if uranium contamination appeared. Uranium was detected above the proposed MCL in only one well in the T Plant area: well 299-W11-14 contained 61 µg/L of uranium in the single FY 1997 sample. The value is consistent with measurements for the past several years. This well is located immediately northwest of T Plant, and the source of the uranium has not been determined (Figure 5.9-3).

Nitrate. Much of the northern part of the 200-West Area continued to contain nitrate at concentrations in excess of the 45-mg/L MCL (see Plate 4). The nitrate contamination is more widespread than the iodine-129/tritium/technetium-99 plumes discussed above. It is probable that there are multiple sources of nitrate in this area. Maximum concentrations in this part of the 200-West Area in FY 1997 ranged up to 320 mg/L in well 299-W12-1, located on the eastern boundary of the 200-West Area. Well 299-W10-1, located west of WMA T near the 216-T-7 and 216-T-32 cribs, had the maximum concentration of nitrate in FY 1996 (1,100 mg/L) but dropped in FY 1997 (140 mg/L). A large amount of nitrate was present in the wastes discharged to these cribs (an estimated 2,300,000 kg of nitrate to the 216-T-7 crib, according to PNL-6456). The area of low nitrate north of WMA T corresponds to the area of low concentration of other constituents discussed above.

Chromium. Chromium contamination continues to be found above the 100-µg/L MCL in the T Plant area (Figure 5.9-4). Chromium is above the MCL in filtered samples from the area north and east of WMA T, where the maximum average annual concentration detected in FY 1997 was 120 µg/L in wells 299-W10-8 and 299-W10-4. Chromium concentrations in well 299-W11-27, which exhibited a peak in FY 1996, remained below the MCL in FY 1997. This peak in chromium occurred earlier and was sharper than the peak in technetium-99. Chromium was also above the MCL in well 299-W15-22, located west of WMA TX-TY. This value is much higher than previous years, and results from a single high sample (306 µg/L on May 12, 1997). The 216-T-28 crib, located to the north of well 299-W14-12, is reported to have received miscellaneous decontamination waste from T Plant. Because hexavalent chromium was frequently used in decontaminating systems containing uranium, that crib is a likely source. Chromium is also above the MCL in wells downgradient of those discussed above, northeast of T Plant, but data are available from only a few wells. The extent shown in Figure 5.9-4 is an approximation.

Fluoride. Fluoride was detected above the primary 4-mg/L MCL and the secondary 2-mg/L MCL near the T Plant waste-disposal facilities. The fluoride contamination was found in a number of wells in the vicinity of WMA T (Figure 5.9-5), where the maximum annual average concentration was 4.1 mg/L in well 299-W10-15. In past years, fluoride was also found above the MCL in well 299-W15-4, located near the 216-T-19 crib south of the WMA TX-TY tank farms but dropped to 1.5 mg/L in FY 1997.

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. An increase in carbon tetrachloride concentrations west of T Plant may be related to that disposal. The carbon tetrachloride distribution in the 200-West Area is shown in Figure 5.9-6. Trichloroethylene is also found at levels above the MCL in the vicinity of T Plant but at levels considerably lower than carbon tetrachloride. The high carbon tetrachloride levels interfere with the analysis of low levels of trichloroethylene. Therefore, the extent of trichloroethylene in the 200-West Area will not be contoured this fiscal year.

WMA T RCRA Parameters. Specific conductance in well 299-W10-15 remained high; however, it remained below the critical mean for WMA T during FY 1997 (1,175 μS/cm). The elevated specific conductance for groundwater in this well is principally a result of elevated concentrations of sodium and nitrate. Nitrate and cocontaminants (tritium and fluoride) have exceeded their MCLs during FY 1997, as has gross beta. This contamination pattern is a result of a regional contaminant plume and not a direct result of contaminants from within WMA T.

Specific conductance in well 299-W11-27 exceeded the critical mean for WMA T during FY 1997, with a maximum value of 1,267 μS/cm in the November 1996 sample (Figure 5.9-7). This increase in specific conductance results from increases in calcium, magnesium, nitrate, and sulfate and was accompanied by increases in technetium-99, tritium, cobalt-60, and chromium. Technetium-99 is the major contaminant present, reaching 21,700 pCi/L, which is ~24 times its interim DWS (see Figure 5.9-2). Nitrate and chromium also exceeded their MCLs in this well in FY 1997. Reported activities of cobalt-60 (29 and 26 pCi/L in May and August 1997, respectively) indicate that this is a cocontaminant.

The sodium:calcium ratio provides information on contaminant source. Although the waste tanks contain considerable sodium, the sodium:calcium ratio will be reduced for low-volume discharges as a result of ion exchange with vadose-zone sediments. Sodium:calcium ratios in well 299-W11-27 dropped to as low as 0.13, much lower than upgradient and area background numbers (3:6), and are consistent with a low-volume tank-waste source that cannot overwhelm the ion-exchange capacity of the vadose zone (PNNL-11470). In addition, the tritium: technetium-99 ratio has fallen as low as 0.2, distinct from the upgradient and area background numbers (>100) and consistent with the magnitude of ratios expected in tank waste (LA-UR-96-3860).

The contaminants affecting groundwater quality in well 299-W11-27 represent a very narrow plume. Wells 299-W10-8 and 299-W11-23, which bracket well 299-W11-27 and are separated by ~55 m, are unaffected by the plume. This lack of lateral dispersion, which indicates a nearby source, coupled with the observed chemistry offers strong indication that the groundwater contamination observed in well 299-W11-27 originated within WMA T.

An assessment report released in 1998 (PNNL-11809) reached the conclusion that the contaminants observed in well 299-W11-27, which peaked in concentration in 1992, are most likely the result of sources within WMA T. It is uncertain, however, whether the observed decreases in contaminant concentrations are a result of a transient source, declining water table, and/or changes in groundwater-flow direction.

WMA TX-TY RCRA Parameters. Specific conductance in WMA TX-TY downgradient well 299-W10-17 remained above the critical mean (668 μS/cm) during FY 1997 (Figure 5.9-8). The elevated specific conductance for groundwater in this well is principally a result of elevated concentrations of sodium and nitrate. Nitrate, tritium, and gross beta exceeded their DWSs during FY 1997. This contamination pattern is a result of a regional contaminant plume, similar to the case for well 299-W10-15.

Specific conductance in WMA TX-TY downgradient well 299-W14-12 remained above the critical mean (668 μS/cm) during FY 1997 (see Figure 5.9-8), the sharp decrease of the past several years having moderated. The high specific conductance in this well is principally a result of elevated calcium, magnesium, nitrate, and sulfate. Concentrations of all contaminants have decreased along with specific conductance; however, in FY 1997, technetium-99, nitrate, tritium, gross beta, and iodine-129 remained above their respective DWSs.

Sodium:calcium ratios in well 299-W14-12 are in the 0.3 to 0.4 range, above a low of ~0.14 reached in 1992. The relationship between contaminant concentrations and sodium:calcium in this well is very similar to that observed in well 299-W11-27 and is consistent with a small-volume tank-waste source. Tritium:technetium-99 ratios, between 40 and 90 during FY 1997, have historically been higher than those found in well 299-W11-27. This may reflect different source characteristics; however, it is more likely a result of proximity to the 216-T-19 crib and tile field that received large quantities of tritium from the 242-T evaporator.

Well 299-W15-22, upgradient to WMA TX-TY, showed an increase in specific conductance (see Figure 5.9-8), nitrate, and calcium over the past several years, a trend that continued in FY 1997. In addition in FY 1997, technetium-99 and chromium exceeded their DWSs. The source for this contamination is uncertain.

5.9.3.2 REDOX Plant

Groundwater plumes originating in the vicinity of the REDOX Plant and its associated waste-storage and -disposal facilities include tritium, iodine-129, technetium-99, uranium, nitrate, chromium, and trichloroethylene. Although in past years a few wells near REDOX disposal facilities contained strontium-90 at levels above the interim DWS, all levels reported in FY 1997 were below the interim DWS. Two facilities in this vicinity (WMA S-SX and 216-S-10 pond and ditch) have RCRA-monitoring requirements and are discussed separately. Other facilities, however, appear to have produced the major part of the groundwater contamination.

Tritium. The movement of tritium plumes in the 200-West Area was consistent with previous observations (see Plate 3). The plume, extending from near the REDOX Plant in the southern part of the 200-West Area, continued to expand slowly to the east and north. Tritium upgradient of the REDOX Plant as far as the 216-S-25 crib was found above the interim DWS. Well 299-W22-9, which historically has contained the maximum tritium concentrations in the 200-West Area, was not sampled because of declining water levels.

The tritium plume from the 200-West Area extends to US Ecology's low-level radioactive waste-disposal facility. The maximum concentrations (4,275 to 4,714 pCi/L) of tritium detected in groundwater at that facility in FY 1997 were in well 699-35-59 (US Ecology well no. 13). Tritium concentrations in that well, located on the western (upgradient) side of the facility, have continued to increase over the past several years. Concentrations of tritium in well 699-35-57 (US Ecology well no. 3), which is on the eastern side of the facility, have decreased since last year, with a maximum of 3,337 pCi/L in FY 1997. 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 sediments in the area and the dissipation of the groundwater mound beneath the 200-West Area since the reduction of effluent discharge.

Iodine-129. An iodine-129 plume from the 200-West Area (see Plate 5) extends into the 600 Area to the east and coincides with the tritium plume originating near the REDOX Plant (see Plate 3). 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. Well 299-W22-9, which historically has contained the maximum iodine-129 concentrations on site (FY 1996 annual average of 66 µg/L), was not sampled because of declining water levels.

Nitrate. Nitrate was detected in FY 1997 above the MCL in two small plumes in the vicinity of the REDOX Plant (see Plate 4). The first plume is located near the 216-S-20 crib, which received laboratory waste from the 222-S building. The trend plot for nitrate in well 299-W22-20 indicates that contamination has been present for at least 35 years (Figure 5.9-9). Nitrate was detected above the MCL in well 299-W23-14, near the 216-S-25 crib and WMA S-SX. Nitrate concentrations in this well peaked in early 1997 and then declined (Figure 5.9-10).

Trichloroethylene. A small trichloroethylene plume with a maximum FY 1997 average concentration of 5.6 µg/L, just above the MCL, is found to the east of the REDOX Plant and is generally coincident with the nitrate plume in that area. The 216-S-20 crib is a likely source of this plume.

Technetium-99. Exceedances of the 900-pCi/L interim MCL for technetium-99 occurred west of the REDOX Plant near WMA S-SX. These occurrences are associated with a small technetium-99 plume that has been noted in previous years. The plume appears to consist of contributions from WMA S-SX and the 216-S-13 crib, both of which received REDOX Plant waste streams. The highest concentration detected in FY 1997 was 5,010 pCi/L in well 299-W22-46 near the southeastern corner of the SX tank farm. An ~1,500-pCi/L exceedance also occurred in an older, non-RCRA well (299-W23-1), located inside the S tank farm.

Uranium. Uranium was found above the proposed MCL to the west of the REDOX Plant (see Figure 5.9-3). The uranium contamination extends from areas upgradient of the technetium-99 plume toward the REDOX Plant. The highest uranium concentration detected in FY 1997 in the vicinity of the REDOX Plant was 150 µg/L in the single sample from well 299-W22-21, located immediately downgradient of the 216-S-13 crib. Concentrations of uranium in this well fluctuate considerably.

WMA S-SX RCRA Parameters. Mobile tank waste cocontaminants (technetium-99, hexavalent chromium, and nitrate) are the primary constituents of concern for assessment purposes in WMA S-SX. A comparison of the major cocontaminants in the RCRA-monitoring well network (see Appendix A) is shown in Figure 5.9-11. The primary change during FY 1997 was the increasing trend in all three cocontaminants in well 299-W22-46, located at the southeastern corner of WMA SX. This recent occurrence was attributed to the same source that caused the earlier peak in 1992-1993 in well 299-W23-15, located upgradient and to the west. If the current trend continues, the contaminant concentrations should decline during the next year.

Cesium-137, a potential tank waste cocontaminant, was also analyzed in samples from some key downgradient WMA S-SX-monitoring wells. Well 299-W23-7, located inside the tank farm fenceline and downgradient from WMA S, continues to exhibit low (up to 14 ± 2.8 pCi/L) but detectable cesium-137. Filtered and unfiltered samples indicate cesium-137 is present in particulate form (PNNL-11470, PNNL-11810). The source of this cesium-137 is unknown. However, its particulate nature, the presence of large amounts of fine sediment in the bottom of the well, the very slow recharge encountered during purging, excessive drawdown, and turbidity problems with this well suggest it may be localized within the well, perhaps introduced during well installation and renovation (PNNL-11810). In addition, low-level gamma spectroscopy was used to check for cesium-137 in the well with the highest technetium-99 concentration for the report period (299-W22-46). Cesium-137 in two samples from the May 1997 sampling (unfiltered) were nondetections (-0.08 ± 4.9 and 3.2 ± 2.5). The highest technetium-99 concentration for the same sampling event was 5,020 pCi/L. If cesium-137 had the same mobility as technetium-99, the expected concentration would be >10,000,000 pCi/L, based on the cesium-137: technetium-99 ratio of tank waste (PNNL-11810).

216-S-10 Pond and Ditch RCRA Parameters. Groundwater quality, drinking water, or site-specific parameters did not exceed the DWSs during FY 1997, except for chromium and pH. The chromium exceedance was in upgradient well 299-W26-7 (368 µg/L in the December 1996 sample) (Figure 5.9-12).

The pH in the June 1997 sample from well 299-W26-8 was higher than the MCL. The mean result was 8.7. The result was still within the critical range for indicator parameter evaluations (see Appendix B).

Specific conductance ranged from 246 to 286 µS/cm (the critical mean is 301.1 µS/cm) in wells that sample the upper portion of the unconfined aquifer system and are subject to statistical testing of indicator parameters. Well 299-W27-2, which samples the bottom of the unconfined aquifer, routinely has specific conductance of ~357 µS/cm.

Total organic carbon ranged from 530 to 960 µg/L, with one result at 2,470 µg/L (probably a laboratory error). The laboratory limit of quantitation is 1,113 µg/L.

The range of total organic halides was 2.65 to 9.6 µg/L, with one result at 25.8 µg/L. The high result did not agree with replicate analyses and is probably a laboratory error. Total organic halides were detected in the upgradient well for the facilities and appears to be unrelated to the facility.

In the past, well 299-W26-8 showed levels of gross alpha slightly elevated over other 216-S-10-monitoring wells (Figure 5.9-13) but gross alpha levels declined in FY 1995 and FY 1996. In late 1996 and 1997, gross alpha concentrations returned to pre-1995 levels. Well 299-W26-8 is an upgradient well, which suggests the 216-S-10 facility is probably not the source of the elevated alpha levels. The source may be the 216-U-10 pond (U Pond [now decommissioned]), which is upgradient of the 216-S-10 facility and known to have received radioactive wastewater.

5.9.3.3 U Plant

Uranium, technetium-99, iodine-129, and trichoroethylene are the major plumes originating in the vicinity of U Plant and associated waste-storage and -disposal facilities. Interim action groundwater pump-and-treat remediation is taking place in the vicinity of U Plant. Because of the effects of the remediation and 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, including the contamination currently being remediated under CERCLA and the specific reporting requirements for RCRA monitoring at the 216-U-12 crib and WMA U.

Uranium. The highest uranium levels in groundwater occurred near U Plant in FY 1997 in wells downgradient from the 216-U-1 and 216-U-2 cribs and adjacent to the 216-U-17 crib (see Figure 5.9-3). Uranium concentrations in wells near the 216-U-1 and 216-U-2 cribs showed a large pulse of uranium in approximately 1986. A trend plot of uranium concentrations in samples from well 299-W19-3, immediately downgradient from the cribs, is shown in Figure 5.9-14. The uranium levels in this well decreased considerably since the maximum measured in 1986 but remained at levels far greater than the proposed MCL since 1990. Concentrations in this well recently increased somewhat, reaching an FY 1997 average of 1,200 µg/L. The maximum average annual concentration detected near U Plant in FY 1996 was 2,700 µg/L in a sample from well 299-W19-24 (see Figure 5.9-3). The uranium concentrations for several wells in the U Plant vicinity represent dose values greater than the DCG. Assuming natural isotopic abundance, a uranium concentration of 790 µg/L represents the 100-mrem/yr dose equivalent for ingestion of drinking water. The uranium plume extends into the 600 Area to the east.

Uranium distribution in the vicinity of the 216-U-17 crib has been affected by pump-and-treat remediation (discussed in Section 5.9.4.1). The remediation system has impacted the flow directions, both through the pumping and because treated groundwater was reinjected upgradient of the pumping well until March 1997. As expected, uranium concentrations have been decreasing near the injection well and increasing near the pumping well as the plume is drawn toward the pumping well.

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 (see Figures 5.9-1 and 5.9-3). The maximum average annual technetium-99 concentration associated with this plume in FY 1997 was 16,000 pCi/L, found in well 299-W19-23 (see Figure 5.9-1). 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. Technetium-99 in the vicinity of the 216-U-12 crib exhibits a distribution similar to nitrate. Time/concentration plots reflect a consistent, low-volume source emanating from below the crib.

The technetium-99 distribution in the vicinity of the 216-U-17 crib has also been affected by pump-and-treat remediation. Further details are given in Section 5.9.4.1.

Iodine-129. Iodine-129 was found above the interim DWS in the immediate vicinity of the 216-U-1 and 216-U-2 cribs (see Plate 5). The maximum average annual concentration of iodine-129 detected near U Plant was 5.7 pCi/L in the single sample from well 699-38-70A, located just outside the eastern fence of the 200-West Area. Downgradient, the iodine-129 plumes from U Plant operations become indistinguishable from the REDOX Plant plume (see Section 5.9.3.2).

Nitrate. Some of the highest onsite nitrate concentrations in FY 1997 continued to be found in wells east of U Plant near the 216-U-17 crib (see Plate 4). The maximum average annual concentration detected was 980 mg/L in well 299-W19-26. Elevated nitrate was observed in wells near this crib before February 1988 when the crib went into operation. The main source of the nitrate is believed to be wastes disposed to the 216-U-1 and 216-U-2 cribs. These cribs received >1,000,000 kg of nitrate during their operation from 1951 to 1967 (PNL-6456). Nitrate concentrations in wells located near these cribs continued to decrease, with concentrations in several wells dropping below the MCL. For example, the nitrate concentration in well 299-W19-3 near U Plant decreased to less than the MCL, as shown in Figure 5.9-15. The distribution of the highest concentrations in the nitrate plume is similar to the technetium-99 plume, which would indicate a common source. Elevated nitrate concentrations are also observed farther south near the 216-U-8 and 216-U-12 cribs. The nitrate distribution near the 216-U-17 crib is being affected by the pump-and-treat remediation discussed in Section 5.9.4.1. The pump-and-treat system initially included injection of treated water within the plume boundary. The plume contours shown in Plate 4 are generalized considerably in the zone of influence of the pump-and-treat system.

Nitrate concentrations downgradient of the 216-U-12 crib continue to exceed the 45-mg/L MCL and are greater than 10 times the average background value established in the upgradient well. The effluent disposed during the last years of crib operation is still believed to be seeping into the aquifer but at a slower rate than when a driving head was available. The fluctuations in the concentration are a result of this noncontinuous effluent migration and heterogeneities within the aquifer. Concentration trends are expected to decline as the vadose zone drains.

Monitoring at downgradient well 299-W22-40 never detected any nitrate contamination; it is most likely outside the flow path of the 216-U-12 crib nitrate plume. This is supported by mapping flow lines on the water-table map (see Plate 2). The spatial relationship of the monitoring network, with respect to the detected contamination, indicates that the current source is already restricted and of relatively low volume and high concentration. This is expected because effluent disposal ceased ~9 years ago.

Trichloroethylene. A relatively low-level trichloroethylene plume can be detected in groundwater near U Plant. The maximum average annual concentration of trichloroethylene found in FY 1997 in this plume was 15 µg/L in well 299-W19-35, located generally downgradient of the U Plant cribs. This plume extends to the east, beyond the 200-West Area boundary.

WMA U RCRA Parameters. Specific conductance values in WMA U downgradient wells ranged from 227 to 465 µS/cm during FY 1997, with the lowest value in well 299-W18-30 and the highest value in well 299-W19-32. These values do not exceed the 533-µS/cm critical mean.

Field pH measurements for downgradient wells ranged from 7.9 to 8.2 for FY 1997. All pH measurements in RCRA-monitoring wells fall within the range bracketed by the upper and lower comparison values (7.4 to 8.6). However, non-RCRA well 299-W19-12, slated for inclusion in the network in FY 1998, had 2 reported values of 8.6. The reason for the higher values in well 299-W19-12 is uncertain.

Reported total organic halide values ranged from 4 to 631 µg/L for FY 1997. The reported concentration for the August 1996 sampling of well 299-W18-30 exceeded the comparison value (241.3 µg/L). The 631-µg/L value is for a November 1997 resampling of well 299-W18-30 and represents the average of samples sent to two independent laboratories and confirms the exceedance noted in August 1996. Increasing total organic halide values at WMA U are a result of carbon tetrachloride, and the pattern of concentrations is consistent with increased encroachment by the Plutonium Finishing Plant's carbon tetrachloride plume and the return of groundwater-flow directions to an east-southeastern direction.

Technetium-99 remained elevated in downgradient wells, particularly 299-W19-31, but below the interim DWS. During FY 1997, gross beta exceeded its interim DWS in downgradient wells 299-W19-12, 299-W19-31, and 299-W19-32.

216-U-12 Crib RCRA Parameters. The groundwater below this crib has been monitored and analyzed as part of the RCRA program since September 1991. The site-specific waste indicators currently selected for the crib's assessment monitoring include nitrate, tritium, gross alpha, gross beta, technetium-99, and iodine-129. The results and findings of Phases I and II of the assessment-monitoring program are given in PNNL-11574. The crib is the source of elevated nitrate and technetium-99 detected in downgradient wells 299-W22-41, 299-W22-42, and 699-36-70A (see Plate 4 and Figure 5.9-1). Sources of nitrate and technetium-99 plumes are a commingled 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 are detected repeatedly in several 216-U-12 crib downgradient monitoring wells but the sources are upgradient near the REDOX Plant.

Waste indicator parameters (specific conductance, total organic halides, total organic carbon, pH, gross alpha, and gross beta) are monitored at the crib as part of RCRA assessment monitoring. Specific conductance continued to be elevated in downgradient wells, exceeding the 457.8-µS/cm critical mean value since groundwater monitoring began in 1991 (Figure 5.9-16). Nitrate and calcium are the greatest contributors to the elevated specific conductance (PNNL-11574). Technetium-99 in the downgradient wells is also elevated above regional background values but does not exceed the 900-pCi/L interim DWS.

The long-term concentration trend for tritium in well 299-W22-42 could be inferred to be a contaminant released from the 216-U-12 crib (tritium is a documented component of the effluent disposed to that crib), but tritium results collected in remediated well 299-W22-23 (located upgradient) suggest that there more likely is an upgradient source from REDOX Plant operations (Figure 5.9-17). Well 699-36-70A shows 300,000+ pCi/L tritium values, well over background and the interim DWS, and appears to be attributable to REDOX Plant sources.

5.9.3.4 Plutonium Finishing Plant

Contamination from volatile organic compounds, predominantly carbon tetrachloride, forms the major plumes discussed in this section. The Plutonium Finishing Plant was not a significant contributor to the tritium or iodine-129 plumes. Migration of plutonium contamination from the vadose zone is of concern because of the large quantities disposed in the area and the presence of complexing agents that could enhance mobility. Nitrate contamination is also present. The only facilities near the Plutonium Finishing Plant with RCRA-monitoring requirements are the burial grounds in LLWMA 4. These are not believed to contribute to groundwater contamination and are discussed in the following sections. Remediation of volatile organic compounds in groundwater and the vadose zone is being undertaken in this area.

Plutonium and Americium. Plutonium-239/-240 and americium-241 were detected at low levels (up to 8.3 and 5.9 pCi/L, respectively) in 1990 and 1991 in well 299-W15-8, which monitors the 216-Z-9 trench. This trench received a large burden of transuranic wastes from Plutonium Finishing Plant liquid effluent streams. That well has not been monitored for transuranic wastes since 1991 because the water level dropped below the well screen. The origin of the transuranic contaminants in the well is unclear but may be associated with poor-quality well completion and, thus, may be very localized or may represent mobilization by complexants in the organic liquid phase (WHC-SD-EN-TI-248).

The potential mobilization of plutonium and americium isotopes in the organic liquid phase discharged to ground in the vicinity of the Plutonium Finishing Plant is discussed in WHC-SD-EN-TI-248.

A liquid phase, containing carbon tetrachloride and tributylphosphate, was used in the purification process to complex and remove plutonium from the aqueous phase. The distribution of transuranic contaminants in the vadose zone suggests an increased mobility because of their transport in the nonaqueous-phase liquid. Transport of transuranics in the vadose zone near the Plutonium Finishing Plant is discussed in Section 4.1.2.

Nitrate. The 216-Z-9 trench received an estimated 1,300,000 kg of nitrate-containing chemicals over the course of 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, with levels in FY 1997 ranging up to a maximum concentration of 480 mg/L in well 299-W15-32 (see Plate 4). This nitrate plume may contribute to the T Plant contamination discussed in Section 5.9.3.1.

Chlorinated Hydrocarbons. Carbon tetrachloride contamination is present in the unconfined aquifer system beneath much of the 200-West Area (see Figure 5.9-6). The contamination is believed to be from pre-1973 waste operations associated with the Plutonium Finishing Plant. The maximum average annual carbon tetrachloride concentration detected in the 200-West Area in FY 1997 was 7,000 µg/L in well 299-W15-32, an extraction well for the 200-ZP-1 Operable Unit pump-and-treat system (Section 5.9.4.2). The MCL for carbon tetrachloride is 5 µg/L. The contaminant concentrations and distribution suggest that nonaqueous-phase liquid is probably present above and below the water table.

The carbon tetrachloride distribution in the 200-West Area groundwater changed slowly since the presence of the contaminant plume was first noted. The influence of the pump-and-treat operations, which were phased into operation starting in 1994, on the carbon tetrachloride distribution is becoming evident. 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. Figure 5.9-18 shows the carbon tetrachloride concentration trends over time for wells located around the plume. Well 699-39-79, to the west of the disposal areas, shows a major increase during 1987 and 1988, indicating arrival of the bulk of the plume at that time but is now declining due to its proximity to the injection wells. Recent trends in the northern part of the plume are difficult to discern because of the highly variable concentrations as shown for wells 299-W6-2 and 299-W7-4. Concentrations in well 299-W18-21, south of the disposal areas, peaked in 1994 and have declined considerably since. Concentrations in well 699-38-70, on the eastern edge of the plume, have remained relatively stable. Carbon tetrachloride concentrations in the central part of the plume declined in recent years but the trend plot in Figure 5.9-19 for well 299-W15-16 shows quite erratic values for FY 1997, with the highest values near the previous maximum in 1988. Overall, the extent of carbon tetrachloride as contoured at the 5-µg/L MCL changed little from previous years. The apparent division into two lobes on the eastern side of the 200-West Area is based on past data from well 299-W14-10 in the eastern part of the 200-West Area. The low values currently seen just east of WMA TX-TY may be related to past discharge of water from the laundry facilities and steam plant. The data available for this area are insufficient to determine if this is the case or if, in fact, two separate lobes actually exist.

As stated in DOE/RL-96-07, the vertical distribution of carbon tetrachloride contamination in the suprabasalt aquifer has not been defined. However, this information will be necessary to support development of a final remedy. Two field activities that are relevant to this issue are decommissioning of well 299-W15-5 in August 1997 and vertical profiling (discrete sampling) at wells 299-W15-7 and

299-W15-10 in 1996. The field activities for the decommissioning work are detailed in BHI-01121. The discrete sampling activities are described in BHI-00952-01.

The highest concentrations of contamination in well 299-W15-5 were surmised to occur in the first 5 m of the aquifer (5,800 and 6,000 µg/L) from sampling results in FY 1996. Below this interval, concentrations decreased with depth in the basalt, from 2,000 µg/L at 33.5 m below the water table to nondetections, based on sample results during the decommissioning. Table 5.9-1 summarizes the depth/ concentration data for carbon tetrachloride, chloroform, and trichloroethylene. The same pattern of depth distribution was found for chloroform, whereas maximum trichloroethylene increased with depth to 33.5 m and then decreased to nondetections in the basalt. Concentrations were found at 33.5 and 86.0 m below the water table.

Vertical profiling of contaminant concentrations at wells 299-W15-7 and 299-W15-10 showed slightly different distribution patterns. Concentrations of carbon tetrachloride sampled to 30.5 m below the water table in well 299-W15-7 were relatively constant with depth (ranging between 703 and 745 µg/L). Concentrations sampled to 15.3 m below the water table in well 299-W15-10 increased with depth (from 1,587 to 1,983 µg/L). The interval 15 m below the water table corresponds to a high hydraulic conductivity zone identified during the tracer test discussed below. These wells were constructed to ~30 m below the water table, so the full thickness of the aquifer could not be sampled. Table 5.9-1 listed the sampling results. Chloroform concentrations increased with depth to 30 m at well 299-W15-7 but decreased with depth and increasing hydraulic conductivity in well 299-W15-10.

In addition to the vertical profiling, a point-dilution tracer test was conducted at well 299-W15-10 to characterize vertical changes in hydraulic conductivity over the completed interval. A thorough discussion of this test is contained in BHI-00952-01. The test results indicated that a high-hydraulic-conductivity interval was present at 15 m below the top of the water table. This interval may represent a preferred flow path for contaminant transport.

It would appear that carbon tetrachloride concentrations are highest in the first 5 m of the aquifer and decrease with depth to near zero at the basalt. The potential for higher concentrations of contamination at deeper intervals existed at well 299-W15-5 prior to decommissioning, given that the well was completed across the entire thickness of the suprabasalt aquifer and in an area of downward hydraulic gradient. The absence of higher concentrations at depth indicates that this well may not have been a significant pathway for contaminant movement to the deeper intervals and/or the contamination has since been flushed by groundwater moving through these lower zones. In contrast, concentrations at well 299-W15-10 increased with depth, corresponding to a high conductivity zone ~15 m below the top of the aquifer.

Information on the vertical distribution of carbon tetrachloride in the vicinity of U Plant, showing the presence of carbon tetrachloride (15.4 µg/L) at greater than the MCL in a zone >60 m below the water table in well 299-W19-34B is provided in BHI-00149. This contamination was found in an interval below the lower Ringold mud unit (see Unit 8 in Figure 3.1-2). The maximum depth of contamination was not determined at other locations.

In addition to carbon tetrachloride, lesser concentrations of trichloroethylene and chloroform were found. Trichloroethylene is slightly above the MCL near the Plutonium Finishing Plant. The source is presumably disposal in the plant area, but disposal near T Plant may have also contributed to the plume.

The origin of the chloroform is unknown but is suspected to be a degradation product of carbon tetrachloride. In the past, septic drainage fields operated in the area close to where the chloroform maximum was measured, so anaerobic bacterial degradation processes are indicated. The MCL for chloroform is 100 µg/L (total trihalomethanes), which is 20 times higher than that for carbon tetrachloride. The distributions of trichloroethylene and chloroform were not precisely defined in FY 1997 because of difficulties in obtaining accurate analyses from the laboratory in the presence of high carbon tetrachloride concentrations.

5.9.3.5 Low-Level Waste Management Area 3

Carbon tetrachloride and nitrate have been consistently above MCLs at LLWMA 3. The elevated values can be attributed to contaminant plumes originating to the south of this area (see Figure 5.9-6 and Plate 3). Additional plumes have been documented elsewhere in this section. Trichloroethylene has exceeded the 5-µg/L MCL in upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21. There does not appear to be any groundwater contamination directly attributable to LLWMA 3.

5.9.3.6 Low-Level Waste Management Area 4

Concentrations of carbon tetrachloride above the MCL were found in most wells in FY 1997; the elevated values are related to the known plumes discussed above. Total organic halide levels in the groundwater have been historically high beneath LLWMA 4 and are related to the carbon tetrachloride plume. The total organic halide levels are generally higher in wells on the east than the wells on the west of LLWMA 4.

Nitrate also exceeded the MCL in wells 299-W15-15, 299-W15-16, 299-W15-18, 299-W15-19, and 299-W18-24 in FY 1997. This is most likely related to the nitrate plume originating from other facilities as discussed above.

There is no indication that LLWMA 4 has contributed to groundwater contamination.

5.9.3.7 State-Approved Land-Disposal Site

This disposal site receives treated effluent containing tritium, which is allowed to infiltrate through the soil column to the water table. Tritium was first detected in groundwater around the facility in July 1996 in upgradient well 699-48-77A, located ~100 m south of the site. A tritium concentration of 2,000,000 pCi/L was determined for this well from the September 1997 sample. Tritium results of up to 3,000 and 80,000 pCi/L have been reported in nearby downgradient wells 699-48-77C and 699-48-77D, respectively. Well 699-48-77C is screened at ~20 m below the water table, leading to more dilute tritium concentrations. Hydrogeologic and hydrochemical evaluations suggest that effluent infiltrating beneath the site may be moving a limited distance southward along the relatively impermeable Plio-Pleistocene unit before reaching the water table. Concentrations of sulfate, calcium, total dissolved solids, and levels of specific conductance parallel the rise in tritium, suggesting these constituents are leached from natural soil components in the vadose zone (PNNL-11633, PNNL-11665).

Comparison of numerical groundwater models applied over the last several years indicate that earlier predictions, which show tritium from this disposal site approaching the Columbia River, were too simplified or overly robust in source assumptions (PNNL-11665). The most recent modeling indicates that concentrations of tritium >500 pCi/L will extend, at most, no farther than ~1.5 km from the disposal site, using the most reasonable projections of operation of the 200 Areas Effluent-Treatment Facility. This extent encompasses only the wells in the current tritium-tracking network (see Appendix A).

5.9.4 Summary of Remediation Effects

5.9.4.1 200-UP-1 Operable Unit

The pump-and-treat system for this operable unit is located on the north side of the 216-U-17 crib. The system was constructed to contain the highest portion of the uranium and technetium-99 plume (ROD 1997). Carbon tetrachloride and nitrate are also present. Early operations consisted of a 57-L/min treatability test conducted from March 1994 to September 1995. Phase I pump-and-treat operations commenced on September 25, 1995, using one extraction well and one injection well, pumping at a rate of 190 L/min. This system operated until February 7, 1997. A pump-and-treat remediation system also 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.

On February 25, 1997, an interim action record of decision was issued (ROD 1997) for the 200-UP-1 Operable Unit pump-and-treat operations. The selected remedy consisted of pumping the highest concentration zone of the uranium and technetium-99 groundwater plumes, using the same extraction well and pumping rate as Phase I operations, and routing the groundwater to the 200 Areas Effluent-Treatment Facility. Prior to issuance of the interim action, groundwater was treated onsite using an ion-exchange medium. The water was injected upgradient from the high-concentration portion of the plume. Since March 1997, contaminated groundwater is pumped from the extraction well, transported in an 11-km-long transfer pipeline to the 200 Areas Effluent-Treatment Facility, and sent to the State-Approved Land-Disposal Site north of the 200-West Area for disposal.

The interim action objectives (ROD 1997) are the following:

- reducing contamination in the areas of highest concentration of uranium and technetium-99 to below 10 times the cleanup level under the Model Toxics Control Act – Cleanup (WAC 173-340) and 10 times the interim DWS for technetium-99

- reducing potential adverse human health risks through reduction of contaminant mass

- preventing further movement of these contaminants from the highest concentration area

- providing information that will lead to development and implementation of a final remedy that will be protective of human health and the environment.

For more detailed information about operations during FY 1997, refer to the Bechtel Hanford, Inc. annual report (BHI-01126). It should be noted that the former injection well (299-W19-36) is now used only for monitoring groundwater quality.

Contaminant Removal and Overall Effectiveness. Until rerouting of groundwater to the 200 Areas Effluent-Treatment Facility in March 1997, treatment consisted of an ion-exchange medium composed of Dowex 21K™ resin to remove uranium and technetium-99 from the groundwater. Following ion-exchange treatment, in-line, liquid-phase, granular, activated carbon was used to filter carbon tetrachloride. After treatment, groundwater was returned to the aquifer via the upgradient injection well. Nitrate was not treated prior to bringing the 200 Areas Effluent-Treatment Facility on line.

Since initiation of pump-and-treat operations in March 1994 (start of the treatability test) and through February 7, 1997 (Phase I operations), >131,500,000 L of water have been treated, resulting in removal of 37.8 g of technetium-99, 45.8 kg of uranium, and 10.6 kg of carbon tetrachloride.

Pump-and-treat operations were shut down in February 1997 while the discharge line from the extraction well was connected to the 200 Areas Effluent-Treatment Facility cross-area transfer line. Operations resumed on March 31, 1997, with contaminated groundwater going to the facility for treatment. In place of the ion-exchange resin previously used, the treatment train at the facility consists of the following process units:

- filtration of suspended solids
- ultraviolet light oxidation for organic destruction
- pH adjustment to neutralize the waste stream
- hydrogen peroxide decomposer to remove excess hydrogen peroxide
- degasification for removal of carbon dioxide
- reverse osmosis to remove dissolved solids and radionuclides
- ion exchange for removal of dissolved solids and radionuclides.

From April through September 1997, >49,400,000 L of water were transported from the 200-UP-1 Operable Unit pump-and-treat site to the 200 Areas Effluent-Treatment Facility at an average flow rate of 190 L/min. Greater than 32,400,000 L of this water were treated, resulting in the removal of 5.6 g of technetium-99, 11 kg of uranium, 0.89 kg of carbon tetrachloride, and 2,260 kg of nitrate.

During FY 1997, technetium-99 concentrations from extraction well 299-W19-39 remained relatively constant, averaging ~3,040 pCi/L, and ranged from 1,790 to 3,540 pCi/L. For comparison, the concentration at the start of Phase I activities in September 1995 was ~6,140 pCi/L. Uranium concentrations were also relatively constant throughout the year, with an average concentration of ~270 µg/L, varying from 196 to 360 µg/L. The highest sustained concentrations of uranium were observed in the February 1995 sample at ~325 µg/L.

Water-Level Impact and Capture-Zone Analysis. Extraction and injection activities, as well as a regional water-level decline affect water levels in the area of the pump-and-treat operations. Water levels are dropping as the residual mound from the now decommissioned U Pond decays. The water level changed 0.7 m/yr (BHI-01126). One significant effect of the declining water levels is that several of the monitoring wells in the 200-UP-1 Operable Unit will be dry in calendar year 1998. This situation may necessitate the installation of additional monitoring wells so the effects of plume remediation can be evaluated.

Groundwater modeling indicates that the targeted plume is captured under the current well configuration (Figure 5.9-20). It is estimated that ~70% of one pore volume has been extracted from the original high-concentration portion of the plume based on the original baseline plume map (BHI-01126). The travel markers on the figure show that much of the water captured during the past 2 years moved from the injection well to the extraction well. Without operation of the injection well, however, the travel markers will broaden and become more coincident with the shown hydraulic flow field. This is already indicated by the high-angle shift in the flow lines near the extraction well. Contaminant concentrations at upgradient monitoring wells near the previous injection well decreased during injection operations but are now increasing since use of this well ceased. The degree of recovery will be useful for determining the long-term effects of cleanup and whether the remedial action objectives can be met.

Technetium and uranium concentrations in wells closer to the extraction well have been increasing (e.g., 299-W19-26), indicating that the core of the plume is moving toward the extraction center (299-W19-39). Figures 5.9-21 and 5.9-22 (from BHI-01126) show the details of the technetium-99 and uranium distributions in the immediate vicinity of the pump-and-treat operations. These figures show some differences in plume configuration from the regional plume maps presented above because a slightly different data set was used for local detail. Technetium concentrations increased from 600 pCi/L in early 1996 to ~2,000 pCi/L in August 1997 at well 299-W19-20 (31 m away). Contaminant concentrations are decreasing at downgradient monitoring well 299-W19-40 (83 m southeast of 299-W19-39), indicating that plume capture and containment are being achieved.

During FY 1997, measurable progress was made toward meeting the 200-UP-1 Operable Unit remedial objectives of reduction of contaminant mass and hydraulic containment. Process- and groundwater-performance data obtained during system operation should contribute toward development and implementation of a final remedy. Additional wells may need to be installed in 1998 or 1999 to continue to monitor the effects of plume remediation.

5.9.4.2 200-ZP-1 Operable Unit

The pump-and-treat system for this operable unit, located north of the Plutonium Finishing Plant, was implemented as an interim action to prevent further movement of groundwater contamination from the high-concentration portion of the carbon tetrachloride plume and to reduce contaminant mass (ROD 1995a). The pump-and-treat operations and system were implemented in a three-phased 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 at a rate of ~150 L/min; 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 in accordance with Milestone M-16-04A (Ecology et al. 1989) and ended on August 8, 1997 for transition to Phase III operations. The well-field configuration during Phase II operations consisted of three extraction wells, pumping at a combined rate of ~570 L/min, and a single injection well. Groundwater was treated using an air stripper followed by granular activated carbon treatment of the air stream.

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, meeting Milestone M-16-04B (Ecology et al. 1989). The well field was expanded to 6 extraction wells, pumping at a combined rate of ~720 L/min, and 5 injection wells.

The interim action objectives (ROD 1995a) are the following:

- preventing 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)
- reducing contamination in the area of highest carbon tetrachloride concentrations
- providing 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 BHI-01126. Figure 5.9-23 shows the area facilities and Phase III extraction, injection, and monitoring well locations.

Contaminant Removal and Overall Effectiveness. The Phase II treatment system combined conventional air stripping with vapor-phase, granular, activated carbon adsorption technology to remove the volatile organic compounds from the contaminated groundwater. Since initiation of pump-and-treat operations in August 1994 (start of the treatability test) through September 1997 (Phase III operations), >259,000,000 L of water have been treated, resulting in removal of ~860 kg of carbon tetrachloride (Table 5.9-2). Greater than 199,000,000 L were removed in FY 1997 alone. Average flow rates were >570 L/min for Phase II and 715 L/min for Phase III operations. (Phase III was initiated at the end of August 1997.)

Influent concentrations at extraction well 299-W15-33 increased ~1,000 µg/L, starting at ~4,500 µg/L at the beginning of the fiscal year and finishing at ~5,500 µg/L. The average concentration during FY 1997 was 5,050 µg/L. Increases in wells 299-W15-34 and 299-W15-35 were also observed but were not as significant. Chloroform and trichloroethylene ranged from ~10 to 31 and ~3 to 13 µg/L, respectively. Contamination data for the 200-ZP-1 Operable Unit extraction wells are summarized in Table 5.9-3.

Carbon tetrachloride concentrations were highest in extraction well 299-W15-32, averaging 7,120 µg/L. The other extraction wells (299-W15-36 and 299-W15-37) averaged 2,280 and 280 µg/L, respectively. These high concentrations at well 299-W15-32 were not unexpected, given the proximity of this well to the 216-Z-9 trench where approximately half of the carbon tetrachloride was disposed. This well was originally constructed for an interwell tracer-partitioning test in 1994 to determine if dense, nonaqueous-phase liquid was present in the groundwater. Because of funding limitations, the tracer test was not completed. During expansion to Phase III operations, this well was adopted for use as one of the six planned extraction wells (in lieu of installing a new well).

Water-Level Impact and Capture-Zone Analysis. The water-table map (Plate 2) indicates that groundwater flow in the vicinity of the Phase II extraction wells is still east-northeast in this area. The persistent broad and relatively flat mound characterizing the water table is a residual groundwater feature from discharges to the now decommissioned U Pond. Water levels are estimated to be declining at a rate up to ~0.7 m/yr (BHI-01126).

During Phase II operations, the extraction wells provided hydraulic capture at the northern end of the high-concentration area of the plume (BHI-01126). Phase III operations have extended the zone of hydraulic containment to the south (see Figure 5.9-22). It appears from the modeling analysis that the high-concentration area of the plume will be captured, and a recirculation cell will be established (BHI-01126).

A fairly significant groundwater mound is developing at injection well 299-W15-29. Water-level buildup near two monitoring wells (699-39-79 and 299-W18-36; 88 and 80 m to the south) is ~0.5 and 1.1 m (see Figure 5.9-22). Only one extraction well was used at the start of Phase III operations, taking the full 715 L/min of discharge, with the other wells expected to come on-line early in FY 1998.

Progress was made toward achieving the interim action objectives at the 200-ZP-1 Operable Unit in FY 1997 through hydraulic containment of the high-concentration area of the carbon tetrachloride plume, reduction of contaminant mass, and collection of additional information that will assist in determining a final remedy.

5.10 200-East Area

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The 200-East Area was used historically for chemical separation and purification of plutonium, with associated waste management. For reasons of safety and security, the area was established with a significant spatial separation from the 200-West Area and with some redundancy of function. Differing hydrogeology between the two sites resulted in significant dissimilarities in the spread of contaminants. The B and PUREX Plants were the major processing facilities in the 200-East Area. Waste-disposal facilities associated with operations included cribs, trenches, tile fields, surface impoundments, injection wells, tank farms, and landfills. Because of the complexity of past waste-disposal operations in the 200 Areas, as well as the close spacing of the facilities, it is often difficult to determine the exact source of contamination. Groundwater remediation activities are grouped into groundwater operable units. These groundwater operable units are distinct from the numerous source area operable units for facility and vadose-zone remediation.

5.10.1 Facilities and Operable Units

5.10.1.1 B Plant

Waste-disposal facilities and single-shell tanks associated with B Plant operations are generally located in the northwestern part of the 200-East Area. The waste-disposal history associated with B Plant is similar to that of T Plant (in the 200-West Area); both plants operated over a similar time period (1944 through 1956) and used the bismuth phosphate process. High-level waste tanks in the B Plant area were used in a fashion similar to the tanks in the T Plant area (see Section 5.9.1.1). Between 1948 and 1956, the tanks were used for settling of solids from second-decontamination-cycle wastes in a cascading system. The supernatant from the last tank in the cascade was discharged to nearby 216-B-7A, 216-B-7B, and 216-B-8 cribs (WHC-MR-0227). From 1951 to 1956, cell-drainage waste was discharged through the cascade with the second-cycle waste. From 1951, the 242-B evaporator was used to reduce the volume of first-cycle wastes, though in 1953-1954, some first-cycle waste was discharged to specific retention trenches. Waste from the original plutonium-concentration facility in the 224-B building was settled in 208,000-L, 200-series, single-shell tanks before being discharged to cribs. In addition, in 1954, evaporator bottoms (concentrated waste) from the 242-B evaporator were discharged to the 216-B-37 trench (WHC-MR-0227). Thus, some of the most radioactive liquid waste was discharged to the ground rather than being stored in tanks. The wastes discharged were closely related to tank wastes; the tanks, however, apparently retained much of the solid fraction in the waste streams. According to WHC-MR-0132, first-cycle waste contained ~10% of the original fission activity and 1% of the plutonium. Second-cycle waste was lower in overall activity, containing <0.1% of the overall fission activity and 1% of the plutonium.

The 216-B-5 injection well was operated from April 1945 to September 1946 and received radioactive wastes from B Plant activities, including some hot-cell drainage and supernatant overflow from settling tanks. The waste was injected below the water table, resulting in radiological contamination that is still apparent 50+ years later. Radiological contaminants associated with the facility include strontium-90, cesium-137, and plutonium. These three contaminants are restricted to the immediate vicinity of the 216-B-5 injection well by their low mobility in groundwater and the extremely low hydraulic gradient in this area.

In 1954 and 1955, scavenged uranium-recovery waste supernatant, containing large amounts of ferrocyanide and other chemical and radiological components from U Plant operations, was discharged to the BY cribs and to a trench in the northern part of the 200-East Area (WHC-MR-0227). This practice was soon discontinued because of the appearance of unacceptably high levels of cobalt-60 in the groundwater.

5.10.1.2 PUREX Plant

The PUREX Plant started operation in 1956, eventually replacing the REDOX Plant as the plutonium-separations facility. The first PUREX operational campaign extended from 1956 to 1972. Following an 11-year shutdown, the PUREX Plant began operations again in 1983, which ended in December 1988 when the weapons-production mission ended. A short run was started in December 1989 to stabilize material in the system. Waste from the PUREX Plant was discharged to a number of nearby cribs, ditches, and ponds. A number of these facilities have RCRA-monitoring requirements.

5.10.1.3 RCRA-Regulated PUREX Cribs

Three liquid waste-disposal facilities for the PUREX Plant require groundwater monitoring under RCRA (216-A-10, 216-A-36B, and 216-A-37-1 cribs).

The 216-A-10 crib, retired from use, was a liquid waste-disposal facility for the PUREX Plant. This crib is located ~122 m south of the PUREX Plant and ~110 m east of the 216-A-36B crib (see Appendix A). This crib is 84 m long, has a V-shaped cross-section, and is 14 m deep. Several waste streams, collectively described as process distillate discharge, were disposed to this crib and were allowed to percolate through the soil column. The crib first received liquid waste over a 4-month period during PUREX startup in 1956. In 1961, the crib replaced the 216-A-5 crib and received PUREX effluent continuously until 1973. Periodic discharges were received in 1977, 1978, and 1981. From 1982 to 1987, effluent discharges resumed on a continual basis. Discharge between 1981 and 1987 averaged 100,000,000 L/yr. In 1987, the crib was taken out of service and replaced by the 216-A-45 crib.

The process distillate waste stream to the 216-A-10 crib was characteristically acidic and contained concentrated salts. Other waste-stream constituents included aliphatic hydrocarbon compounds; organic complexants; and tritium, uranium, strontium-90, cobalt-60, cesium-134, cesium-137, plutonium, ruthenium-103, and ruthenium-106 (RHO-HS-SR-86-3-4Q LIQ P).

The 216-A-36B crib, also retired from use, was a liquid waste-disposal facility for the PUREX Plant. The crib is located ~360 m south of the PUREX Plant and ~110 m east of the 216-A-10 crib. The 216-A-36B crib is the south end (150 m) of the crib, originally known as the 216-A-36 crib (see Appendix A). The original crib dimensions were 180 m long, 4 m wide, and 4 m deep. A 0.15-m-dia. perforated distributor pipe was placed at the bottom of the crib on a 0.3-m bed of gravel, covered with another 0.3 m of gravel, and backfilled to grade. Ammonia scrubber distillate waste from the PUREX Plant was discharged through the distribution pipe to the crib and allowed to percolate through the soil column.

The original 216-A-36 crib received liquid effluent from September 1965 to March 1966. A substantial inventory of radionuclides was disposed to the crib and was assumed to have infiltrated sediments near the inlet to the crib. To prevent radionuclides from reaching the water table, the north end of the crib was used as a specific retention facility. This practice limited the amount of water discharged to the crib (RHO-HS-EV-18). To continue effluent discharges to the crib, it was divided into two sections (216-A-36A and 216-A-36B). Grout was injected into the gravel layer to form a curtain separating the two sections. The liquid effluent-discharge point was moved to the 216-A-36B section and the 216-A-36A section was no longer used. Discharge to the 216-A-36B crib resumed in March 1966 and continued until 1972, when the crib was temporarily removed from service. The crib was placed back in service in November 1982 and continued to operate until it was permanently taken out of service again in October 1987.

Ammonia scrubber distillate discharged to the crib consisted of condensate from nuclear fuel-decladding operations, in which zirconium cladding was removed from irradiated fuel by boiling in a solution of ammonium fluoride and ammonium nitrate. Other waste-stream constituents included tritium, iodine-129, uranium, strontium-90, cobalt 60, cesium-137, and ruthenium-106 (PNL-6463).

The 216-A-37-1 crib, also retired from use, was a liquid waste-disposal facility for the PUREX Plant. It is located near the former Grout Treatment Facility (see Appendix A), ~600 m east of the PUREX Plant. The original crib dimensions were 213 m long, 3 m wide, and 3.4 m deep. A 0.25-m-dia. corrugated, galvanized, perforated distributor pipe was placed on 1 m of gravel fill. The distributor pipe was covered with gravel, a layer of plastic, and backfill material. Wastewater entered at the southeast end of the crib, which is at a lower elevation than the northwest end. This configuration favored infiltration at the southeast end of the crib.

The 216-A-37-1 crib first received liquid waste in March 1977 and continued until April 1989. The waste stream included process condensate from the 242-A evaporator and included the radionuclides uranium, strontium-90, cobalt-60, cesium-137, plutonium, and ruthenium-106 (RHO-HS-EV-18). The process condensate was regulated as a mixed waste because it contained radionuclides, spent halogenated and nonhalogenated solvents, and ammonia. The estimated annual quantity of dangerous waste (49,120 kg) represents the maximum annual output of evaporator process condensate during operating campaigns.

5.10.1.4 216-A-29 Ditch

This is an earthen ditch 2 m wide and 2,000 m long. The depth of the ditch varies from 1 m at the head end (southwestern end) to 5 m at the point of discharge. The ditch conveyed PUREX chemical waste to B Pond from 1955 to 1986. In 1984, administrative and physical controls were implemented to avoid inadvertent discharges of hazardous waste to the ditch. All effluent sources were rerouted in July 1991, and use of this ditch for disposal was discontinued. The ditch was backfilled and revegetated for interim stabilization later that year. Prior to deactivation, the ditch received an average of 950 to 2,000 L/min of effluent from the PUREX Plant chemical sewer. The lower range of effluent discharges continued after production was halted in 1986 because cleanout runs were performed prior to PUREX decommissioning.

The ditch received effluents that contained hazardous and radiological waste. Stratigraphic control of migrating effluents is limited to sporadic perching horizons composed of silt and other fine-grained sediments. Of primary concern for RCRA were discharges of sodium hydroxide and sulfuric acid, which occurred on a daily basis from 1955 until February 1986. These wastes were produced as a result of ion-exchange regeneration at PUREX.

5.10.1.5 216-B-3 Pond

B Pond is a RCRA-regulated wastewater-disposal facility for effluents generated by past operations in the 200-East Area that is located east of the 200-East Area. For the purpose of RCRA monitoring, B Pond consists of a main pond, three expansion ponds, and contiguous portions of the 216-B-3 ditches (see Appendix A). The main pond, which began receiving effluent in 1945, was located in a natural topographic depression and was diked on the eastern margin. The pond covered ~14.2 ha and had a maximum depth of ~6.1 m. Three expansion ponds (216-B-3A, 216-B-3B, and 216-B-3C) were placed in service in 1983, 1984, and 1985, respectively. The 216-B-3A and 216-B-3B expansion ponds are ~4.5 ha; the 216-B-3C expansion pond is ~16.6 ha. Water discharged to these ponds infiltrated into the ground and recharged the underlying aquifer. Details of the operation of these ponds are presented in DOE/RL-89-28, Rev 2. Adjacent portions of the three ditches (no longer in use) leading to the ponds are included in the system for groundwater-monitoring purposes.

In 1994, the main pond and the 216-B-3 ditch were filled with clean soil, and all vegetation was removed from the perimeter as part of interim stabilization activities. Also in 1994, the expansion ponds were RCRA clean closed. In April 1994, discharges to the main pond ceased, and some effluents were rerouted to the 216-B-3C expansion pond via a bypass pipeline. The other streams were sent to the newly constructed 200 Areas Treated Effluent-Disposal Facility (formerly known as the W-049H Project). In

August 1997, the remaining streams discharging to the 216-B-3C expansion pond were diverted to the 200 Areas Treated Effluent-Disposal Facility, thus ending the operation of the B Pond system.

In the past, B Plant steam condensate and chemical sewerage and PUREX Plant chemical sewerage were also discharged to the B Pond system (primarily the main pond). Potential contaminants contained within past waste streams, which may have entered the groundwater, included tritium, aluminum nitrate, potassium hydroxide, nitric acid, sulfuric acid and other acids (DOE/RL-89-28, Rev. 2).

5.10.1.6 200 Areas Treated Effluent-Disposal Facility

This facility is a non-RCRA waste-disposal site built to provide an infiltration area for treated liquid effluent from the generating facilities in the 200 Areas. The facility is located ~600 m east of the 216-B-3C expansion pond (see Appendix A). In operation since June 1995, the facility allows infiltration of steam condensate and other clean water to the soil column. Some of the streams formerly discharged to the 216-B-3C expansion pond were rerouted to this facility in 1995 and the remainder of the 216-B-3C expansion pond streams were diverted to this facility in August 1997.

5.10.1.7 216-B-63 Trench

This trench, in service from March 1970 to February 1992, received liquid effluent (378,540 to 1,514,160 L/d) from the B Plant chemical sewer. The liquid effluent was a mixture of 70% steam condensate and 30% raw water, which was disposed to the west end of the open, unlined earthen trench. Past releases to the trench included radioactive and dangerous waste. Documented hazardous discharges occurred from 1970 to October 1985 and consisted of aqueous sulfuric acid and sodium hydroxide solutions that exceeded 2.0 and 12.5 pH, respectively. Radioactive soils were dredged from the trench in August 1970 but no records exist of radioactive waste disposal to the trench. Starting in 1985, physical controls, radiation monitoring, and operating procedures were modified to avoid inadvertent discharge of chemicals or radioactive substances to the wastewater stream. Liquid effluent discharge to this trench ceased in February 1992.

5.10.1.8 Single-Shell Tank Farms

The single-shell tanks that are currently storing hazardous, radioactive wastes in the 200-East Area are located in WMAs A-AX, B-BX-BY, and C. These WMAs, which stopped receiving waste in 1980, have been designated as RCRA facilities since 1989. Currently, the single-shell tanks are used to store radioactive and mixed waste generated by chemical processing of spent fuel rods using the tributyl phosphate, bismuth phosphate, REDOX or PUREX processes. The types of waste added to the single-shell tanks and their general composition are discussed in WHC-MR-0132.

The tanks were constructed between 1943 and 1964 and, depending on dimensions, each held between 1,892,500 and 3,785,000 L. WMAs B and C each contain four smaller, 200-series tanks that hold 208,175 L each. WMA A-AX contains 10 tanks, 5 of which are known or assumed to have leaked; WMA B-BX-BY contains 40 tanks, 20 of which are known or assumed to have leaked; and WMA C contains 16 tanks, 6 of which are known or assumed to have leaked.

The single-shell tanks received mixtures of organic and inorganic liquids containing radionuclides, solvents, and metals that were originally discharged as alkaline slurries. Waste management operations have mixed various waste streams from numerous processes generated in processing spent fuel rods. Thus, the contents within each tank are difficult to determine. The situation is further complicated by subsequent chemical reactions, degradation, and decay of radionuclides. The radionuclide and chemical inventory of the single-shell tanks is summarized in WHC-SD-WM-TI-565, Rev. 1; historical operations at the tank farms are summarized in WHC-MR-0227 and WHC-MR-0132. In the case of WMA B-BX-BY, source determination for the single-shell tanks is further complicated because tank wastes were discharged to nearby cribs, unlined specific retention trenches, unlined ditches, french drains, and ponds.

Tank waste exists in the form of salt cake and sludge, which is the residual left after the liquids were removed. However there are small quantities of supernatant and interstitial liquids that could not be removed by pumping. The waste chemistry consists of sodium hydroxide, sodium salts of nitrate, nitrite, carbonate, aluminate, and phosphate. Some hydrous oxides of iron and manganese also are present. Fission-product radionuclides, such as technetium-99, strontium-90, cesium-137, and actinide elements, such as uranium, thorium, plutonium, and neptunium, constitute the principal radioactive components. Some of the single-shell tanks also contain ferrocyanide or organic salts.

5.10.1.9 Low-Level Waste Management Areas

LLWMA 1 is located in the northwestern corner of the 200-East Area, is currently following interim-status detection-level monitoring regulations, and includes all of the 218-E-10 burial ground (see Appendix A). This WMA is divided by an east-west access road. The southern portion of the burial ground is currently active, while the portion north of the road is for future expansion. The active area measures 22.9 ha, and the area for future expansion measures 15.3 ha, for a total area of 38.2 ha. Disposal activities began in 1960 and continue to the present. Materials placed in this facility are primarily dragoff waste, failed equipment, and mixed industrial waste from the PUREX Plant, B Plant, and N Reactor.

LLWMA 2 is currently in indicator parameter evaluation status. This WMA is located in the northeastern corner of the 200-East Area and includes all of burial ground 218-E-12B (see Appendix A). This burial ground has a total area of 70.1 ha and has been in use since 1968. The majority of the waste is in the eastern half of the burial ground and consists primarily of miscellaneous dry waste and submarine reactor compartments. Parts of two trenches contain transuranic waste.

5.10.1.10 Liquid Effluent-Retention Facility

This facility consists of three 24,600,000-L surface impoundments (basins), located on a 15.8-ha site northeast of the 200-East Area (see Appendix A). The three basins were constructed of two composite liners, a leachate-collection system between the liners, and a floating cover. The fourth basin is excavated but is not completed and will not be used.

This facility serves as temporary storage for evaporator process condensate. The 242-A evaporator is used to substantially reduce the quantity of waste stored in the double-shell tanks, and the effluent is discharged to cribs in the 200-East Area. The evaporator was shut down when listed waste was found in the effluent stream but was restarted on April 14, 1994.

Primary constituents detected in the effluent stream from the 242-A evaporator were ammonium, acetone, aluminum, 1-butanol, 2-butanone, tritium, strontium-90, ruthenium-106, and cesium-137. Further information of the effect on groundwater from release of this waste stream is documented in WHC-EP-0367.

The 242-A evaporator process condensate effluent, stored at the Liquid Effluent-Retention Facility, is regulated as a dangerous waste under WAC 173-303 because of the toxicity of the ammonium and the presence of listed waste constituents. A RCRA interim-status groundwater-monitoring system is in place at the Liquid Effluent-Retention Facility to detect any impact on groundwater quality. The facility is monitored under an indicator evaluation program.

5.10.1.11 Operable Units

Two groundwater operable units relate to 200-East Area contamination (200-BP-5 and 200-PO-1). The boundaries for these two operable units were defined (WHC-SD-EN-TI-019) by an east-west-trending groundwater divide across the 200-East Area (see Figure 5.2-4). The 200-BP-5 Operable Unit lies to the north of this divide, whereas the 200-PO-1 Operable Unit is south of the divide. The divide itself is caused by hydraulic interference between wastewater mounding at the 216-B-3 pond (also known as B Pond) with groundwater flowing from the 200-West Area. The geographic boundary between the two operable units extends from B Pond southwest through the PUREX tank farms and then in an east-to-west direction just south of the Semiworks and B Plant facilities. A number of RCRA and CERCLA source and vadose-zone units are encompassed in the operable units.

200-BP-5 Operable Unit. This operable unit contains all plumes located north of the groundwater divide. Important plumes within the unit originated from B Plant's bismuth phosphate liquid disposal and include the strontium-90/ cesium-137/plutonium-239/-240 plume centered around the 216-B-5 injection well. The 200-BP-5 cobalt-60/technetium-99/cyanide/nitrate plume is centered in the area of well 699-50-53A. This latter plume was derived from liquid waste disposal to the BY cribs.

Both the 216-B-5 injection well and the BY crib plumes were the target of pump-and-treat programs in FY 1995, which successfully removed quantities of radionuclides and cyanide. Following these treatability tests, it was determined that no further action at either plume was required. The plume at the 216-B-5 injection well has a low-migration potential. Even though the BY crib plume is more mobile, it poses a small health risk and, therefore, continued treatment was deemed unnecessary. Instead, an annual groundwater-monitoring program will track migration of these plumes.

200-PO-1 Operable Unit. This operable unit is being addressed as a RCRA past-practice unit and encompasses the area south of the 200-East Area groundwater divide. The unit consists generally of plumes derived from PUREX Plant operations. Plumes of concern extend mostly to the south and east from the PUREX Plant. This operable unit was the subject of a RCRA facility investigation/corrective measure study because remediation is being carried out under RCRA requirements (DOE/RL-95-100, Rev. 1). The study examined existing groundwater-monitoring data for the last 10 years.

The RCRA facility investigation report (DOE/RL-95-100, Rev. 1) evaluated three low-to-medium-concentration, widespread plumes. These plumes of tritium, iodine-129, and nitrate cover broad areas within and southeast of the 200-East Area. A number of small plumes or sporadic detections were identified for arsenic, manganese, chromium, strontium-90, and vanadium, occurring either as one-time hits or within a very limited area.

The RCRA corrective measure study (DOE/RL-96-66), which included numerical modeling and a risk assessment, identified only the tritium and iodine-129 plumes for further evaluation. The corrective action evaluation considered only the no-action and institutional control alternatives because of the widespread nature of the plumes, the low concentrations over much of the plume area, and the lack of a suitable treatment technology. Also, because of its 12.3-year half-life, tritium is expected to decay to acceptable concentrations in the next 50 years. No other actions are expected at this time.

5.10.2 Compliance Issues

5.10.2.1 PUREX Cribs

Interim-status RCRA groundwater-monitoring networks have been in place for the 216-A-10 and 216-A-36B cribs since 1988 (WHC-SD-EN-AP-170, Rev. 0-A). Groundwater-monitoring programs at these cribs were in RCRA indicator parameter evaluation status until June 30, 1997. Starting July 1, 1997, these two cribs and the 216-A-37-1 crib were combined into one groundwater quality assessment program (PNNL-11523) because they have similar hydrogeology and waste constituents. The groundwater-monitoring plan (PNNL-11523) was changed from an indicator parameter evaluation program to a groundwater quality assessment program because of known groundwater contamination and the high probability that a new indicator parameters program for the cribs would show that critical means are exceeded. By combining them into one RCRA groundwater-monitoring area, there would be savings in sampling and analysis costs as a result of a reduction in the number of near-field wells sampled. Groundwater-monitoring results from one downgradient well (299-E17-9) near the 216-A-36B crib show that specific conductance is significantly higher than in the corresponding upgradient well, providing additional evidence that the crib has contaminated groundwater. Prior to July 1, 1997, the 216-A-37-1 crib was monitored under the Operational Monitoring Program. Monitoring networks and analyte lists for the PUREX cribs are included in Appendix A. Appendix B shows the statistical evaluation of the groundwater results from the first part of the year while the cribs were monitored under interim-status detection.

Water levels are measured regularly, and the adequacy of the existing monitoring networks of the PUREX cribs is evaluated accordingly. Although water levels were decreasing prior to FY 1996, they appear to have stabilized. Therefore, there is no near-term need to replace any of the existing groundwater-monitoring wells. Furthermore, the new well network contains 11 near-field wells and 57 far-field wells, which adequately monitor the quality of groundwater in the area containing the plumes of groundwater contamination, including tritium, iodine-129, and nitrate, emanating from the PUREX cribs.

5.10.2.2 216-A-29 Ditch

Background sampling for indicator parameter evaluation was completed in August 1989. The monitoring network for this ditch was sampled semiannually for indicator parameters and annually for groundwater quality and drinking water parameters. In the January 1990 sample, specific conductance increased beyond the critical mean, and an assessment-monitoring program was initiated. The assessment program was resolved in October 1995 by confirming that the ditch was the likely source of the elevated specific conductance. However, the source constituents were determined to be sulfate, calcium, and sodium, which are nonregulated substances (WHC-SD-EN-EV-032). The program subsequently reverted to indicator evaluation monitoring.

Water levels in each well of the 216-A-29 ditch-monitoring network were compared to the depth of the screened interval and the pump-intake elevation to ensure that sufficient volumes of water exist for sampling purposes. There is no short-term need to replace any of the existing groundwater-monitoring wells.

5.10.2.3 216-B-3 Pond

Interim-status detection-level groundwater monitoring of B Pond began in 1988 and was changed to assessment status in 1990 because of elevated total organic halide levels in two downgradient wells. The B Pond system continued in an assessment program until October 1997. At that time, a detection-level program was restored, as recommended in PNNL-11604. That report concluded that no definable hazardous waste contamination had affected groundwater beneath the B Pond system, despite erratic occurrences of elevated total organic halides (Section 5.10.3.2).

The locations of wells in the B Pond system RCRA groundwater-monitoring networks are shown in Appendix A. The maximum number of wells (25) was monitored from 1993 until late 1995. In 1995, the number of wells in the network was reduced to 14. Three of the wells no longer in the B Pond network are part of the 200 Areas Treated Effluent-Disposal Facility groundwater-monitoring network. In 1996, one of two upgradient wells (299-E18-1) was dropped from the network. This well was part of the 2101-M pond facility, which was clean closed. The current upgradient well (299-E32-4) is shared with the still-active low-level burial grounds in the 200-East Area (see Appendix A).

Water levels in the 25 wells in the original network have generally declined during the life of the RCRA program. Exceptions to this trend occurred during the early to mid-1990s in some downgradient wells, such as wells 699-40-40A, 699-40-40B, 699-41-42, and wells around the 200 Areas Treated Effluent-Disposal Facility. During the past year, however, water levels in all wells have resumed a definite downward trend (see Section 5.10.1.5). Water levels have dropped dramatically during the past year in many wells, particularly, 699-40-40A, 699-42-39A, 699-42-39B, 699-42-40A, 699-42-42B, 699-43-40, 699-43-41E, 699-43-41G, 699-43-43, and 699-44-42. Some wells are estimated to have only a few years of potential service remaining. Wells in the western portion of the network (e.g., well 699-44-42) generally have fewer years of service left than those elsewhere in the network. Wells shared with the 200 Areas Treated Effluent-Disposal Facility, southeast of the B Pond system, appear to be the least affected by the declining water levels.

The redirection in 1994 of effluent discharges from the main B Pond to the 216-B-3C expansion pond probably introduced wastewater into the Hanford formation above the relatively impermeable Ringold lower mud unit. Thus, a locally perched, artificial aquifer likely exists beneath the 216-B-3C expansion pond. No monitoring wells are completed at this depth, nor have any regulatory or technical needs for such monitoring been identified. In August 1997, discharges were diverted from the 216-B-3C expansion pond to the 200 Areas Treated Effluent-Disposal Facility, thus ending all disposal activity at the B Pond system.

As noted in Section 3.6.7, groundwater flow in the vicinity of the B Pond system is assumed to be radially away from the apex of a hydraulic mound created by past discharges. Theoretically, any well placed within the influence of this mound would be able to effectively monitor any potential contamination in groundwater emanating from the facility.

To maintain an adequate monitoring network, several aspects of the system are considered, such as the areal distribution of wells, depth at which wells are screened, expected life of the well, and groundwater-flow direction in relation to the facility. For the B Pond system, "the facility" is determined to consist of the main pond and adjoining portions of the 216-B-3 ditches (see Appendix A). The three expansion ponds were RCRA clean closed in 1994 (DOE/RL-89-28, Rev. 2). This closure is a determination that the expansion ponds are no longer considered potential sources of contamination to groundwater. Although near-surface sediments beneath the main pond have been investigated for contamination (see Section 3.6.7), the results are regarded as incomplete. Thus, the main pond, though now interim stabilized, is still considered a potential source of contamination, along with adjoining portions of the 216-B-3 ditches. Continued groundwater monitoring will focus on this portion of the B Pond system.

5.10.2.4 200 Areas Treated Effluent-Disposal Facility

Groundwater sampling and analysis in the three monitoring wells at this facility (see Appendix A) are governed by a state waste-discharge permit (WAC 173-216). The constituent list and frequency of sampling are controlled by conditions specified in the permit. Currently, the sampling frequency is quarterly but is expected to be reduced to semiannually during FY 1998. No permit criteria for constituents in groundwater were exceeded in FY 1997.

5.10.2.5 216-B-63 Trench

Groundwater monitoring continues to provide no evidence that dangerous nonradioactive constituents from the site entered the groundwater from this trench. The RCRA indicator parameters are specific conductance, pH, 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. There were no significant detections that could be attributed to this trench. The statistical analyses presented in Appendix B revealed no exceedances in pH, specific conductance, total organic carbon, or total organic halides.

Based on the Wilson et al. (1992) groundwater-modeling program, the existing network should provide a monitoring efficiency of 66% to 85% for this trench. The 66% monitoring efficiency results from a flow-direction azimuth of 270 (toward the west), while the 85% monitoring efficiency is associated with an azimuth of 225 (toward the southwest).

The current network is composed of six wells drilled specifically to monitor this trench. The network also includes five upgradient wells drilled to monitor the low-level burial grounds located just north of the trench and one upgradient well drilled to monitor the single-shell tanks. The network is considered adequate but will be continuously evaluated as water levels and groundwater gradients change with time.

5.10.2.6 Single-Shell Tank Farms

WMA B-BX-BY. This WMA is currently in interim groundwater quality assessment for exceedances of the specific conductance critical mean in the February 1996 sample. For FY 1997, there were no exceedances for the indicator parameters (pH, total organic carbon, and total organic halides). However, specific conductance was above the critical mean (365.7 µS/cm) in at least one RCRA well for the last three quarters of FY 1997. This indicator parameter is rising in all downgradient wells monitoring this WMA; upgradient wells remain at ~280 µS/cm.

Exceedances also occurred in nitrate and technetium-99 for well 299-E33-41. The February 1997 sample had nitrate at 61 mg/L, which is above the 45-mg/L MCL. Nitrate was again above the MCL in August 1997 with a value of 48 mg/L. Technetium-99 exceeded the 900-pCi/L interim MCL in February 1997 with a value of 5,740 pCi/L and again in August 1997 with a value of 1,320 pCi/L.

Regionally, the RCRA groundwater-monitoring network appears to comply with the standard of one upgradient and three downgradient wells. However, hydraulic gradients are almost flat in most of the 200-East Area. It is particularly flat under WMA B-BX-BY, with differences in water-table elevation of 10 cm. However, this does not necessarily mean that groundwater velocities are slow because the permeability of the Hanford formation is generally high. Determination of the true groundwater-flow direction at this WMA will require further study during Phase II of the RCRA assessment.

The assessment-monitoring network has been expanded to include 11 surrounding wells. Two of these wells are RCRA compliant; the remaining nine are older non-RCRA wells installed to monitor liquid effluent discharges to the soil column from past-practice waste-disposal sites. No changes to the well network have been proposed yet for the assessment program.

WMAs A-AX and C. At these WMAs, groundwater samples from single-shell tank-monitoring wells were analyzed semiannually for potential contaminants, indicator parameters, and water quality parameters under interim-status detection monitoring during FY 1997. Concentration values of the indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) were not exceeded during FY 1997.

All wells at both WMAs show concentrations of iodine-129 above the 1-pCi/L interim DWS, as in past years. Chromium and nickel exceedances were seen at WMA A-AX in well 299-E24-19. This well has shown high chromium and nickel in the past.

Currently, the well networks for these two WMAs appear to comply with the required placement of groundwater-monitoring wells. However, continued observation is required as the B Pond mound dissipates. With an expected change in flow direction, both networks will require further evaluation with time. An additional monitoring well has been proposed for WMA A-AX to provide additional coverage on its northwestern corner. Before the location is finalized, the groundwater-flow direction will be reevaluated. If the groundwater flow does change to a southeast direction, new drilling will be considered to provide coverage on the southeastern side of the WMA. Groundwater-monitoring coverage for WMA C, though sparse, still meets the minimal requirements.

5.10.2.7 Low-Level Waste Management Area 1

This LLWMA continued in RCRA interim-status regulation in FY 1997. Groundwater sampling was on a semiannual schedule. Appendix A contains a list of monitoring wells and analytical constituents for LLWMA 1. There were no exceedances of the upgradient/ downgradient comparison values for the averages of indicator parameters in FY 1997.

The groundwater-monitoring network at LLWMA 1 continues to meet requirements. There are no plans for additional groundwater-monitoring wells at this time.

5.10.2.8 Low-Level Waste Management Area 2

LLWMA-2 contaminant indicator parameters were compared semiannually to comply with RCRA interim-status regulations. The quadruplicate average for total organic carbon from downgradient well 299-E34-12 exceeded the critical mean in the November 6, 1996 sampling event. All of the results appear to be slightly biased high; however, 1 of the 4 reported results was >20% higher than the highest of the other 3. The average of the three lower values is below the critical mean. The total organic carbon results from the May 5, 1997 sampling event were all below the critical mean. The high bias in some total organic carbon results has been noticed in other recent analyses and has been corrected (see Appendix D). LLWMA 2 remains in detection monitoring.

The monitoring network continues to satisfy the requirement for at least one upgradient and three downgradient wells and is adequate to monitor the burial ground. No additional monitoring wells are planned for the LLWMA 2 monitoring network.

5.10.2.9 Liquid Effluent-Retention Facility

Groundwater monitoring continues to provide evidence that no dangerous nonradioactive constituents entered the groundwater from this facility. The RCRA indicator parameters are specific conductance, pH, total organic carbon, and total organic halides (40 CFR 265.92[b][3]). Included in the analysis list are a gamma scan, alkalinity, gross beta, and turbidity. There were no significant detections in these analyses that could be attributed to this facility. Statistical analyses results are presented in Appendix B, and there were no exceedances of critical mean values for the RCRA indicator parameters.

The current groundwater-monitoring network is composed of four wells, one of which is upgradient. The network is considered adequate but will be continuously evaluated as water levels and groundwater gradients change with time. The Wilson et al. (1992) groundwater program calculated monitoring efficiency at 95.5%. No additional wells are under consideration at this time.

5.10.2.10 Drinking Water Standards and Derived Concentration Guides

Tritium was detected at levels above the DCG at one well south of the PUREX Plant. Tritium contamination at levels above the interim DWS was found through much of the 200-East Area. Strontium-90 was detected at levels over five times the DCG in one well near the 216-B-5 injection well. Localized strontium-90 contamination was found at levels above the interim DWS south of the PUREX Plant.

Iodine-129, cesium-137, plutonium, technetium-99, and uranium were also found at levels above the interim DWS in the 200-East Area. Nitrate was detected at levels above its MCL in the 200-East Area.

5.10.3 Extent of Contamination

During site operations, considerable waste was produced in the 200-East Area and disposed to numerous facilities. The exact source of the contamination detected in the groundwater cannot always be defined with a high degree of certainty. The discussion below divides the extent of contamination into that found generally in the vicinity of B Plant and that found in the vicinity of and downgradient of the PUREX Plant. The low-level burial grounds and Liquid Effluent-Retention Facility are discussed separately. Additional detail is provided for facilities with specific RCRA-monitoring requirements.

5.10.3.1 B Plant Area

With the decommissioning of Gable Mountain Pond, groundwater near B Plant began flowing northward and a number of groundwater-contaminant plumes reappeared north of the 200-East Area boundary. Several facilities in the vicinity of B Plant are notable with regard to groundwater contamination. Radiological contaminants, including substantial levels of technetium-99 as well as some cobalt-60, are found near the BY cribs. Chemical contaminants include nitrate and cyanide. Uranium contamination is also detected in limited areas. Injection of waste below the water table at the 216-B-5 injection well produced localized groundwater contamination. The waste stream apparently contained a large amount of suspended solids and some of the waste was most likely emplaced as particulate matter. The constituents detected in groundwater (strontium-90, cesium-137, and plutonium) typically have low mobilities because of their sorption to aquifer sediments. Characterization activities in the vicinity of the 216-B-5 injection well were reported in RHO-ST-37. Tritium and iodine-129 contamination is widespread in the 200-East Area, and the sources are difficult to ascertain.

Tritium. Tritium contamination is widespread throughout the northwestern part of the 200-East Area and extends northward through the gap between Gable Mountain and Gable Butte (see Plate 3). The maximum average annual tritium concentration detected in this part of the 200-East Area in FY 1997 was 46,000 pCi/L in well 299-E28-27, located outside the southeastern corner (upgradient) of LLWMA 1. In FY 1996, 96,000 pCi/L of tritium were measured in well 299-E28-6, located immediately east of B Plant; however, that well was not sampled for tritium in FY 1997. Another pulse of tritium at levels above the interim DWS can be seen between Gable Mountain and Gable Butte, where the maximum average annual concentration for FY 1997 was 63,000 pCi/L in well 699-61-62. The exact sources of the tritium were not determined.

Iodine-129. Iodine-129 forms another widespread contaminant plume in the 200-East Area, and the contamination also extends northward through the gap between Gable Mountain and Gable Butte (see Plate 5). The maximum average annual iodine-129 concentration detected in this part of the 200-East Area in FY 1997 was 6.2 pCi/L in well 299-E33-41. Iodine-129 concentrations in this well have remained fairly stable for the past several years. The exact sources for the iodine-129 contamination, like tritium, were not determined; however, the concentrations of iodine-129 in this vicinity do not correlate well with tritium concentrations. The highest concentrations of iodine-129 are located generally eastward of the highest parts of the tritium plume. Iodine-129 concentrations have declined slightly in wells east (upgradient) of WMA B-BX-BY. The presence of iodine-129 contamination upgradient of this WMA at similar levels found downgradient indicates that the WMA is not the source of the iodine-129. The iodine-129 distribution is also inconsistent with a source from the BY cribs because the high concentrations do not correlate with technetium-99.

Technetium-99. Elevated technetium-99 levels apparently associated with the BY cribs' plume continued to be observed in FY 1997 (Figure 5.10-1). Well 699-50-53A was used in FY 1995 for an extraction well in treatability testing and contained up to 9,910 pCi/L of technetium-99 in FY 1995. This well was sampled in FY 1997 for the first time after the completion of the test, and the technetium-99 concentration was only 730 pCi/L. The maximum average annual technetium-99 detected in the area north of the 200-East Area in FY 1997 was 2,000 pCi/L in wells 699-52-54 and 699-49-57A. Concentrations of technetium-99 that were less than the interim DWS were detected north of Gable Mountain and indicate that this plume is moving into and through the gap between Gable Mountain and Gable Butte. Because of the extremely flat water-table configuration in the northwestern part of the 200-East Area, the flow direction in the vicinity of the BY cribs is uncertain and possibly variable. There is some indication that the technetium-99 plume from the cribs may be spreading southward and impacting wells monitoring WMA B-BX-BY. The plume also impacts wells that monitor the northwestern corner of LLWMA 1, resulting in elevated gross beta measurements in some wells in the monitoring well network.

In well 299-E33-33, the upgradient well for WMA B-BX-BY, the value of technetium-99 has been <10 pCi/L since the March 1991 sample. As can be seen in Figure 5.10-2, this value is low compared to data from the downgradient wells on the west side of the WMA. Well 299-E33-43 displays the next lowest values, ranging from 10 to 55 pCi/L. Technetium-99 in the remaining downgradient wells is not only at significantly higher concentrations but displays more fluctuations over time.

In wells downgradient of WMA B-BX-BY (Figure 5.10-3), there was an upward trend of technetium-99 in FY 1997. Until recently, technetium-99 has not been above 900 pCi/L, except in well 299-E33-31 for the February 1993 sample and in well 299-E33-41 for the August 1995 sample. These appear to be isolated occurrences. Technetium-99 began rising sharply in downgradient wells on the northwestern side of the WMA during the last half of 1996. Samples from well 299-E33-42 show the highest value of 751 pCi/L.

Technetium-99 values in well 299-E33-41, on the east side of the BX tank farm, rose from 488 pCi/L in the November 1996 sample to 5,740 pCi/L in February 1997. For the next quarterly sampling, the value dropped to 506 pCi/L only to rise again in August 1997 to 12,000 pCi/L (see Figure 5.10-3). To verify these results and to check for laboratory error, split samples were collected 3 weeks later and analyzed by independent laboratories. Analyses from both laboratories agreed and showed that the technetium-99 concentration in this well fell to 1,490 pCi/L. Although the quarterly quality control blind samples indicate that values for gross beta in the May 1997 data may be too high, no sampling or laboratory error could be found to explain this high-amplitude, high-frequency character in the technetium-99 trend plot (see Figure 5.10-3). This is the only well in the area that displays such sudden extreme fluctuations. It is important to notice that if this WMA had been in interim-status detection-level monitoring and sampled on a semiannual basis, these sudden increases in technetium-99 would not have been observed.

The high technetium-99 in well 299-E33-41 appears to have a source from this WMA because of its local extent, its lack of correlation with other constituents of the preexisting plume from the BY cribs, and its high-amplitude, high-frequency fluctuations in concentration.

Uranium. Uranium is sporadically detected at levels above the 20-µg/L proposed DWS in a few wells in the vicinity of B Plant. The distribution of uranium contamination suggests the plumes are of limited extent and the source of this uranium is not understood. Uranium also increased sharply in several wells in the vicinity of WMA B-BX-BY and associated cribs and trenches. The maximum average annual uranium concentration in the 200-East Area was 200 µg/L in well 299-E33-13, located to the east of the BY cribs, west of the 216-B-8 crib, and northeast of WMA B-BX-BY. Concentrations in this well have been rising since 1991 and continued to increase dramatically in the last year (Figure 5.10-4). In FY 1997, uranium also increased (average of 140 µg/L) in well 299-E33-18, located just north (downgradient) of WMA B (see Figure 5.10-4). Prior to 1997, well 299-E33-18 had not been sampled for uranium or gross alpha, so the shape of the trend curve is uncertain though uranium levels in FY 1994 were greater than in previous years. Well 299-E33-38, located near the BY cribs, also shows elevated uranium. These data show that both the magnitude and extent of the uranium contamination are increasing but the major impacts are in wells north and east of WMA B-BX-BY, not in the wells with increasing technetium-99 discussed above.

Uranium was very slightly elevated in well 299-E33-41 during the initial year of sampling (1991). Uranium fell to background levels in early 1992 but some time during mid-1993, uranium concentrations rose to 9 µg/L. The August 1997 value is 12 µg/L for this well; above background but considerably lower that in nearby wells discussed earlier. It is too soon to determine if this is part of a rising trend or an isolated occurrence.

Strontium-90. There is a small strontium-90 plume around the 216-B-5 injection well. Concentrations of strontium-90 in FY 1997 ranged up to 5,800 pCi/L (above the 1,000-pCi/L DCG) in well 299-E28-23 (Figure 5.10-5). Strontium-90 increased to 140 pCi/L in well 299-E28-2, which is ~150 m from the 216-B-5 injection well. This injection well received an estimated 27.9 Ci of strontium-90 (decayed through April 1, 1986) during 1945 to 1946 when it was used for waste disposal (PNL-6456).

Cobalt-60. Wells located north of the 200 Areas, in an area affected by waste disposed to the BY cribs, consistently show the presence of detectable cobalt-60. Much of that discharged cobalt-60 has now decayed away because of its relatively short half-life (5.3 years). In FY 1997, the maximum average annual cobalt-60 detected in this vicinity was 33 pCi/L in well 699-52-54, below the 100-pCi/L interim DWS. 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. The presence of complexed cobalt-60 in ferrocyanide-scavenged wastes from the bismuth phosphate process was known by 1957 to result in little retention by sediments (HW-48862).

Cesium-137. Concentrations of cesium-137 in FY 1997 reached 1,600 pCi/L in well 299-E28-23, located near the 216-B-5 injection well. The interim DWS for cesium-137 is 200 pCi/L and the DCG is 3,000 pCi/L. This is the only part of the 200-East Area where cesium-137 is reliably detected. Occasional, extremely low concentrations seen in other wells appear to be the result of uncertainties inherent in radionuclide analyses.

Plutonium. The maximum concentration of plutonium-239/-240 detected near the 216-B-5 injection well in FY 1997 was 25.6 pCi/L in the single sample from well 299-E28-24. As expected, plutonium concentrations were considerably lower in the filtered samples from this and other nearby wells as shown in Table 5.10-1. Plutonium had been detected in FY 1996 in well 299-E28-2, ~150 m northwest of the 216-B-5 injection well (0.11 pCi/L) but was below the detection level in FY 1997. It is unusual to see plutonium that far from Hanford Site sources. Plutonium is generally considered to bind strongly to sediments and, thus, has limited mobility in the aquifer. The DCG for plutonium-239 is 30 pCi/L. There is no explicit interim DWS for plutonium-239; however, the gross alpha 15-pCi/L MCL would be applicable, at a minimum. Alternatively, if the DCG, which is based on a 100-mrem dose standard, is converted to the 4-mrem dose equivalent used for the interim DWS, 1.2 pCi/L would be the relevant guideline.

Nitrate. The plume originating from facilities in the northwestern part of the 200-East Area contains some of the highest groundwater nitrate levels on the site (see Plate 4). The maximum concentration detected in this area in FY 1997 was 300 mg/L in well 299-E33-16 (the MCL is 45 mg/L). This plume extends northwest through the gap between Gable Mountain and Gable Butte and has a configuration similar to the technetium-99 plume.

Cyanide. Cyanide was detected in samples collected from wells in and directly north of the BY cribs, and the source is believed to be wastes containing ferrocyanide disposed to the cribs. The MCL for cyanide is 200 µg/L. There is some evidence that contamination in this area migrated to some depth in the flow system, including detection of cyanide and cobalt-60 in the upper basalt-confined aquifer, discussed in Section 5.15. However, characterization of the deeper parts of the unconfined and confined aquifers in the vicinity of the BY cribs is considerably less complete than the characterization of the top of the unconfined aquifer system. Migration through the unconsolidated sediments may have been increased by the higher hydraulic head caused by past disposal activities and by the high density of some of the waste streams (RHO-RE-ST-12P, RHO-ST-37, WHC-SD-EN-AP-170). The maximum average annual concentration of cyanide detected in FY 1997 was 120 µg/L in well 699-52-54. Wells containing elevated cyanide often contain elevated concentrations of several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it can be chemically complexed and mobilized by cyanide or ferrocyanide.

WMA B-BX-BY RCRA Parameters. In the February and June 1996 samples, specific conductance was found to be elevated above the upgradient statistical critical mean in a downgradient well located next to WMA B-BX-BY. Because of the elevated specific conductance, this facility was placed in a quality assessment program with quarterly monitoring of the groundwater. The ongoing investigation is in accordance with the RCRA interim-status regulations (40 CFR 265.93 [d]). Results and conclusions of the Phase I investigation will be released in 1998. It was concluded that the WMA was, most likely, the cause of the elevated specific conductance seen in well 299-E33-41. Consequently, the WMA will continue in Phase II assessment. Technetium-99 and uranium results from the assessment were discussed in the previous subsection; specific conductance and pertinent relationships between constituents are discussed below.

Background field specific conductance values for groundwater under the 200 Areas plateau are 344 µS/cm (WHC-EP-0595). The statistical critical mean for this WMA is 365.7 µS/cm. Trend plots of specific conductance data are shown in Figure 5.10-6. The following observations are made.

- With the exception of upgradient well 299-E33-33, specific conductance is slowly rising across the WMA from initial values of 280 to ~340 µS/cm.

- For well 299-E33-32, specific conductance rose in FY 1995. When values exceeded the critical mean in the February 1996 sample and verification sampling confirmed the high levels in June 1996, groundwater monitoring was changed from detection level to groundwater quality assessment. In August 1996, the level dropped to 334 µS/cm. At that time, a false-positive claim was considered. During FY 1997, specific conductance rose again in well 299-E33-32 to 385 µS/cm in the August 1997 sampling event.

- Specific conductance has risen steadily in well 299-E33-31 to 377 µS/cm (May 1997 sampling event), which is above the critical mean.

- Trends for specific conductance, nitrate, and technetium-99 in well 299-E33-42 are shown in Figure 5.10-7. Both specific conductance and nitrate follow the increase in technetium-99. The same covariances are seen for wells 299-E33-31 and 299-E33-32.

- In well 299-E33-41, specific conductance rose to 394 µS/cm in the February 1997 sample, dropped in May 1997, then rose to 542 µS/cm in early August 1997. Three weeks later, it dropped to 316 µS/cm. If this WMA had been monitored semiannually, neither of these high specific conductance values would have been observed. Specific conductance and technetium-99 show a strong correlation in well 299-E33-41 (Figure 5.10-8). Nitrate, chloride, and sulfate are the primary anions that cause the changes in specific conductance.

Although observed in the past, these fluctuations in specific conductance values appear to be increasing in frequency across the WMA. This apparent increase in frequency may be a function of the change from semiannual to quarterly sampling. Whether changes of this nature occurred in the past is unknown. The high-amplitude, high-frequency character of specific conductance values shown in Figure 5.10-6 for well 299-E33-41 should be particularly noted.

As discussed in Section 3.6.9.2, the groundwater-flow direction at this WMA is uncertain, with different data sets providing conflicting information. Consequently, for the elevated specific conductance seen on the west side of the WMA, it is too soon to determine if a high specific conductance plume is moving out from the tank farms.

The gradual rise in background values may be related to natural recharge moving through the highly contaminated soils under the WMA. The significant increase in annual snowmelts in the last few years and the possible consequences to remobilizing waste in vadose-zone plumes are discussed in PNNL-11810.

Sodium/Calcium. Tank wastes are high in sodium from the addition of sodium hydroxide used to neutralize the nitric acid during processing. Consequently, a tank-waste signature in the groundwater chemistry should be higher than background sodium. However, at some single-shell tanks, the calcium concentration was anomalously high in the groundwater, suggesting that the sodium cation replaced the calcium in the soil column during waste migration through the vadose zone (PNNL-11810). A calcium-enriched groundwater may have existed under the surrounding past-practice liquid-discharge facilities in the past because these facilities received large volumes of supernatant and tank-scavenged wastes. Currently, however, calcium enrichment is not observed in the WMA B-BX-BY vicinity.

Sodium concentrations, however, are close to background values for all wells in the area, except well 299-E33-41. When sodium is plotted for selected RCRA and surrounding non-RCRA wells, the unique chemistry of well 299-E33-41 emerges (Figure 5.10-9). The sudden sodium increase corresponds to the February 1997 sample increase in technetium-99 for this well. The rise in sodium also corresponds to an increase in nitrate, suggesting a tank source for this contamination.

216-B-63 Trench RCRA Parameters. Groundwater monitoring continues to provide no evidence that dangerous nonradioactive constituents entered the groundwater from this trench. Included in the trench analysis list are pH, total organic carbon, total organic halides, gamma scan, alkalinity, gross beta, and turbidity. There were no significant detections that could be attributed to this trench.

5.10.3.2 PUREX Plant Area

Numerous disposal facilities received waste from PUREX Plant operations. In particular, numerous cribs located 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 tritium, nitrate, and iodine-129. Three cribs (216-A-10, 216-A-36B, and 216-A-37-1) were monitored under RCRA in FY 1997, but it is clear that the impacts to groundwater also result from other facilities, located generally northeast and east of the plant, that are being addressed under the CERCLA process. The 216-A-29 ditch and B Pond are monitored under RCRA. In addition, high-level waste tanks in WMAs A-AX and C will be discussed in this section. This section also discusses the large plumes from the vicinity of PUREX that migrated through the 600 Area as far as the Columbia River and the 300 Area.

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). Concentrations greater than the 2,000,000-pCi/L DCG were detected only in well 299-E17-9, located next to the 216-A-36B crib. The maximum concentration detected in this well in FY 1997 was 3,070,000 pCi/L, which was also the maximum tritium concentration detected in any well onsite during FY 1997. The FY 1997 annual average tritium concentration was 3,000,000 pCi/L in that well. Tritium concentrations exceeding the 20,000-pCi/L interim DWS continued to be found in many wells affected by cribs near the PUREX Plant.

Tritium concentrations in a new well (699-37-47A), located just outside the southeastern corner of the 200-East Area, were lower than expected, with an average of 14,000 pCi/L. One explanation for this is that it is impacted by discharges of large amounts of nonradioactive water at the 216-A-37-2 crib.

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 Section 6.10 of PNNL-11470. Separate tritium pulses associated with the two PUREX operational periods contributed to the plume. The first pulse, which resulted from discharges during the PUREX operation from 1956 to 1972, can be detected near the Columbia River (e.g., well 699-40-1, Figure 5.10-10). Elevated tritium concentrations measured immediately downgradient from the 200-East Area represent the second pulse of tritium associated with the restart of operations between 1983 and 1988. The area immediately downgradient of the cribs, where concentrations are >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 5.10-11 clearly shows the arrival of the plume at well 699-24-33, located near the Central Landfill, in early 1987, well after the passage of the plume from the earlier operation. The tritium concentrations in this well during passage of the first pulse were at least three times the maximum concentrations in the pulse from the second period. 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 indicate that the greatest impacts expected at the Columbia River have already occurred.

The zone of lower tritium concentrations near the Washington Public Power Supply System may be related to an area where Ringold Formation sediments are present at the water table. This suggests that a zone of lower hydraulic conductivity sediments is present in this area that may be diverting the bulk of the contaminant transport to the north and south.

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 FY 1997 was 140 mg/L in well 299-E17-9, which is adjacent to the 216-A-36B crib. The extent of the nitrate plume emanating from the 200-East Area (see Plate 4) is nearly identical to that of the tritium plume. However, the area with nitrate greater than the 45-mg/L MCL is considerably more restricted than the area with tritium above the interim DWS. Nitrate at levels above the MCL north of the 400 Area, within the area impacted by PUREX operations, is attributable to 400 Area disposal as discussed in Section 5.11.

Iodine-129. The highest iodine-129 concentrations observed in the 200-East Area in FY 1997 were near the PUREX Plant cribs (see Plate 5). The maximum detected iodine-129 concentration in FY 1997 (18 pCi/L) in well 299-E24-16 was somewhat higher than in previous years. This well monitors the 216-A-10 crib. Concentrations of iodine-129 in groundwater near the PUREX cribs are generally declining slowly or are stable, as shown for well 299-E17-9 (Figure 5.10-12). The iodine-129 plume extends southeast into the 600 Area and appears to coincide with the tritium and nitrate plumes (see Plates 3, 4, and 5). Seep sampling along the Columbia River shoreline shows that iodine-129 is being discharged to the river near the Old Hanford Townsite but at levels lower than can be detected by the standard groundwater analytical techniques (Section 4.2 of PNNL-11472). The concentrations and overall extent of this plume did not change greatly from FY 1996.

Strontium-90. A single well near cribs located south of the PUREX Plant revealed a concentration above the interim DWS for strontium-90 in FY 1997 (see Figure 5.10-5). The maximum annual average strontium-90 concentration detected in FY 1997 was 15 pCi/L from well 299-E17-14, located next to the 216-A-36B crib. The impact is very localized because of the lower mobility of strontium-90 as compared to tritium, iodine-129, and nitrate. In FY 1997, few wells were sampled for strontium-90 based on the restricted extent seen in past years.

Cobalt-60. A review of FY 1996 and past data for groundwater near the Old Hanford Townsite showed the presence of extremely low but detectable concentrations of cobalt-60. Data from the 1970s and 1980s indicate that cobalt-60 was detected in wells within the area of the current tritium plume and the source is probably in the 200-East Area. This detection indicates that, at least at low levels, cobalt-60 is relatively mobile; further detail is given in Section 6.10 of PNNL-11141. Monitoring reports from the

1970s (BNWL-2199, PNL-2624) indicate that cobalt-60, detected in large-volume resin-bed samples, was predominantly retained on the anion resin, indicating transport as an anionic complex.

PUREX Cribs RCRA Parameters. The 216-A-10, 216-A-36B, and 216-A-37-1 cribs are monitored under RCRA and are located in a region where several groundwater plumes contain constituents that exceed the DWSs. Examples of these exceedances include tritium, iodine-129, strontium-90, and nitrate. 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. The data from RCRA monitoring of these facilities are integrated into the assessment of the overall extent of contamination for these constituents.

WMA A-AX RCRA Parameters. Critical mean values of the indicator parameters (specific conductance, pH, total organic carbon, and total organic halides) were not exceeded during FY 1997. Although there were increases in total organic carbon in some wells above the limit of quantitation that is used for comparison, these data are associated with a laboratory problem (see Appendix D). All wells show concentrations of iodine-129 above the 1-pCi/L interim DWS, as in past years. The iodine-129 plume extends from north of the PUREX Plant through the groundwater underneath the WMA. For FY 1997, iodine-129 concentrations ranged from 2.74 to 5.71 pCi/L. For the RCRA network wells, tritium values for FY 1997 ranged from 2,430 to 4,850 pCi/L, considerably less than the 20,000-pCi/L interim DWS.

Chromium and nickel were seen in filtered samples from well 299-E24-19 at levels above their MCLs (Figure 5.10-13). This well has shown high chromium and nickel in the past. The FY 1997 values of chromium for well 299-E24-19 were 1,440 and 1,660 µg/L in the February and August 1997 samples, respectively; nickel ranged from 335 to 359 µg/L (the MCL is 100 µg/L). This is the only well in the network to display high values of chromium. Other network wells showed chromium values below 12 µg/L for FY 1997. Nickel was not detected in the other network wells for FY 1997.

In FY 1997, technetium-99 in well 299-E24-19 declined to 13.4 pCi/L but rose in well 299-E25-46 (from 111.3 pCi/L in FY 1996 to 374 pCi/L in August 1997) (Figure 5.10-14). As can be seen, technetium-99 has been rising in well 299-E25-46 since early 1994. There is a slight but steady corresponding increase in specific conductance, chloride, and sulfate but no noticeable increase in nitrate. With the 900-pCi/L interim DWS, it is not an exceedance, only an anomaly. Because there is no covariance of the increasing technetium-99 with nitrate and the other increases are not significant, it is unlikely that the technetium-99 is from a tank source. However, this well will be closely monitored during the next year.

WMA C RCRA Parameters. Critical mean values of the indicator parameters (specific conductance, pH, total organic carbon, and total organic halides) were not exceeded during FY 1997 (Figure 5.10-15). For iodine-129, all wells showed concentrations above the 1-pCi/L interim DWS because the iodine-129 plume extends through this region. Values for FY 1997 ranged from 2.74 to 5.09 pCi/L. These were the only DWS exceedances for WMA C.

Technetium-99 values for three of the five RCRA network wells were below the detection limit (Figure 5.10-16). Only upgradient well 299-E27-14 and downgradient well 299-E27-13 showed any detectable technetium-99, with values from 155 to 37.4 pCi/L in FY 1997. As can be seen in Figure 5.10-16, there is no discernible trend for these two wells, and the values are well below the 900-pCi/L interim DWS. There were no other indications of hazardous or radioactive trends close to MCLs or interim DWSs for this WMA for FY 1997.

216-A-29 Ditch RCRA Parameters. The levels of sulfate (as noted in WHC-SD-EN-EV-032) in the groundwater under this ditch had been declining steadily since the facility stopped receiving sulfate-bearing effluent. This trend did not continue in FY 1997. Sample results confirmed that a slight elevation was observed in nearly all network wells, with the greatest increase in well 299-E25-35 (Figure 5.10-17). The same upward trend can be seen in specific conductance in both upgradient and downgradient wells (Figure 5.10-18). Assessment monitoring performed between 1990 and 1995 confirmed that the elevated specific conductance was related to calcium, sodium, and sulfate, which are nonregulated substances.

The groundwater in the vicinity of this ditch contains iodine-129 at levels above the interim DWS (see Plate 5). In contrast to the area of the 216-A-10 and 216-A-36B cribs, this contamination is not associated with high levels of tritium (see Plate 3).

216-B-3 Pond RCRA Parameters. 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. From that time until mid-1996, comprehensive sampling and analyses were performed to determine the cause of these anomalies. The assessment report concluded that these occurrences were essentially isolated, and that no total organic carbon or total organic halides could be attributed to hazardous waste (PNNL-11604).

Comprehensive chemical analysis of groundwater samples from 1994 through 1996 revealed one compound (tris[2-chloroethyl]phosphate) that may have contributed to elevated total organic halide concentrations. No compound was identified as a contributor to total organic carbon. Detailed evaluations of total organic carbon, total organic halides, and tris(2-chloroethyl)phosphate and comparison of occurrences of these parameters lead to the conclusions that 1) with few exceptions, these constituents occur at low concentrations below or near the limits of quantitation; 2) it is problematic whether the low concentrations of tris(2-chloroethyl)phosphate represent a contaminant originating from the facility, or if it is a product of well construction; and 3) given the low and diminishing concentrations of total organic carbon, total organic halides, and tris(2-chloroethyl)phosphate, further investigation into the occurrence of these constituents is not justifiable.

The only contaminants consistently detected in groundwater that could be ascribed to B Pond operations were tritium (maximum 232,000 pCi/L) and nitrate (maximum 22.5 mg/L). Only tritium occurred in concentrations above the interim DWS. Both of these constituents have displayed downward trends in concentrations since monitoring began at the facility. Figure 5.10-19 illustrates the trends in wells with the highest historical results. Nitrate in wells 699-43-41E and 699-42-39B shows a slight increase in the most recent results but the trends are generally lower. Chromium, iron, and manganese have historically exceeded their MCLs in several wells. Concentrations of these metals have been attributed to well construction and the effects of dissolved oxygen on aquifer sediments. Arsenic has been detected at extremely low levels (far below its MCL) in wells near the west end of the main B Pond, but is described in WHC-EP-0813 as probably having originated from 200-East Area cribs and trenches. Likewise, four wells (699-42-42B, 699-43-40, 699-43-41E, and 699-43-45) produced iodine-129 results above the interim DWS in FY 1997. These wells have historically produced elevated iodine-129 results of the same magnitude as in FY 1996, and are thought to be a remnant of a larger plume originating from the 200-East Area, before the B Pond hydraulic mound was established.

Groundwater samples were taken once each quarter of FY 1997 for the required indicator parameters (see Appendix A). Concentrations of some parameters, such as sulfate and specific conductance, appear to be recovering slightly from artificially low values. Natural groundwater, normally higher in some anionic species, was temporarily displaced by dilute discharges to the B Pond system.

5.10.3.3 Low-Level Waste Management Area 1

Although there is no evidence of any contribution from LLWMA 1, contaminant plumes are affecting the groundwater quality beneath it. Nitrate and tritium plumes are evident and appear to be the major contaminants in the area of LLWMA 1. Tritium values indicate the presence of a plume beneath LLWMA 1 with a source to the southeast. The data suggest that the maximum concentrations have already passed beneath LLWMA 1 and the values continue to decline.

5.10.3.4 Low-Level Waste Management Area 2

Values of iodine-129 were slightly above the interim DWS in several of the wells along the southern boundary of LLWMA 2. These are related to the widespread iodine-129 plume beneath the 200-East Area. There is no evidence of contamination from LLWMA 2.

5.10.3.5 Liquid Effluent-Retention Facility

Groundwater monitoring continues to provide evidence that no dangerous nonradioactive constituents entered the groundwater from this facility. Included in the analysis list are specific conductance, pH, total organic carbon, total organic halides, gamma scan, alkalinity, gross beta, and turbidity. There were no significant detections in these analyses that could be attributed to this facility.

5.11 400 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 restart decision for the production of medical isotopes and tritium. Assessment efforts associated with the CERCLA 300-FF-2 Operable Unit will extend to include groundwater contamination in the 400 Area.

5.11.1 Facilities

5.11.1.1 Process Ponds

The 4608 B/C ponds (also called the 400 Area process ponds), located north of the 400 Area perimeter fence, are unlined infiltration ponds that receive wastewater from the 400 Area facilities. The waste stream consists primarily of cooling water and intermittent small contributors (e.g., sinks and drains). The facility is designated as a WAC-173-216 discharge permit site and the permit was issued on

August 1, 1996. One permit condition identified was the addition of another downgradient well to the monitoring network. Well 699-2-6A was installed in August and September 1997 for this purpose. Sampling of this well will be initiated during FY 1998.

5.11.1.2 Water-Supply Wells

The water supply for the 400 Area, including the drinking water, is provided by wells completed in the unconfined aquifer system. The original water-supply wells (499-S0-7 and 499-S0-8) were completed near the top of the aquifer. When tritium contamination was detected in the water supply, an additional well (499-S1-8J) was drilled in the lower unconfined aquifer in 1985 to reduce the tritium concentration below the 4-mrem/yr effective dose equivalent standard. Well 499-S1-8J is now the primary water-supply well, and well 499-S0-7 is used as a backup supply well. Well 499-S0-8 is maintained for emergency use.

5.11.2 Compliance Issues

Tritium was detected at levels above the interim DWS in the 400 Area groundwater, and nitrate was detected at levels above the MCL just north of the perimeter fence near the process ponds. Tritium was consistently detected at levels above the interim DWS in the backup water-supply well for this area. However, the interim DWS is set at a level that ensures that any one radionuclide would not exceed a 4-mrem/yr dose if ingested at the average annual rate of consumption. Because the backup well is seldom used, the monthly water-supply sampling indicates that the concentration in the drinking water is maintained at a level below 4 mrem/yr even if the dose-conversion factor used in setting the 20,000-pCi/L interim DWS is used. As discussed in Section 5.1.6, the dose-conversion factor used in setting the interim DWS is more conservative than that used in more current methodology.

5.11.3 Extent of Contamination

Nitrate is the only significant contaminant attributable to 400 Area operations detected in the current downgradient well (699-2-7) to the process ponds. Elevated nitrate concentrations of up to 95 mg/L (45-mg/L MCL) found in well 669-2-7 were attributed to the sanitary sewage lagoon located immediately west and upgradient of the process ponds (Figures 5.11-1 and 5.11-2). Groundwater samples associated with this well are also frequently elevated with respect to nitrite (Figure 5.11-3), 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 MCL (as NO_2), however. A recently constructed treatment system for sanitary sewage should eliminate this source of groundwater contamination.

Slightly elevated manganese concentrations have been noted in the effluent wastewater discharged to the process ponds. A few of the manganese values are in excess of the discharge permit (50 µg/L, unfiltered) and, thus, are of concern. An ongoing effort is under way to determine the source and form of the manganese (i.e., dissolved or particulate). The source of the manganese may be within the 400 Area facilities, such as corrosion within a holding tank, or may be related to the source of water for the facility, which is primarily groundwater from well 499-S1-8J. Collection and analysis of unfiltered and filtered effluent water and groundwater from well 499-S1-8J are currently being performed to resolve this question.

Elevated levels of tritium (Figure 5.11-4) associated with the groundwater plume from the vicinity of the PUREX Plant in the 200-East Area were identified in 400 Area wells. This source of groundwater contamination is relevant to the water-supply wells. The tritium activities in wells 499-S0-7, 499-S0-8, and 499-S1-8J are compared in Figure 5.11-5 to that of the 400 Area drinking water supply. Tritium was found at levels above the interim DWS in most samples from well 499-S0-7, where the average annual concentration was 21,000 pCi/L in FY 1997. One sample collected from well 499-S0-8 exceeded the interim DWS in FY 1997. The tritium low north of the 400 Area is probably related to discharge at the process ponds.

Tritium remained below the 20,000-pCi/L interim DWS and the 4-mrem/yr dose equivalent in the drinking water supply (sampled at a tap) for all sampling events in FY 1997 (see Figure 5.11-5). Nitrate remained below the MCL in FY 1997 for the water-supply wells, indicating they are not affected by the 400 Area process ponds. A review of FY 1997 and past data from 400 Area and surrounding wells indicates that no other constituents are present at levels above their MCLs or interim DWSs.

5.12 600 Area

F. N. Hodges, P. E. Dresel

The 600 Area consists of all parts of the Hanford Site not specifically included in other operational areas. Most groundwater contamination found in the 600 Area is related to sources in the operational areas discussed previously. However, several other sources or potential sources of contamination exist, including the Central Landfill and Gable Mountain Pond. Chromium was detected in wells in the Central Plateau; its source and extent, however, are uncertain. Also, uranium was detected in a well near the 618-10 burial grounds. Nitrate found in the western part of the 600 Area appears to have an offsite source.

5.12.1 Facilities

5.12.1.1 Solid Waste Landfill

The Solid Waste Landfill (SWL) is a 27-ha facility located ~5.6 km southeast of the 200-East Area (see Appendix A and Plate 1). The SWL, along with the adjacent Nonradioactive Dangerous Waste Landfill (NRDWL), are parts of the former Central Landfill; however, the two facilities are now considered separately and under differing regulations. SWL groundwater is monitored according to WAC 173-304. Beginning operation in 1972, SWL received principally solid waste, including paper, construction debris, asbestos, and lunchroom waste. In addition to the solid waste, ~3,800,000 to 5,700,000 L of sewage were disposed in trenches along the east and west sides of the SWL between 1975 and 1987, and ~380,000 L of Hanford Site bus/garage washwater were disposed in three short trenches along the west side of the site between 1985 and 1987.

5.12.1.2 Nonradioactive Dangerous Waste Landfill

The NRDWL is a 4-ha, inactive, RCRA-regulated landfill located ~5.5 km southeast of the 200-East Area (see Appendix A and Plate 1). The NRDWL received waste from 1975 to 1985 that included asbestos, miscellaneous laboratory wastes, solvents, paints, sewerage, sulfamic and other acids, batteries and battery acid, and mercury. The NRDWL continued to receive asbestos waste until 1988 (DOE/RL-90-17).

5.12.1.3 Other Facilities

Gable Mountain Pond. This pond was a liquid waste-disposal area located south of Gable Mountain (see Plate 1) that received 200-East Area liquid wastes from 1957 until it was decommissioned in 1987. The surface area of the pond reached at least 28 ha during its operational period (RHO-ST-38). The pond is currently dry and covered with fill. Discharge to the pond included cooling water and condensate from a variety of sources in the 200-East Area. In addition, an unplanned release from a cooling coil in the PUREX Plant contributed ~100,000 Ci of fission products to Gable Mountain Pond and B Pond (RHO-ST-38). The primary radiological constituents discharged to the pond were strontium-90, cesium-137, and ruthenium-106.

618-10 Burial Ground and 316-4 Crib. The burial ground and adjacent crib are located southeast of the 400 Area, adjacent to Route 4S. The burial ground operated from 1954 to 1963 and received a variety of low- to high-activity radioactive waste, mostly composed of fission products with some plutonium-contaminated material (DOE/RL-96-42). These wastes were disposed in caissons and trenches and may have included liquid and solid waste forms. The crib began receiving uranium-bearing waste solutions in 1948 and continued to periodically receive nitrate, hexone, and organic wastes through at least 1962 (DOE/RL-96-42). This site was investigated as part of a CERCLA limited field investigation report for the 300-FF-2 Operable Unit (DOE/RL-96-42).

5.12.2 Compliance Issues

5.12.2.1 Solid Waste Landfill

Activities at the SWL are regulated by WAC 173-304 and are detailed in WHC-SD-EN-AP-043. The SWL is part of the 200-IU-3 Operable Unit. A permit application for operation of the site was submitted to the Benton-Franklin District Health Department in 1991 (DOE/RL-90-38) and was rejected. Responsibility for the site was assumed by the state and a revised permit application was submitted in 1993 (DOE/RL-90-38, Rev. 1). As part of the permit review, Ecology requested that a corrective action program be established for the site, and a corrective action plan was submitted (DOE/RL-94-143). In 1995, because of groundwater contamination at the site, Ecology informed DOE that all future trenches must be lined. DOE decided to close the site, and operations ceased in March 1996. The final closure plan for the site is pending. As part of closure activities for the site, a conceptual model for contamination at the site has been developed (BHI-01063).

Two downgradient wells were installed in December 1993, completing the shallow compliance-point monitoring network. The presence of the two downgradient wells raises the monitoring efficiency from 68% to 94% (calculated using the method of Wilson et al. [1992]). Additional wells will be needed only if it is shown that significant quantities of contaminants have migrated south of the site boundary (DOE/RL-94-143).

5.12.2.2 Nonradioactive Dangerous Waste Landfill

As part of the Tri-Party Agreement (Ecology et al. 1989), it was agreed to close the NRDWL under RCRA (WAC 173-303) and monitor it under RCRA interim-status regulations. A closure/postclosure plan was submitted in 1990 (DOE/RL-90-17). The NRDWL is part of the 200-IU-3 Operable Unit. The principal activity at the NRDWL during FY 1997 has been a soil-vapor survey (BHI-01115). This survey, which resampled several of the points reported in WHC-SD-EN-TI-199, also sampled the deeper vadose zone, down to 29.7 m using hydraulic probes.

Values for RCRA indicator parameters at the NRDWL did not exceed their critical means in FY 1997.

The uncertainty in groundwater-flow directions beneath the NRDWL (see Section 3.7.2) makes the evaluation of the monitoring network more difficult. If the groundwater flows toward the southeast, as indicated by the tritium and nitrate plumes (see Plates 3 and 4), the boundary between the NRDWL and the SWL should be part of the compliance point. If the groundwater flows in an east-northeast direction, as indicated by the water-level data, the north boundary of the NRDWL should be part of the compliance point. The two monitoring wells along the north and south boundaries of the NRDWL, completed in 1992, solve this problem and provide the monitoring efficiency between 96% and 99% (Wilson et al. 1992), depending on groundwater-flow directions. The current shallow monitoring network is adequate.

5.12.2.3 Drinking Water Standards and Derived Concentration Guides

Strontium-90 was detected at levels above the DCG near the decommissioned Gable Mountain Pond in FY 1997. No other radionuclides exceeded the DCG in the 600 Area. Contamination from other operational areas impacted the 600 Area at levels that exceeded the interim DWSs or MCLs, as discussed in Sections 5.3 through 5.10. Additional contamination at levels greater than the interim DWSs or MCLs in the 600 Area includes strontium-90 near Gable Mountain Pond, uranium in the vicinity of the 618-10 burial ground and 316-4 crib, and chromium in the southern Central Plateau and south of the 200-East Area. Nitrate concentrations that exceeded the MCL were found upgradient of the operational areas and probably result from offsite agriculture. 600 Area contamination associated with sources in the 100 and 200 Areas is discussed in previous sections.

5.12.3 Extent of Contamination

5.12.3.1 Solid Waste Landfill

The SWL has had little negative impact on Hanford Site groundwater, except minor (below-MCL) contamination with chlorinated hydrocarbons. Analytical results for groundwater-sampling events are presented in the material contained on the diskette included with this report. Results of statistical evaluations are presented in Appendix B. This section discusses the constituents required by WAC 173-304; chlorinated hydrocarbons, which are site-specific constituents; and tritium, which is monitored to provide information on groundwater-flow direction and rate.

Downgradient wells show higher specific conductance, alkalinity, total carbon, cation concentrations, and lower pH than upgradient wells. This is apparently a result of high vadose-zone concentrations of carbon dioxide, resulting from the degradation of sewage material beneath the SWL (Section 5.3 of DOE/RL-93-88).

Indicator Parameters. Average values for replicate temperature determinations measured during sampling in downgradient wells ranged from 17.3° to 19.6°C. All measurements were below the tolerance interval of 21°C. There is a tendency for the higher temperatures to occur at the north end of the site, near the axis of the tritium and nitrate plumes (see Plates 3 and 4).

Average values for replicate specific conductance measurements in downgradient wells ranged from 558 to 822 µS/cm. Replicate averages for monitoring wells 699-22-35 and 699-23-34B exceeded the 700-µS/cm standard (WAC 246-290-310). The 550-µS/cm tolerance interval value was exceeded for all samples from downgradient wells.

Average values for replicate pH measurements in downgradient wells ranged from 6.6 to 7.2. None of the pH measurements exceeded the tolerance interval range of 6.2 to 8.5. As in the past, the lower values occurred in the southernmost downgradient monitoring wells.

The average (of replicates) total organic carbon concentrations in downgradient wells were reported as <530 µg/L, with one exception: the February 1997 sample from well 699-23-34B had a value of 560 µg/L. All results for the August 1997 samples were reported as <370 µg/L. The reported values did not exceed the 1,250-µg/L tolerance interval value.

Reported total organic halides in downgradient wells ranged from <2.65 to 29 µg/L (Table 5.12-1). The values increased from north to south along the line of compliance-point wells, consistent with the pattern for the chlorinated hydrocarbons.

Anions. Chloride concentrations in downgradient wells ranged from 5,340 to 7,690 µg/L. The 9,045-µg/L tolerance interval value was not exceeded. There is a tendency for the higher values to occur in the northernmost wells.

Nitrate concentrations in the downgradient monitoring wells ranged from 11,200 to 22,300 µg/L. The 33,800-µg/L tolerance interval value and the 45,000-µg/L standard (WAC 173-200) were not exceeded. The highest nitrate concentrations occur in the northernmost wells.

All nitrite analytical results were nondetections (i.e., below the tolerance interval of 356 µg/L).

With one exception, results for ammonium in downgradient wells were nondetections (reported as <28 or <34 µg/L). A concentration of 69 µg/L was reported for the February 1997 sample. The tolerance interval of 100 µg/L was not exceeded.

Reported sulfate concentrations in downgradient wells ranged from 38,400 to 53,900 µg/L. A reported value of 527,000 µg/L, reported for the February 1997 sample from well 699-22-35, is believed to be a result of laboratory error and is not considered here. Three samples from well 699-22-35 and one sample from well 699-23-34B exceeded the 51,500-µg/L tolerance interval value. None of the samples exceeded the 250,000-µg/L standard (WAC 173-200). There is a strong tendency for the highest sulfate concentrations to occur in the southernmost wells.

Dissolved Metals. Reported values for filtered iron showed a high degree of variability, ranging from 31.4 to 241 µg/L in downgradient wells. Reported filtered iron concentrations exceeded the 78-µg/L tolerance interval value for the February 1997 sample from well 699-24-34C and the August 1997 sample from well 699-23-34B.

Reported values for filtered manganese concentrations in downgradient wells ranged from 2.2 to 6.5 µg/L. None of the manganese concentrations exceeded the 11-µg/L tolerance interval value or the 50-µg/L standard (WAC 173-200).

Reported values for filtered zinc concentrations in downgradient wells ranged from 5.7 to 315 µg/L. Concentrations exceeded the 34-µg/L tolerance interval value in wells 699-22-35, 699-23-34B, 699-24-34A, 699-24-34B, 699-24-34C, and 699-25-34C. The 5,000-µg/L standard (WAC 173-200) was not exceeded.

Chemical Oxygen Demand. Values for chemical oxygen demand in downgradient wells were reported as <3,000 or <3,070 µg/L, with 3 exceptions: 3,000 µg/L for well 699-23-34A (May 1997 sample), 6,000 µg/L for well 699-24-34B (August 1997 sample), and 7,000 µg/L for well 699-24-34C (February 1997 sample). The latter two exceeded the 3,000-µg/L tolerance interval value.

Total Coliform. With three exceptions, all in the November 1996 sampling event, reported values for total coliform were nondetections (i.e., 0.0 col/100 mL). In November 1996, values of 0.1 col/100 mL were reported for well 699-23-34A, 2.2 col/100 mL for well 699-24-34A, and 2.2 col/100 mL for well 699-25-34C. The 16 col/100-mL tolerance interval value was not exceeded.

Chlorinated Hydrocarbons. A number of chlorinated hydrocarbons were detected at low concentrations (see Table 5.12-1). These included 1,1,1-trichloroethane, trichloroethylene, tetrachloroethylene, and 1,1-dichloroethane. Several of these constituents occurred in low concentrations in the upgradient wells. The highest concentrations consistently occurred in the downgradient wells, particularly toward the south end of the SWL.

Carbon tetrachloride was detected in both downgradient and upgradient wells (<0.2 to 4.6 µg/L); however, the most consistent detection and the highest concentrations (1.9 to 4.6 µg/L) occurred in southernmost downgradient well 699-22-35. Low concentrations of chloroform (<0.2 to 0.9 µg/L) were detected in all downgradient wells.

There was a decline in the concentration of chlorinated hydrocarbons during FY 1997; however, several remained above the groundwater quality criteria set forth in WAC 173-200. The range of reported concentrations of chlorinated hydrocarbons was given in Table 5.12-1. Only tetrachloroethylene, 1,1-dichloroethane, and carbon tetrachloride exceeded their respective criteria.

Chlorinated hydrocarbons occurred in all monitoring wells; however, the southernmost monitoring wells have had the highest concentrations since the initiation of sampling in 1988. The concentrations generally increased from north to south along the line of downgradient wells, with the exception of tetrachloroethylene, indicating that the highest concentration is south of the area sampled by the southernmost downgradient well. This demonstrates that the principal sources probably migrated south of the SWL boundary; however, the principal source of tetrachloroethylene is probably still within the boundaries. The concentrations of 1,1,1-trichloroethane, tetrachloroethylene, trichloroethylene, and 1,1-dichloroethane, as a function of distance from the south end of the SWL downgradient monitoring network, are shown in Figures 5.12-1 through 5.12-4.

The most likely cause of the widespread chlorinated hydrocarbon contamination at the SWL, including upgradient wells and the adjacent NRDWL, is the dissolution of vadose-zone vapors into groundwater. However, the source of the vadose-zone vapors is uncertain. Total inorganic carbon (total carbon minus total organic carbon) increases southward along with the chlorinated hydrocarbons. This correspondence suggests a link between the chlorinated hydrocarbon contaminants and the sewage waste, which is the most probable source of the elevated inorganic carbon in groundwater. Thus, the source(s) may be chlorinated hydrocarbons dissolved in sewage liquids that are migrating southward (downdip) along silt layers in the vadose zone.

Tritium. Tritium, which has a source in the 200-East Area (see Section 5.10.3), was added to the constituent list in 1989 as an aid in determining groundwater-flow directions and rates. Tritium concentrations in groundwater-monitoring wells ranged from <83 to 106,000 pCi/L and are decreasing. The tritium concentrations in seven monitoring wells were above the interim DWS (see Plate 3).

5.12.3.2 Nonradioactive Dangerous Waste Landfill

Monitoring of the NRDWL concentrates on the RCRA indicator parameters (specific conductance, pH, total organic carbon, and total organic halides). Chlorinated hydrocarbons are monitored because they may represent groundwater contamination originating from the NRDWL. Tritium and nitrate are also included in NRDWL monitoring but have a source in the 200-East Area (see Section 5.10.3).

The values for RCRA indicator parameters did not exceed their critical means in FY 1997. Reported total organic halide values for FY 1997 samples ranged from nondetections up to 8.5 μg/L in the shallow downgradient wells and up to 8.5 μg/L in the shallow upgradient wells. The reported values for the deep wells ranged from nondetections up to 7.5 μg/L. The total organic halide values are related to the presence of volatile chlorinated hydrocarbons.

Five chlorinated hydrocarbons were detected; however, none exceeded their MCLs. 1,1,1-trichloroethane and trichloroethylene are believed to be present in groundwater at the NRDWL, principally as a result of vadose-zone vapor transport from the adjacent SWL. Tetrachloroethylene is present in vadose-zone vapor beneath the SWL and is the principal vadose-zone vapor contaminant around the chemical disposal trenches at the NRDWL; thus, there may be contributions from both sources. Carbon tetrachloride and chloroform may be a result of vadose-zone contamination at the NRDWL. Distributions of chlorinated hydrocarbon concentrations along the compliance-point boundaries of the NRDWL and SWL were presented in Section 5.12.2.

5.12.3.3 Other Facilities

Gable Mountain Pond. Concentrations of strontium-90 above the interim DWS were detected in several wells near Gable Mountain Pond (see Figure 5.10-5). Strontium-90 in that area apparently resulted from the discharge of waste to that pond during its early use. The maximum annual average concentration of strontium-90 detected in the pond area in FY 1997 was 1,300 pCi/L in well 699-53-47A. Wells completed above the basalt in the vicinity of this pond are becoming difficult to sample because of declining water levels. Strontium-90 concentrations have increased in wells monitoring the pond over the past several years. An example of the increase is shown for well 699-53-47B in Figure 5.12-5.

618-10 Burial Ground and 316-4 Crib. This burial ground and adjacent crib are located southeast of the 400 Area, adjacent to Route 4S. This site was investigated as part of a CERCLA limited field investigation for the 300-FF-2 Operable Unit (DOE/RL-96-42). In FY 1995, high levels of uranium (768 µg/L, unfiltered) and the presence of hydrocarbon contamination (total petroleum hydrocarbon 104 mg/L; alkane and assorted decanes at estimated values ranging from 770 to 1,800 µg/L; unknown volatile organics estimated at 3,200 µg/L) were detected in well 699-S6-E4A, which is adjacent to both the burial ground and crib. Subsequently, tributyl phosphate was detected in well 699-S6-E4A. The CERCLA investigation included reconfiguration 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.

During FY 1996, well 699-S6-E4C previously completed in multiple zones was reconfigured to provide two deep, depth-discrete monitoring intervals within the unconfined 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 piezometer 699-S6-E4CT at 26 m below the water table and 699-S6-E4CS at 50 m below the water table. Tritium concentrations in piezometer 699-S6-E4CT declined to 6,600 pCi/L in FY 1997 from 27,800 pCi/L shortly after reconfiguration in FY 1996. This suggests that the earlier value resulted from intercommunication down the well bore prior to reconfiguration and that the value at depth is considerably lower. The tritium value for 699-S6-E4CS was still lower, 1,060 pCi/L in FY 1997. Continued monitoring as the well effect dissipates is needed to determine the tritium value at these depths.

In FY 1997, uranium in well 699-S6-E4A increased dramatically to a maximum of 225 µg/L (Figure 5.12-6) but did not reach the level found in FY 1995. This increase suggests that the low levels found in 1996 may have been related to the well-reconfiguration activities.

Tributyl phosphate continued to be detected in well 699-S6-E4A in FY 1997. The levels reported were 700 and 420 µg/L in the January and June 1997 samples, respectively.

Central Plateau. Chromium was detected in filtered samples at levels above the 100-µg/L MCL in well 699-32-62, south of the 200-East Area where the concentration measured in the single sample for FY 1997 was 230 µg/L (Figure 5.12-7). Several other wells contained chromium at levels below the MCL. Although one of the wells is located near the BC cribs, the other two wells are upgradient, suggesting that the cribs are not the source of chromium. 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.

Western 600 Area. Nitrate was detected in wells in the western part of the site but fell to levels less than the MCL in FY 1997 (see Plate 4). Nitrate upgradient of the 200-West Area and in well 699-17-70, located north of the Rattlesnake Hills, appears to have an offsite source, 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 Section 3.4). For this reason and the lack of other Hanford Site contaminants, such as tritium, nitrate south of the ridge is not believed to result from Hanford Site activities.

5.13 300 Area

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Activities in the 300 Area have been historically related to various research activities and the processing of uranium into fuel elements for the reactors. In addition to the fuel-fabrication processes, many technical-support, service-support, and research-and-development activities related to fuel fabrication were carried out. Fuel-fabrication activities ended in 1987. During fuel fabrication, uranium was disposed to the process ponds and trenches in dissolved and particulate forms. Facilities known to have received uranium include the 316-1 south process pond, the 316-2 north process pond, and the 316-5 process trenches (see Plate 1). The process ponds were removed from service in the mid-1970s; discharge to the process trenches ceased in December 1994.

5.13.1 Facilities and Operable Units

5.13.1.1 Facilities

The facilities in the 300 Area that affected the groundwater include the 316-5 process trenches, operating until December 1994, which have RCRA requirements for groundwater monitoring, and many of the other past-practice waste sites. Three of the most significant of these are the 316-1 south and 316-2 north process ponds and the 300 Area Fire Station.

316-5 Process Trenches. The two unlined trenches were constructed in 1975. From 1975 until shutdown of fuel-fabrication activities in 1987 and other operations in 1988, the trenches were used for the disposal of most liquid wastes generated in the 300 Area. The liquid waste was known or suspected of including the following (PNL-6716):

ammonium
barium
chloride
chloroform
cis-1,2-dichloroethylene
copper
iron
methyl chloride
nitrate
potassium
sodium
sulfate
tetrachloroethylene
trichloroethylene
uranium, or other alpha emitters
vanadium
at least one beta emitter.

The discharge rate reached a maximum of ~7,600 L/min. After 1988, the wastewater consisted of cooling water with small quantities of nonhazardous maintenance and process water. In July 1991, the trenches were modified as part of an expedited response action. The modification of the trenches involved removing bottom sediment from the inflow end of each trench and placing it at the opposite end on the trenches behind a berm. The trenches were used on an alternating, as-needed basis. The west trench was rendered inoperable on November 20, 1992. Subsequently, the east trench received all discharges. The average discharge to the east trench was ~850 L/min in the latter years of operation. In December 1994, all discharges to the trenches were terminated.

316-1 and 316-2 Process Ponds. These process ponds were the main facility for the disposal of uranium-contaminated wastewater until 1975 when the 316-5 process trenches were constructed and put into use.

300 Area Fire Station and 382 Pumphouse. In April 1992, an unknown quantity of contaminated soil was found under the fuel-dispensing island at the 3709-A building (300 Area Fire Station). This fueling facility consisted of two 1,893-L underground storage tanks and ~10 m of piping leading to the fuel-dispensing island. One tank contained unleaded gasoline and the other contained diesel fuel. Releases to the soil column occurred reportedly as a result of failure of corroded flex piping located directly beneath the dispensing island and also possibly from loose fittings. The underground storage tanks, piping, and dispensing island have since been removed.

Also, an unknown amount of petroleum product was released from the 382-1 underground storage tank, located at the 382 pumphouse building. The tank system was physically removed, along with an unknown quantity of petroleum-contaminated soil, for disposal on September 29, 1992.

5.13.1.2 Operable Units

The largest volume of waste generated in the 300 Area is from the fuel-fabrication operations associated with three source operable units. The 300-FF-1 Operable Unit contains the 316-1 south and 316-2 north process ponds, the sanitary leaching trenches, and the 316-5 process trenches. The 300-FF-2 Operable Unit consists primarily of waste management units that received solid waste and contaminated equipment in the north and northwestern parts of the area. The 300-FF-3 Operable Unit includes a variety of miscellaneous waste management units, including solid and liquid wastes in the southern portion of the area.

The 300-FF-5 Operable Unit is the groundwater beneath the three source operable units. The extent of the 300-FF-5 Operable Unit includes all contamination, emanating from the source operable units, detected in groundwater and sediments below the water table that exceeds ARARs (applicable or relevant and appropriate federal and state environmental requirements).

Groundwater beneath the 300 Area is potentially affected by inflowing groundwater from several source areas in addition to the 300 Area source operable units. The other potential sources are the following:

- the 300-IU-1 Operable Unit, located 3.8 km northwest (upgradient) of the 300 Area, consists of various waste management units that received waste from fuel-fabrication operations and miscellaneous construction debris

- the 300-FF-4 Operable Unit, located at the 400 Area (Fast Flux Test Facility), which is approximately upgradient

- the southeastern portion of the tritium plume emanating from the 200 Areas (200-PO-1 Operable Unit)

- the 1100-EM-1 Operable Unit associated with the Horn Rapids Landfill, which contains a plume of trichloroethylene that is migrating in the direction of the 300 Area.

5.13.2 Compliance Issues

5.13.2.1 316-5 Process Trenches

A RCRA interim-status quality assessment well network monitored the groundwater near the 300 Area process trenches from June 1985 until December 1996. In December 1996, the well network was changed to a final-status compliance-monitoring network. The schedule for modifying the RCRA sitewide permit (Ecology 1994) required that a closure plan and accompanying revised groundwater-monitoring plan be submitted. A closure plan and a revised groundwater-monitoring plan were written. The closure plan (DOE/RL-93-73) includes the revised groundwater-monitoring plan (WHC-SD-EN-AP-185). The closure plan and accompanying groundwater-monitoring plan are referenced in the revised RCRA sitewide permit (Ecology 1994) and became effective December 26, 1996.

As expected, groundwater samples from well 399-1-16B, a downgradient well sampling the base of the unconfined aquifer system, showed that cis-1,2-dichloroethylene and trichloroethylene were in concentrations higher than the required limits (70- and 5-µg/L MCLs, respectively). Similarly, all three wells monitoring the aquifer at the water table and located downgradient from the 316-5 process trenches showed that uranium exceeded the 20-µg/L proposed MCL. After the first four independent samples were collected in FY 1997, the exceedances were confirmed and Ecology was notified. As required, the monitoring plan was modified for corrective action to be implemented in 1998.

The objective of groundwater monitoring during the corrective action is to monitor the trend of the constituents of concern to confirm that they are naturally attenuating, as expected by the CERCLA record of decision for the 300-FF-5 Operable Unit (ROD 1996b). The plan calls for samples from the same wells that were being sampled in the previous compliance period but at a reduced number of independent samples from each well during each sampling period (i.e., four to one). Also, each well showing an exceedance (four of eight wells) of one of the constituents of concern will be on a quarterly sampling schedule to better follow the trends of groundwater contaminant concentration. The other wells in the network will continue to be sampled on a semiannual basis.

Until the corrective action is implemented in 1998, the current final-status compliance-monitoring program (WHC-SD-EN-AP-185) will remain in effect. The program calls for 4 independent groundwater samples from each network well (8) during each semiannual sampling period (2/yr) (i.e., 64 well trips/yr). Efforts are under way to propose an alternate final-status/compliance-monitoring plan that will accomplish the same goals as the original final-status/compliance-monitoring plan but without the requirement of the four independent samples collected during each semiannual sampling event.

The eight network wells for the 316-5 process trenches are functioning well and are adequate to satisfy the goals of monitoring the groundwater during the current final-status/compliance-monitoring period and the goals of the future corrective action plan (WHC-SD-EN-AP-185).

5.13.2.2 300 Area Fire Station

Groundwater monitoring has been conducted semiannually at the facility since 1993. Two wells were sampled and analyzed for benzene, toluene, ethylbenzene, xylene, and total petroleum hydrocarbons. No groundwater impacts were observed. The monitoring requirements were fully met in 1997, and no further monitoring will be required. Results were reported to DOE, who formally transmitted them to Ecology.

In April 1992, an unknown quantity of contaminated soil was found under the fuel-dispensing island at the 3709-A building (300 Area Fire Station). This fueling facility consisted of two 1,893-L underground storage tanks and ~10 m of piping leading to the fuel-dispensing island. One tank contained unleaded gasoline and the other contained diesel fuel. Releases to the soil column occurred reportedly as a result of failure of corroded flex piping located directly beneath the dispensing island and also possibly from loose fittings. The underground storage tanks, piping, and dispensing island have since been removed.

Also, an unknown amount of petroleum product was released from the 382-1 underground storage tank, located at the 382 pumphouse building. The tank system was physically removed, along with an unknown quantity of petroleum-contaminated soil, for disposal on September 29, 1992.

5.13.2.3 300-FF-1 and 300-FF-5 Operable Units Remedial Actions

The record of decision for the 300-FF-1 and 300-FF-5 Operable Units was approved in July 1996 (ROD 1996b). The major components of the selected remedy for the 300-FF-1 Operable Unit include the following:

- removal of contaminated soil and debris
- disposal of contaminated material at the Environmental Restoration Disposal Facility
- recontouring and backfilling of waste sites, followed by revegetation
- institutional controls to ensure that unexpected changes in land use do not occur that could result in unacceptable exposures to residual contamination.

The selected remedy for the 300-FF-5 Operable Unit is an interim action that involves imposing restrictions on the use of the groundwater until such time as health-based criteria are met for uranium, trichloroethylene, and cis-1,2-dichloroethylene. This is an interim action because there are other constituents (e.g., tritium) migrating into the unit that have not yet been fully addressed and because a portion of the unit is overlaid by uncharacterized waste sites in the 300-FF-2 Operable Unit. A final-action decision for the 300-FF-5 Operable Unit will be made after these issues have been addressed. The selected interim measure includes the following:

- continued monitoring of groundwater that is contaminated above health-based levels to ensure that concentrations continue to decrease

- institutional controls to ensure that groundwater use is restricted to prevent unacceptable exposures to contamination.

An operation and maintenance plan for the 300-FF-5 Operable Unit was released in September 1996 (DOE/RL-95-73). The purpose of that plan is to identify tasks necessary to verify the effectiveness of the selected alternative. The plan describes the monitoring program and administrative tasks that will be used as the selected alternative for the remediation of the groundwater in the operable unit. The routine operation-and-maintenance activities include three tasks:

- monitor groundwater (chemistry, depth to water)
- monitor near-shore riverwater (chemistry and river stage)
- post warning signs.

5.13.2.4 Drinking Water Standards and Derived Concentration Guides

No radiological constituents in 300 Area groundwater were detected at levels above the DCG in FY 1997. Uranium is detected at levels above the proposed MCL in much of the eastern part of the 300 Area. Trichloroethylene and cis-1,2-dichloroethylene are found at levels above the MCL in the deeper part of the unconfined aquifer system. Trichloroethylene was detected at the MCL in one well in the southwestern part of the 300 Area. Iron and manganese are found at levels above the secondary MCL in the deeper part of the unconfined aquifer system but this appears to be the result of naturally occurring material.

5.13.3 Extent of Contamination

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 DWS. The tritium contamination is discussed in Sections 5.10.3.2 and 5.14.3.1. Additional constituents detected include strontium-90, nitrate, trichloroethylene, cis-1,2-dichloroethylene, iron, and manganese. Petroleum hydrocarbons are being monitored near the 300 Area Fire Station.

5.13.3.1 Uranium

The uranium distribution in the 300 Area is shown in Figure 5.13-1. The highest uranium concentrations are located in the northern part of the 300 Area, downgradient from the 316-5 process trenches and near the 316-1 and 316-2 process ponds. Because the process ponds are 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-µg/L proposed DWS) detected in the 300 Area was 357 µg/L in well 399-2-2 in the August 20, 1997 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 concentration in the 300 Area and are aligned along the groundwater-flow direction (southeast). This alignment suggests that the major source of the uranium contamination is the 316-5 process trenches.

Figure 5.13-2 shows the historical trend for uranium in well 399-1-17A (the well located closest to the inflow portion of the trenches). Uranium concentrations dropped dramatically in 1991 as a result of the expedited response action but then began to rise sharply again when process trench discharges ceased in December 1994. In FY 1996 and FY 1997, the rise continued, though not at the rapid rate it did in FY 1995.

Presumably, the contribution of uranium to the unconfined aquifer system by the soil column 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 concentration since January 1995 indicates that uranium continues to be contributed to the groundwater by the soil column at the 316-5 process trenches. The lack of dilution by large quantities of process wastewater caused the concentration of uranium in the groundwater to continue to rise during FY 1996 and FY 1997. The total activity of uranium contributed by the soil column at the trenches during FY 1997 may actually be the same, or even lower, than it was prior to January 1995.

Another zone of elevated uranium concentration in FY 1996 was near the 324 building (immediately west of well 399-3-11). However, in FY 1997, the zone of higher uranium concentration moved downgradient (southeast) to the area near well 399-4-9 (see Figure 5.13-1). In FY 1996, the uranium concentration at well 399-3-11 (near the 324 building) was 130 µg/L; in FY 1997, it dropped to 66 µg/L. In FY 1996, the average uranium concentration at well 399-4-9 (southeast of the 324 building near the river) was 74 µg/L; in FY 1997, it rose to 130 µg/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.

5.13.3.2 Strontium-90

The concentration of strontium-90 (8-pCi/L interim DWS) at well 399-3-11, near the 324 building, returned to levels determined prior to the elevated level recorded in the December 1995 sampling event (8.7 pCi/L). Typical for this well since 1987 is a fluctuation between 3 and 7 pCi/L. Groundwater samples from well 399-3-11 were collected with a bailer and were not filtered, so it is probable that much of the strontium-90 is sorbed to sediment in the samples. Since the high result in December 1995, the results have been 3.0 and 3.1 pCi/L in August 1996 and September 1997, respectively. 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 is the only result greater than the interim DWS since 1986.

5.13.3.3 Trichloroethylene and cis-1,2-Dichloroethylene

In past years, trichloroethylene was above the 5-µg/L MCL in wells 399-1-16B and 399-1-17B that monitor the base of the unconfined aquifer system downgradient of the 316-5 process trenches. It continued to decline in well 399-1-17B during FY 1997, but in well 399-1-16B, the concentration began to rise again (Figure 5.13-3). Trichloroethylene was above or equal to the 5-µg/L MCL in 6 of the 8 samples collected from well 399-1-16B during FY 1997. The range of concentration measured is 20 to 2 µg/L in December 1996 and June 1997, respectively.

The concentration of cis-1,2-dichloroethylene (70-µg/L MCL) remained elevated in FY 1997 samples from deep well 399-1-16B (Figure 5.13-4). The high for FY 1997 was 190 µg/L in February 1997 and the low was 140 µg/L in June 1997. Average cis-1,2-dichloroethylene for FY 1997 was 166 µg/L; the average for FY 1996 was 155 µg/L.

5.13.3.4 Iron and Manganese

Iron and manganese in filtered samples exceeded secondary MCLs (300 and 50 µg/L, respectively) in wells 399-1-16B, 399-1-17B, and 399-1-18B during FY 1997. These wells are deeper and sample groundwater at the bottom of the unconfined aquifer system. In the two downgradient wells (399-1-16B and 399-1-17B), manganese was above the secondary MCL in both wells (59 and 80 µg/L, respectively), and iron was above the secondary MCL in well 399-1-17B (448 µg/L). However, iron is also above the MCL in upgradient well 399-1-18B (410 µg/L). Manganese is below the secondary MCL in well 399-1-18B (39 µg/L), but this concentration is generally higher than the concentration of manganese in the downgradient wells that monitor groundwater at the top of the unconfined aquifer system, averaging between 2 and 3 µg/L. Therefore, the iron and manganese in these deeper wells probably is not related to waste products discharged in the 316-5 process trenches. It is more likely due to naturally occurring iron and manganese in the deeper portions of the aquifer that have greater reducing conditions that are more likely to mobilize these metallic ions.

5.13.3.5 Other Constituents

In April 1993, two groundwater-monitoring wells (399-5-4B and 399-6-2) were installed ~23 to 46 m southeast of the 300 Area Fire Station, specifically for the purpose of monitoring potential contamination downgradient of the former fueling facility. Samples were collected 3 times in 1993, 2 times in 1995, 2 times in 1996, and once in 1997. The samples were analyzed for total petroleum hydrocarbons (gasoline and diesel ranges), benzene, toluene, ethylbenzene, and total xylenes.

Low levels of diesel (e.g., 690 µg/L) were detected in well 399-6-2 in the May and September 1993 and October 1995 samples. Concentrations for the remaining constituents have been below applicable detection limits for all sampling events. Additional samples from one upgradient and five downgradient wells were also below detection for hydrocarbons.

5.14 Richland North Area

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The Richland North Area is located in the southern part of the Hanford Site (see Figure 1.1) and though not formally defined, includes the 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.

5.14.1 Facilities and Operable Units

Facilities or activities of interest with respect to groundwater in the Richland North Area include the City of Richland's North Well Field recharge basins, Siemens Power Corporation, Richland Landfill, Lamb-Weston Richland Plant, Interstate Nuclear Services, Allied Technology Group, and agricultural and residential irrigation. Additionally, one new heavy industry is under construction and a second is planned.

The Richland North Area also contains two operable units: 1100-EM-1 and 1100-EM-2. Of particular concern is the potential for future impacts from these facilities and activities as well as Hanford Site operations (i.e., the tritium plume) at the city's north well field, which serves as the city's secondary drinking water-supply system.

5.14.2 Compliance Issues

5.14.2.1 1100-EM-1 Operable Unit Remedial Investigation

The 1100-EM-1 Operable Unit contains the Horn Rapids Landfill. CERCLA investigation results for this operable unit are presented in the final remedial investigation study (DOE/RL-92-67, Draft B) and the record of decision (ROD 1993). The selected remedy for groundwater is monitored natural attenuation, with institutional controls on drilling of new water-supply wells. The 1100-EM-1 Operable Unit was removed from the National Priorities List (40 CFR 300, Appendix B) in September 1996. Well 699-S41-E12, downgradient of the 1171 building, is sampled annually for the 1100-EM-2 Operable Unit.

A compliance network of 11 groundwater wells is monitored annually for volatile organic constituents adjacent to the Horn Rapids Landfill (Table 5.14-1). Three of these wells establish the downgradient point of compliance for the landfill and are approximately parallel to the George Washington Way diagonal. In FY 1997, samples from the northwest and center point-of-compliance wells (699-S27-E12A and 699-S28-E13A, respectively) had concentrations equal to the 5-µg/L MCL for trichloroethylene. The sample from the southeast point-of-compliance well (699-S29-E13A) showed a concentration of 1 µg/L. Of note, well 399-5-1, located in the southwestern part of the 300 Area, also had a trichloroethylene concentration equal to the MCL, indicating that the plume has moved downgradient ~150 m beyond the point of compliance. However, steady or declining concentrations in the majority of wells downgradient of the Horn Rapids Landfill suggest some elements of natural attenuation (e.g., volatilization through passive pumping) may be reducing the plume mass.

Groundwater from well 699-S41-E12 is analyzed specifically for filtered and unfiltered chromium. The filtered chromium concentration for FY 1997 was estimated at 3.3 µg/L. An unfiltered concentration of 220 µg/L was reported. The MCL for chromium is 100 µg/L.

5.14.2.2 Drinking Water Standards and Derived Concentration Guides

Nitrate, trichloroethylene, and fluoride were detected in groundwater at concentrations above their respective MCLs in the Richland North Area during FY 1997. Likely sources of these constituents include offsite industry and agriculture.

5.14.3 Extent of Contamination

Fifty groundwater wells were sampled in the Richland North Area during FY 1997. Of those, 44 were sampled annually, 5 were sampled semiannually, and 1 was sampled quarterly. The samples were analyzed predominantly for tritium, nitrate, and trichloroethylene. Selected samples were also analyzed for alkalinity, gross alpha, anions, gross beta, gamma emitters, metals, oil and grease, technetium-99, total petroleum hydrocarbon, total uranium, and isotopic uranium. In addition, Siemens Power Corporation selectively sampled 16 offsite groundwater wells quarterly, semiannually, and annually (EMF-1865). Analyses for these samples included gross alpha, gross beta, trichloroethylene, ammonia, nitrate, fluoride, chloride, sulfate, and total dissolved solids.

Constituents of concern in groundwater in the Richland North Area include trichloroethylene, nitrate, gross alpha, and uranium. The potential for tritium transport from the Hanford Site south into this area is also addressed here.

5.14.3.1 Tritium

Discharges in and near the 200-East Area resulted in tritium being transported via groundwater to the Columbia River as far south as the southeastern part of the 300 Area (Figure 5.14-1). The plume configuration for FY 1997 is similar to FY 1996, where the 2,000-pCi/L contour extends to the river immediately south of well 399-4-12. Average concentrations ranged from 17 to 14,000 pCi/L, with the highest concentration detected in well 699-S19-E13. Figure 5.14-1 showed tritium concentrations as a function of time in selected wells along a north-south transect through the 300 and Richland North Areas. Tritium levels have been increasing generally with time in and north of the 300 Area and have been remaining steady in the Richland North Area. Well 399-1-17A is unique, in that concentrations remained relatively low until December 1994 and then increased dramatically. The trend plot clearly indicates when discharge to the 316-5 process trenches, and the resulting dilution, ceased. Tritium concentrations at the City of Richland's North Well Field recharge basins are comparable to those in the Columbia River at the Richland Pumphouse (Section 4.2 of PNNL-11472).

The southward migration of the tritium plume and increasing concentrations with time in the 300 Area continue to raise concern over potential future impacts at the city's north well field. Several factors are believed to limit significant migration into the Richland North Area: 1) groundwater flow is generally from west to east, being recharged by the Yakima River and discharging to the Columbia River; 2) artificial recharge from agricultural irrigation occurs between the Richland Landfill and the 1100 Area, and contributes to the eastward flow; and 3) net recharge at the city's north well field has resulted in a groundwater mound that directs flow outward from the well field. These factors produce converging flow lines in the 300 Area and discharge to the Columbia River (see Figure 3.8-2 and Plate 2). The current flow field is based, in part, on the net recharge to the city's north well field; however, recent modeling efforts indicate groundwater flow would still be predominantly west to east without this recharge. Thus, there is still no indication that the well field would be impacted by the tritium plume.

5.14.3.2 Nitrate

Nitrate contamination is found in the Richland North Area likely as a result of disposal of liquid wastes containing nitrate to the 316-5 process trenches and offsite industrial and agricultural uses. The

FY 1997 distribution in groundwater (see Plate 4) appears similar to FY 1996 and supports previous discussions on groundwater-flow directions in this area. Concentrations above the 45-mg/L MCL are found offsite both upgradient and downgradient of Siemens Power Corporation (EMF-1865, EMF-1933). In FY 1997, concentrations in the upgradient and downgradient wells adjacent to the facility generally remained steady or increased slightly over FY 1996 levels. Concentrations in the downgradient wells near Horn Rapids Road increased sharply since March and June 1986. The maximum concentration in FY 1997 was 187 mg/L (as NO_3) in well GM-8. Potential nitrate sources from Siemens Power Corporation are discussed in DOE/RL-92-67 (Draft B). Fertilizer applied to the agricultural fields upgradient of Siemens Power Corporation and potato-processing waste from the Lamb-Weston Richland Plant are the probable sources.

Nitrate concentrations onsite ranged from 0.88 to 170 mg/L, with the highest in well 699-S30-E10A. This well is located downgradient of the Horn Rapids Landfill. Concentrations exceeding the MCL are found in the southwestern part of the 300 Area and as far south as well 699-ATH, near the Horn Rapids Athletic Complex (see Plate 4). Nitrate levels in wells at the City of Richland's North Well Field recharge basins were lower than ambient groundwater, probably as a result of dilution from infiltration of riverwater at the settling and recharge basins.

5.14.3.3 Trichloroethylene

Trichloroethylene concentrations in the Siemens Power Corporation wells in FY 1997 ranged from less than detection to 6 µg/L, with the highest concentration in well GM-8 (EMF-1865, EMF-1933). Concentrations in these wells generally continue to decrease with time. The 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).

The trichloroethylene distribution in groundwater beneath the Richland North Area (Figure 5.14-2) supports the tritium discussion with respect to northeastward flow around the City of Richland's North Well Field recharge basins. Trichloroethylene was found onsite beneath the Horn Rapids Landfill and offsite in Siemens Power Corporation wells. Compared with FY 1996, the FY 1997 plume has a more elongated configuration and extends ~150 m northeast of the point of compliance (i.e., the George Washington Way diagonal), established in the record of decision for the 1100-EM-1 Operable Unit (ROD 1993). Average concentrations equal to the 5-µg/L MCL were found in the northwest point-of-compliance well (699-S27-E12A), the center point-of-compliance well (699-S28-E13A), and well 399-5-1 in the southwestern part of the 300 Area. Concentrations in the other onsite wells ranged from less than detection to 11 µg/L, with the highest concentration in well 699-S31-E10A, located immediately downgradient of the Horn Rapids Landfill. Concentrations in the majority of wells downgradient of the Horn Rapids Landfill remained steady or decreased from FY 1996 levels, suggesting some elements of natural attenuation (e.g., volatilization through passive pumping) may be reducing the plume mass. Sufficient data have not been collected to establish trends with time in downgradient wells 699-S27-E12A, 699-S28-E13A, 699-S29-E10A, 699-S29-E11A, and 699-S30-E13A.

5.14.3.4 Gross Alpha and Uranium

Gross alpha levels in offsite wells upgradient of Siemens Power Corporation generally decreased in FY 1997 (EMF-1865, EMF-1933). Concentrations in the downgradient wells may be related to the nearby process lagoons. Wells GM-5, GM-8, and GM-10 are directly downgradient from Lagoon 1 and have concentrations ranging from 23 to 104 pCi/L. Wells GM-6, GM-7, GM-11, GM-12, and GM-16 are downgradient of Lagoon 5A and have lower concentrations, ranging from 5 to 25 pCi/L. Although no uranium measurements were made in these wells, it is probable that uranium makes a large contribution to the gross alpha measurements at this location because Siemens Power Corporation produces fuel pellets for commercial nuclear power plants.

The maximum gross alpha measurement on the Hanford Site (10.1 pCi/L) was reported in well 699-S31-E10A downgradient of the Horn Rapids Landfill. Uranium concentrations in onsite wells ranged from 1 to 17 µg/L, with the highest concentration in well 699-ATH. Because well 699-ATH is a water-supply well upgradient of Siemens Power Corporation, the uranium is probably natural.

5.14.3.5 Other Constituents

Ammonia. Ammonia concentrations in the Siemens Power Corporation wells generally remained steady in FY 1997, with the exception of one downgradient well (EMF-1865, EMF-1933). This well (GM-10) had the highest concentration detected at 20 mg/L (as N). 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. No onsite wells were analyzed for ammonia in the Richland North Area.

Fluoride. Two downgradient Siemens Power Corporation wells (GM-5 and GM-10) had fluoride concentrations above the 4-mg/L MCL. The highest concentration in FY 1997 was 6.15 mg/L in well GM-5. Average fluoride concentrations in onsite wells for this area were all below 1 mg/L.

Gross Beta. Gross beta measurements in the Siemens Power Corporation wells exhibited similar trends to the gross alpha measurements (EMF-1865, EMF-1933). Low levels of technetium-99, detected near the Horn Rapids Landfill, may be related to the gross beta measurements.

5.15 Radiological and Chemical Monitoring for the Upper Basalt-Confined Aquifer

D. B. Barnett

The upper basalt-confined aquifer, which lies immediately below the unconfined aquifer system, is affected far less by Hanford Site contamination than the unconfined aquifer system. Minor amounts of contamination reached the upper basalt-confined aquifer through various mechanisms (PNNL-11141):

- local erosion of confining basalt layers, allowing intercommunication between aquifers
- disposal of large quantities of water, resulting in groundwater mounding in the unconfined aquifer system and a downward hydraulic gradient to the upper basalt-confined aquifer
- wells penetrating the confined aquifer(s), providing a pathway for downward contaminant migration.

These conditions can allow groundwater and any potential entrained contaminants to flow from the unconfined aquifer system to the underlying confined aquifer, thus increasing the potential to spread contamination. Because fewer wells are available to monitor the confined aquifer, it is important to consider contamination trends at levels well below the DWS to provide for timely detection of potentially higher levels.

The hydrochemical and hydrogeologic conditions within the upper basalt-confined aquifer and the potential for offsite migration of contaminants through confined-aquifer pathways were documented in PNL-10817. The upper basalt-confined aquifer was monitored to determine the extent of groundwater contamination resulting from interaction between the unconfined and confined aquifers. Also identified in PNL-10817 were several confined-aquifer wells north and east of the 200-East Area that show evidence of intercommunication with the overlying unconfined aquifer system. Groundwater chemical data from most confined-aquifer wells in other areas of the Hanford Site show no evidence of contamination, with the exception of wells that were previously open to both the unconfined and confined aquifers and, thus, provided routes for the downward transport of contamination.

Results of the 1995 sampling and analyses of groundwater from the upper basalt-confined aquifer indicated only a few areas of concern that warranted continued annual monitoring. Consequently, the number of wells to be sampled has been progressively reduced since 1995. The few, significant analytical results obtained during FY 1997 are discussed below. Figure 5.15-1 shows the locations of wells used for monitoring confined-aquifer groundwater chemistry. Results for tritium are shown in Figure 5.15-2. In that figure, nondetected values are shown as less than the minimum detectable activity because analytical methods with vastly different detection limits were used. Results selected for other radionuclides are shown in Figure 5.15-3 and for nitrate in Figure 5.15-4.

Well 199-B3-2P (in the 100-B Area) has been sampled annually for the last several years, including 1997, but recent results in water-level measurement and chemistry suggest that samples from this piezometer were not representative of the confined aquifer. Recent information gathered during decommissioning of this well in late 1997 indicates that both hydrologic and chemistry data for the entire period of record are suspect because the structural integrity of the well and of the piezometers may have been severely compromised during construction. This has significant implications for the evaluation of the direction of flow in the confined aquifer because there are no other confined-aquifer wells in this part of the site.

Well 199-B3-2P had been open to both the unconfined aquifer and the Rattlesnake Ridge interbed of the confined aquifer between 1953 and 1970, prior to installation of the piezometers. Although the well was cased through the upper part of the confined aquifer to an interval below the Ringold lower mud unit, an apparent hole in the casing was discovered during abandonment. This shows the possibility that the well provided a conduit for contamination to the confined aquifer. A large groundwater mound was produced in the 100-B,C Area during its period of operation. This mound potentially reversed the gradient, driving contamination to the confined aquifer. A groundwater sample taken from this well in 1997 produced a strontium-90 result of 62.9 pCi/L, far higher than any previous result from this well since analysis for this constituent began in 1994. Previous strontium-90 results ranged from 3.9 to 21 pCi/L. Although the source of this contamination is problematic, further investigation of this region is warranted by the unexpected high strontium-90 result.

Intercommunication between the unconfined aquifer and underlying confined aquifer in the vicinity of the northern part of the 200-East Area was identified in RHO-BWI-ST-5 and RHO-RE-ST-12P. This intercommunication was attributed to erosion of the upper Saddle Mountains Basalt and downward vertical gradients resulting from wastewater disposal that produced groundwater mounding within the unconfined aquifer system.

Well 299-E33-12 (north of the 200-East Area) continued showing a decline in specific conductance and cyanide (below detection in FY 1997), but produced a technetium-99 result (1,290 pCi/L) slightly higher than FY 1996. Well 699-42-E9B (near the eastern shore of the Columbia River) yielded a potassium-40 result of 115 pCi/L (somewhat higher than the counting error of 42.4 pCi/L) and a typically high pH of 9.49. Potassium-40 is a naturally occurring radionuclide.

Only three monitoring wells completed in the upper basalt-confined aquifer in the vicinity of the BY cribs (299-E33-12, 699-49-57B, and 699-50-53B) were analyzed for cobalt-60 and/or cyanide during FY 1997. Of these, only well 299-E33-12 produced a result (12.9 pCi/L for cobalt-60) above detection for these constituents. Most of the other wells were last sampled in FY 1995. During FY 1995, well 699-49-55B, completed in the confined aquifer northwest of the BY cribs, produced a cobalt-60 result of 154 pCi/L. This well is scheduled for sampling in FY 1998.

Table 5.1-1. Maximum Contaminant Levels and Interim Drinking Water Standards

Constituent	MCL or DWS	Agency[a]	EPA Status
Aluminum[b]	0.05 mg/L	EPA	Final
Antimony	0.006 mg/L	EPA	Final
Arsenic	0.05 mg/L	EPA, DOH	Under review
Barium	2 mg/L	EPA	Final
	1 mg/L	DOH	
Cadmium	0.05 mg/L	EPA	Final
Carbon tetrachloride	5 µg/L	EPA, DOH	Final
Chloride[b]	250 mg/L	EPA, DOH	Final
Chloroform (THM) (c)	80 µg/L	EPA	Proposed
	100 µg/L	EPA, DOH	Final
Chromium	100 µg/L	EPA, DOH	Final
cis-1,2-Dichloroethylene	70 µg/L	EPA	Final
Copper[b]	1.0 mg/L	EPA, DOH	Final
Cyanide	200 µg/L	EPA	Final
1,4-Dichlorobenzene	75 µg/L	EPA	Final
Fluoride	4 mg/L	EPA, DOH	Final/under review
	2 mg/L[b]	EPA	Final
Iron[b]	0.3 mg/L	EPA	Final
Lead	0.015 mg/L[d]	EPA	Final
	0.05 mg/L	DOH	
Manganese[b]	50 µg/L	EPA, DOH	Final
Mercury (inorganic)	0.002 mg/L	EPA, DOH	Final
Methylene chloride	5 µg/L	EPA	Final
Nickel	0.1 mg/L	EPA	Final/being remanded
Nitrate, as NO_3^-	45 mg/L	EPA, DOH	Final
Nitrite, as NO_2	3.3 mg/L	EPA	Final
Pentachlorophenol	1 µg/L	EPA	Final
pH[d]	6.5 to 8.5	EPA	Final
Selenium	0.05 mg/L	EPA	Final
	0.01 mg/L	DOH	
Silver[b]	0.1 mg/L	EPA, DOH	Final
Sulfate	500 mg/L	EPA	Proposed
	250 mg/L[b]	EPA	Final
Tetrachloroethylene	5 µg/L	EPA, DOH	Final
Thallium	0.02 mg/L	EPA	Final
Total dissolved solids[b]	500 mg/L	EPA	Final
1,1,1-Trichloroethane	0.2 mg/L	EPA	Final
Trichloroethylene	5 µg/L	EPA, DOH	Final
Zinc[b]	5 mg/L	EPA, DOH	Final
Antimony-125	300 pCi/L[e]	EPA	Interim
Beta particle and photon activity	4 rem/yr[f]	EPA, DOH	Final
Carbon-14	2,000 pCi/L[e]	EPA	Interim
Cesium-137	200 pCi/L[e]	EPA	Interim
Cobalt-60	100 pCi/L[e]	EPA	Interim
Iodine-129	1 pCi/L[e]	EPA	Interim
Ruthenium-106	30 pCi/L[e]	EPA	Interim
Strontium-90	8 pCi/L[e]	EPA	Interim
Technetium-99	900 pCi/L[e]	EPA	Interim
Total alpha (excluding uranium)	15 pCi/L[e]	EPA, DOH	Final
Tritium	20,000 pCi/L[e]	EPA	Interim
Uranium	20 µg/L	EPA	Proposed

(a) DOH = State of Washington Department of Health at WAC 246-290;
EPA = U.S. Environmental Protection Agency at 40 CFR 141, 40 CFR 143, and EPA 822-R-96-001.

(b) Secondary maximum contaminant level.

(c) Standard is for total trihalomethanes (THM).

(d) Action level.

(e) Concentration assumed to yield an annual dose equivalent of 4 mrem/yr.

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

DWS = Drinking water standard.
MCL = Maximum contaminant level.

Table 5.1-2. Derived Concentration Guides[a, b, c] and 4-mrem Effective Dose Equivalent Concentrations for Drinking Water[d]

Radionuclide	Derived Concentration Guide, pCi/L	4-mrem Effective Dose Equivalent, pCi/L
Tritium	2,000,000	80,000
Carbon-14	70,000	2,800
Chromium-51	1,000,000	40,000
Manganese-54	50,000	2,000
Cobalt-60	5,000	200
Zinc-65	9,000	360
Krypton-85	NS	NS
Strontium-90	1,000	40
Technetium-99	100,000	4,000
Ruthenium-103	50,000	2,000
Ruthenium-106	6,000	240
Antimony-125	60,000	2,400
Iodine-129	500	20
Iodine-131	3,000	120
Cesium-134	2,000	80
Cesium-137	3,000	120
Cerium-144	7,000	280
Uranium-234	500	20
Uranium-235	600	24
Uranium-238	600	24
Plutonium-238	40	1.6
Plutonium-239	30	1.2
Plutonium-240	30	1.2
Americium-241	30	1.2

(a) Concentration of a specific radionuclide in water that could be continuously consumed at average annual rates and not exceed an effective dose equivalent of 100 mrem/yr.

(b) Values in this table represent the lowest, most conservative derived concentration guides considered potentially applicable to Hanford Site operations, and may be adjusted upward (larger) if accurate solubility information is available.

(c) From DOE Order 5400.5.

(d) Concentration of a specific radionuclide in water that would produce an effective dose equivalent of 4 mrem/yr if consumed at average annual rates.

NS = No standard.

Table 5.9-1. Sample Results for Decommissioning Task at Well 299-W15-5 and Vertical Profiling at Wells 299-W15-7 and 299-W15-10

Depth Below Water Table, m	Sample Date	Carbon Tetrachloride, µg/L	Chloroform, µg/L	Trichloroethylene, µg/L
		299-W15-5		
1.5	07/18/96	5,800	560	2.0J
4.6	05/16/96	6,000	300	U
33.5	06/25/97	2,600	46	10
65.8	07/16/97	850	37	U
86.0	07/24/97	120	18	10
102.7	08/06/97	1.0J	1.0J	3.0J
112.2	08/12/97	U	U	U
		299-W15-7		
0.3	August 1996	713	28.9	0.62
6.5		745	52.6	0.8
12.6		717	80	0.78
19.4		738	93	0.96
25.1		707	100	0.81
30.5		703	113	0.95
		299-W15-10		
3.5	August 1996	1,587	68	7
9.5		1,847	59	8.2
15.3		1,983	54	8.3

J = Estimated.
U = Undetected.

Table 5.9-2. Volume of Groundwater Treated and Mass of Carbon Tetrachloride Removed Since Startup of Operations at 200-ZP-1 Operable Unit

Reporting Period	Influent Treated, L	Mass Removed, kg
August 1994 through July 1996	26,676,000	75.85
August 1996 through September 1996	33,232,327	60.96
October 1996 through December 1996	44,583,715	143.54
January 1997 through March 1997	69,869,604	237.3
April 1997 through June 1997	41,877,094	137.3
July 1997 through September 1997	42,926,565	203.6
Total	259,165,396	858.55

Table 5.9-3. Statistical Summary of Contaminant Data for 200-ZP-1 Operable Unit Extraction Wells, Fiscal Year 1997

Well Number	Mean Concentration, µg/L	Minimum Value, µg/L	Maximum Value, µg/L	Mean Flow Rate, L/min	Overall Trend
299-W15-33	5,058	3,700	6,600	25	Increasing
299-W15-34	2,900	2,200	3,500	35	Increasing
299-W15-35	3,351	1,900	4,000	85	Increasing
299-W15-32	7,120	6,500	8,200	35	Decreasing
299-W15-36	2,820	2,600	3,100	25	Steady
299-W15-37	280	250	350	15	Steady

Table 5.10-1. Comparison of Plutonium-239/-240 in Filtered and Unfiltered Samples from Wells Near 216-B-5 Injection Well

Well Number	Sample Date/Time	Unfiltered Plutonium-239/-240, pCi/L	Filtered Plutonium-239/-240, pCi/L
299-E28-24	04/28/97 9:45 AM	25.6 ± 3.27	0.952 ± 0.437
299-E28-25	04/15/97 11:06 AM	0.826 ± 0.441	1.07 ± 0.472

Table 5.12-1. Ranges of Chlorinated Hydrocarbon Concentrations (μg/L) in Groundwater at Solid Waste Landfill, November 1996 to August 1997

	699-22-35	699-23-34A	699-23-34B	699-24-34A	699-24-34B	699-24-34C	699-25-34C	699-24-35	699-26-35A
Carbon tetrachloride	0.66-1.3	<0.5-0.20	0.44-0.7	<0.5-0.52	<0.5-0.42	<0.5-0.44	<0.5-0.20	<0.5-0.58	<0.50-0.23
Chloroform	1.9-4.6	0.17-0.2	0.70-0.90	<0.20-0.27	<0.20-0.26	<0.20-0.31	0.20-0.30	<0.20-0.34	<0.20-0.20
1,1-Dichloroethane	3.0-4.6	0.4-2.6	3.1-4.4	1.2-1.6	1.2-1.5	0.93-1.6	0.3-0.50	0.26-0.40	<0.20-0.09
1,2-Dichloroethane	<0.02-<0.20	<0.2-0.20	<0.02-<0.20	<0.02-<0.20	<0.02-<0.20	<0.02-<0.20	<0.02-<0.20	<0.02-0.50	0.02-<0.20
1,4-Dichlorobenzene	<0.03-0.20	<0.03-0.60	<0.03-0.40	<0.03-0.40	>0.03-0.30	<0.03-0.04	<0.03-<0.20	<0.03-0.07	<0.03-<0.20
cis-1,2-Dichloro-ethylene	<0.20-<0.04	<0.20-0.05	<0.20-0.07	<0.20-0.12	<0.20-0.16	<0.20-0.15	<0.20-0.04	<0.20-0.23	<0.05-<0.20
trans-1,2-Dichloro-ethylene	<0.03-<0.20	<0.03-<0.20	<0.03-<0.20	<0.20-0.04	<0.03-0.23	<0.03-<0.20	<0.03-<0.20	<0.20-0.15	<0.05-<0.20
Tetrachloroethylene	1.7-2.1	1.0-3.0	1.9-2.3	2.1-2.6	2.5-3.2	2.2-3.6	1.1-1.8	0.95-1.4	0.53-0.70
Total organic halides	20-29	8-12	12-21	5.5-11	7.4-14	4.0-11	<2.65-8.6	3.6-13	<4.62-4.5
Trichloroethylene	0.9-1.5	0.8-1.4	1.0-1.4	0.93-1.3	1.1-1.3	0.9-1.4	0.6-0.9	0.4-1.1	0.29-0.30
1,1,1-Trichloroethane	8-15	2.0-8.9	8.9-13	4.6-10	3.5-5.3	3.2-5.1	1.2-2.9	3.3-4.2	1.0-1.6
1,1,2-Trichloroethane	<0.04-<0.20	<0.04-0.06	<0.04-<0.20	<0.04-<0.20	<0.04-<0.20	<0.04-<0.20	<0.04-<0.20	<0.04-0.28	<0.04-<0.20

Table 5.14-1. Compliance[(a)] Monitoring Wells at Horn Rapids Landfill

Well Number	Point-of-Compliance Location	Frequency
699-S27-E12A	Northwest	Annual
699-S28-E12	Downgradient	Annual
699-S28-E13A	Center	Annual
699-S29-E10A	Downgradient	Annual
699-S29-E13A	Southeast	Annual
699-S30-E10A	Downgradient	Annual
699-S30-E11A	Downgradient	Annual
699-S31-E10A	Downgradient	Annual
699-S31-E10C	Downgradient	Annual
699-S31-E10D	Downgradient	Annual
699-S31-E11	Downgradient	Annual

(a) Volatile organic analyses are performed using Method 8260A (SW-846).

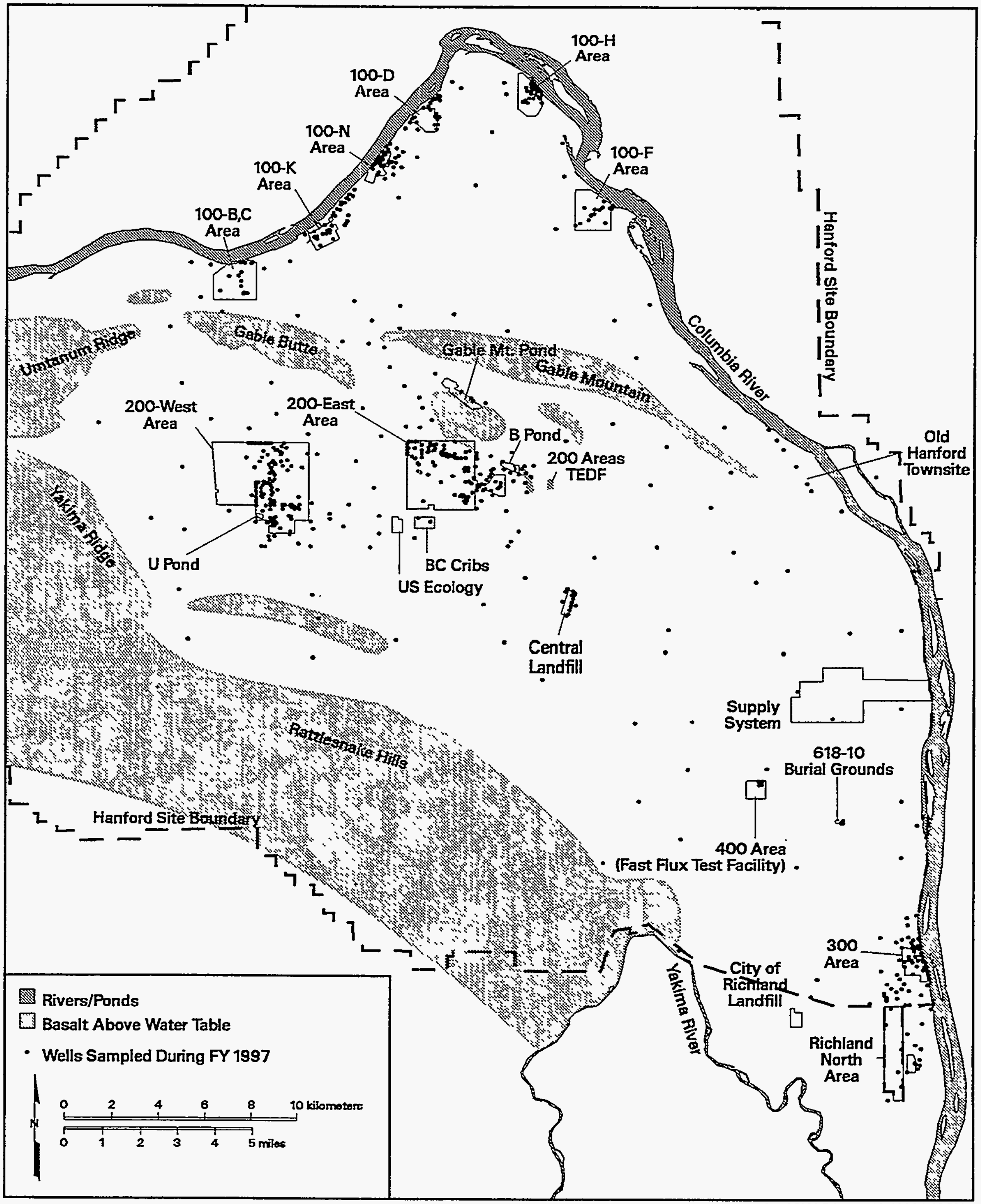

Figure 5.1-1. Wells Sampled During Fiscal Year 1997

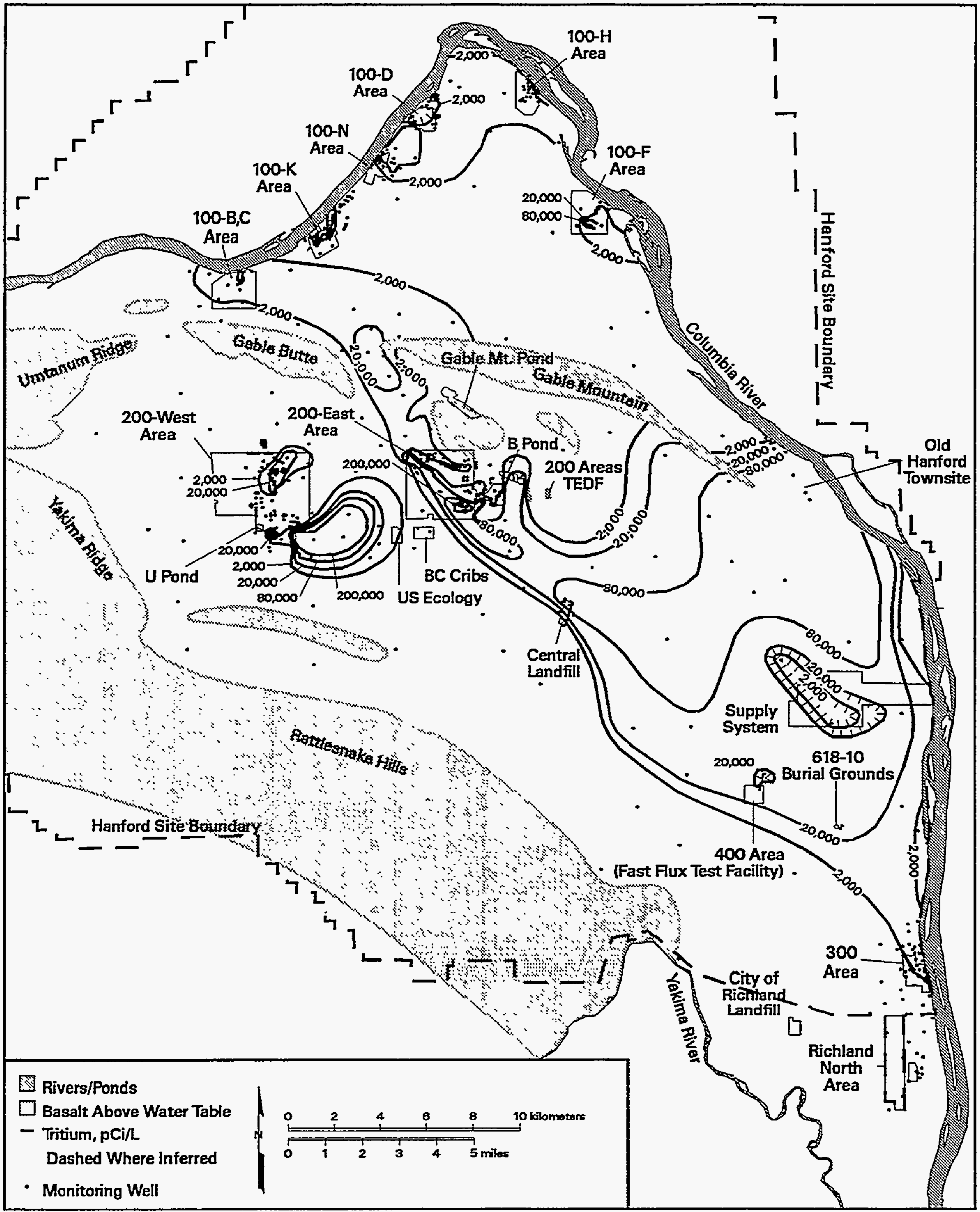

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Figure 5.2-1. Average Fiscal Year 1997 Tritium Concentrations

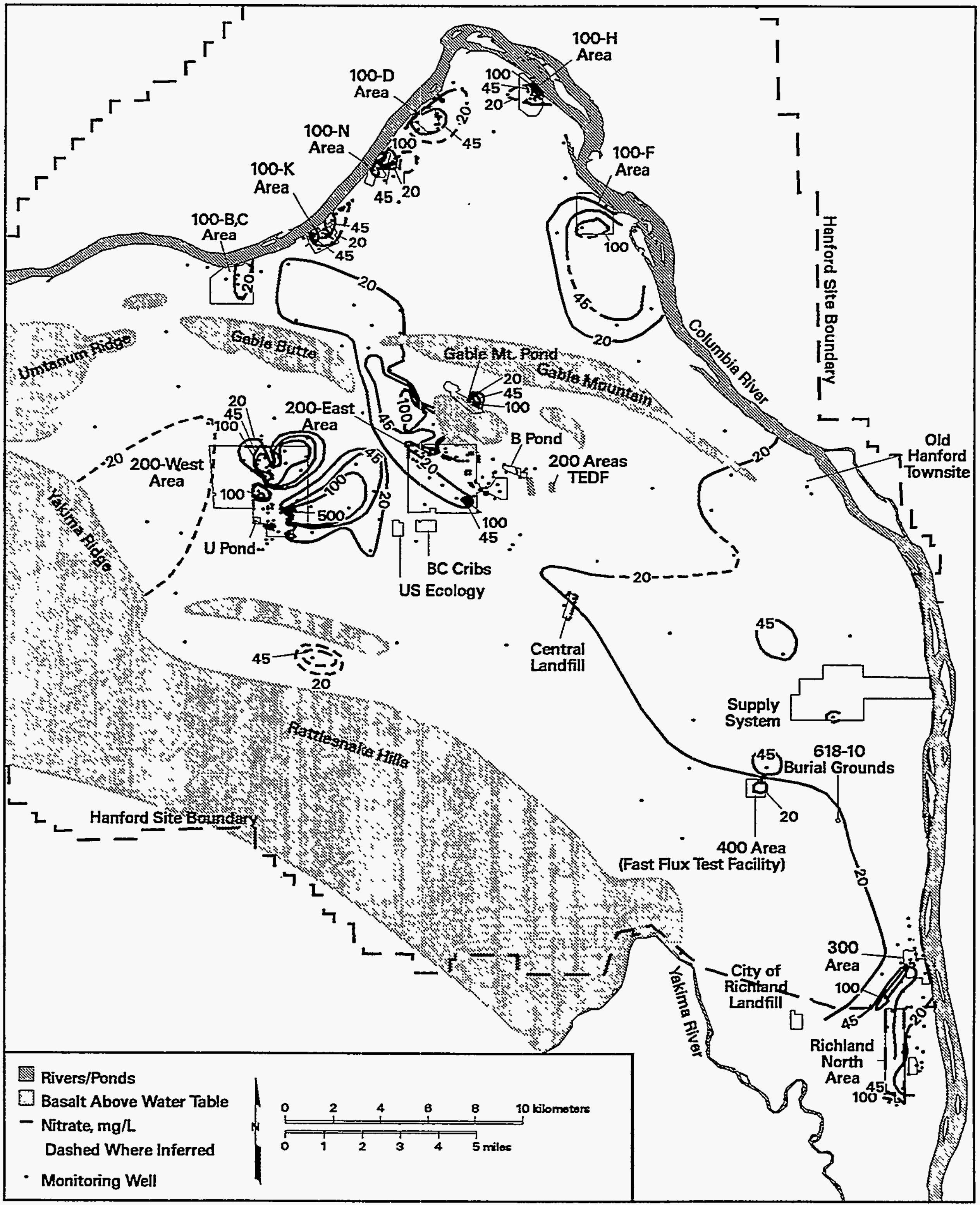

Figure 5.2-2. Average Fiscal Year 1997 Nitrate Concentrations

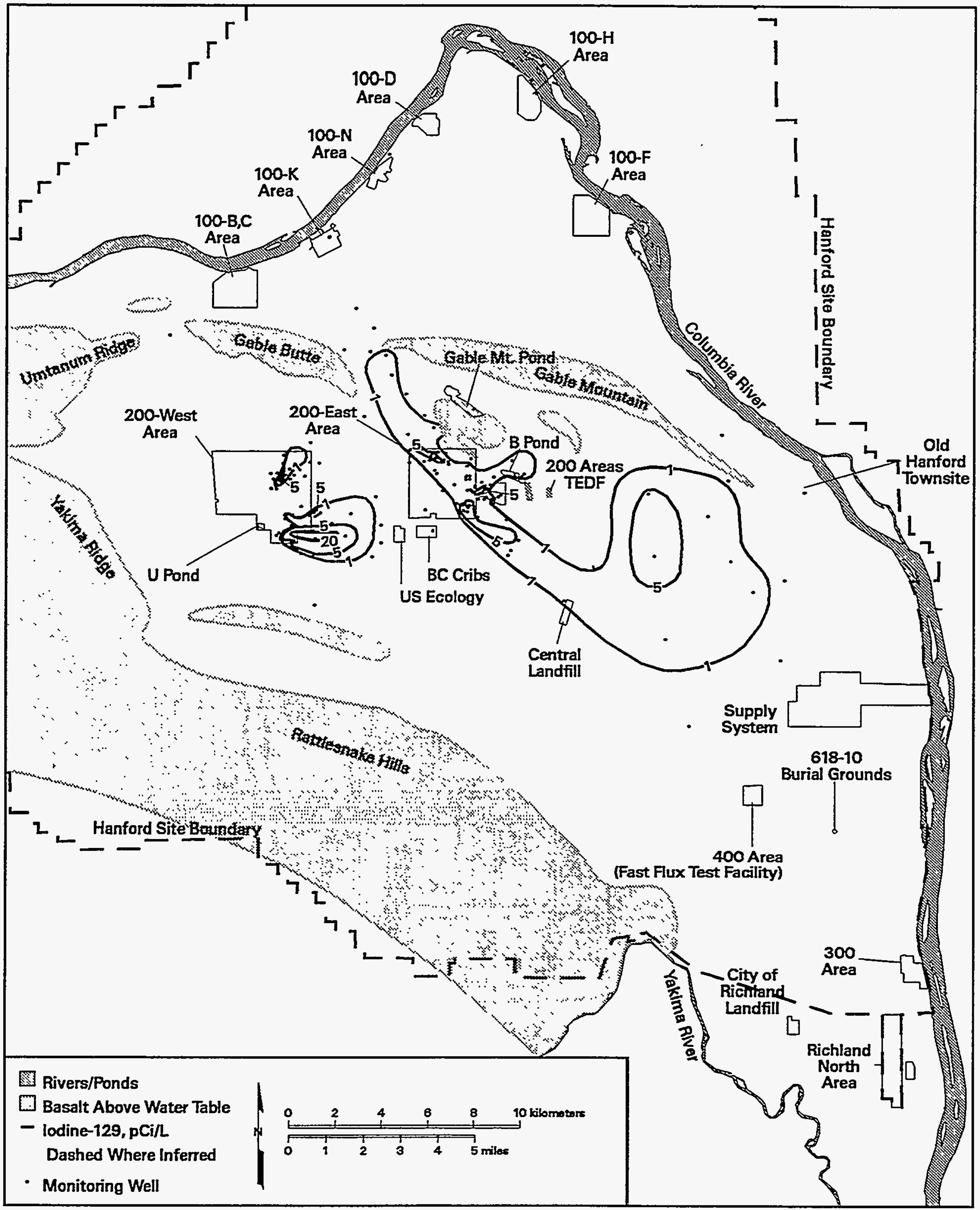

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Figure 5.2-3. Average Fiscal Year 1997 Iodine-129 Concentrations

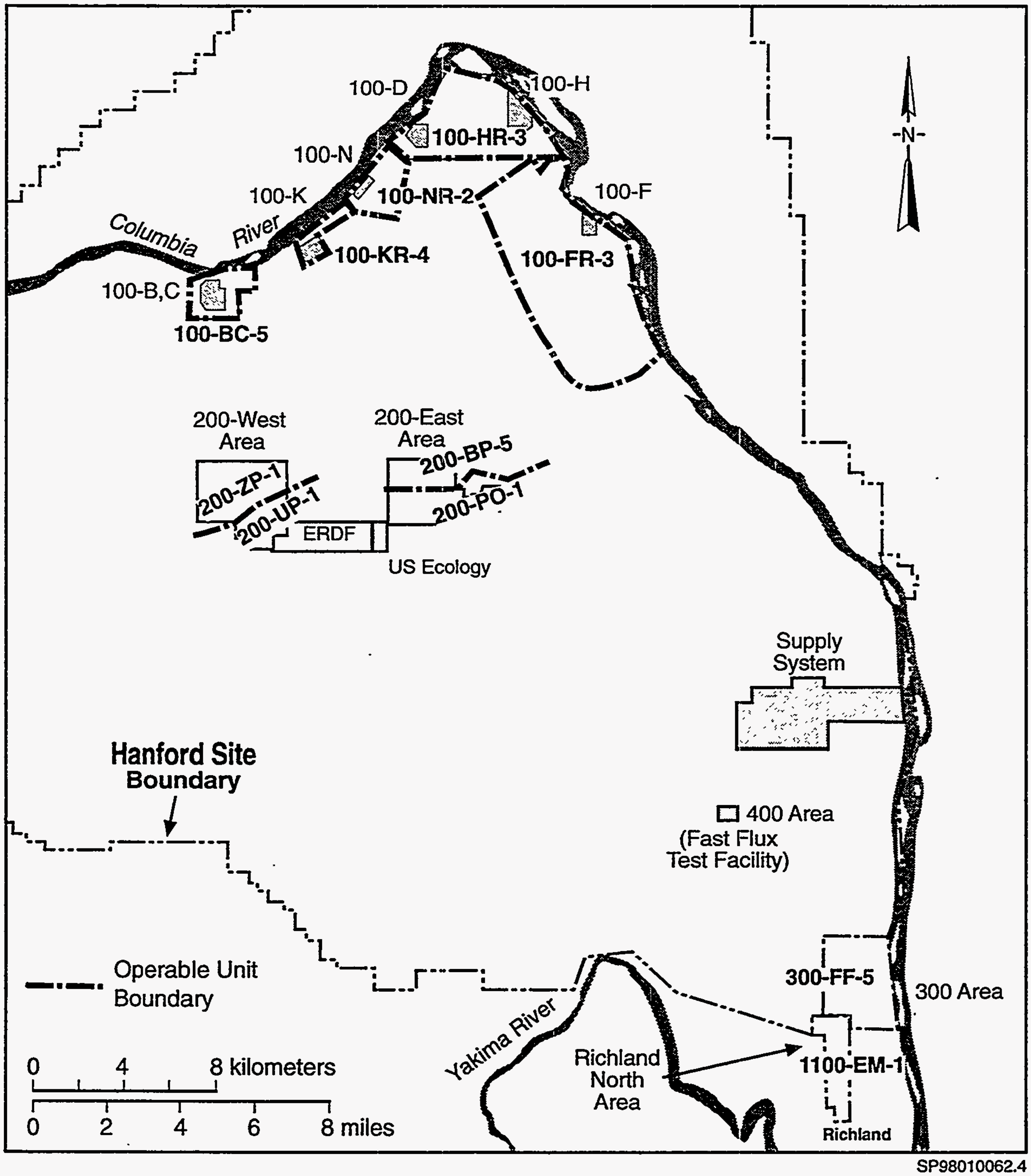

Figure 5.2-4. Groundwater Operable Units

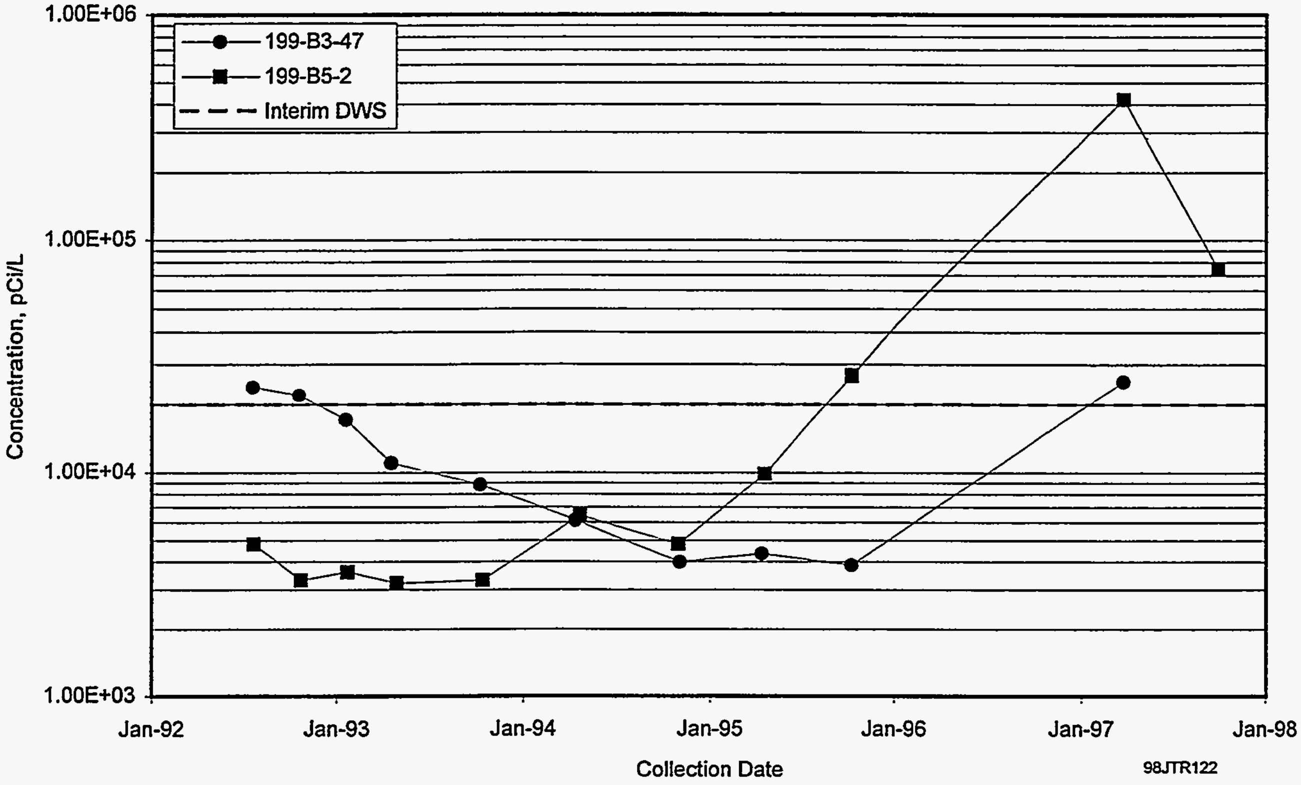

Figure 5.3-1. Tritium Concentrations in Wells 199-B3-47 and 199-B5-2

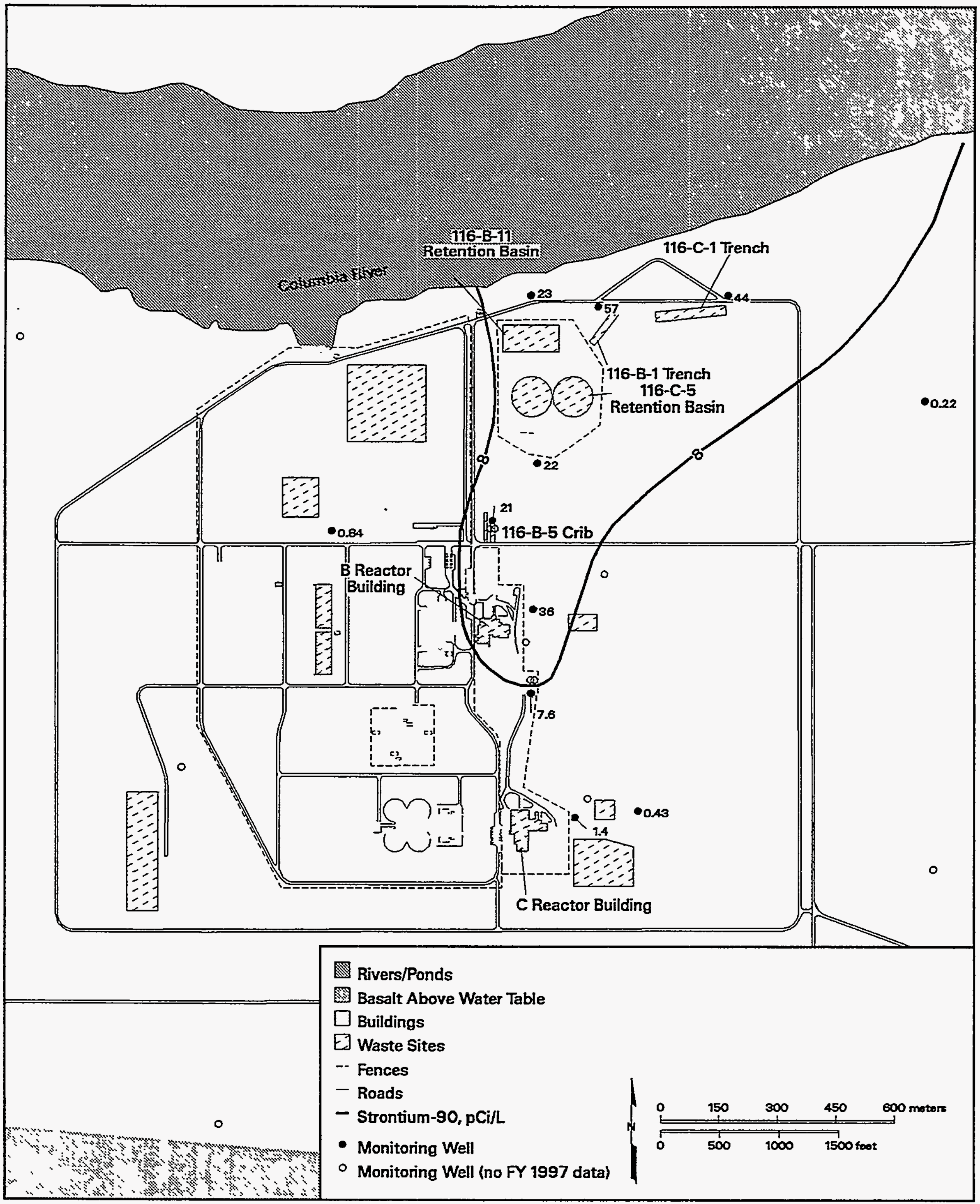

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Figure 5.3-2. Average Fiscal Year 1997 Strontium-90 Concentrations in 100-B,C Area

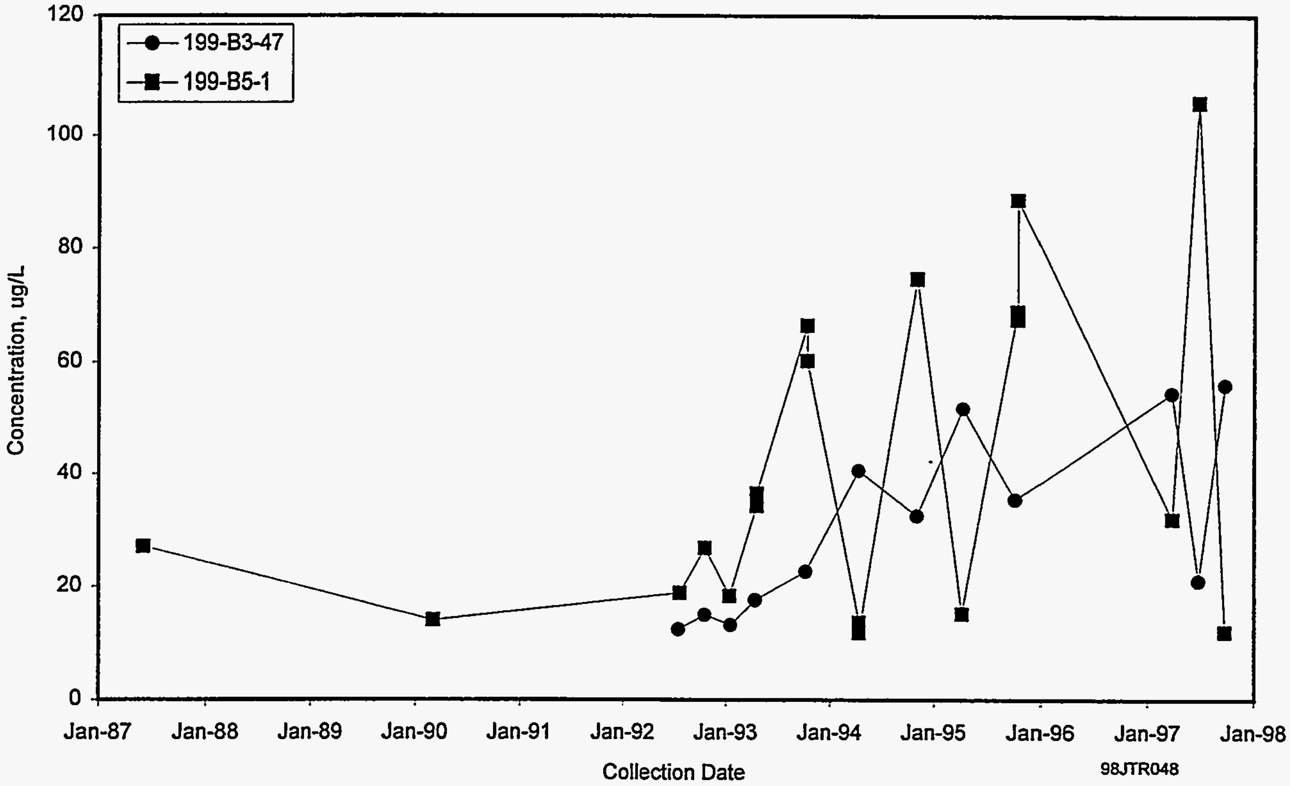
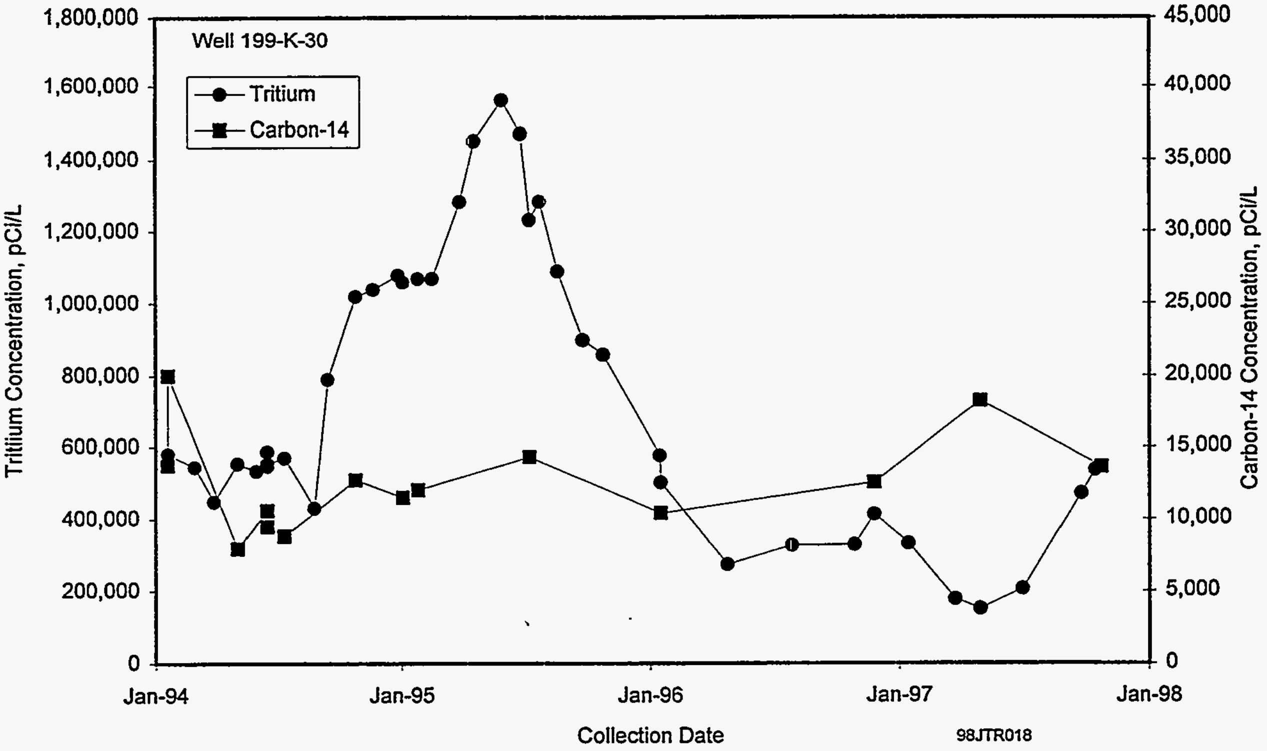


Figure 5.3-3. Filtered Chromium Concentrations in Wells 199-B3-47 and 199-B5-1



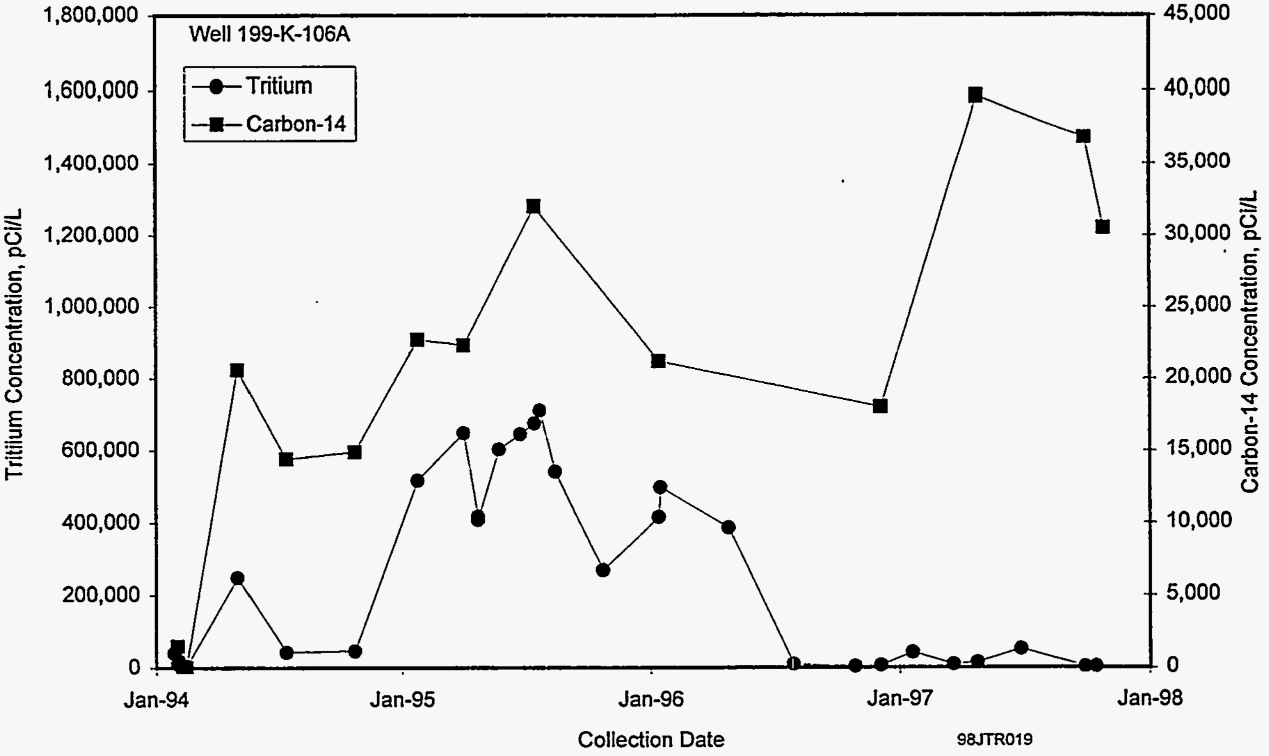


Figure 5.4-1. Tritium and Carbon-14 Concentrations in Wells 199-K-30 and 199-K-106A

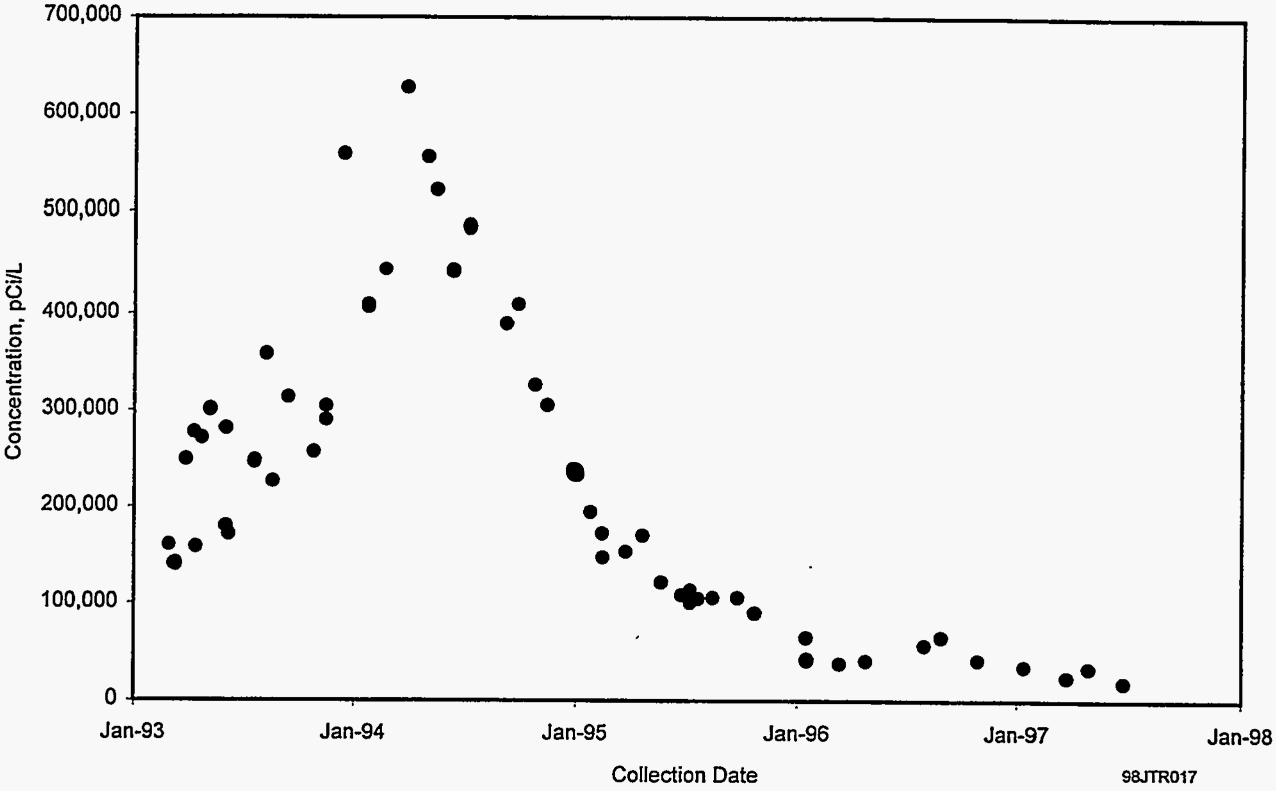


Figure 5.4-2. Tritium Concentrations in Well 199-K-27

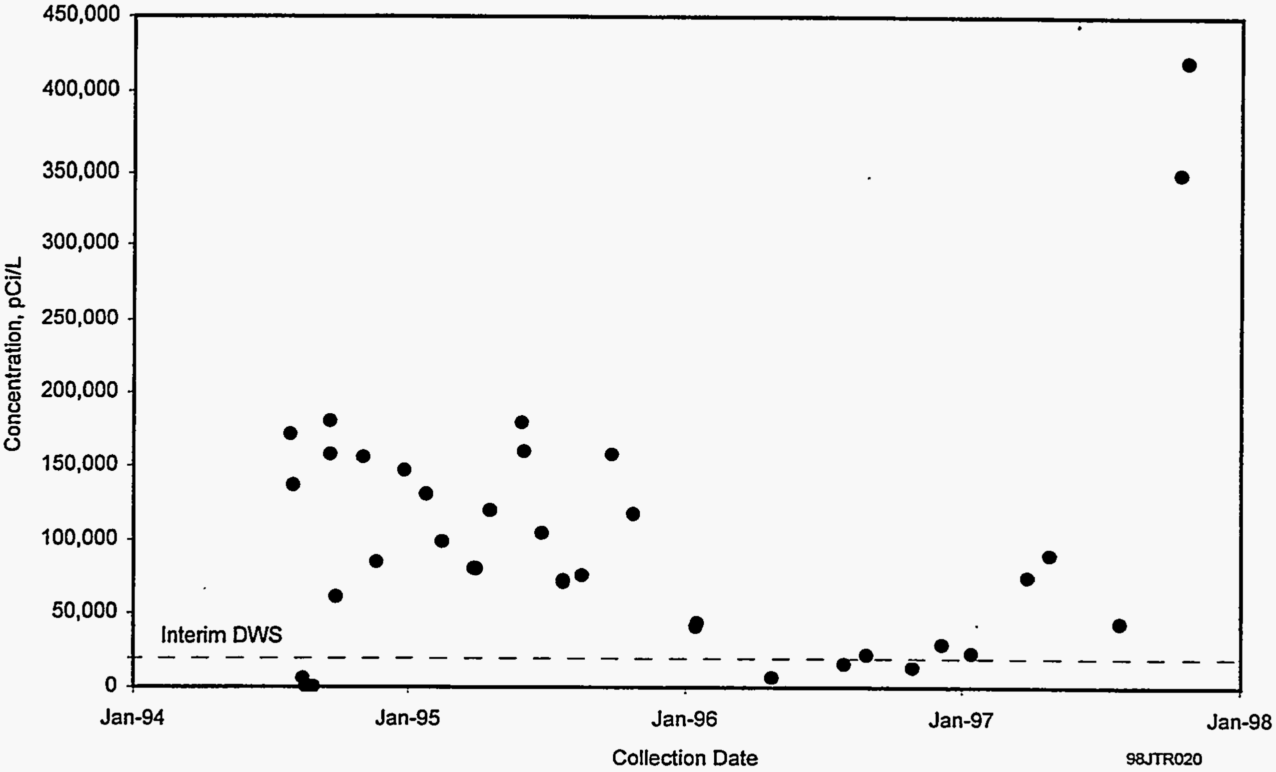


Figure 5.4-3. Tritium Concentrations in Well 199-K-109A

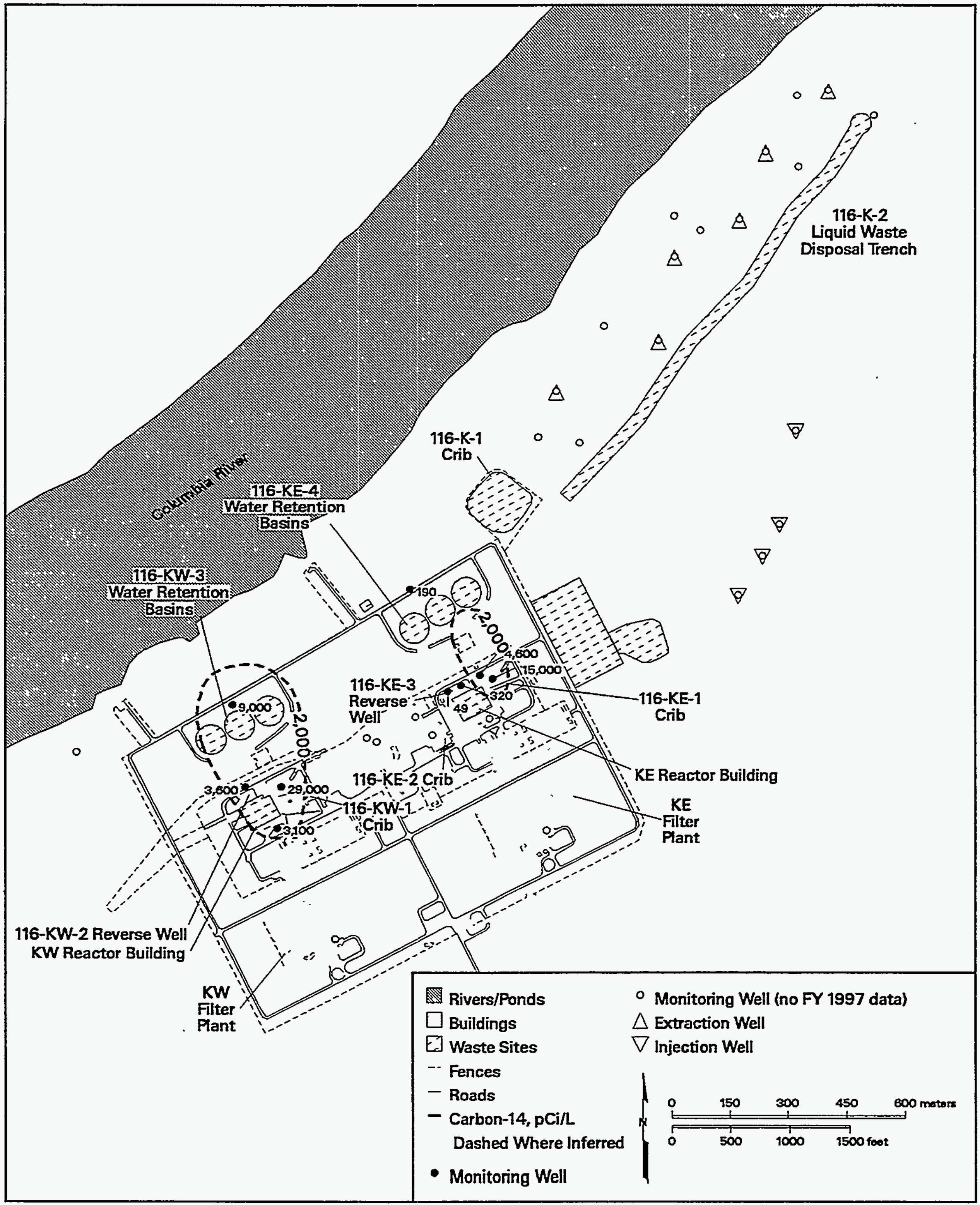


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Figure 5.4-4. Average Fiscal Year 1997 Carbon-14 Concentrations in 100-K Area

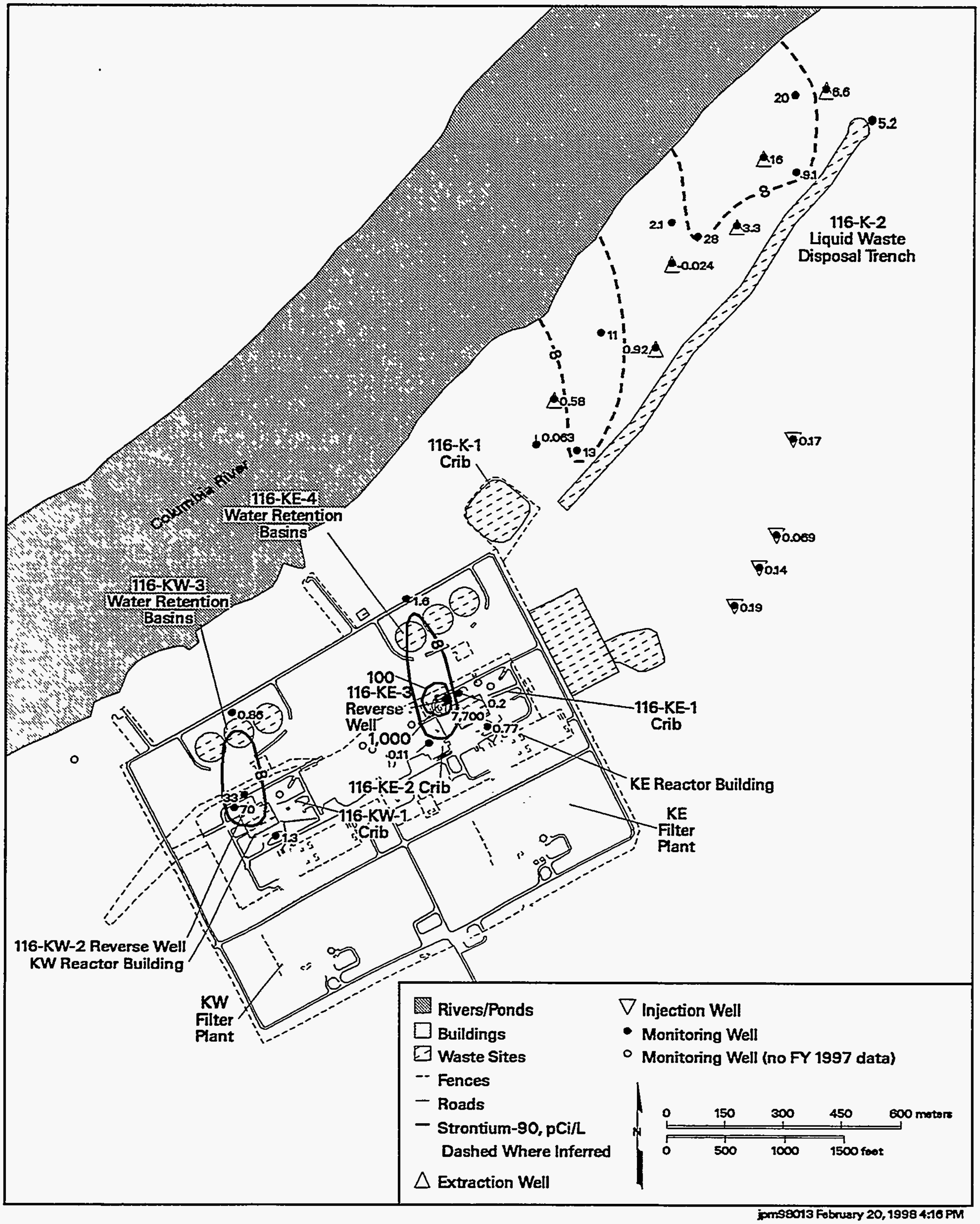

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Figure 5.4-5. Average Fiscal Year 1997 Strontium-90 Concentrations in 100-K Area

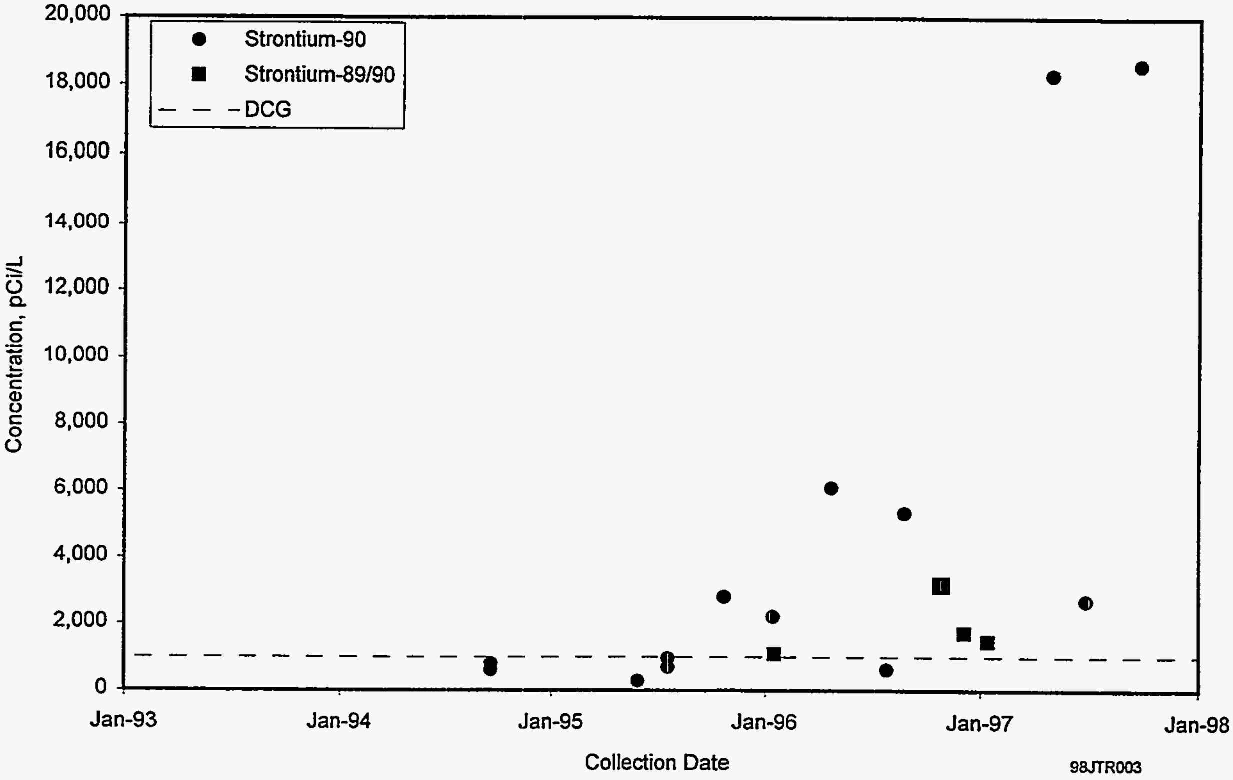

Figure 5.4-6. Strontium-90 Concentrations in Well 199-K-109A

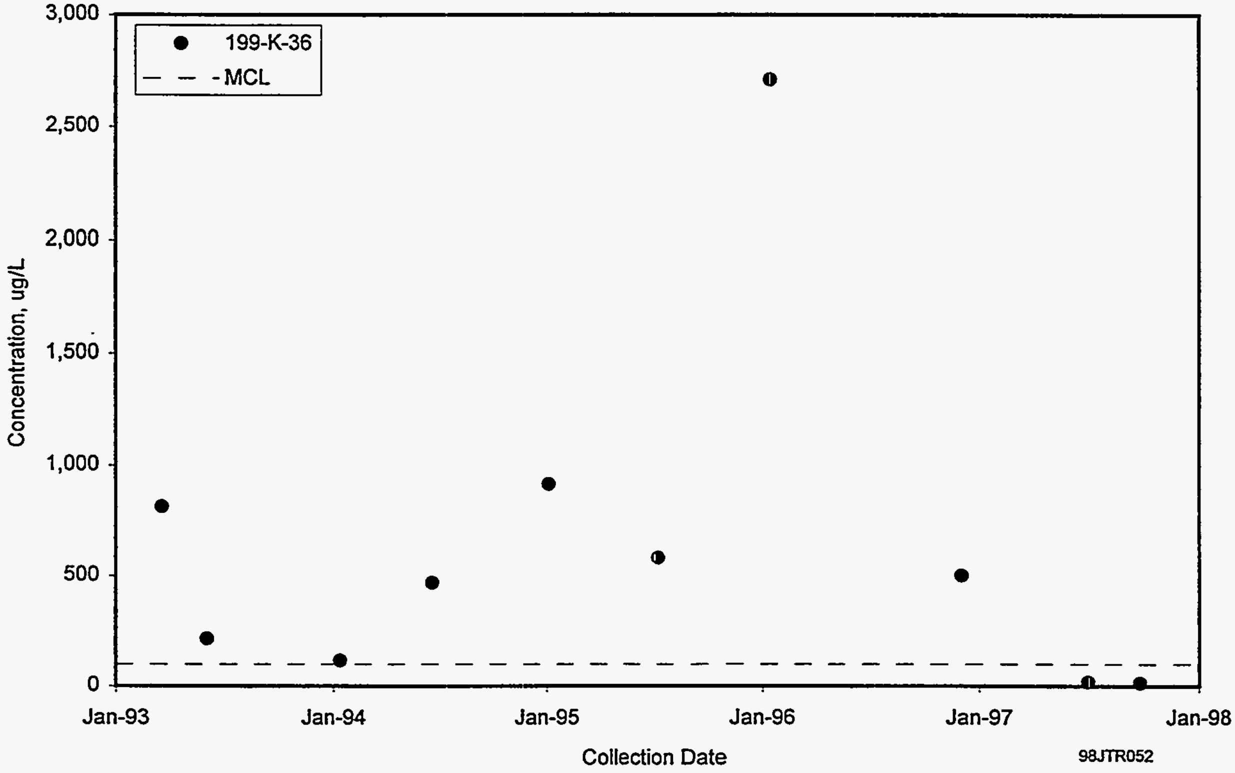

Figure 5.4-7. Filtered Chromium Concentrations and Water Levels in Well 199-K-36

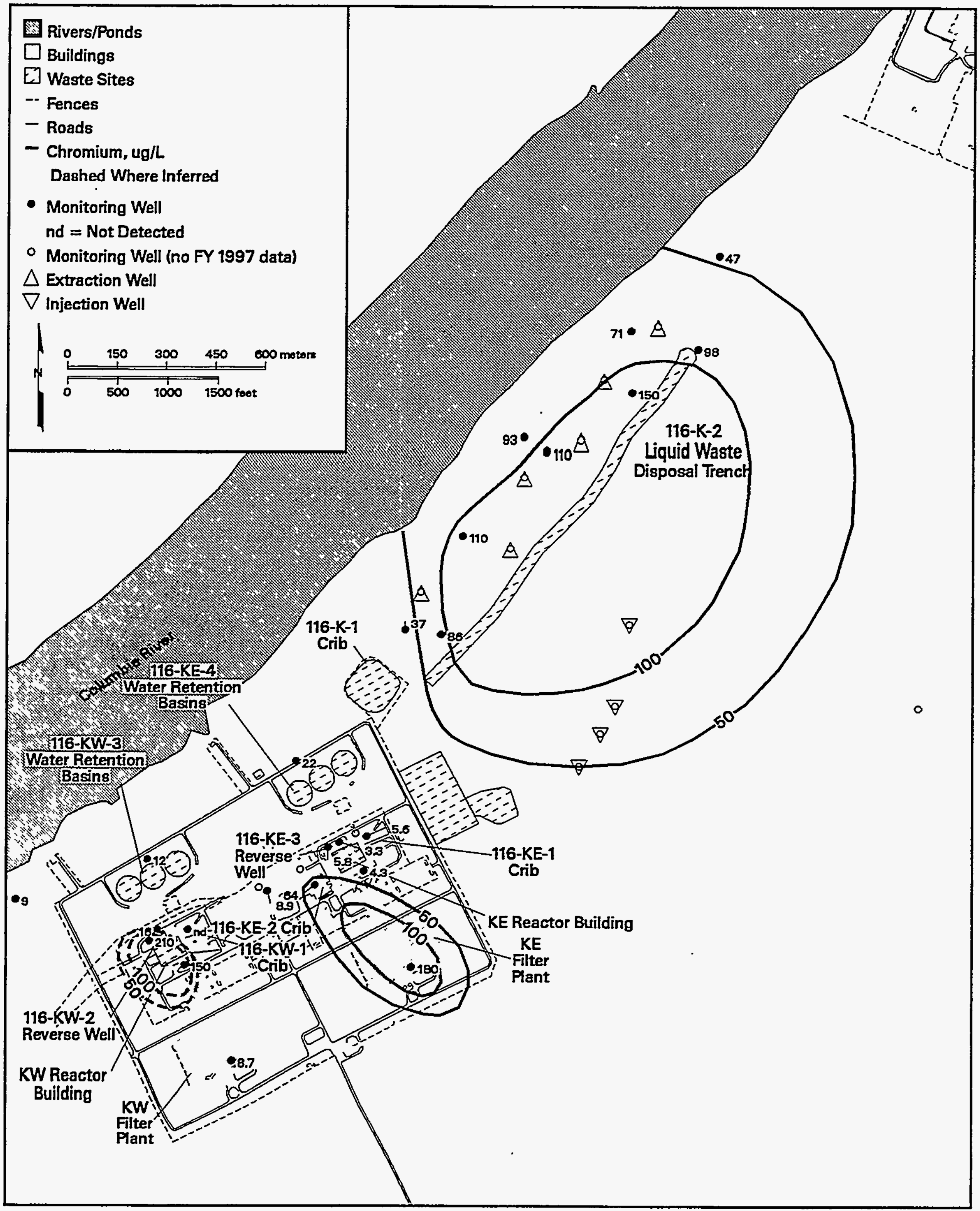

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Figure 5.4-8. Average Fiscal Year 1997 Filtered Chromium Concentrations in 100-K Area

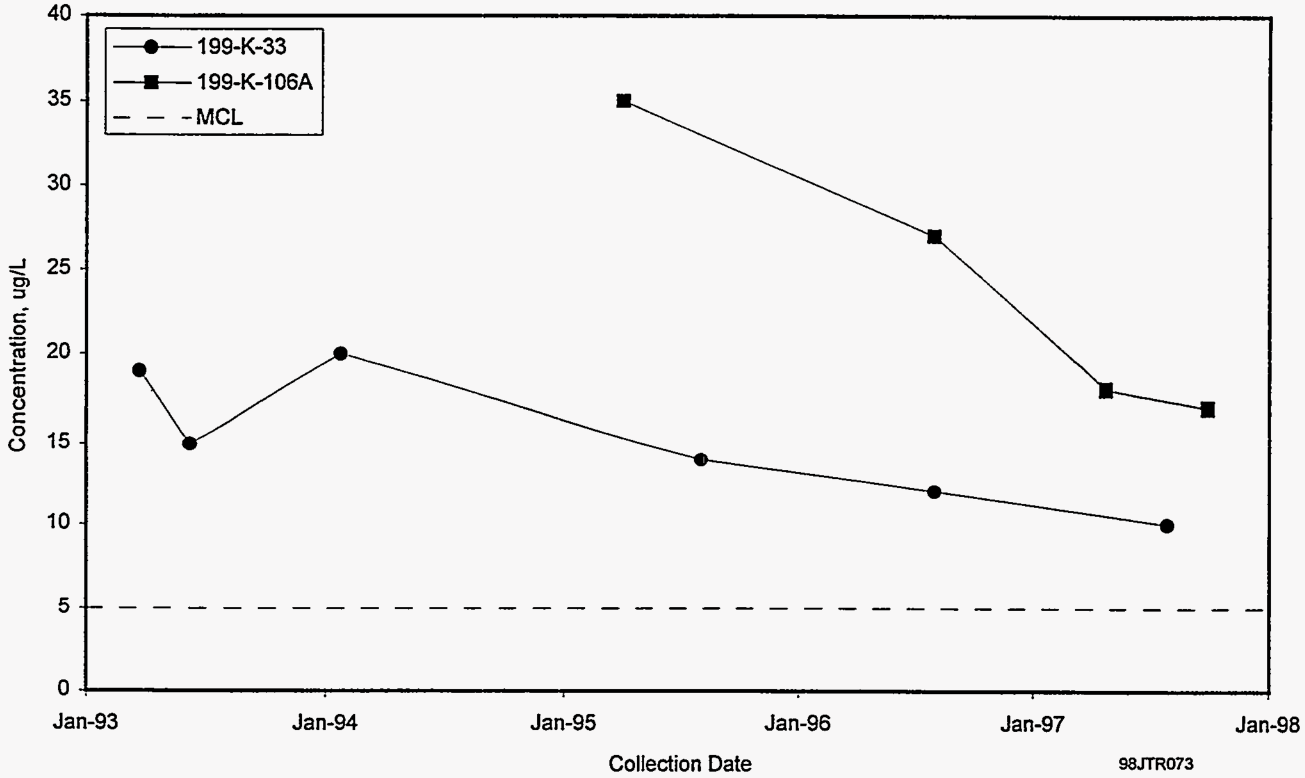
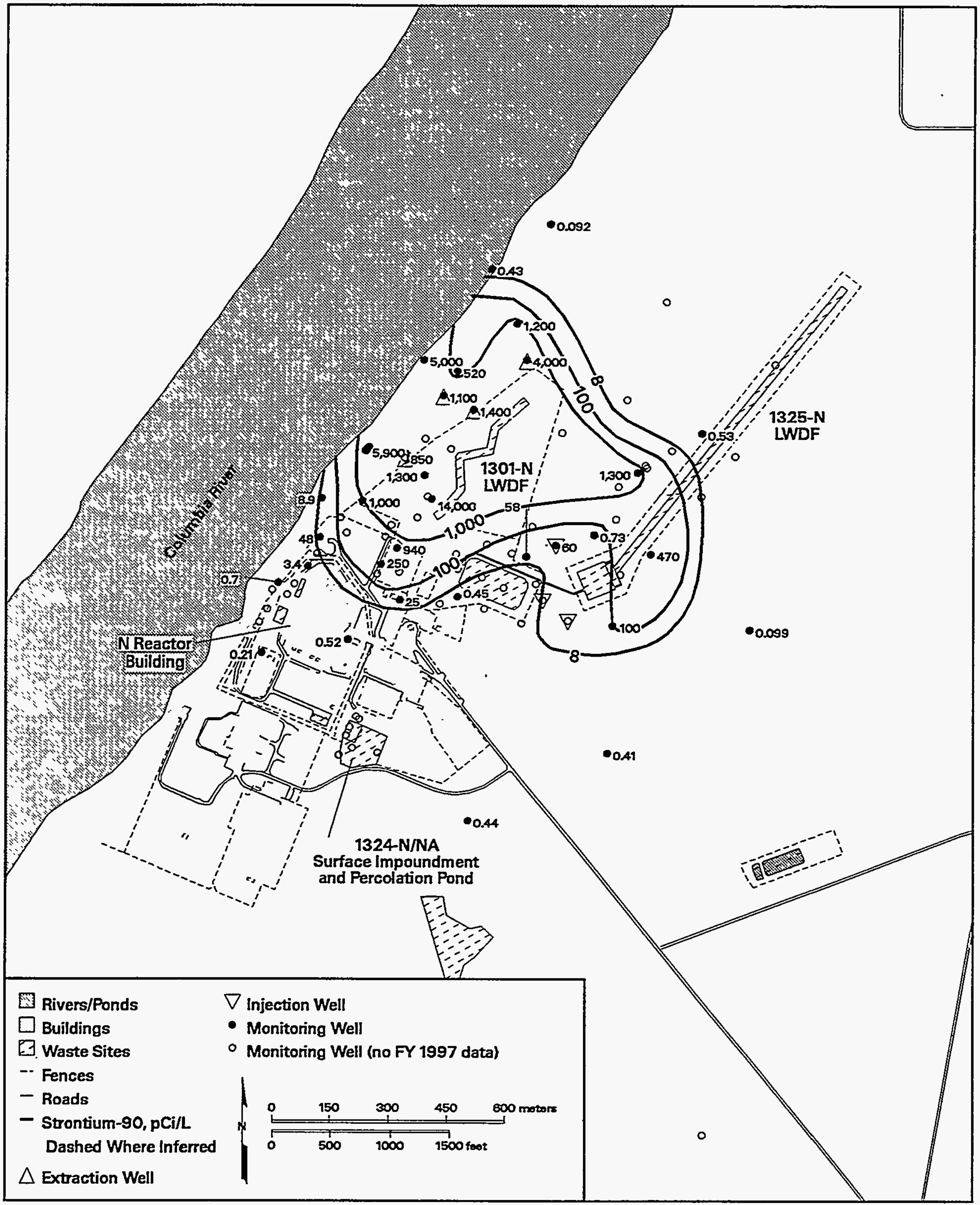


Figure 5.4-9. Trichloroethylene Concentrations in Wells 199-K-33 and 199-K-106A



jpm98015 February 22, 1998 4:13 PM

Figure 5.5-1. Average Fiscal Year 1997 Strontium-90 Concentrations in 100-N Area

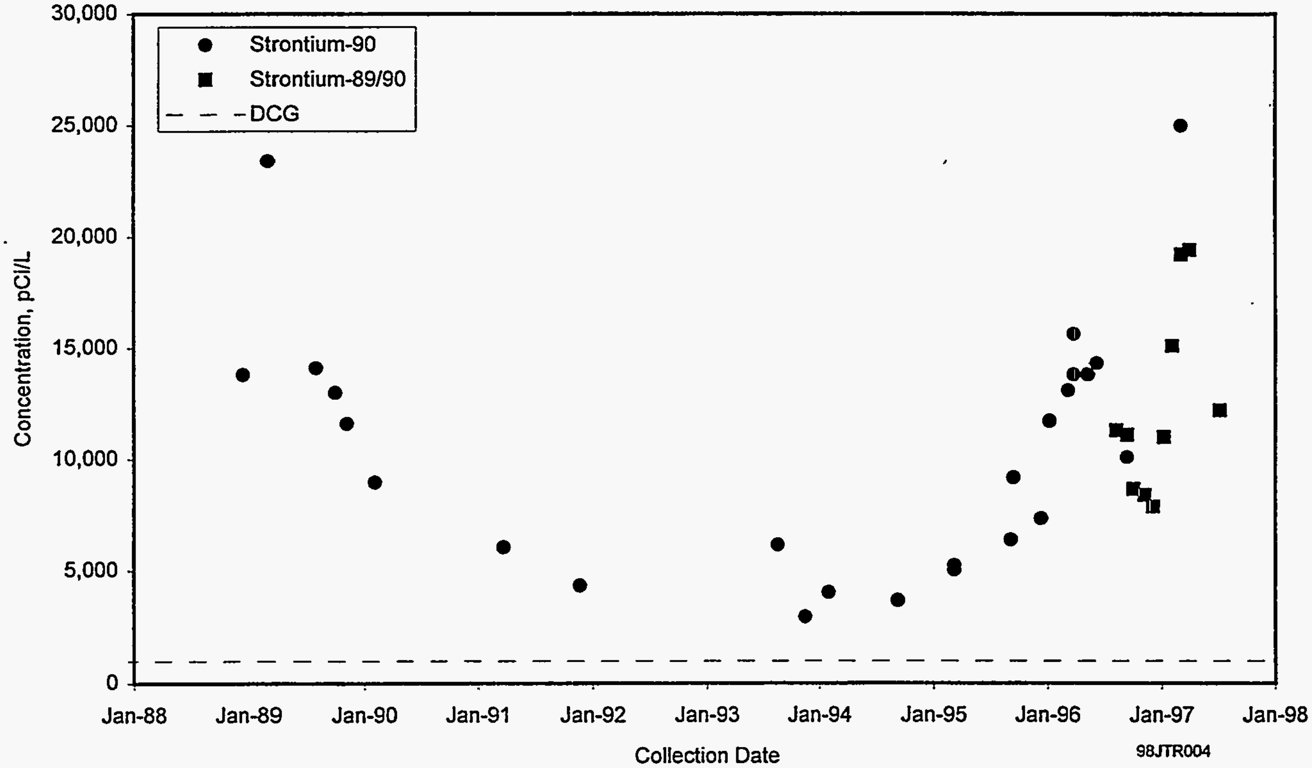


Figure 5.5-2. Strontium-90 Concentrations in Well 199-N-67

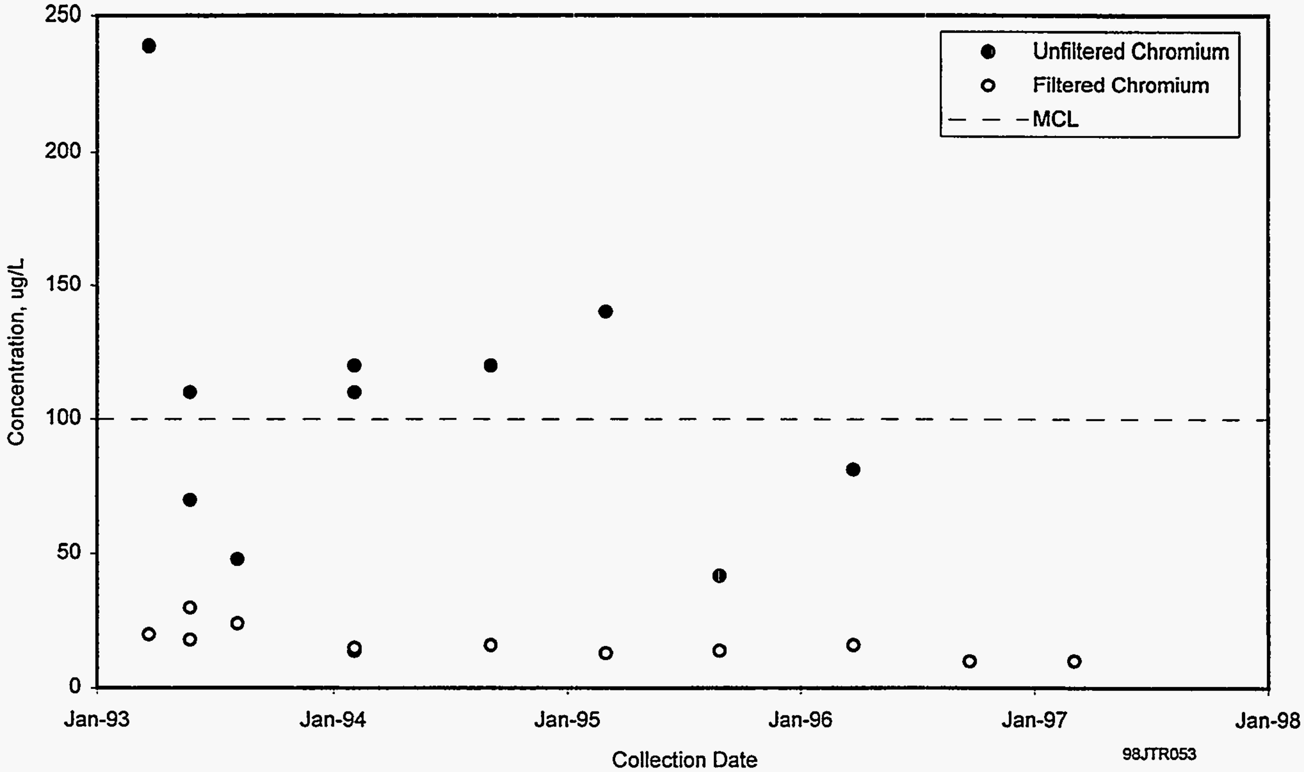


Figure 5.5-3. Chromium Concentrations in Well 199-N-74

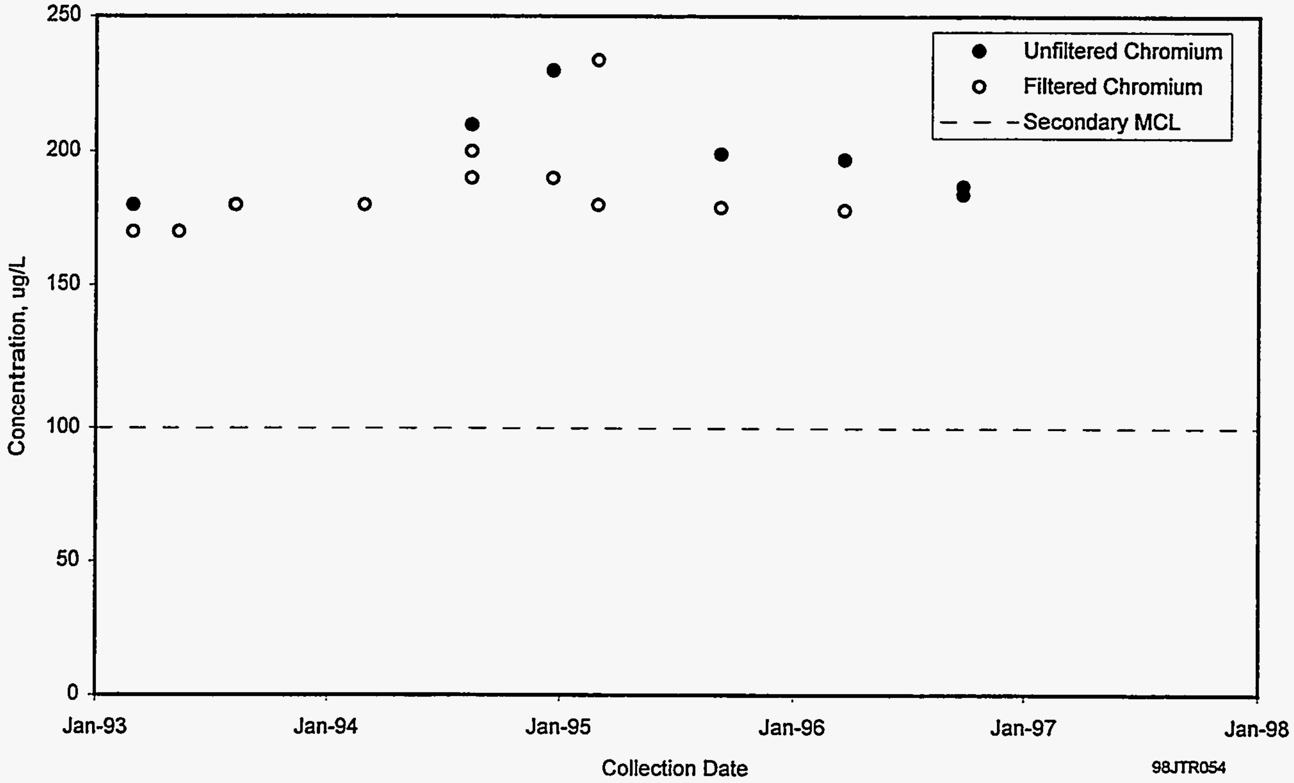


Figure 5.5-4. Chromium Concentrations in Well 199-N-80

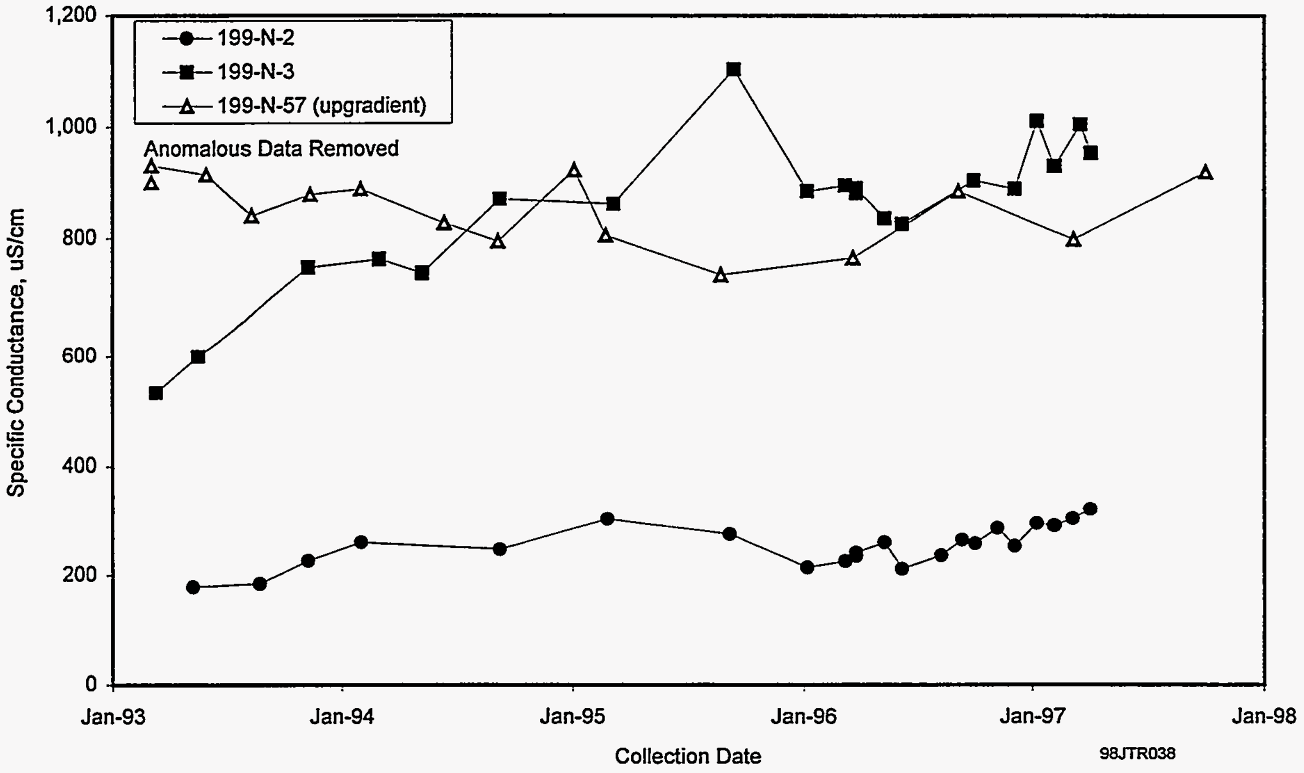


Figure 5.5-5. Specific Conductance in Wells Monitoring 1301-N Liquid Waste-Disposal Facility

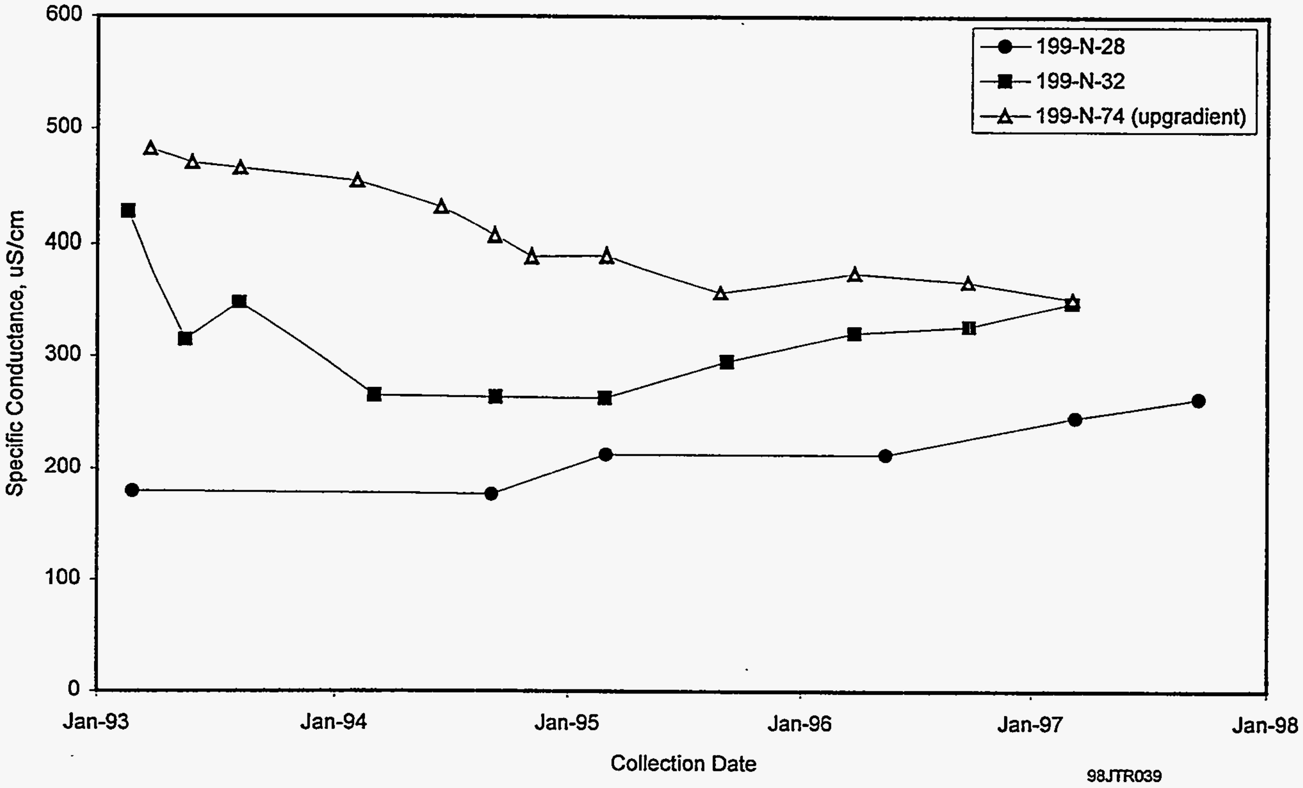


Figure 5.5-6. Specific Conductance in Wells Monitoring 1325-N Liquid Waste-Disposal Facility

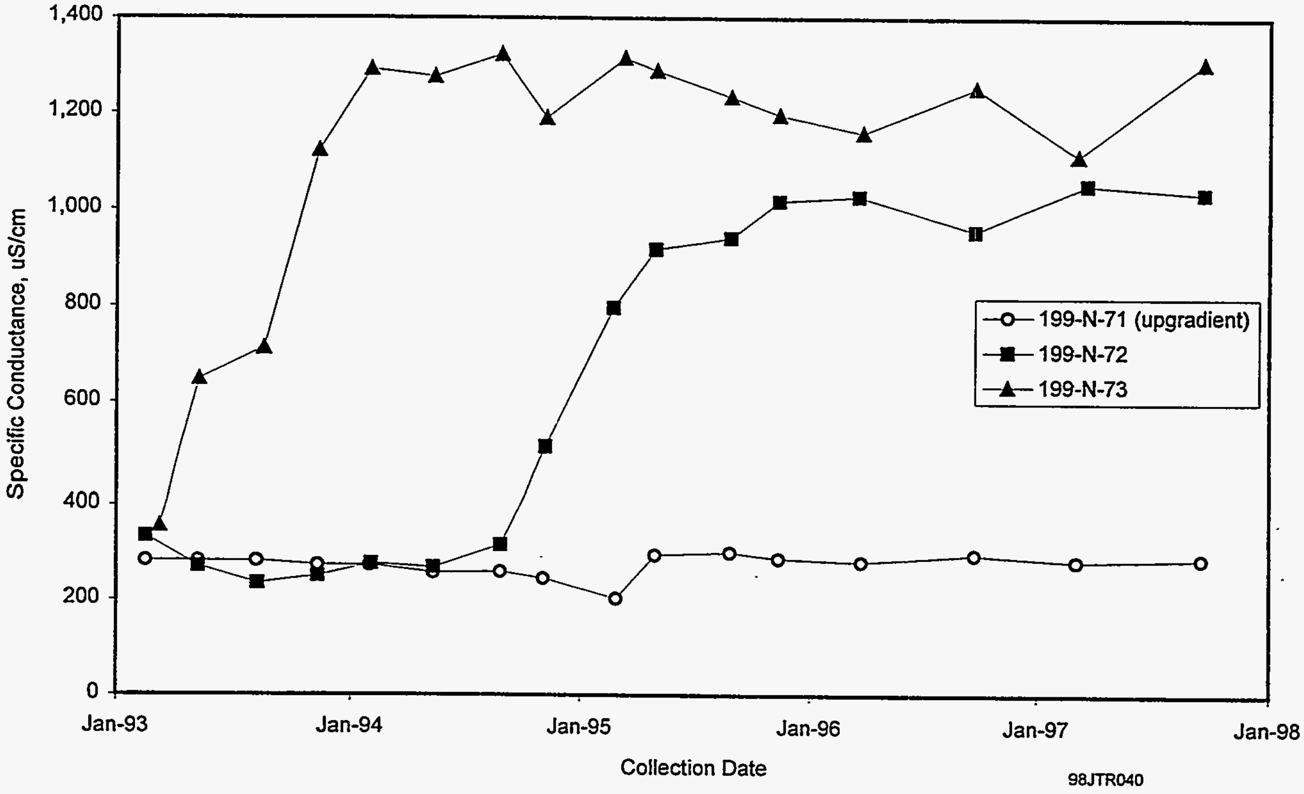


Figure 5.5-7. Specific Conductance in Wells Monitoring 1324-N/NA Facilities

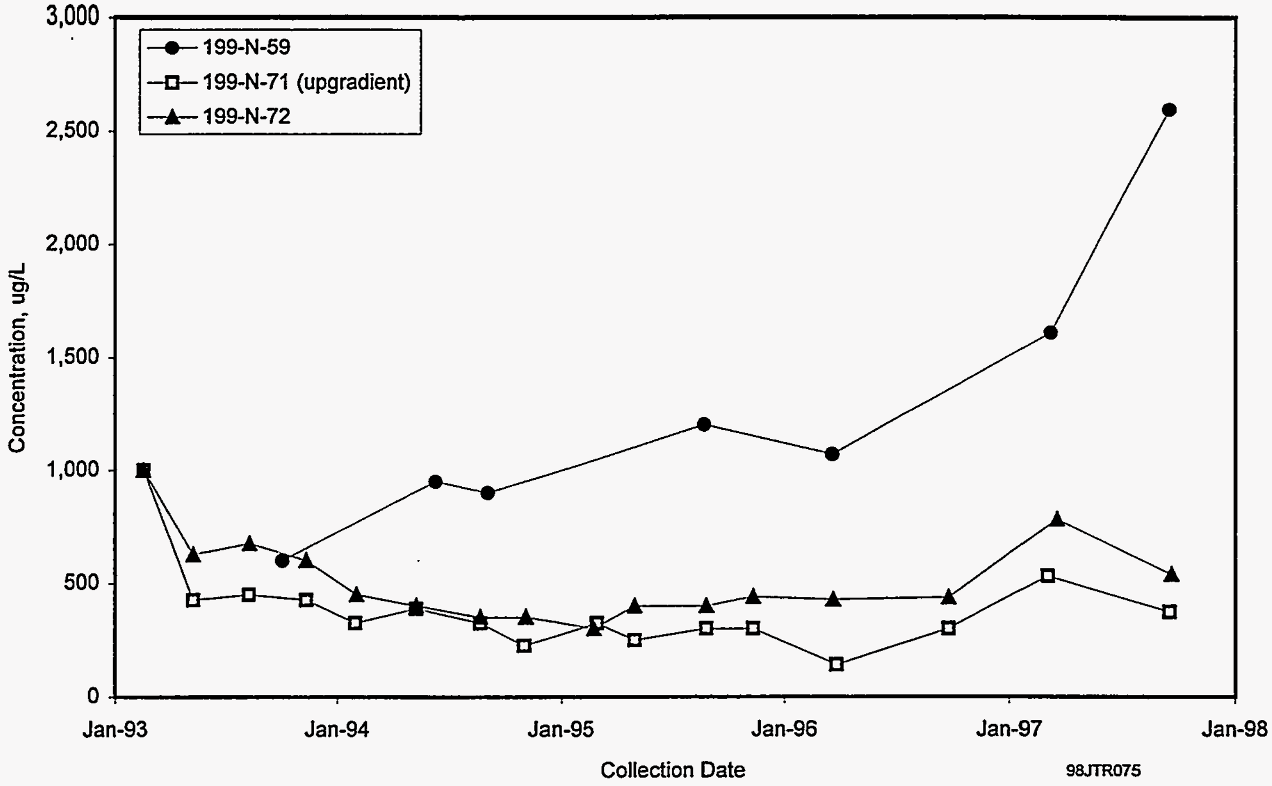


Figure 5.5-8. Total Organic Carbon Concentrations in Wells Monitoring 1324-N/NA Facilities

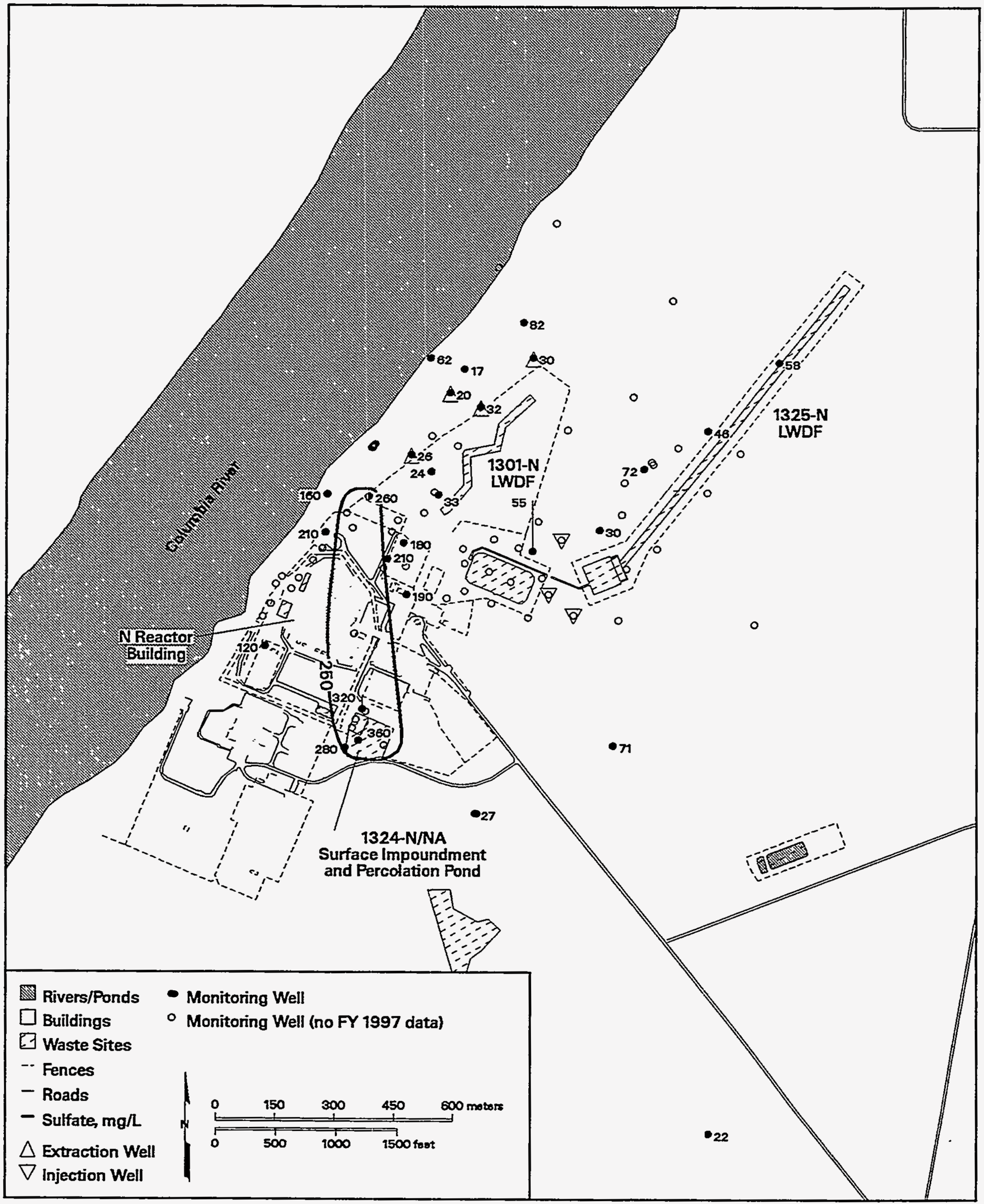


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Figure 5.5-9. Average Fiscal Year 1997 Sulfate Concentrations in 100-N Area

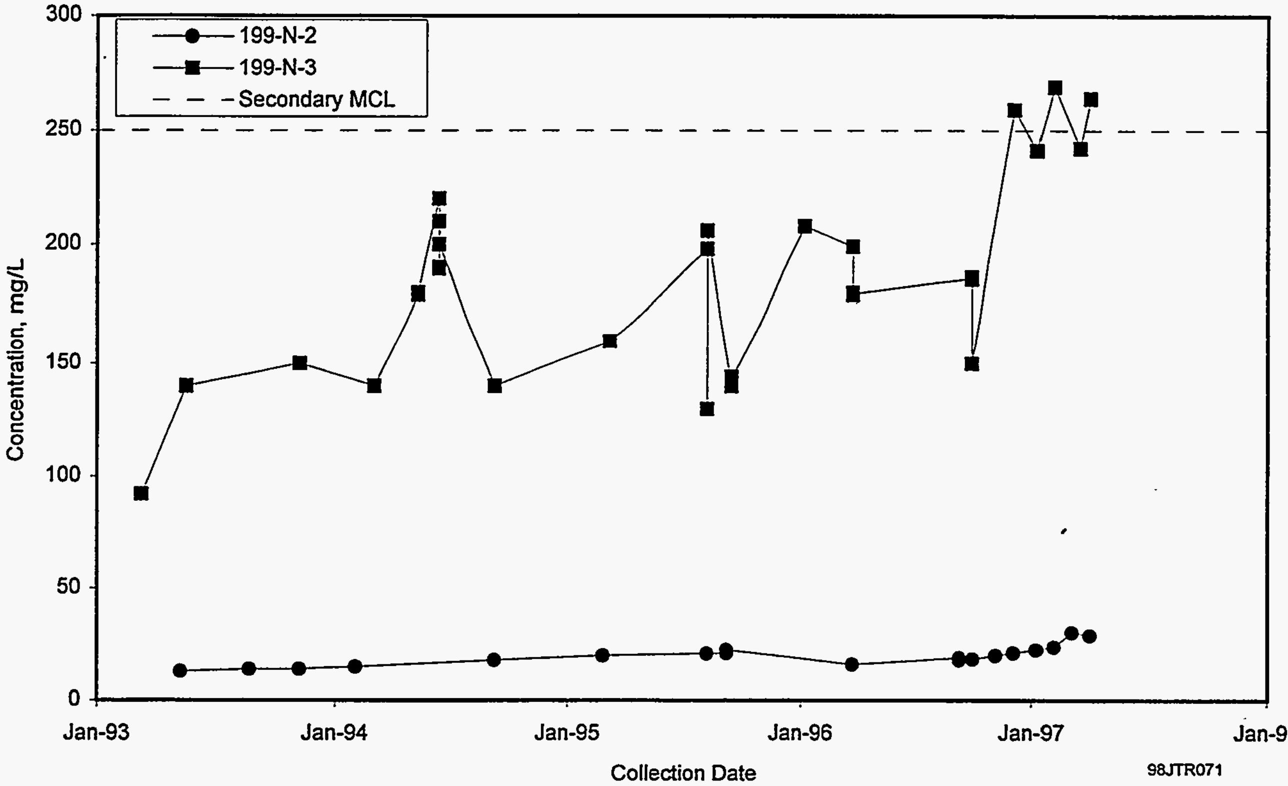


Figure 5.5-10. Sulfate Concentrations in Wells 199-N-2 and 199-N-3

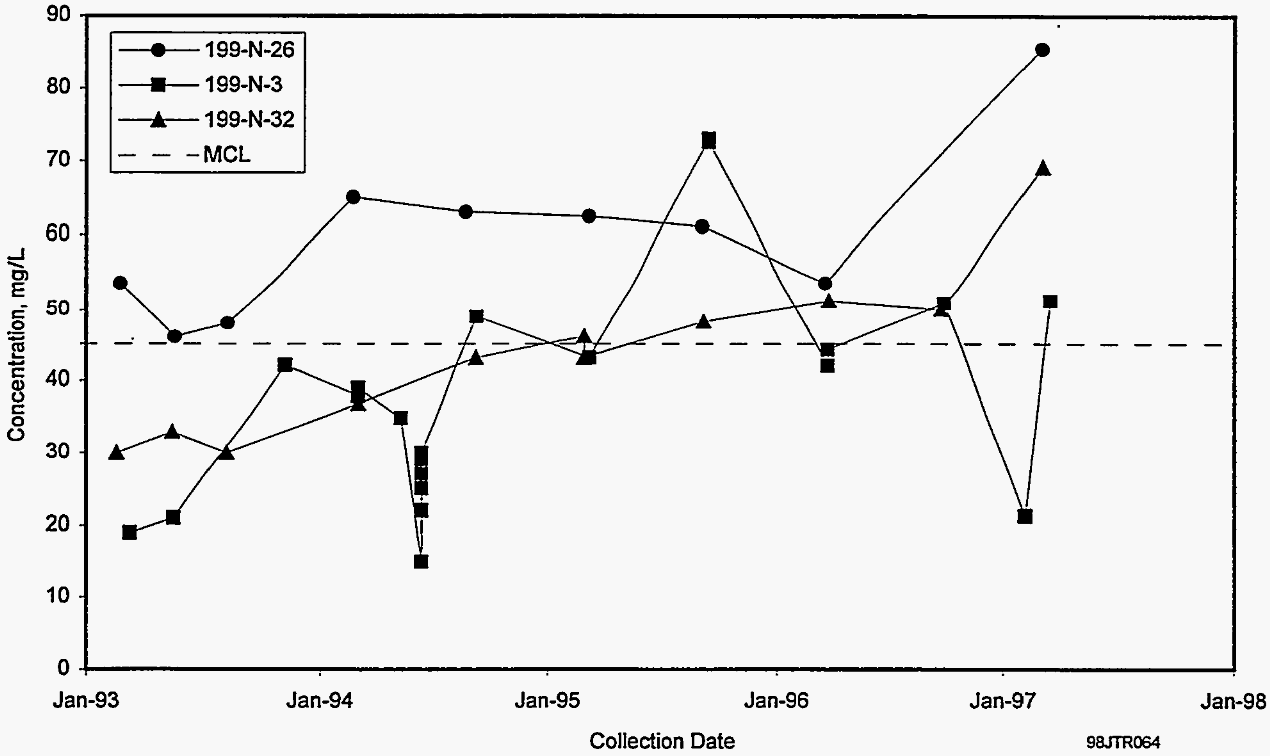


Figure 5.5-11. Nitrate Concentrations in Wells Monitoring 100-N Area

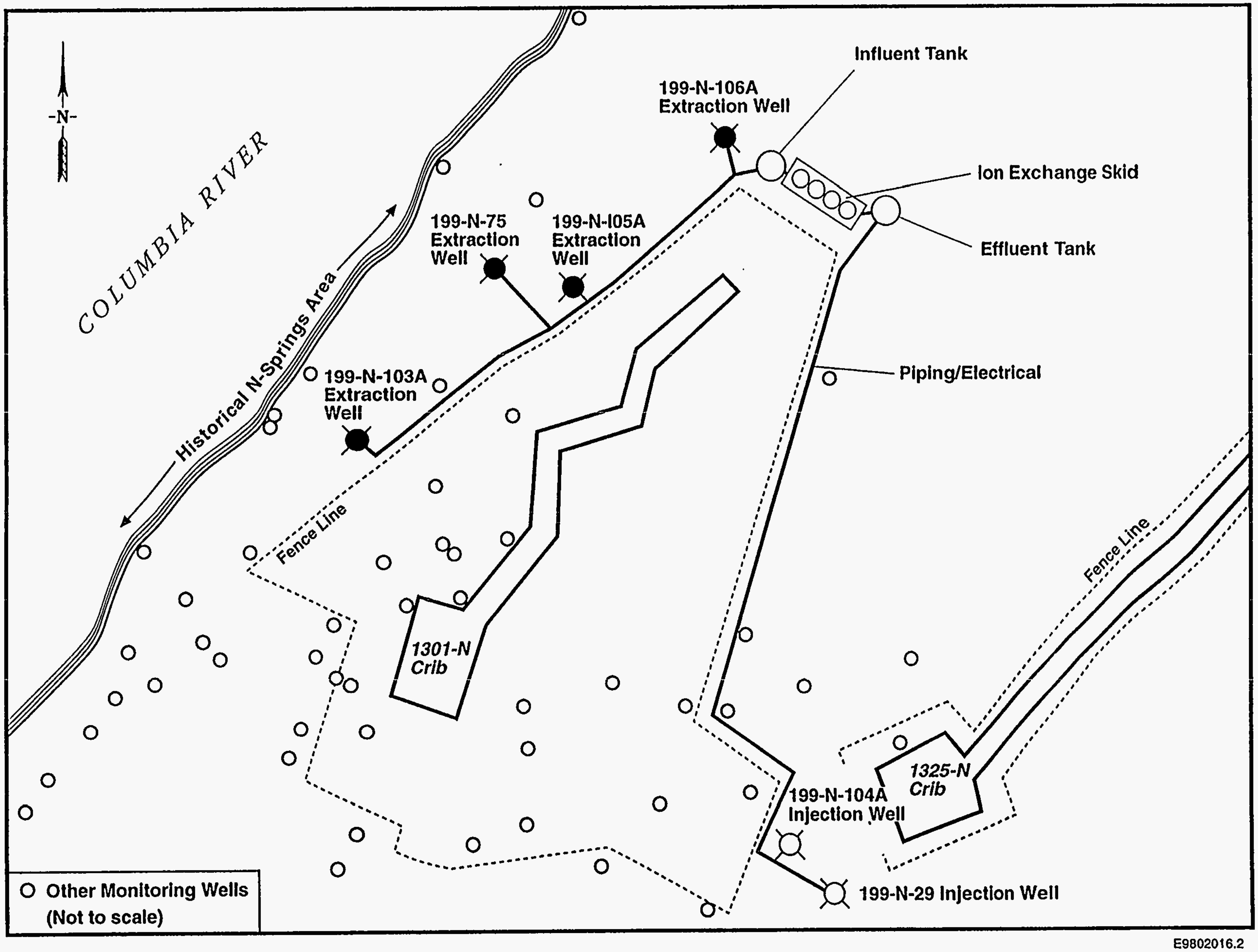


Figure 5.5-12. N Springs Expedited Response Action Pump-and-Treat System

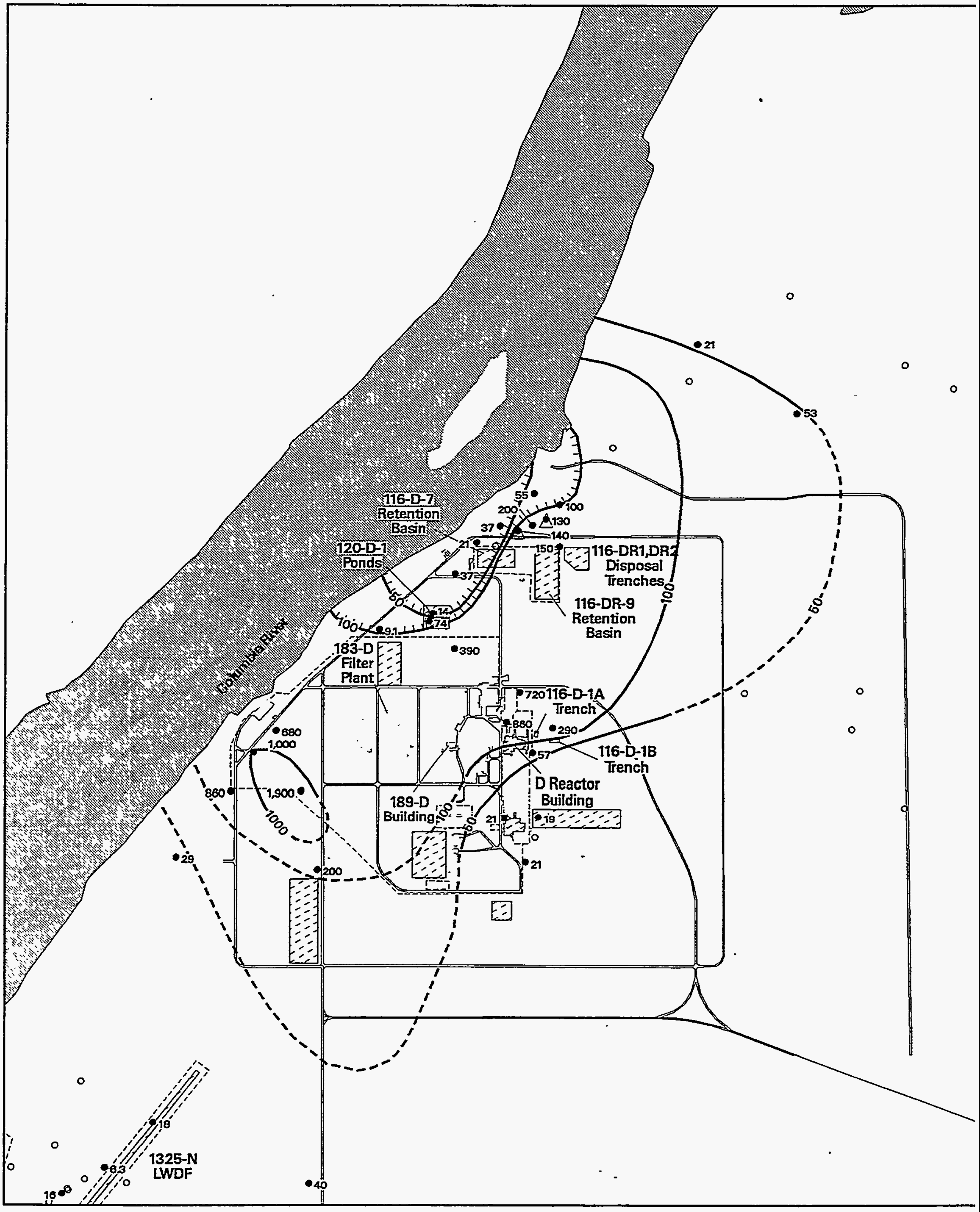
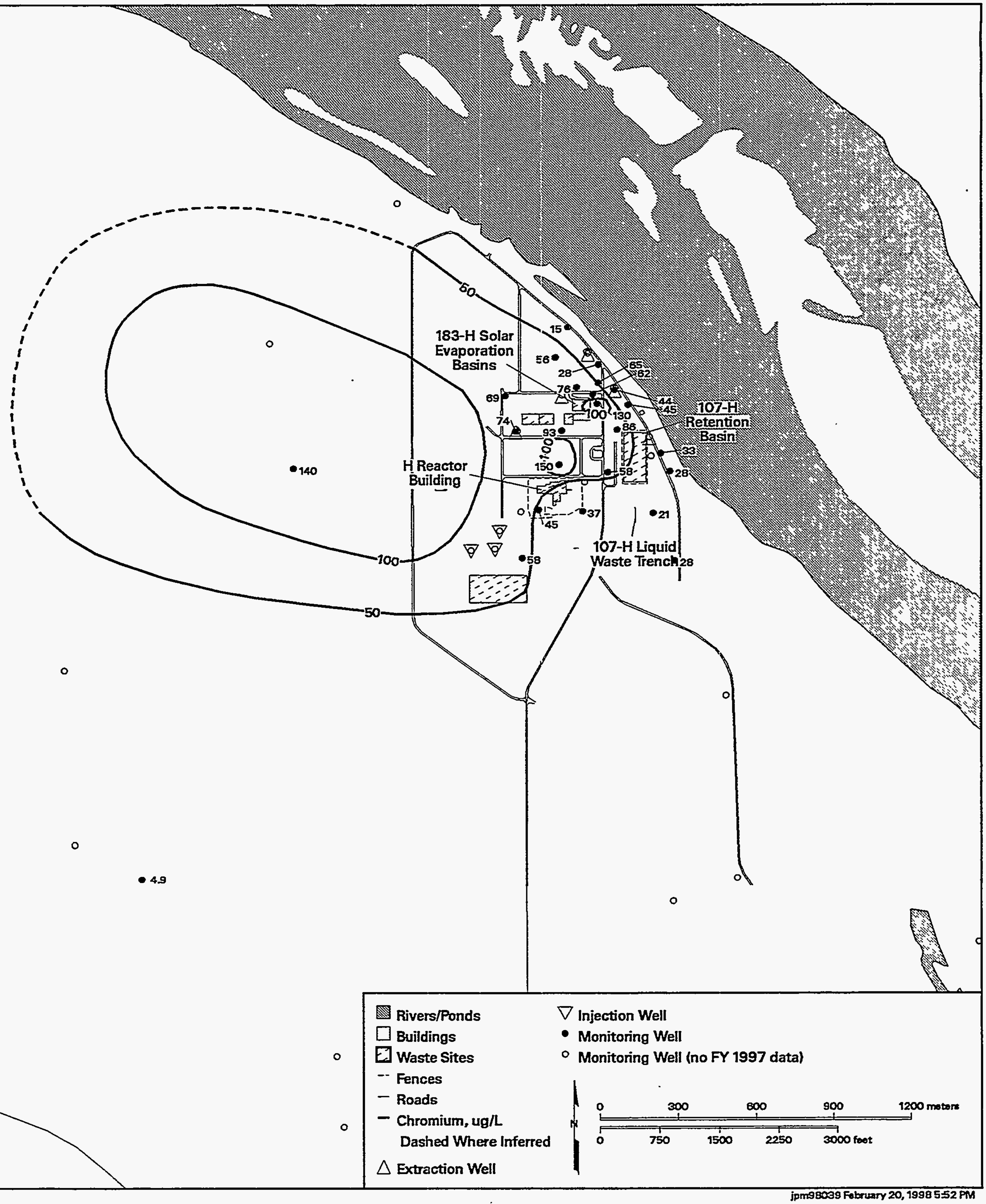


Figure 5.6-1. Average Fiscal Year 1997 Filtered Chro



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um Concentrations in 100-D and 100-H Areas

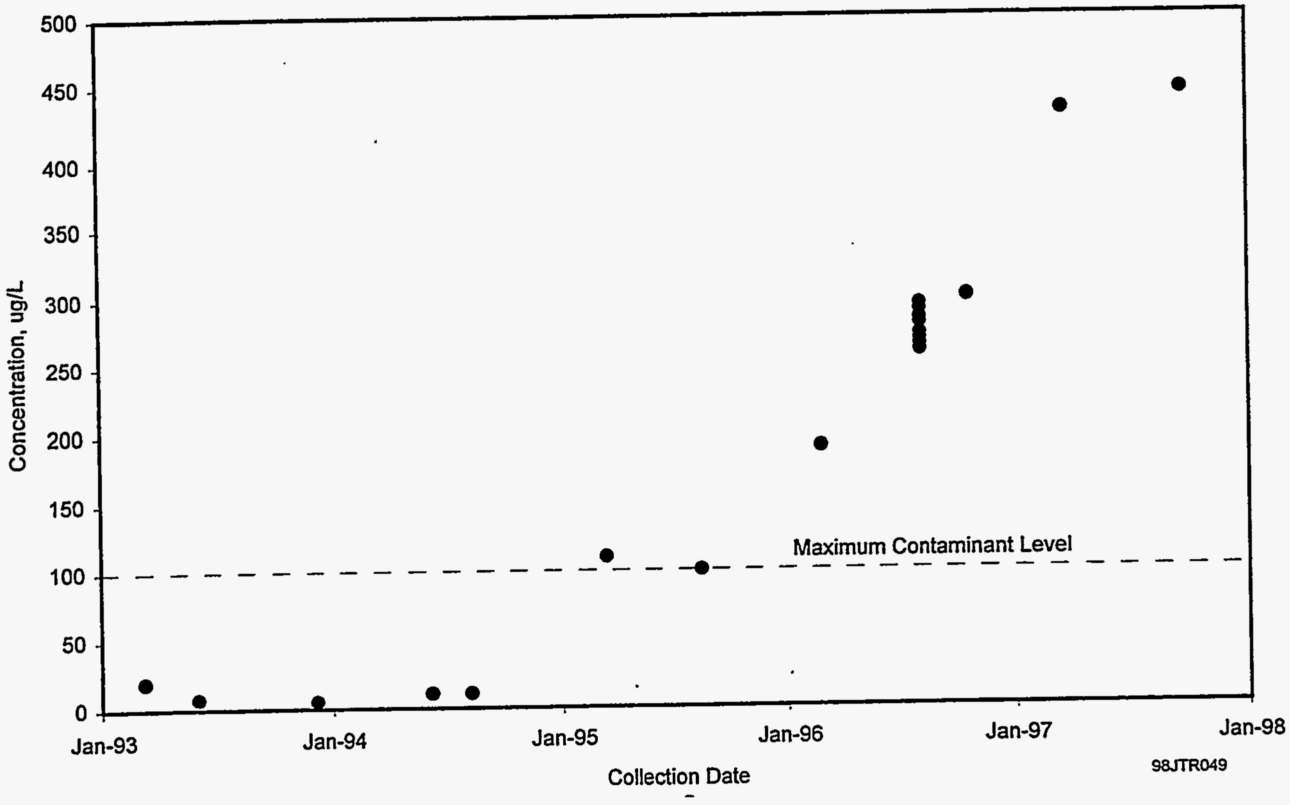

Figure 5.6-2. Filtered Chromium Concentrations in Well 199-D5-13

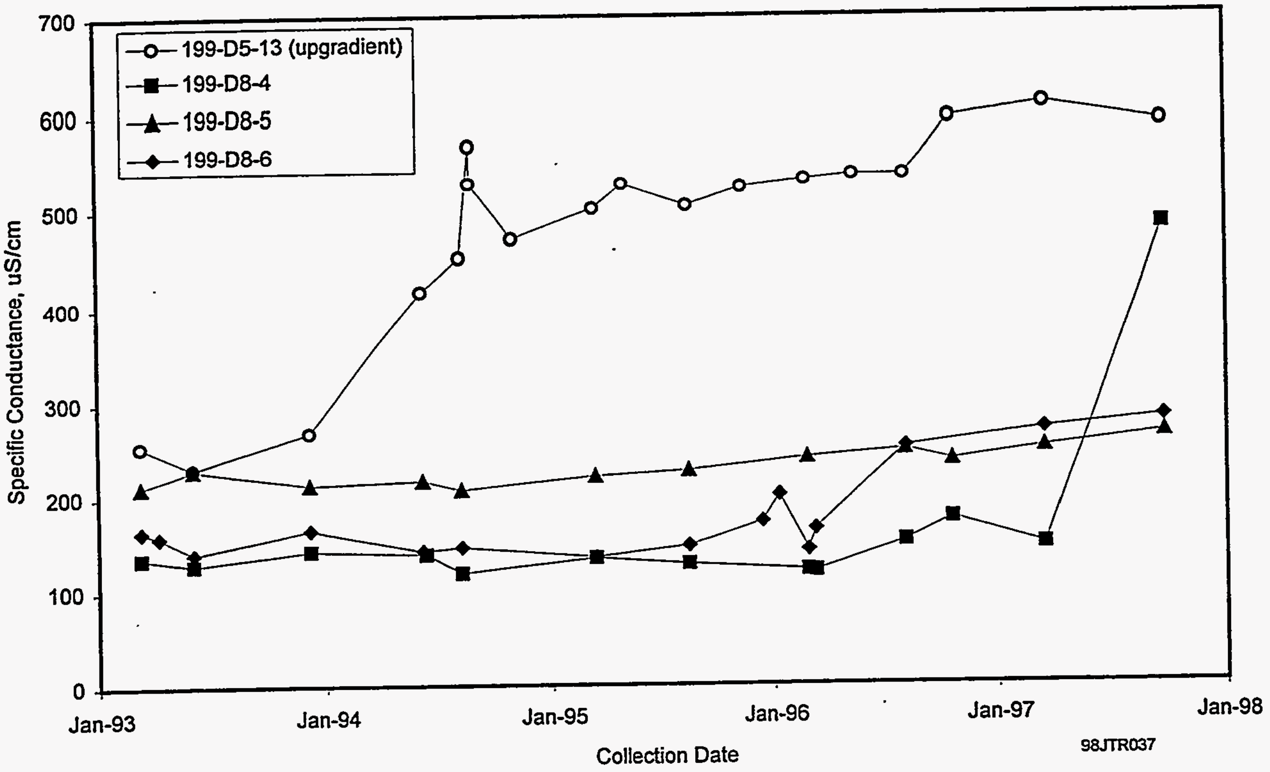

Figure 5.6-3. Specific Conductance in Wells Monitoring 120-D-1 Ponds

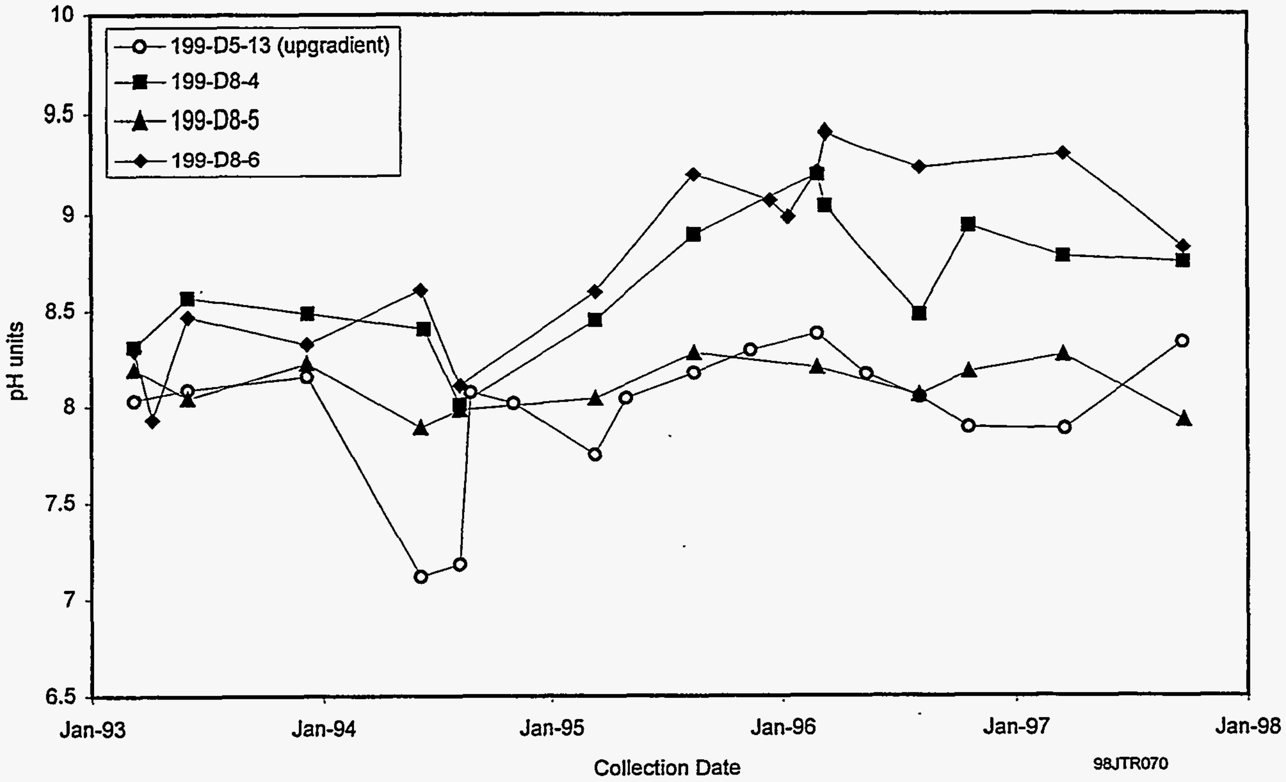

Figure 5.6-4. pH in Wells Monitoring 120-D-1 Ponds

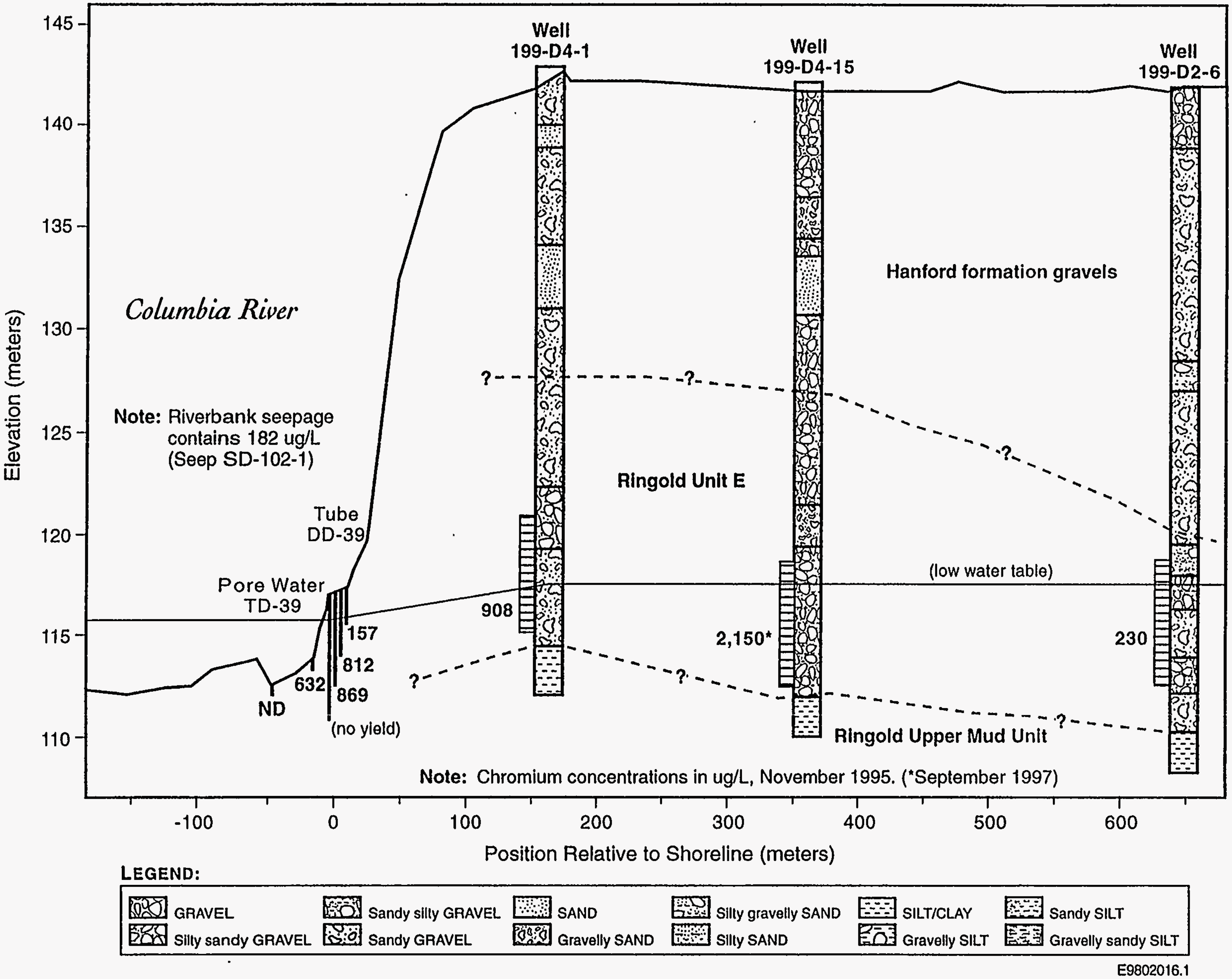

Figure 5.6-5. Cross-Section Showing Distribution of Chromium at 100-D Area Hot Spot (from BHI-00153)

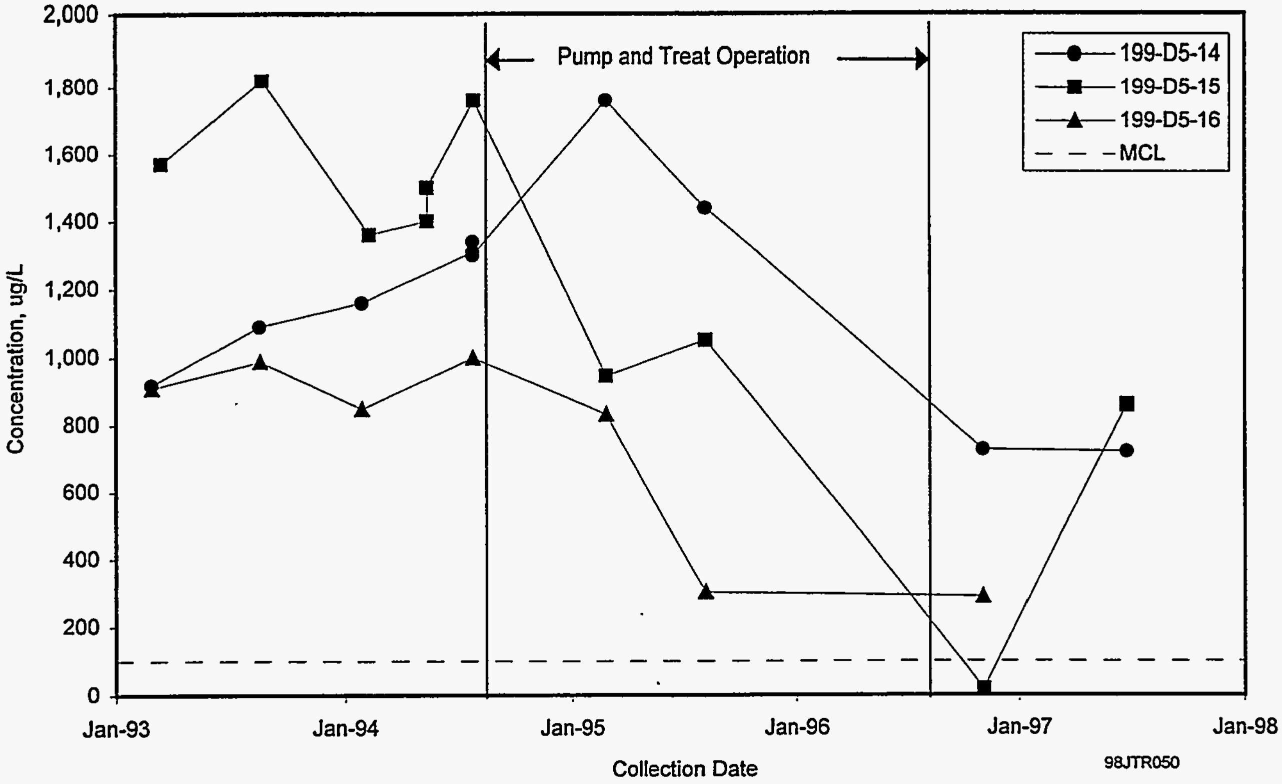

Figure 5.6-6. Filtered Chromium Concentrations in 100-D Area Pilot-Scale Extraction Wells

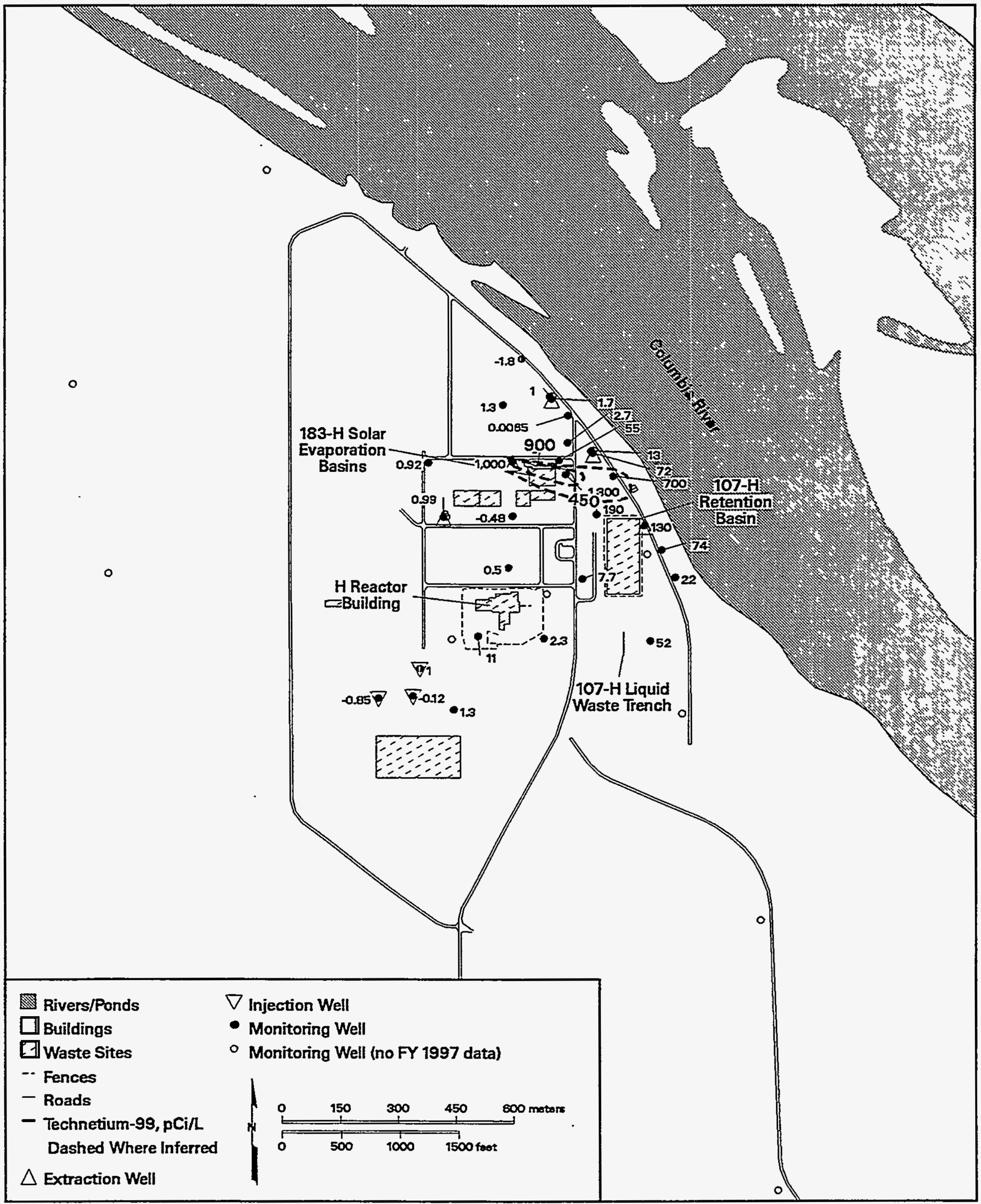

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Figure 5.7-1. Average Fiscal Year 1997 Technetium-99 Concentrations in 100-H Area

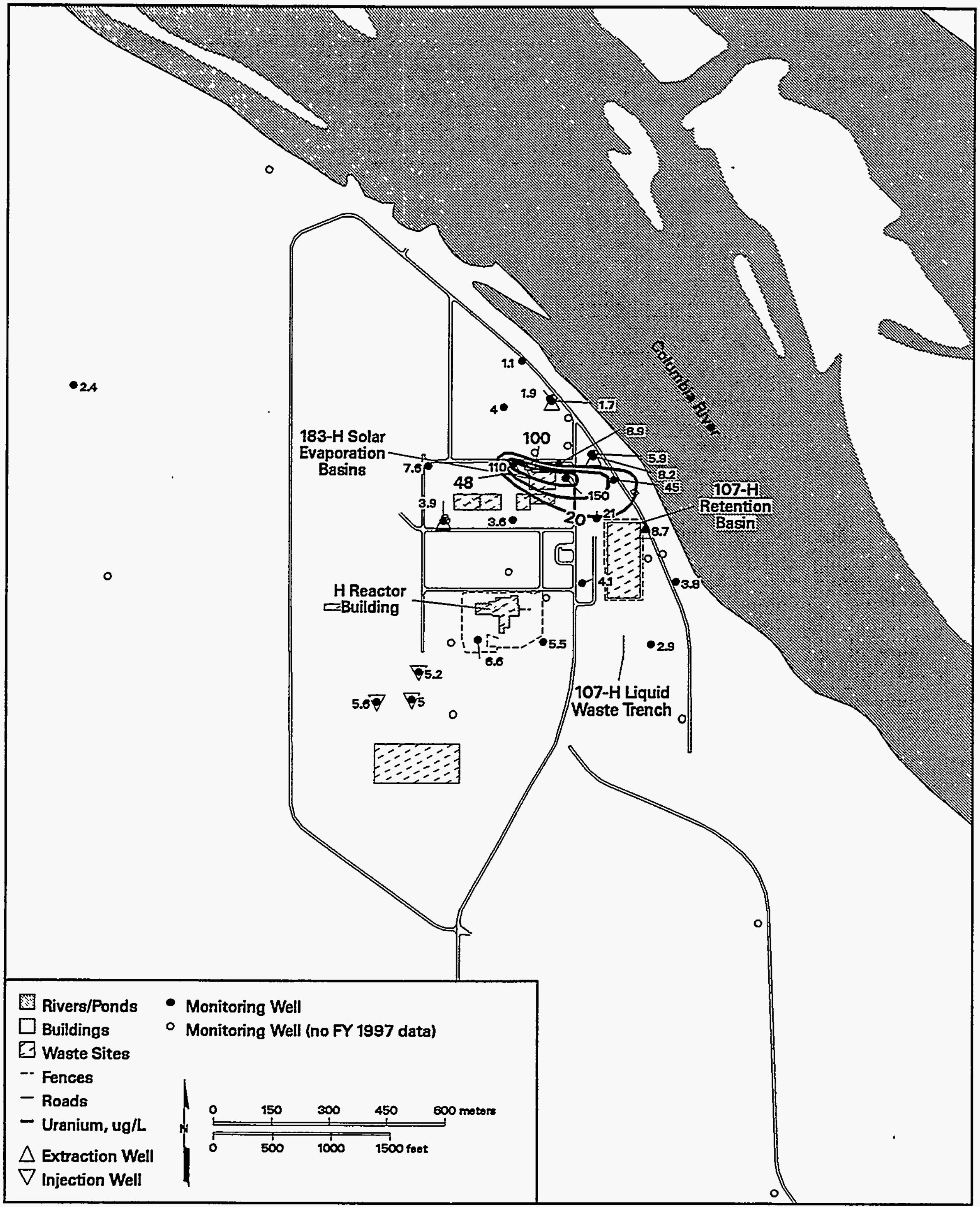

Figure 5.7-2. Average Fiscal Year 1997 Uranium Concentrations in 100-H Area

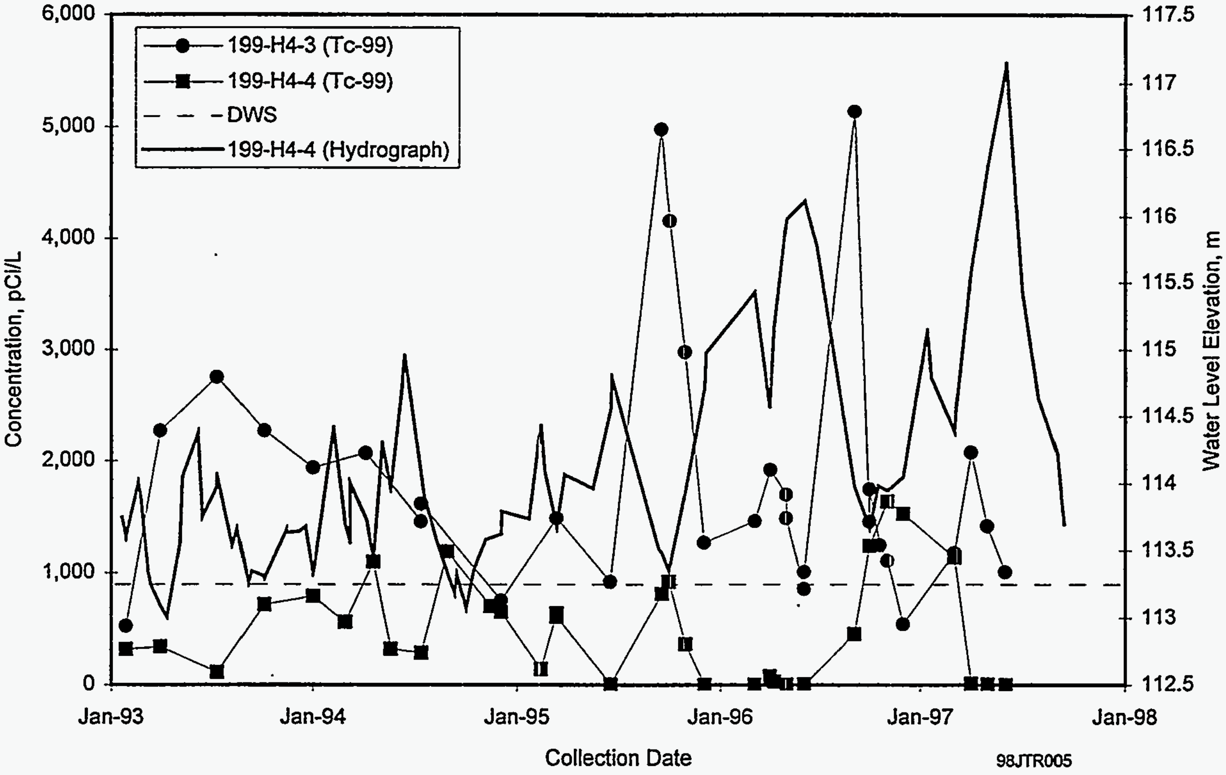

Figure 5.7-3. Technetium-99 Concentrations and Water Levels in Wells Monitoring 183-H Solar Evaporation Basins

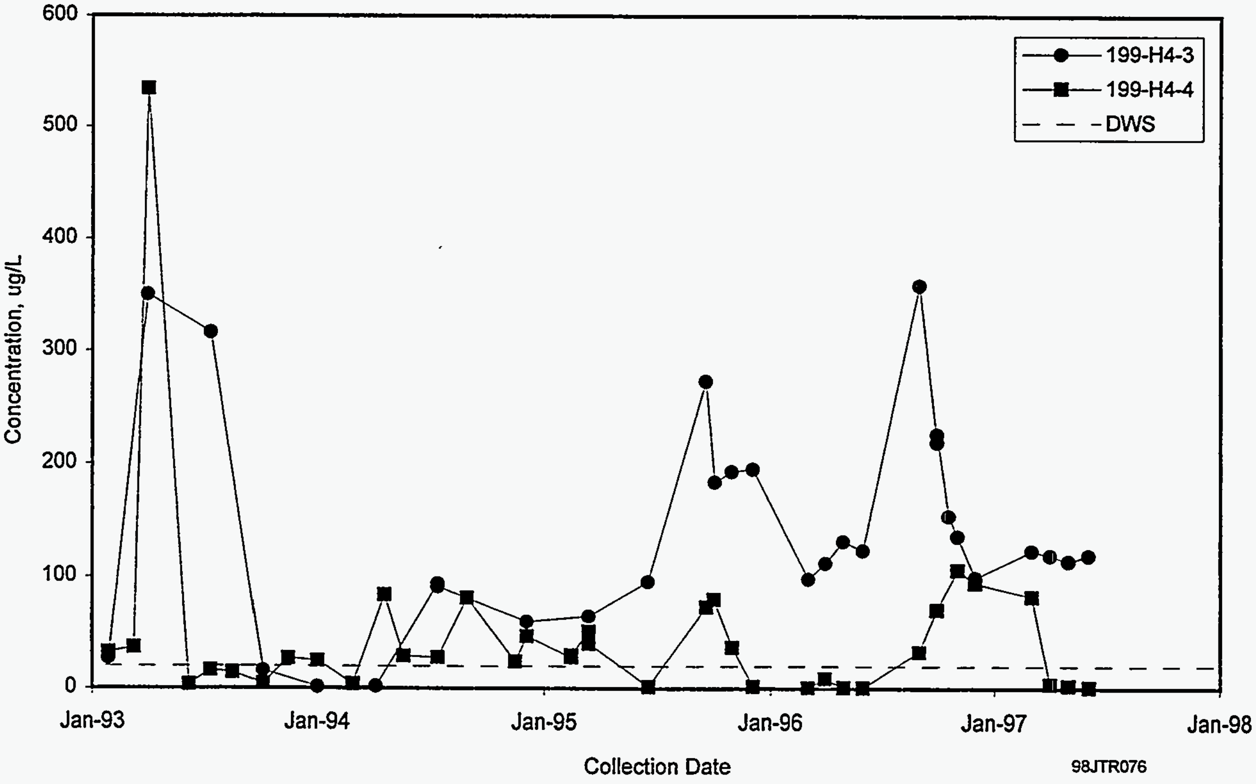

Figure 5.7-4. Uranium Concentrations in Wells Monitoring 183-H Solar Evaporation Basins

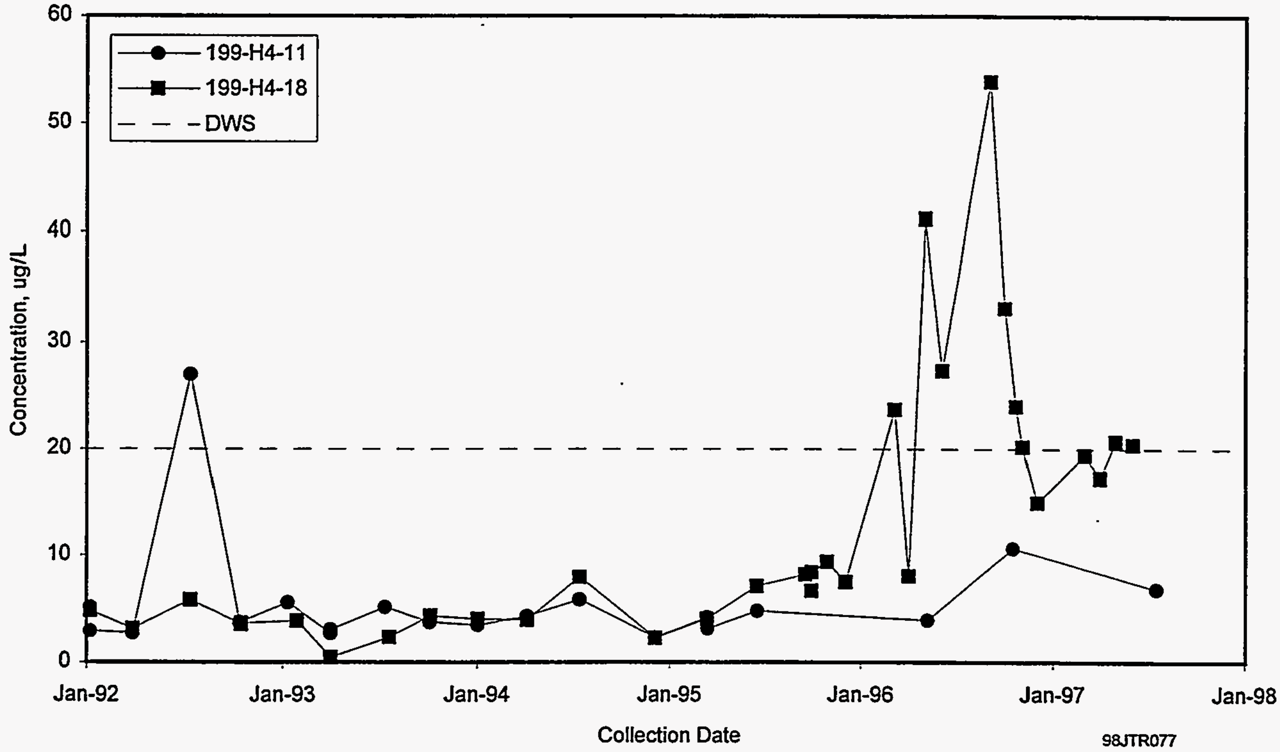

Figure 5.7-5. Uranium Concentrations in Wells 199-H4-18 and 199-H4-11

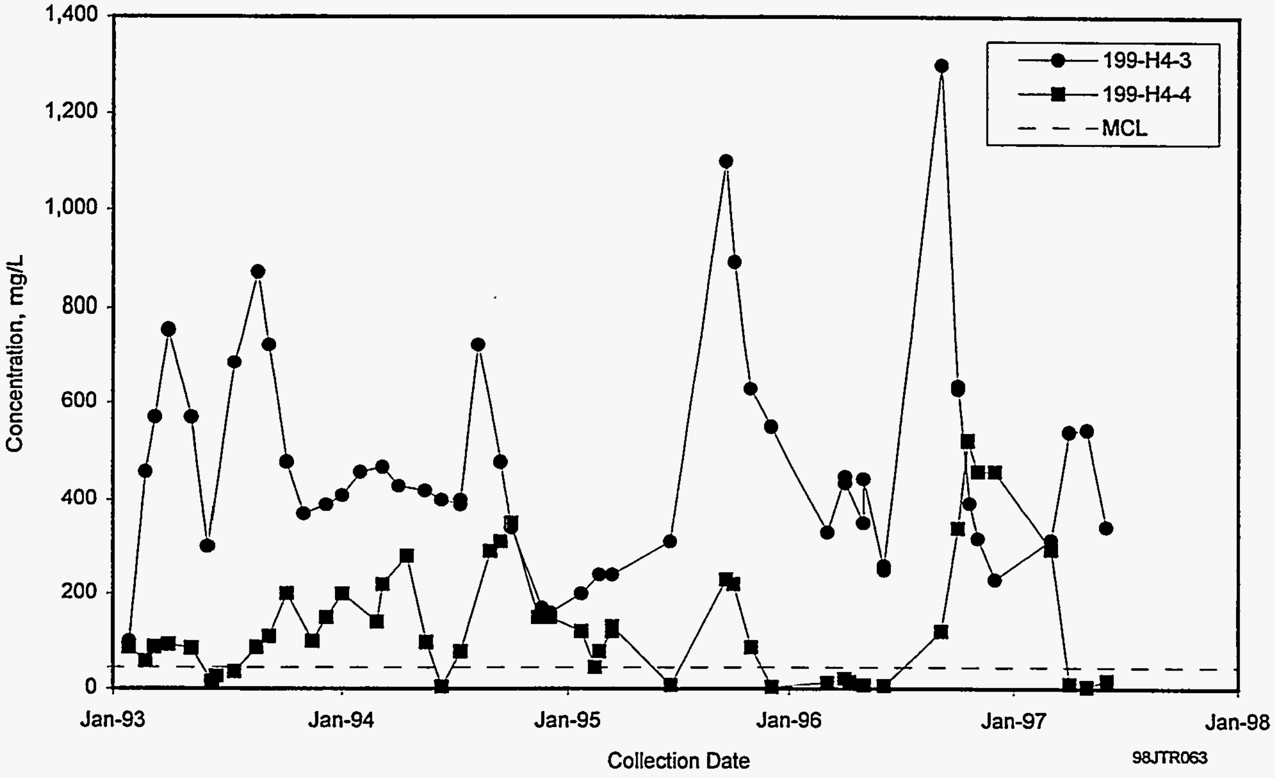

Figure 5.7-6. Nitrate Concentrations in Wells Monitoring 183-H Solar Evaporation Basins

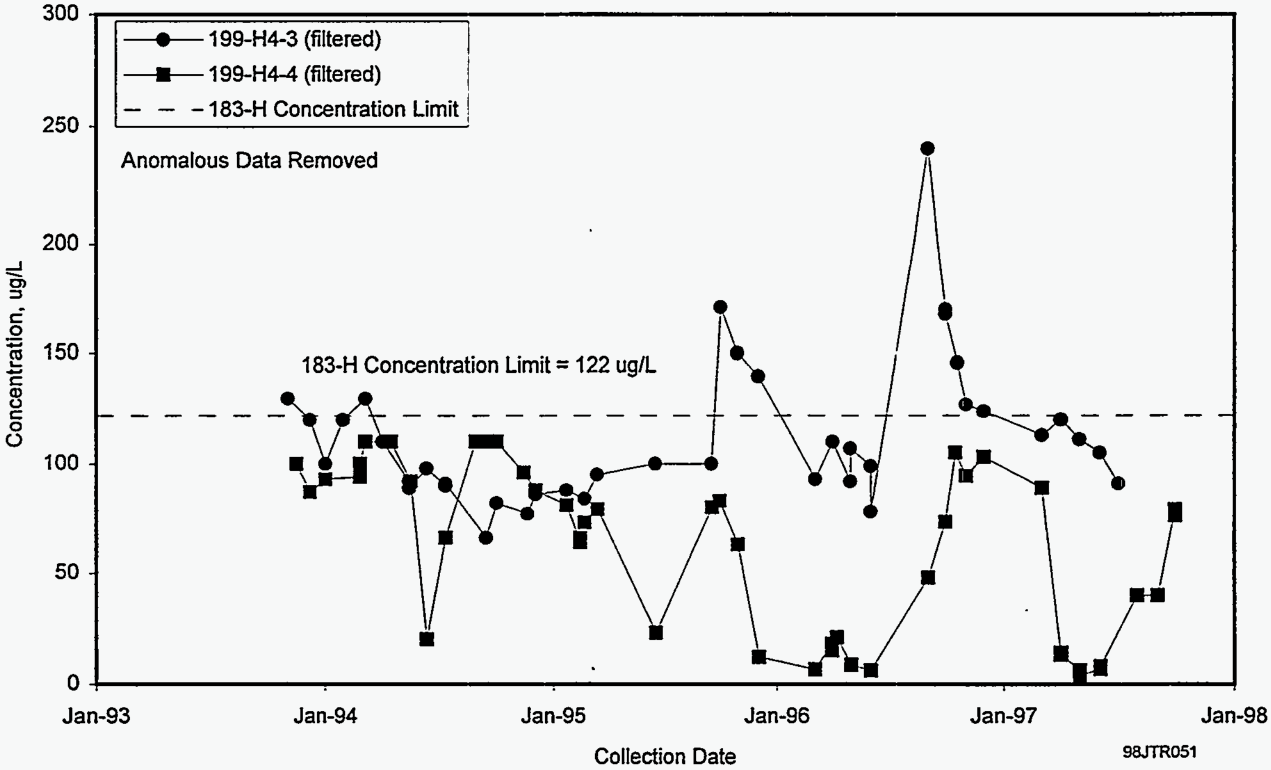

Figure 5.7-7. Filtered Chromium Concentrations in Wells Monitoring 183-H Solar Evaporation Basins

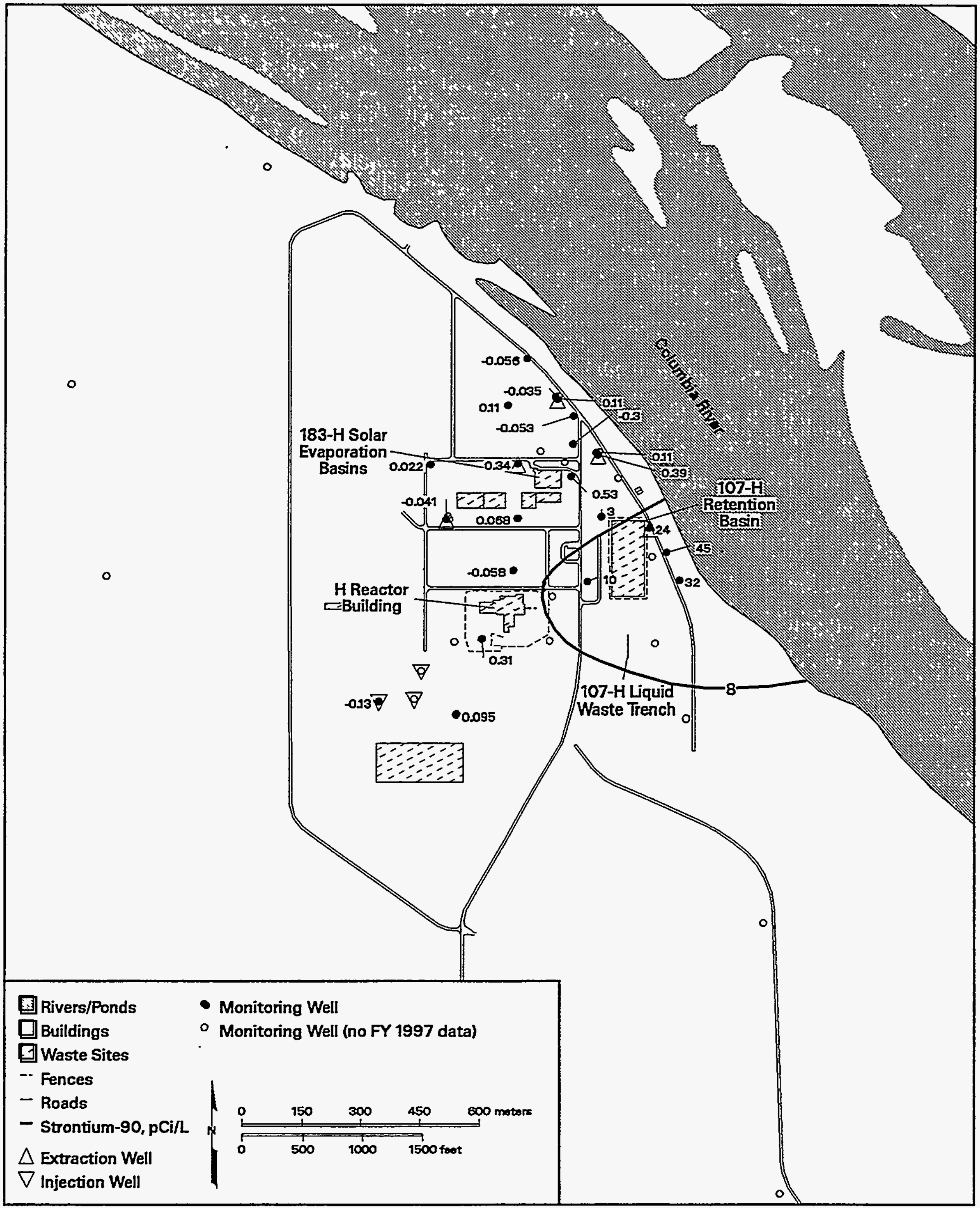

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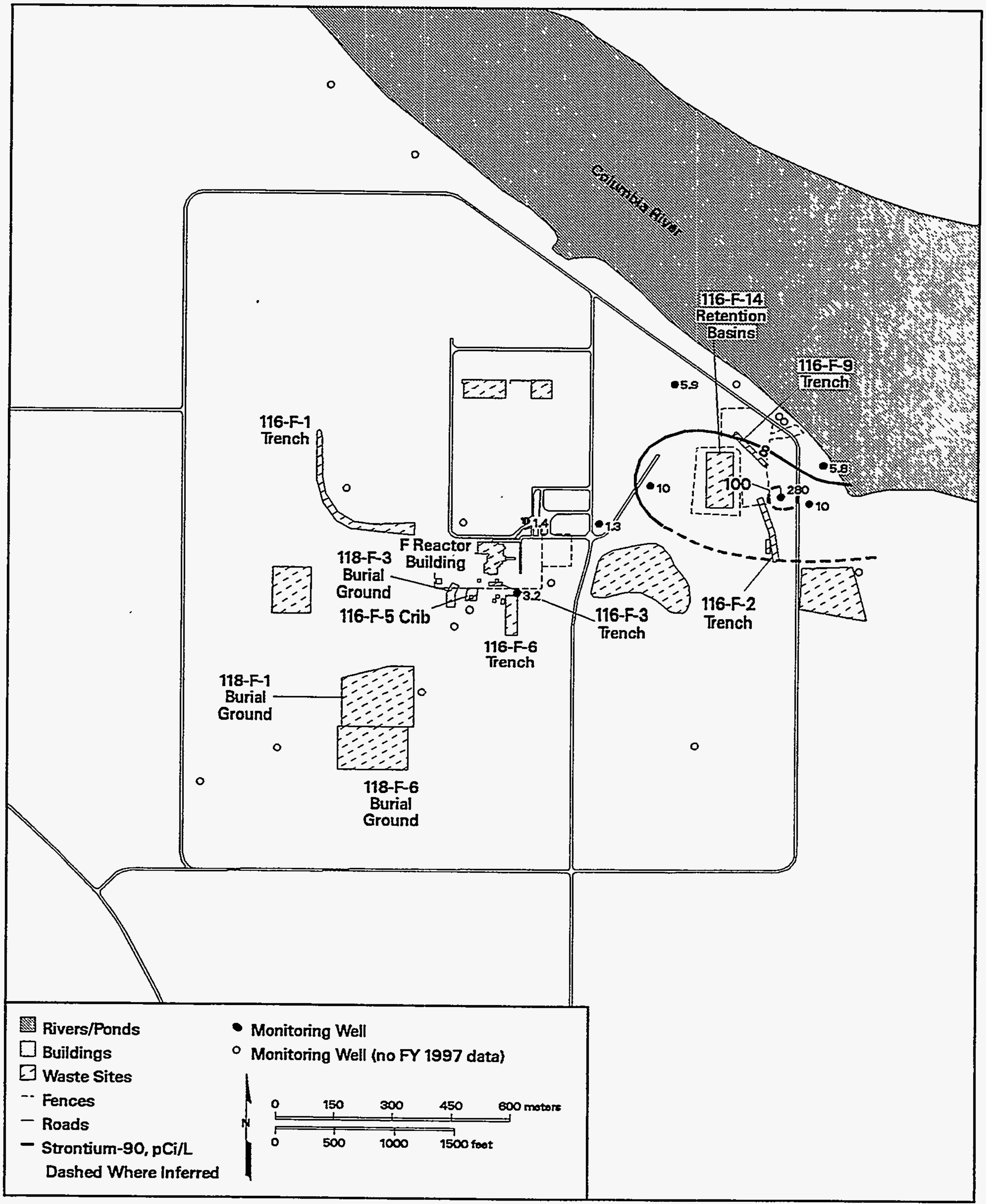
Figure 5.7-8. Average Fiscal Year 1997 Strontium-90 Concentrations in 100-H Area



jpm98010 February 20, 1998 5:37 PM

Figure 5.8-1. Average Fiscal Year 1997 Strontium-90 Concentrations in 100-F Area

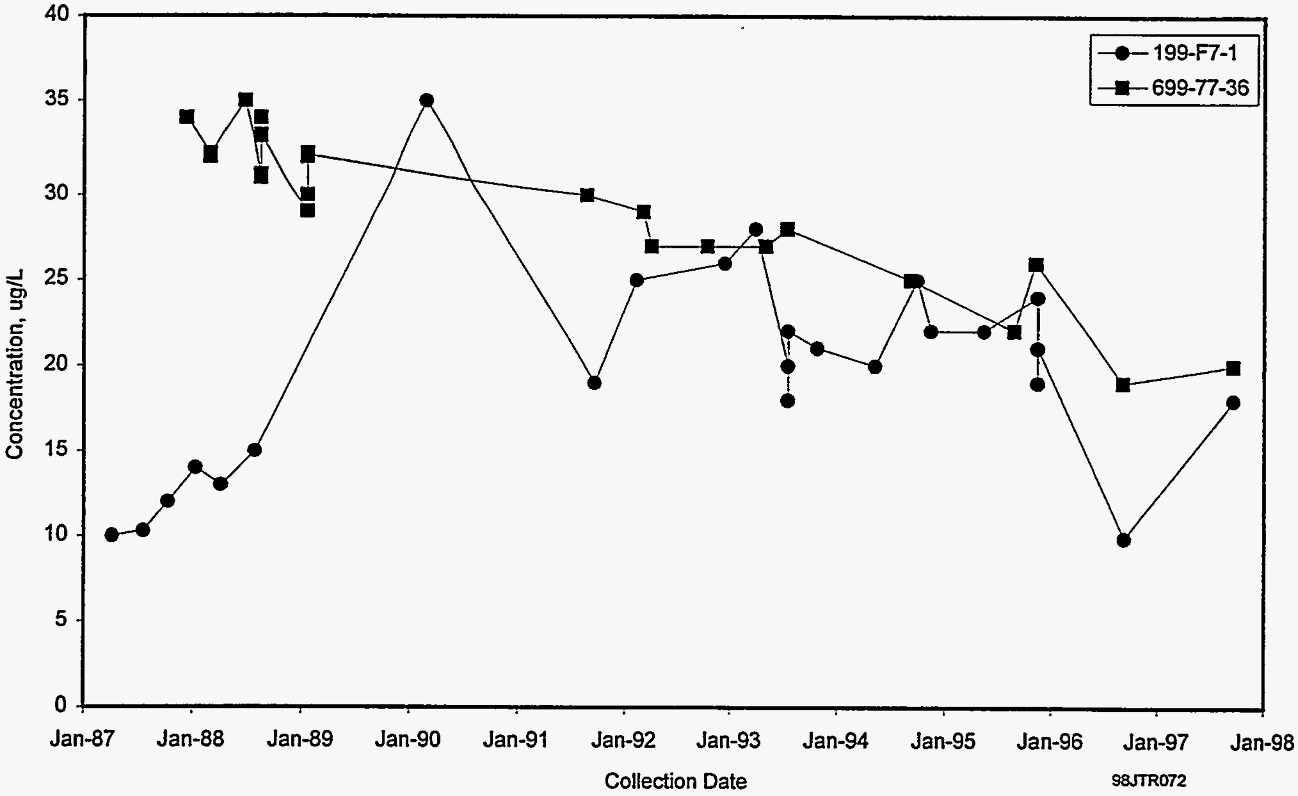
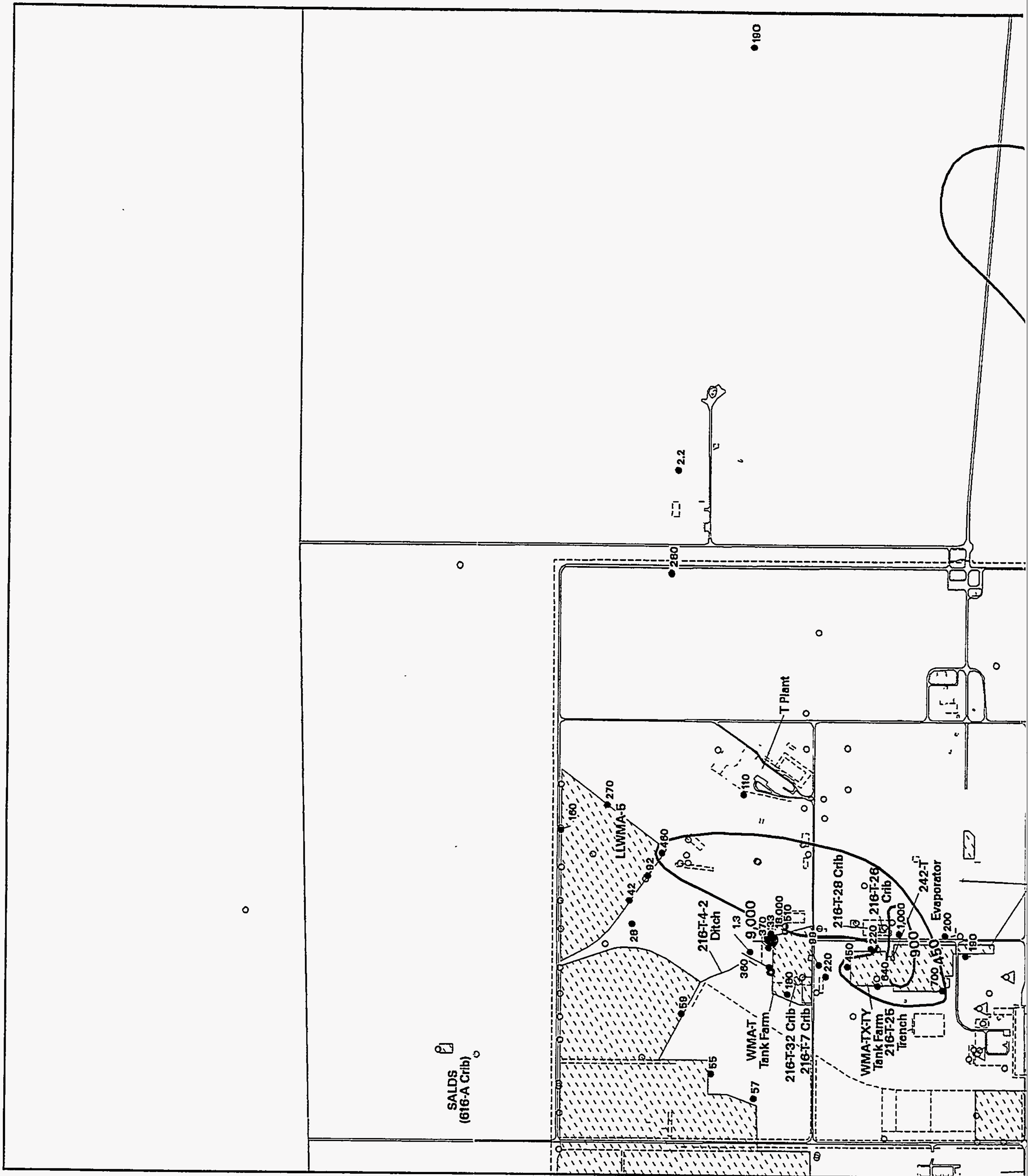


Figure 5.8-2. Trichloroethylene Concentrations in Wells Monitoring 100-F Area


190
2.2
280
T Plant
110
270
160
LLWMA-5
460
82
42
28
216-T-4-2
Ditch
1.3
9,000
370
33
18,000
510
360
59
55
57
WMA-T
Tank Farm
216-T-32 Crib
216-T-7 Crib
190
99
220
216-T-28 Crib
450
220
216-T-26
Crib
1,000
242-T
Evaporator
200
900
450
840
700
190
WMA-TX-TY
Tank Farm
216-T-25
Trench
SALDS
(616-A Crib)

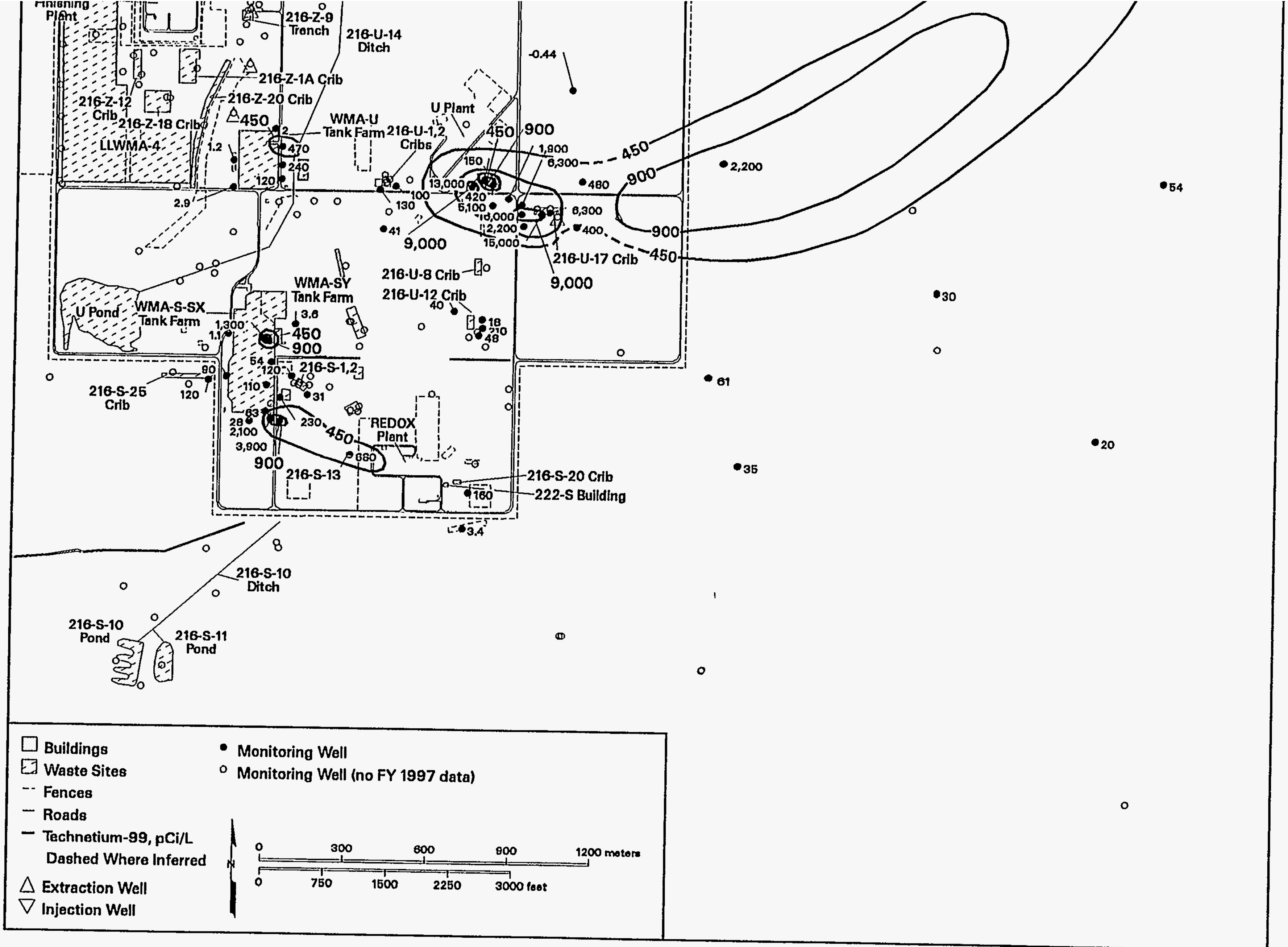


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Figure 5.9-1. Average Fiscal Year 1997 Technetium-99 Concentrations in 200-West Area

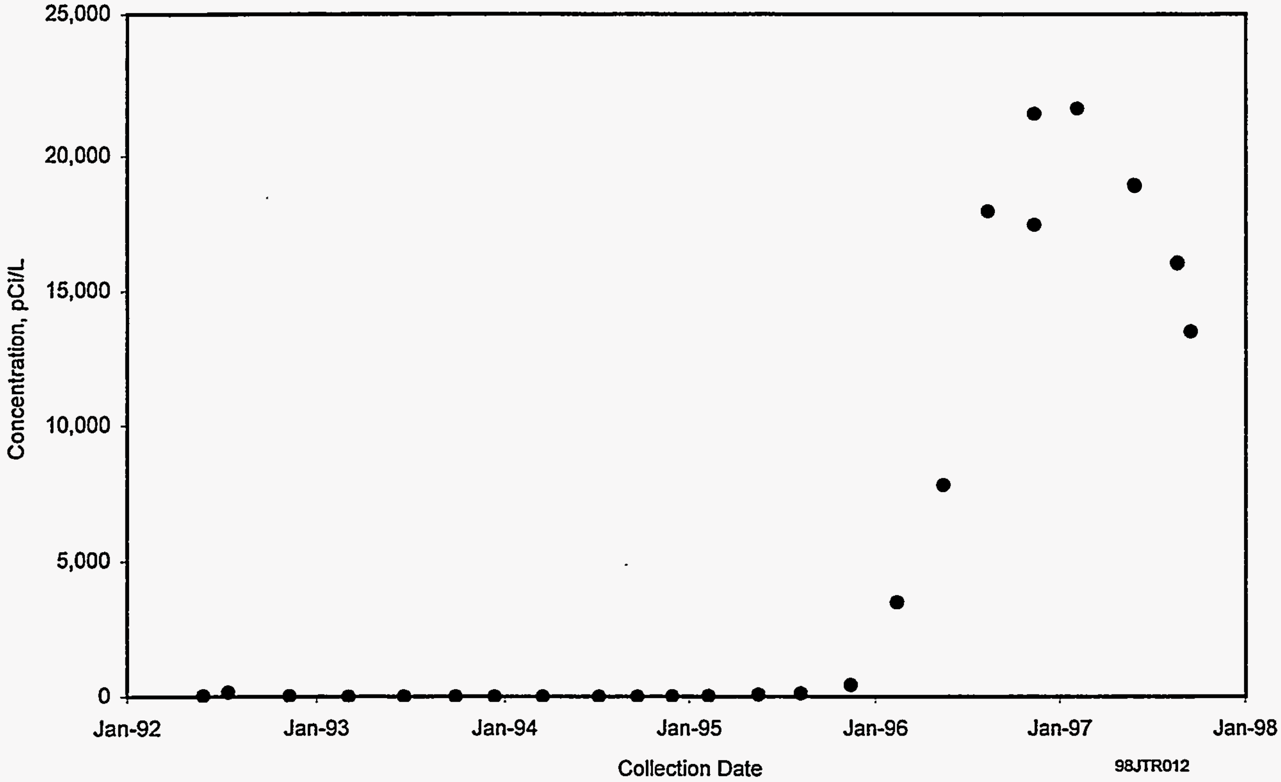
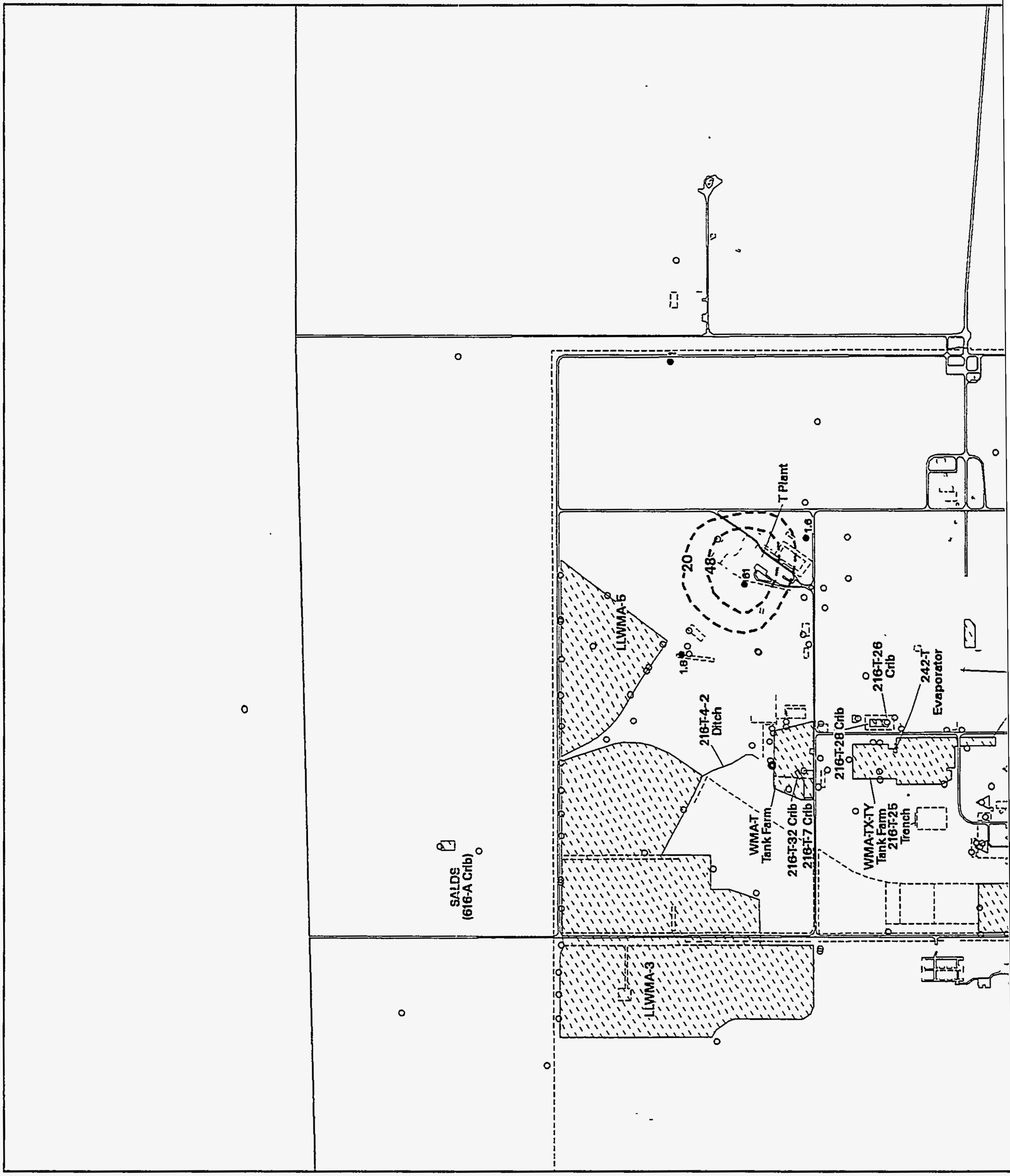
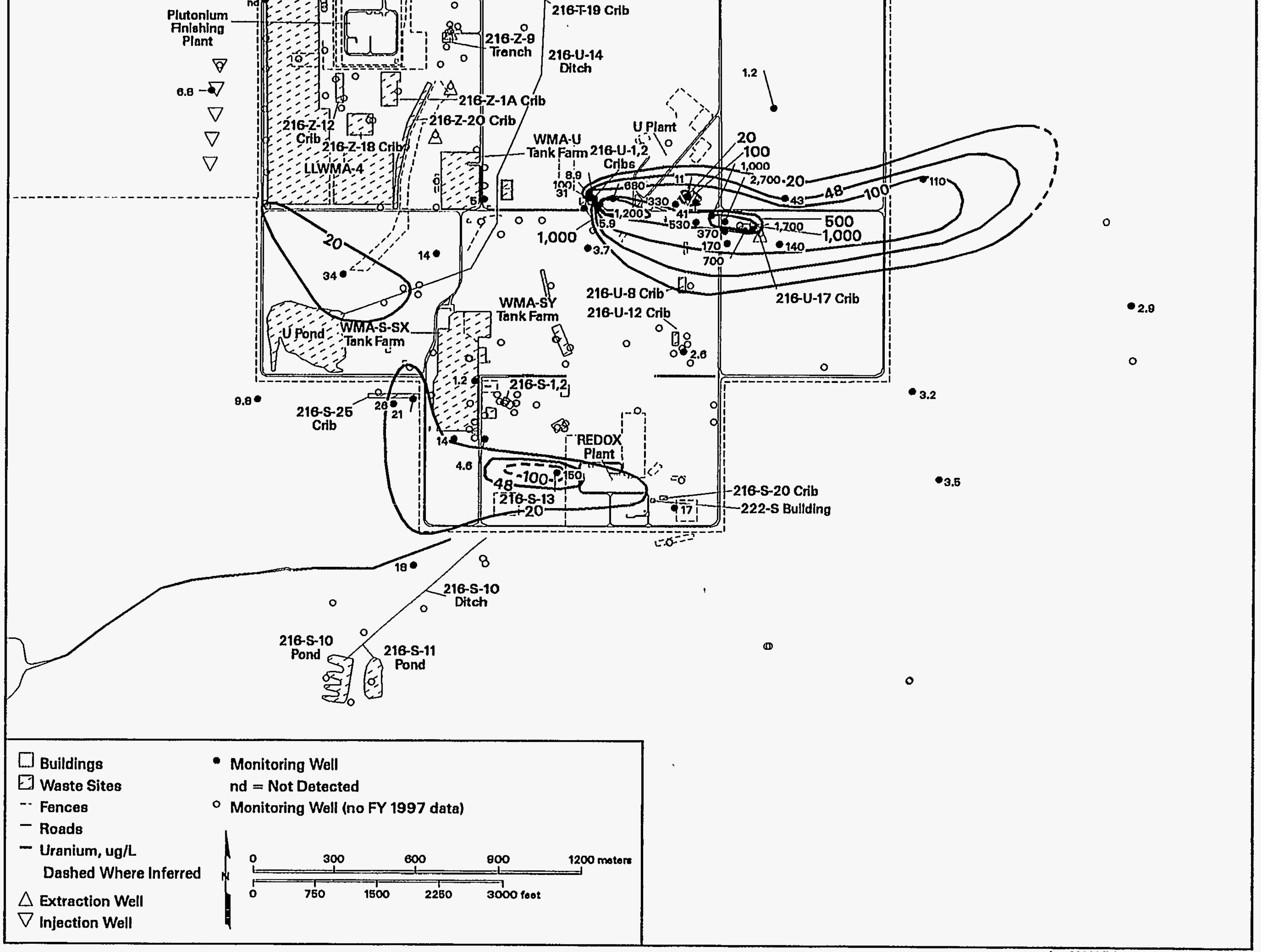


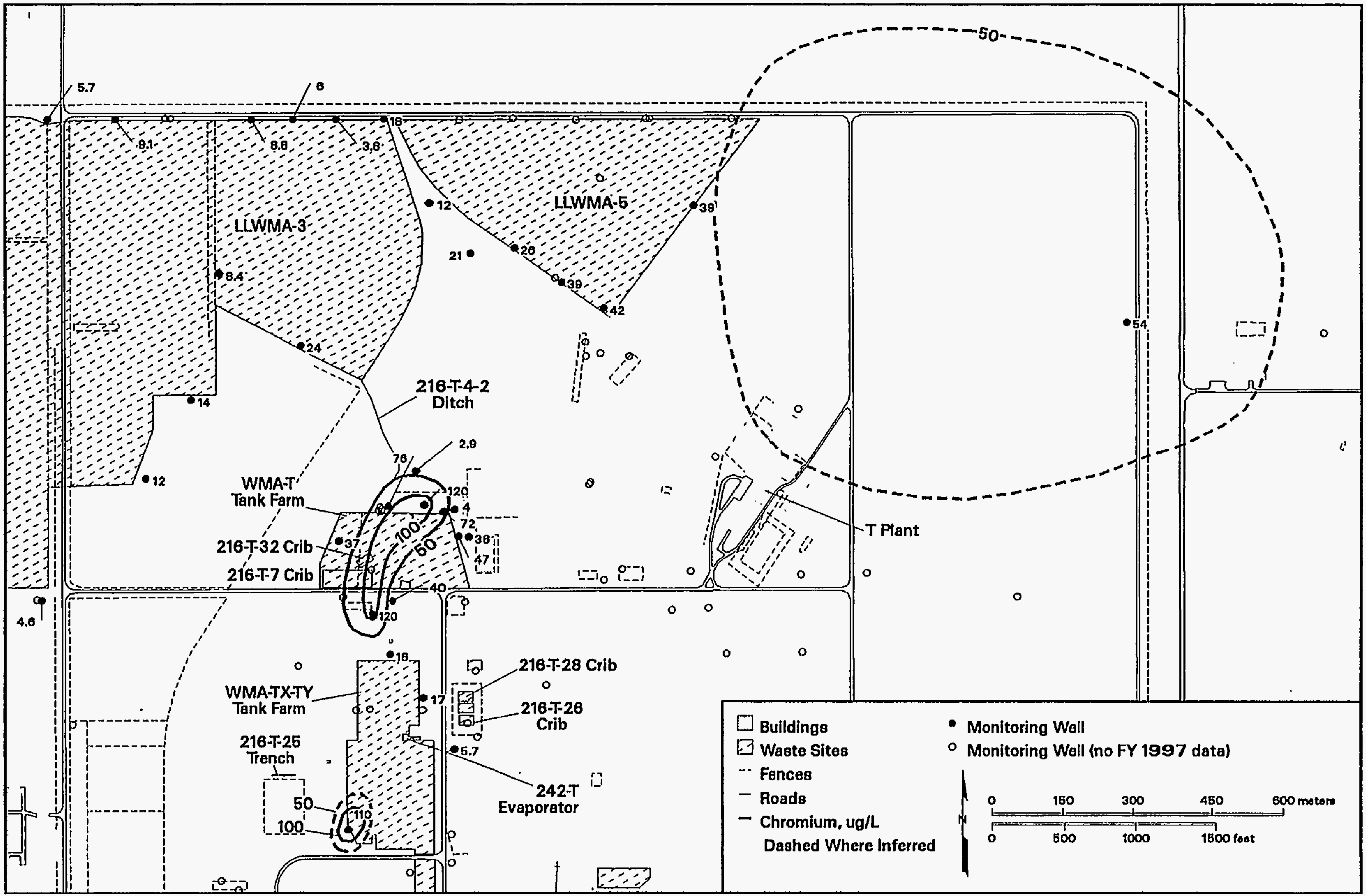
Figure 5.9-2. Technetium-99 Concentrations in Well 299-W11-27


T Plant
1.6
20
48
61
LLWMA-5
1.8
216-T-4-2 Ditch
216-T-26 Crib
242-T Evaporator
216-T-28 Crib
WMA-T Tank Farm
216-T-32 Crib
216-T-7 Crib
WMA-TX-TY Tank Farm
216-T-25 Trench
SALDS (616-A Crib)
LLWMA-3



jpm98016 February 20, 1998 8:02 PM

Figure 5.9-3. Average Fiscal Year 1997 Uranium Concentrations in 200-West Area



jpm98031 February 21, 1998 9:34 AM

Figure 5.9-4. Average Fiscal Year 1997 Filtered Chromium Concentrations in 200-West Ara Near T Plant

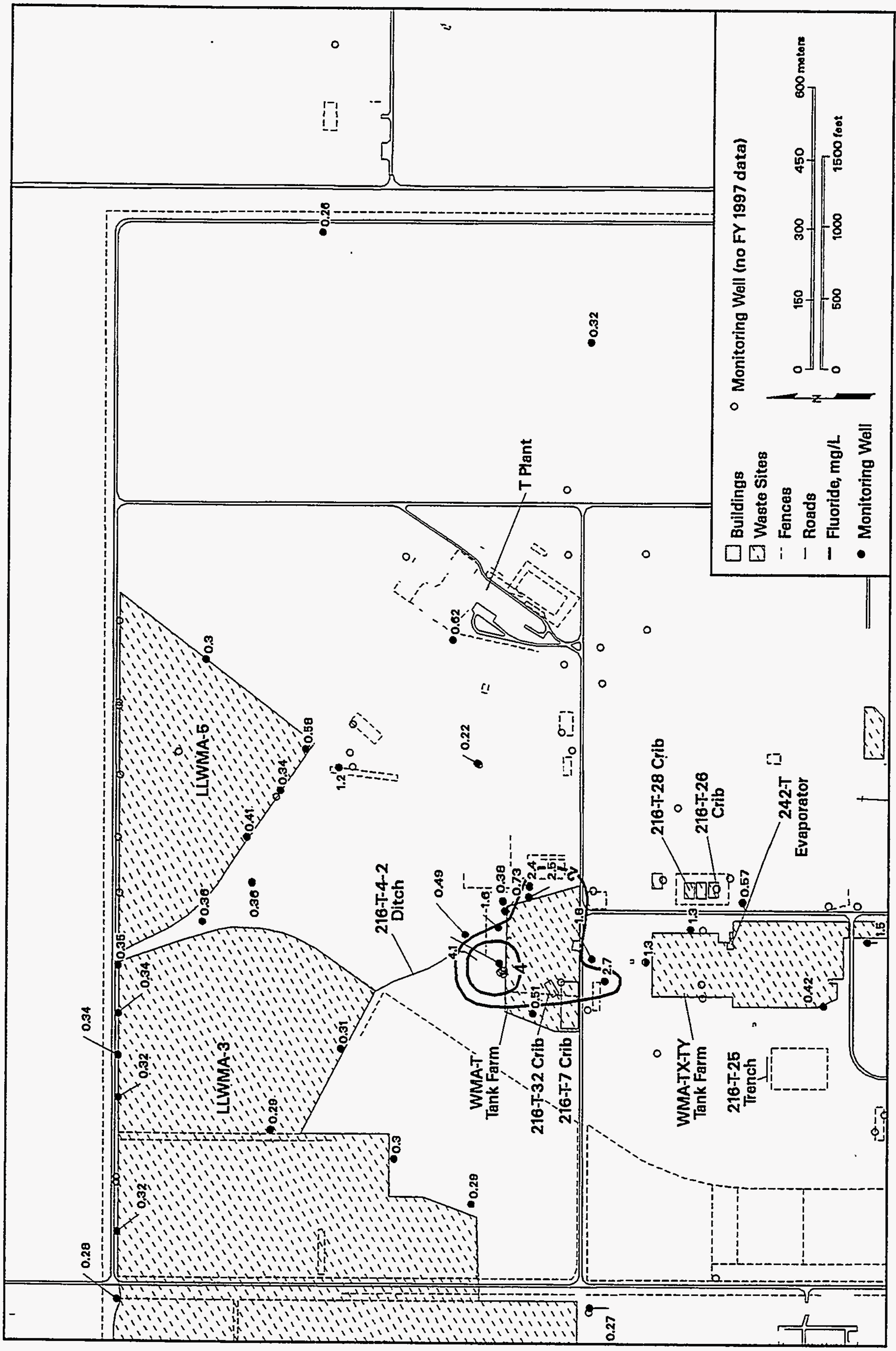
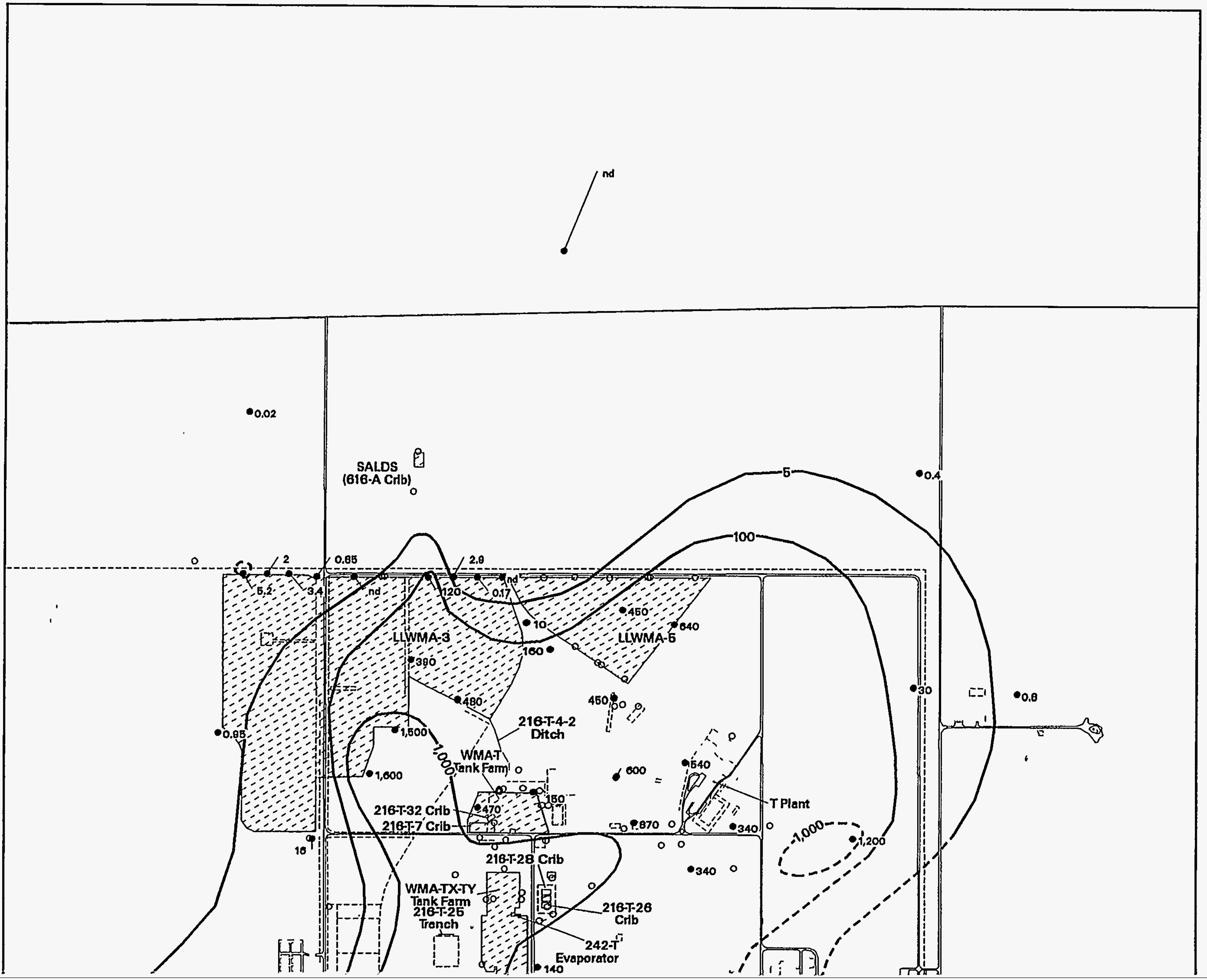


Figure 5.9-5. Average Fiscal Year 1997 Fluoride Concentrations in 200-West Area Near T Plant


nd
0.02
SALDS
(616-A Crib)
0.4
5
100
0.8
30
0.65
2
2.9
5.2
3.4
nd
120
0.17
nd
450
640
10
LLWMA-3
LLWMA-5
160
390
480
450
216-T-4-2
Ditch
0.95
1,500
1,000
WMA-T
Tank Farm
1,600
600
540
T Plant
216-T-32 Crib
470
150
216-T-7 Crib
670
340
1,000
1,200
15
216-T-28 Crib
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WMA-TX-TY
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216-T-25
Trench
216-T-26
Crib
242-T
Evaporator
140

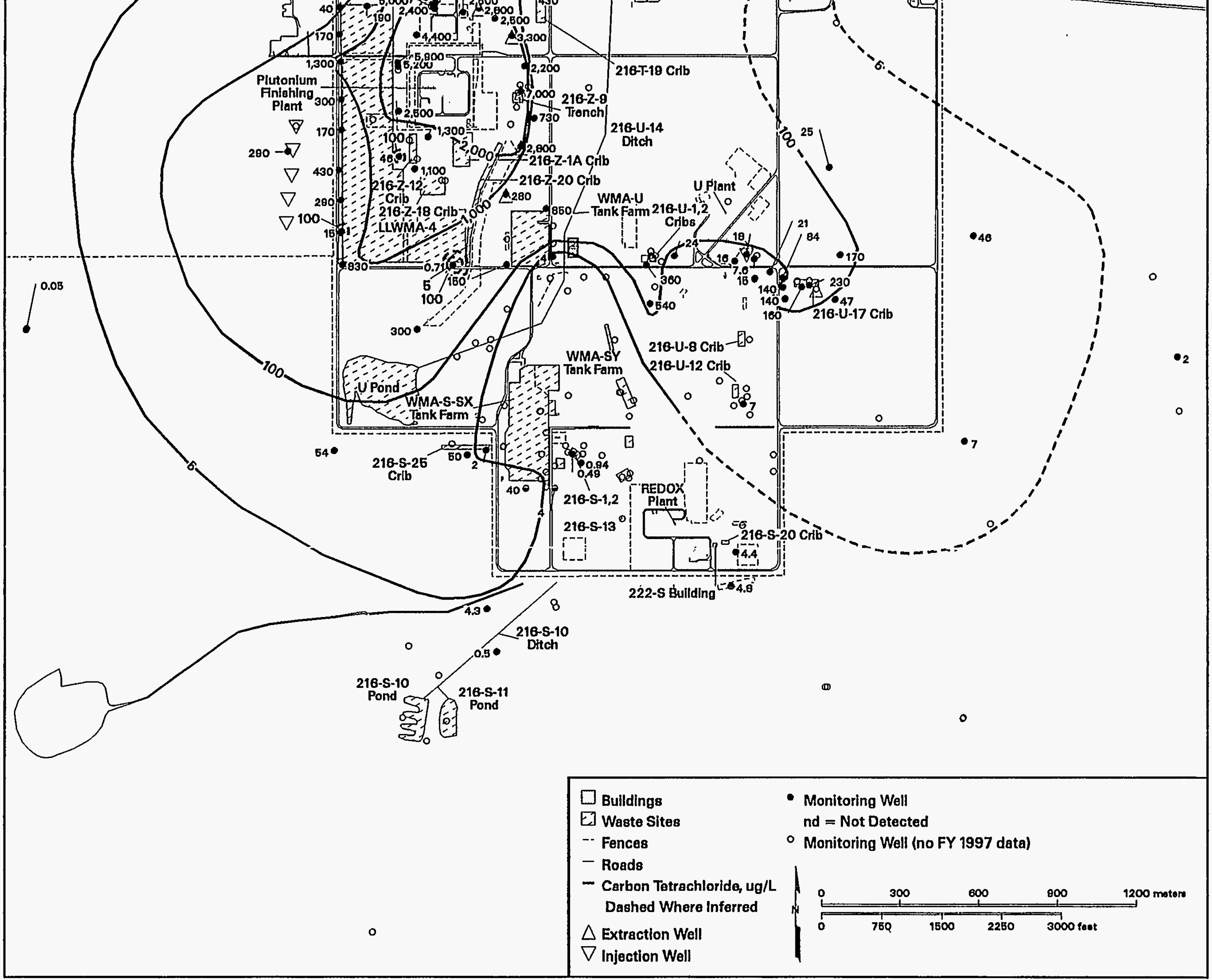

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Figure 5.9-6. Average Fiscal Year 1997 Carbon Tetrachloride Concentrations in 200-West Area

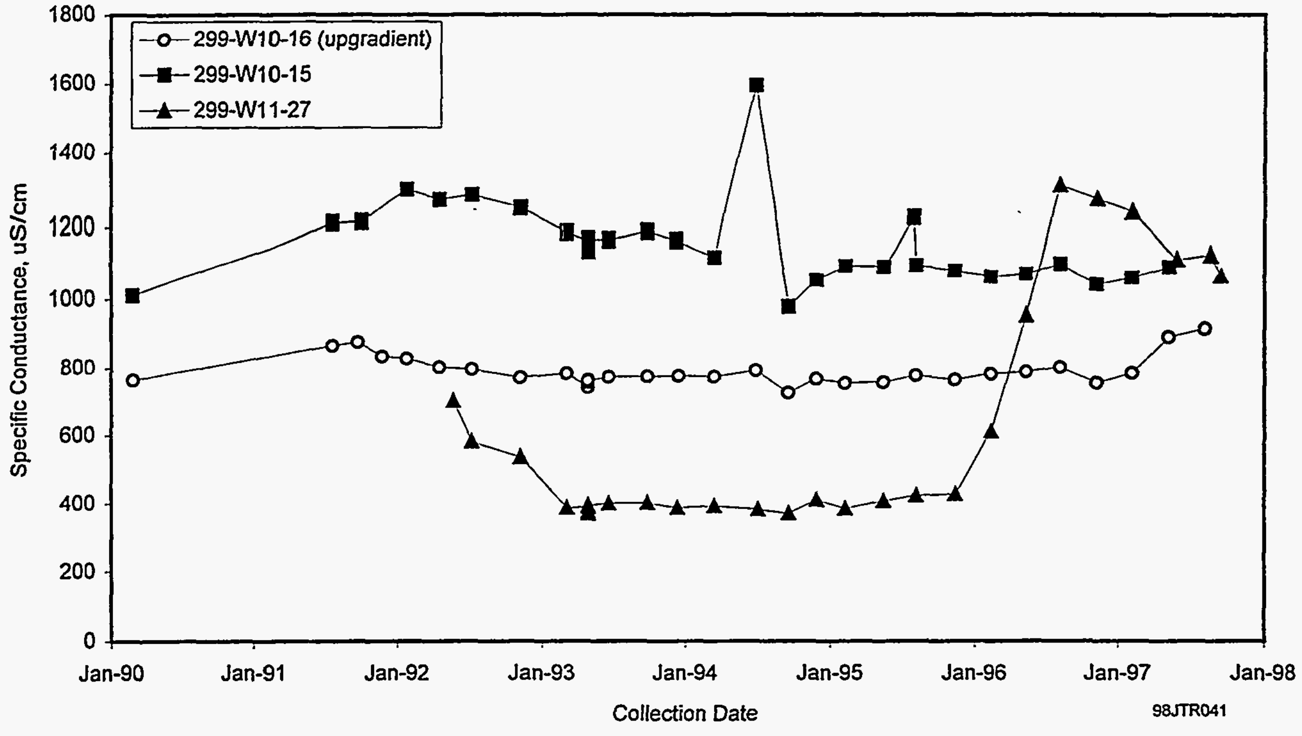

Figure 5.9-7. Specific Conductance in Selected Wells Monitoring WMA T

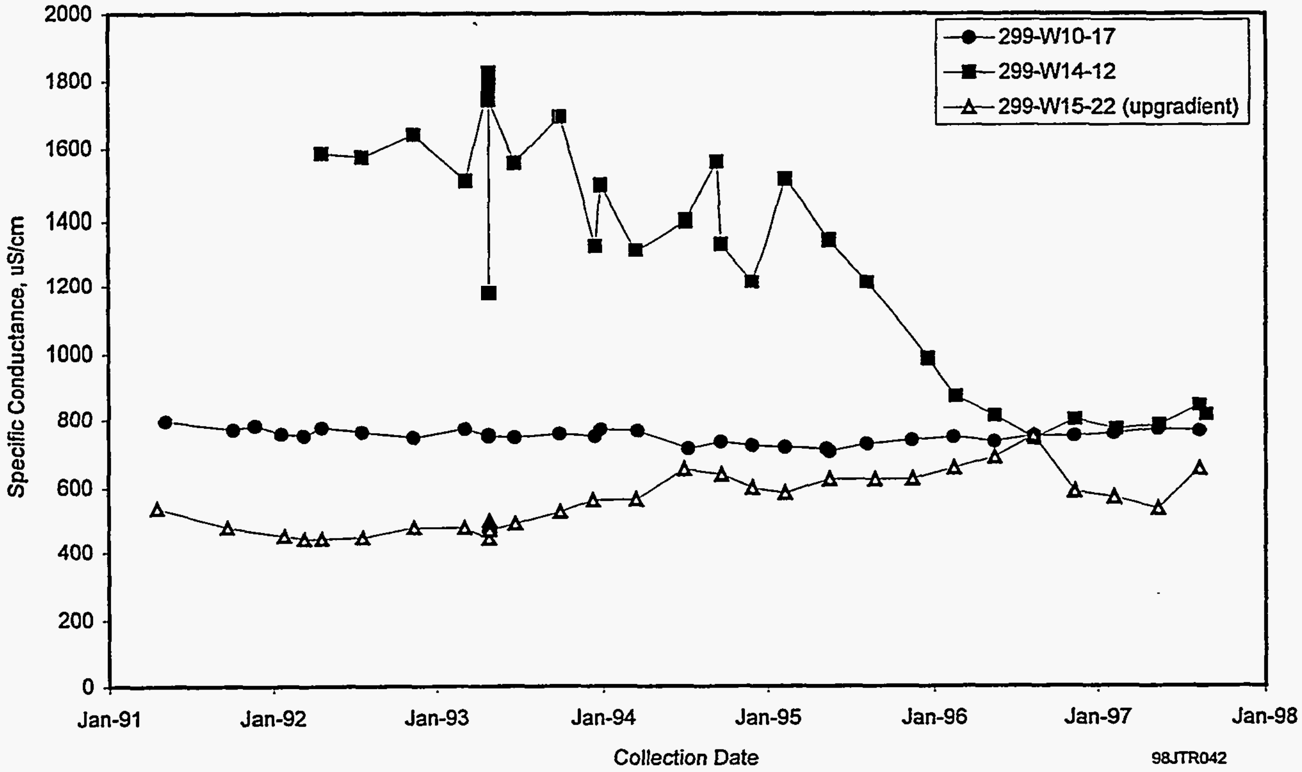

Figure 5.9-8. Specific Conductance in Selected Wells Monitoring WMA TX-TY

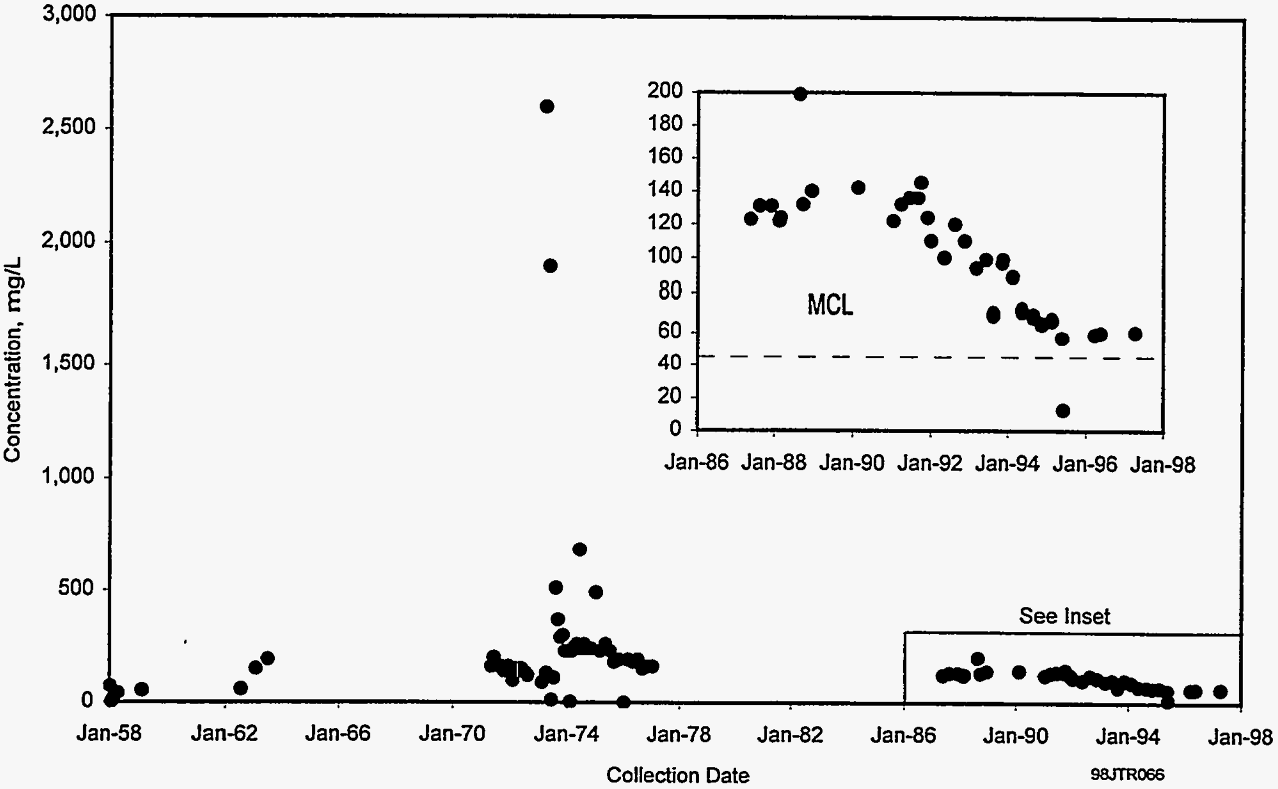

Figure 5.9-9. Nitrate Concentrations in Well 299-W22-20

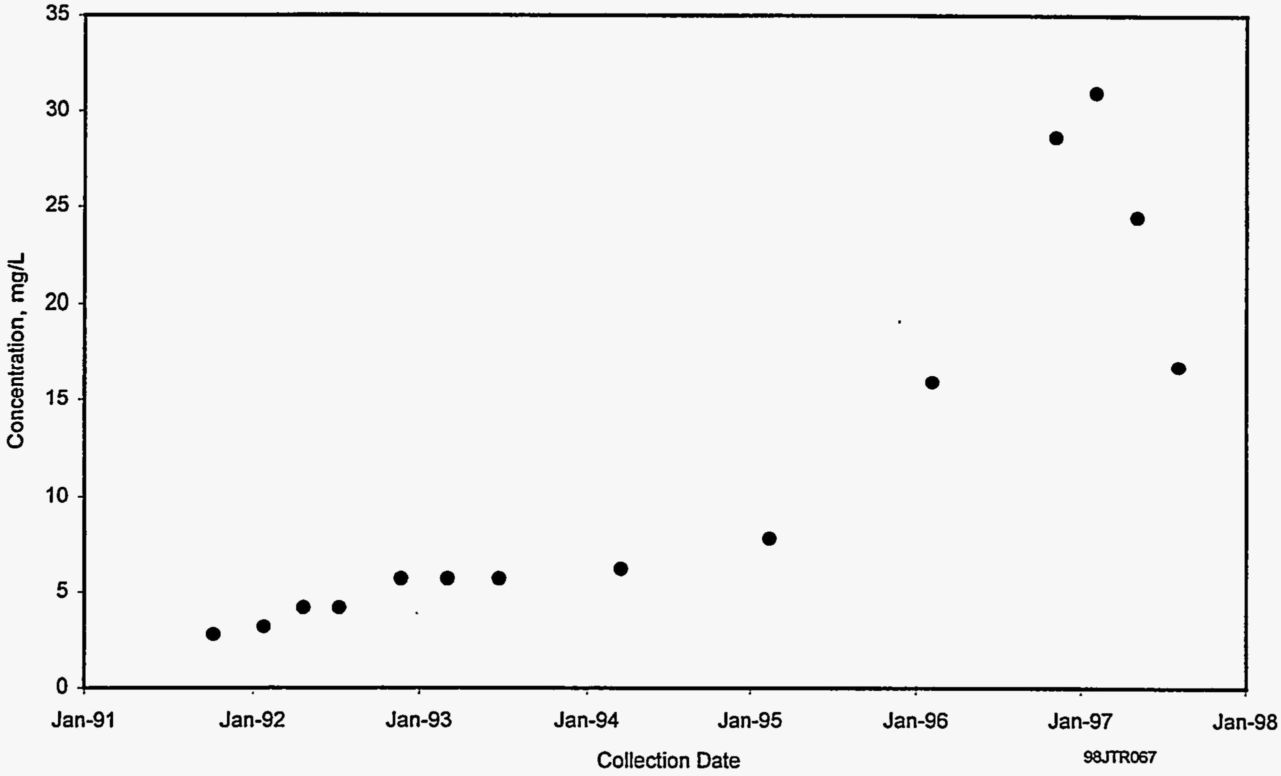

Figure 5.9-10. Nitrate Concentrations in Well 299-W23-14

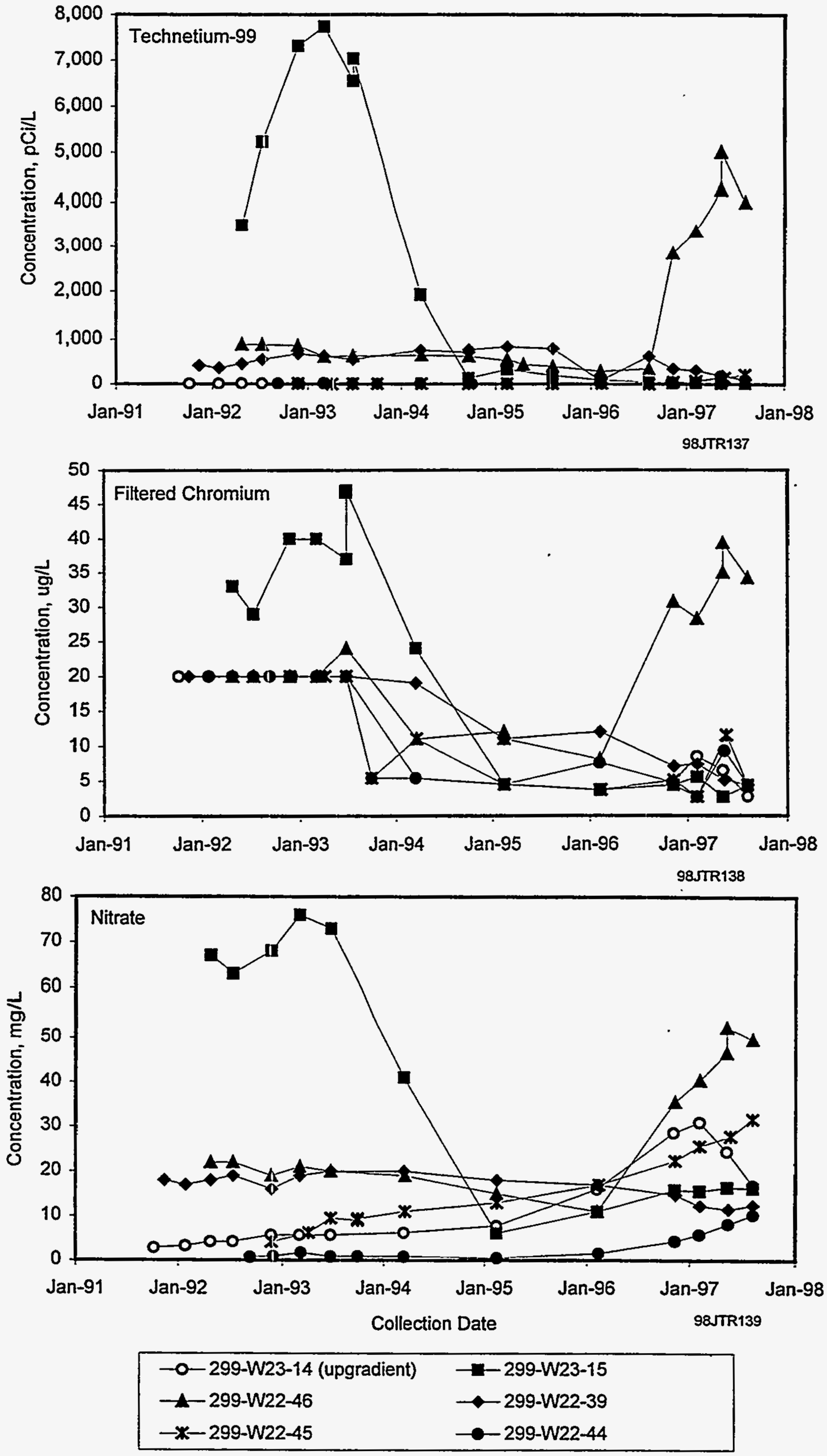

Figure 5.9-11. Time-Series Plot of Technetium-99, Chromium, and Nitrate in RCRA Monitoring Wells at WMA S-SX

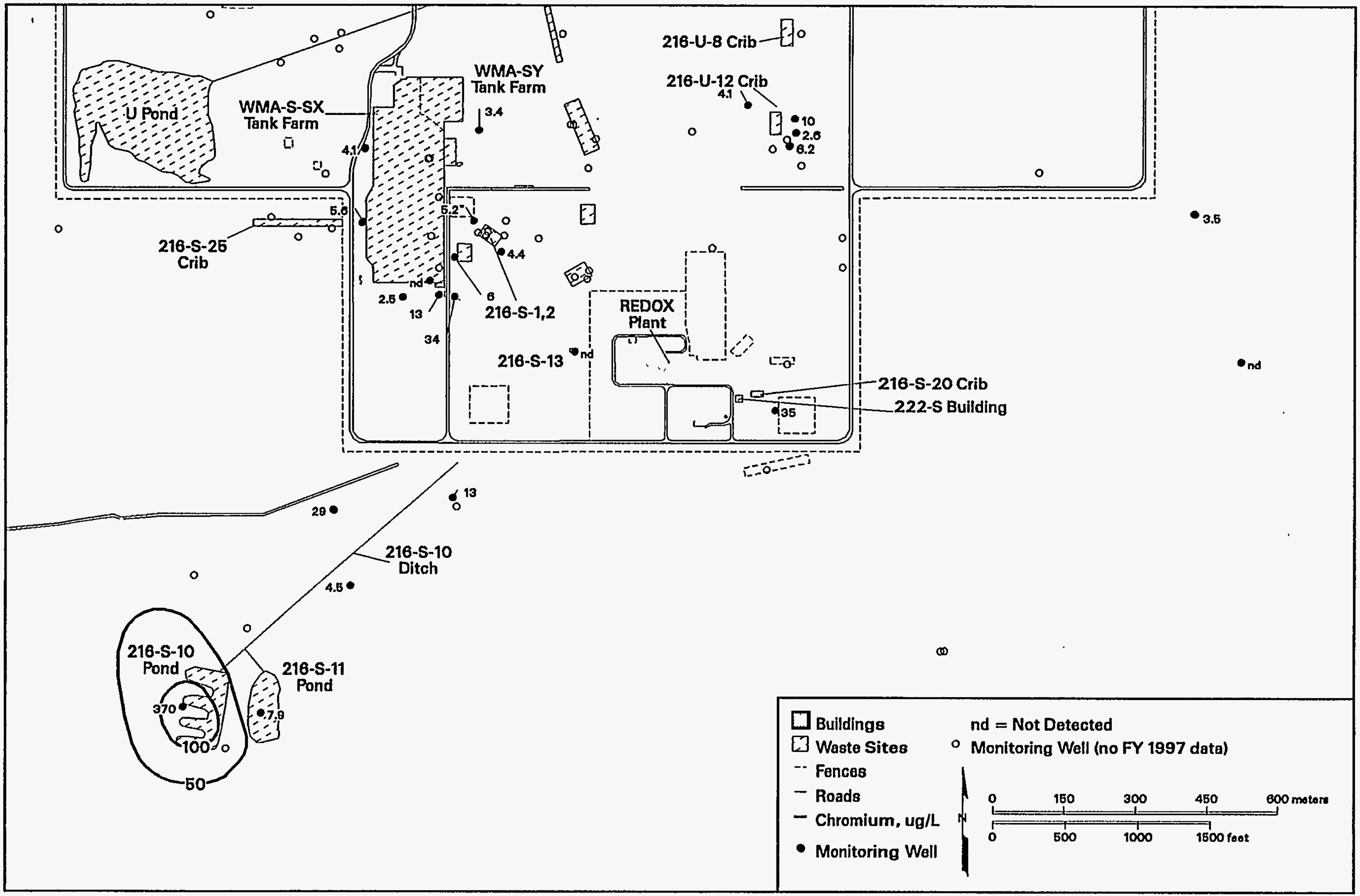

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Figure 5.9-12. Average Fiscal Year 1997 Chromium Concentrations in Wells Monitoring 216-S-10 Pond and Ditch

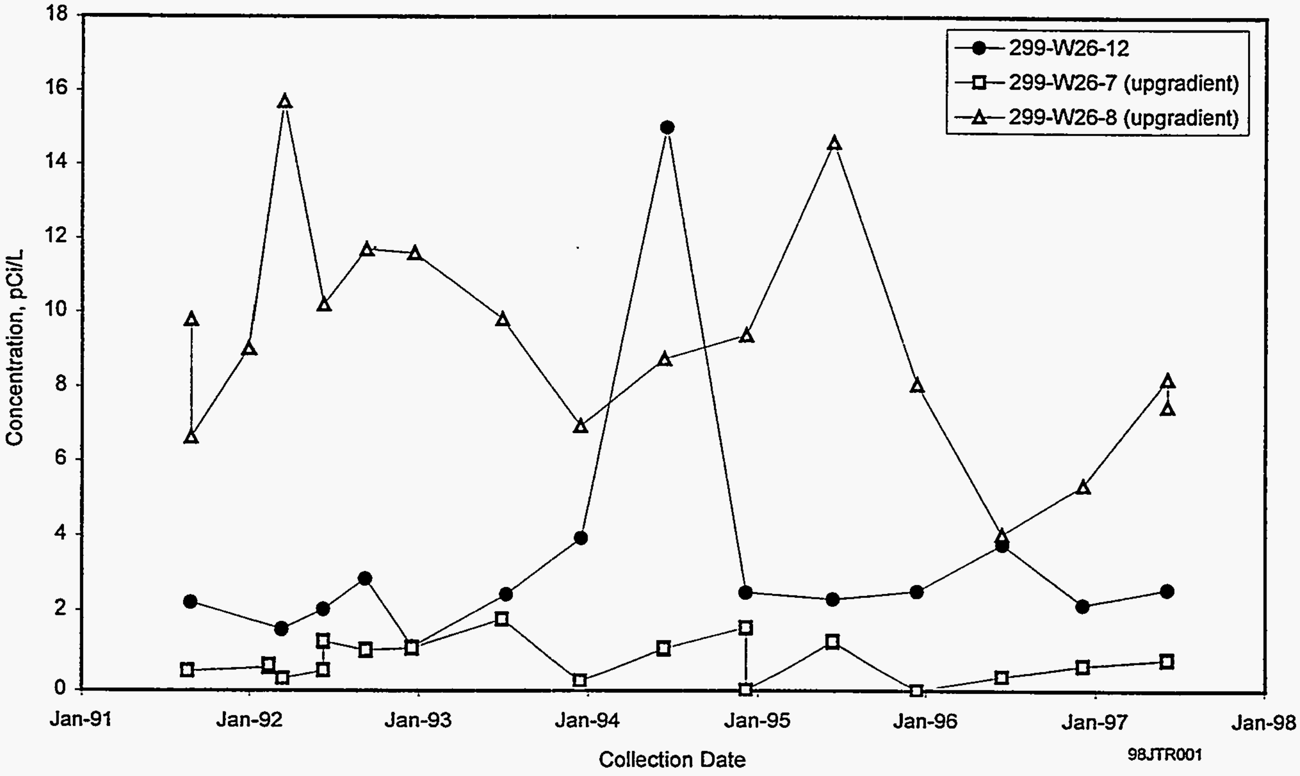

Figure 5.9-13. Gross Alpha Concentrations in Wells Monitoring 216-S-10 Pond and Ditch

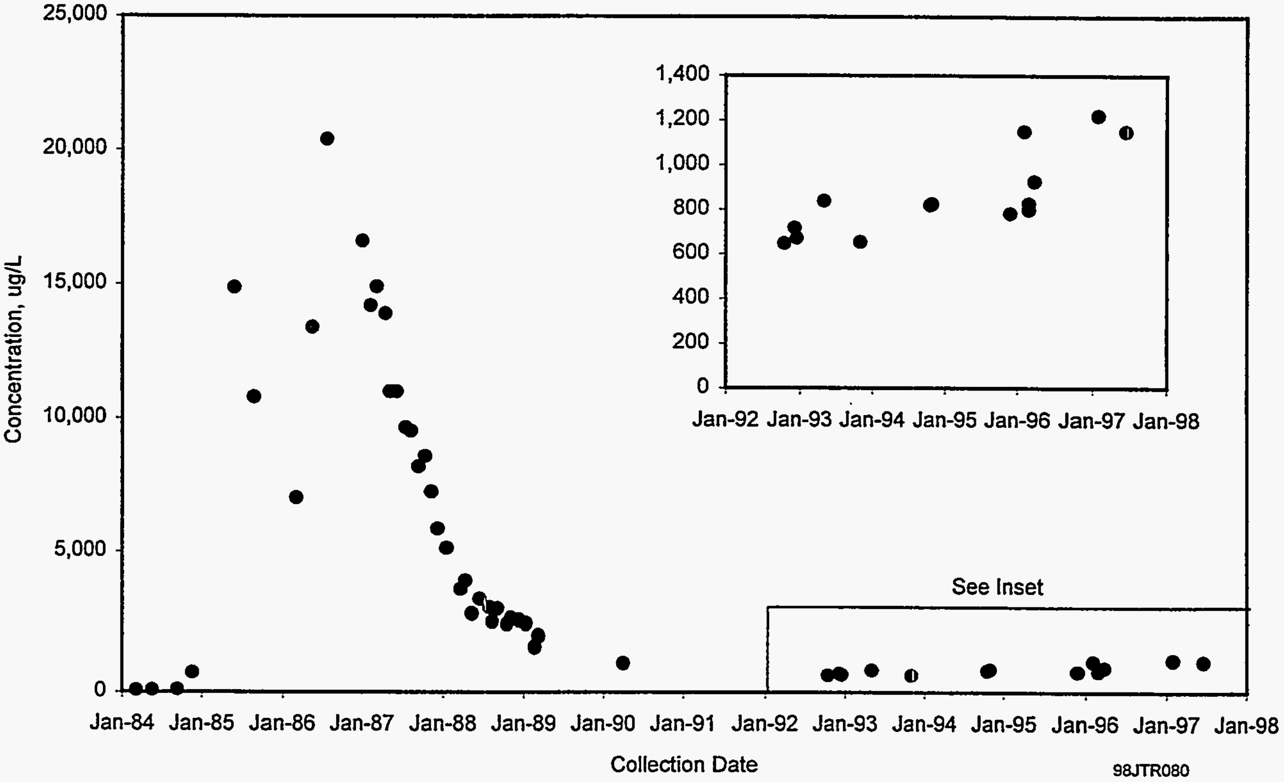

Figure 5.9-14. Uranium Concentrations in Well 299-W19-3

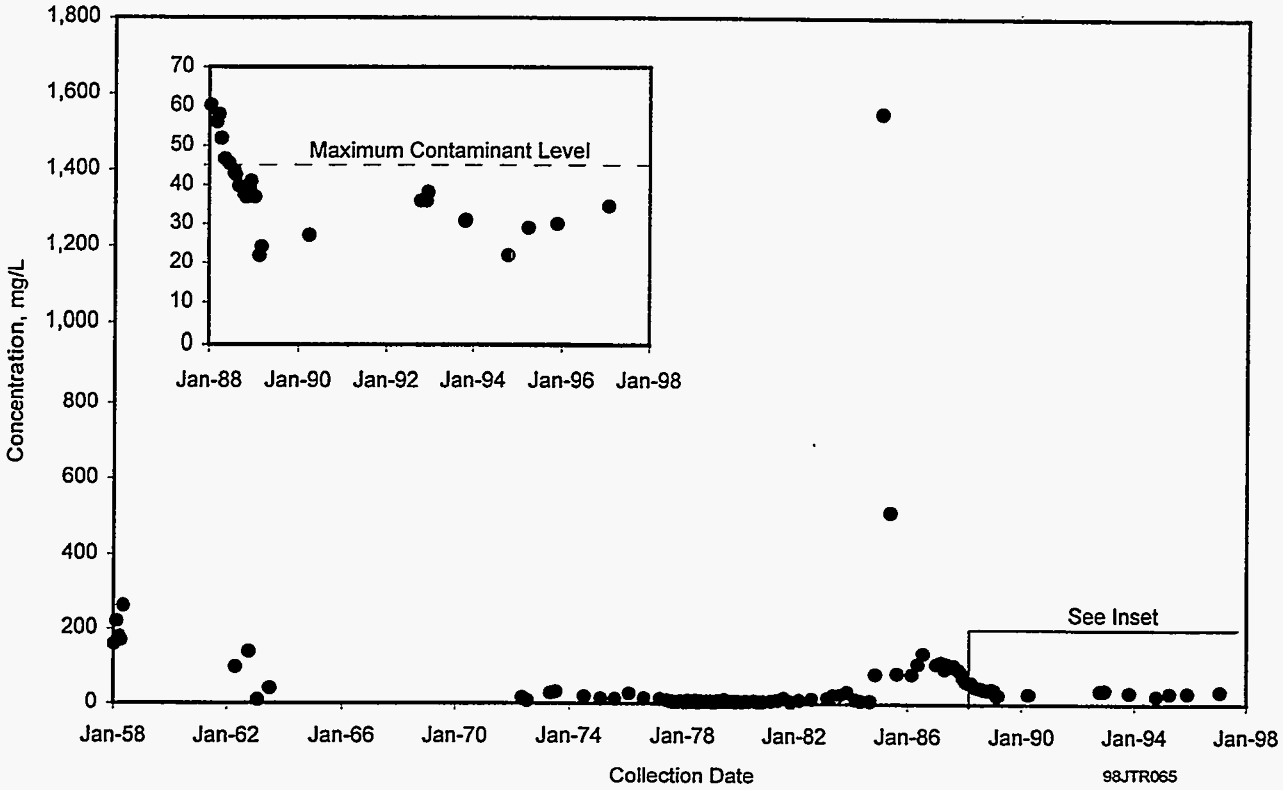

Figure 5.9-15. Nitrate Concentrations in Well 299-W19-3

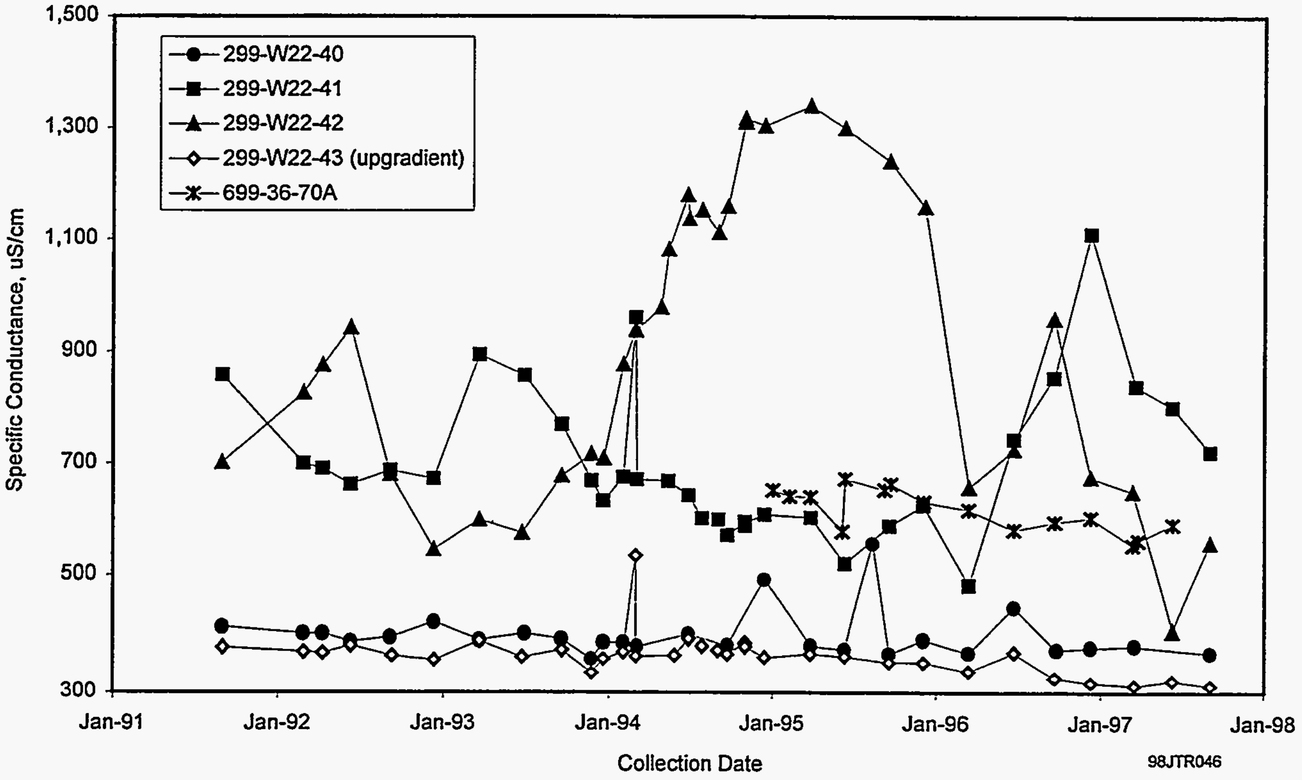

Figure 5.9-16. Specific Conductance in Wells Monitoring 216-U-12 Crib

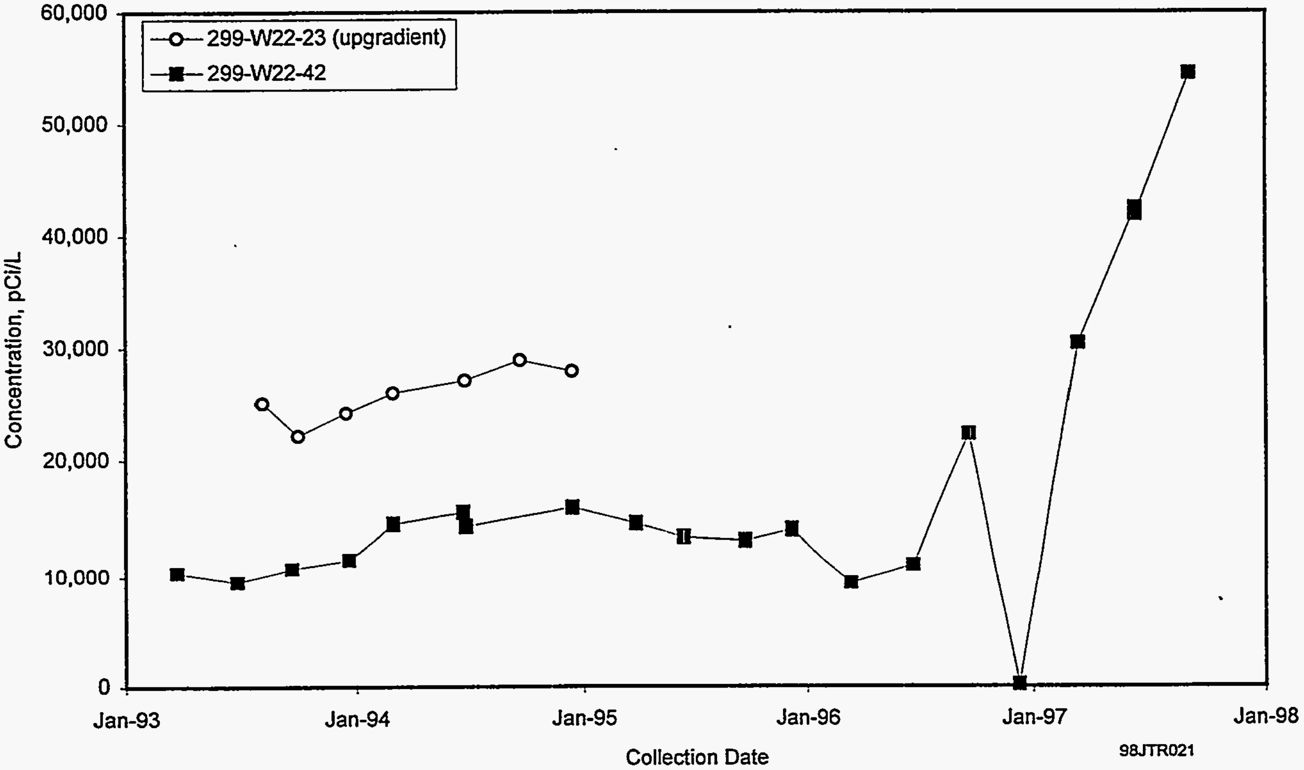

Figure 5.9-17. Tritium Concentrations in Wells Monitoring 216-U-12 Crib

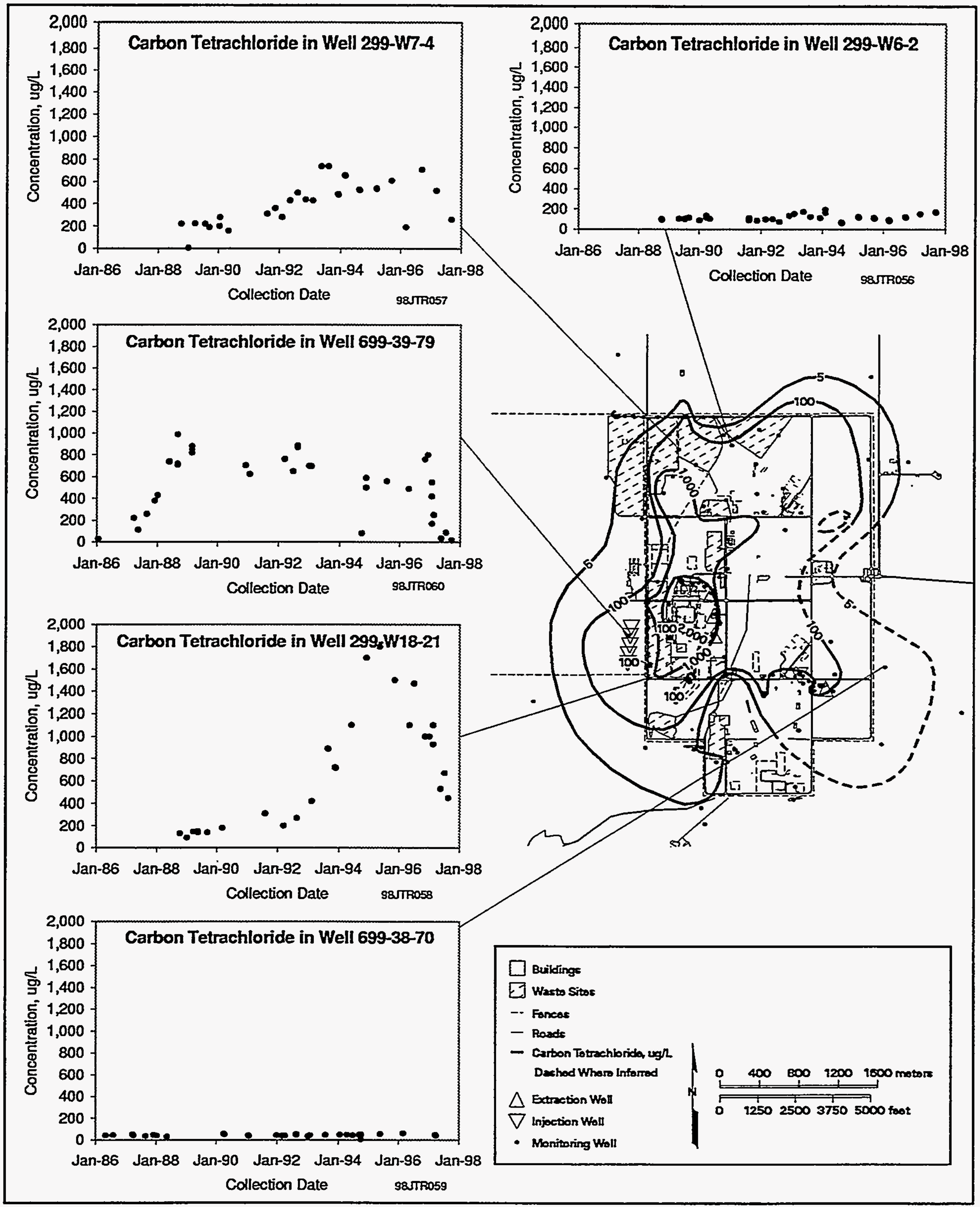

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Figure 5.9-18. Carbon Tetrachloride Concentrations in Wells Monitoring 200-West Area

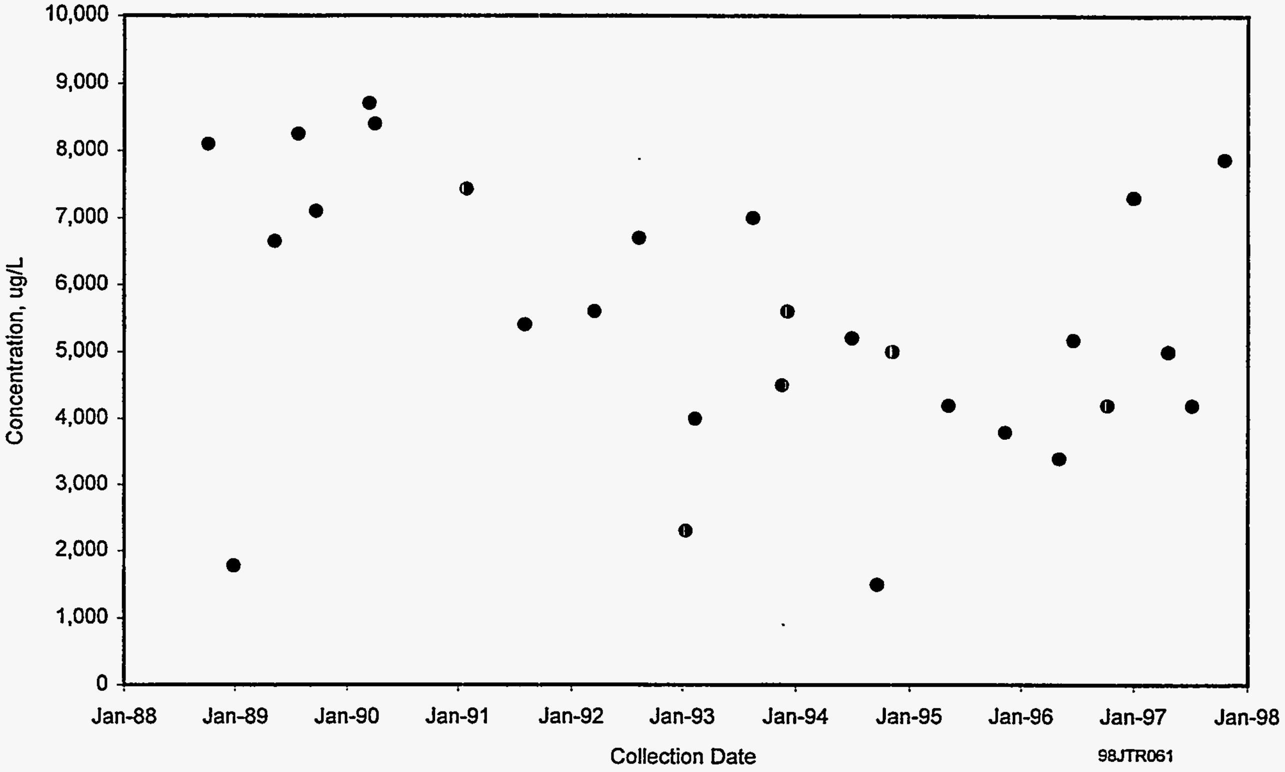


Figure 5.9-19. Carbon Tetrachloride Concentrations in Well 299-W15-16

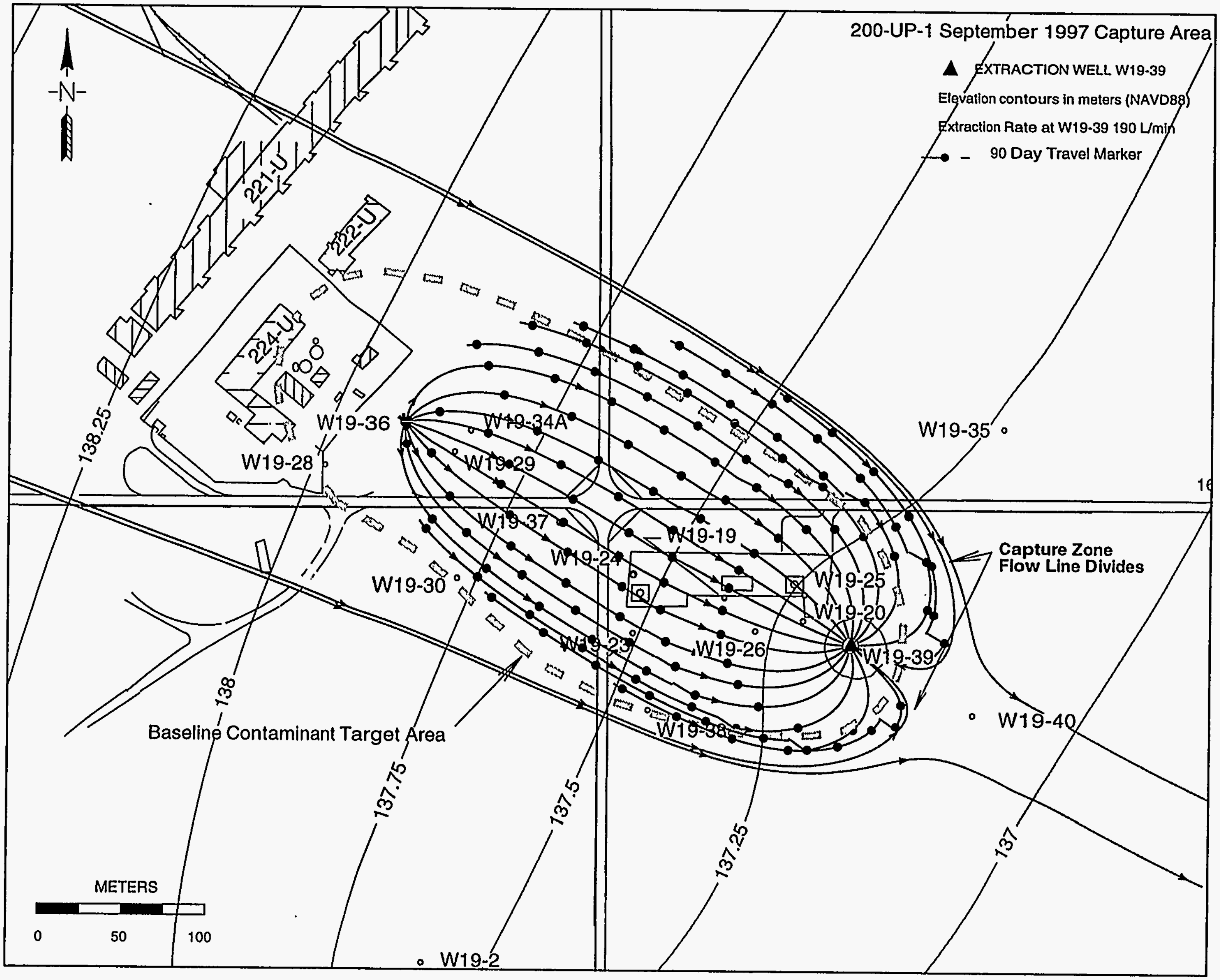


Figure 5.9-20. 200-UP-1 Operable Unit Pump-and-Treat Capture-Zone Analysis (from BHI-01126)

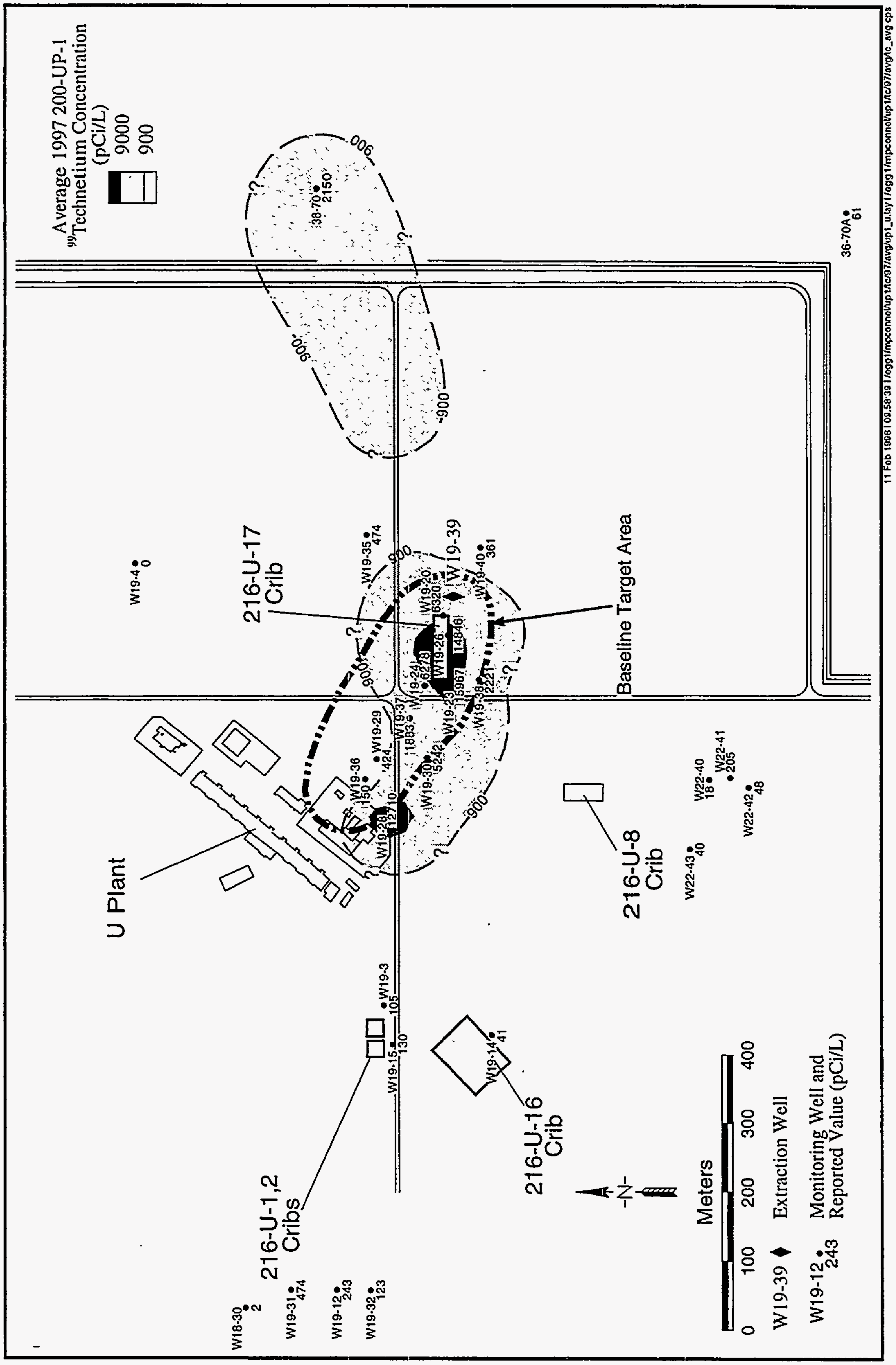


Figure 5.9-21. 200-UP-1 Operable Unit Technetium-99 Measurements (from BHI-01126)

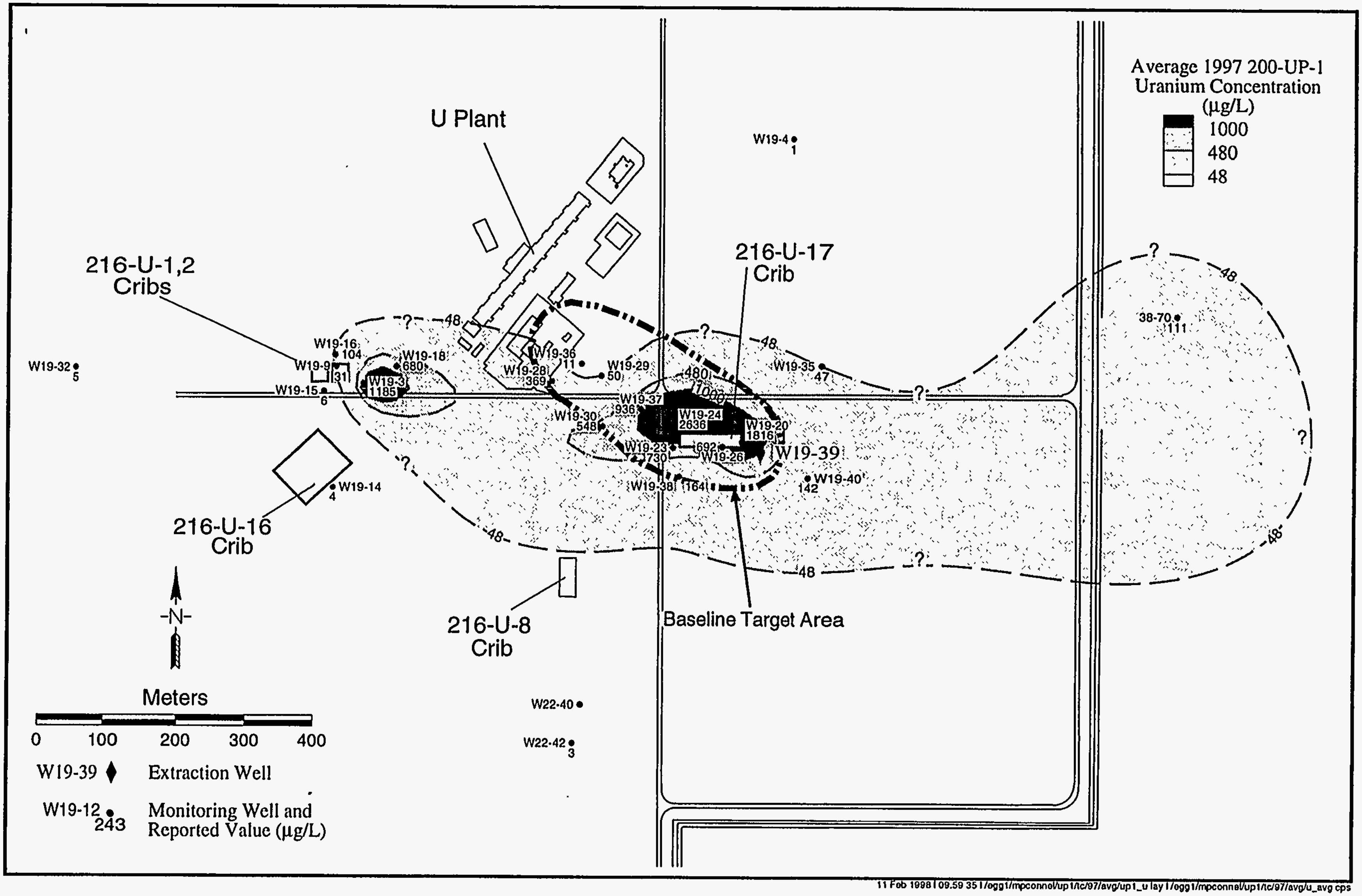


Figure 5.9-22. 200-UP-1 Operable Unit Uranium Measurements (from BHI-01126)

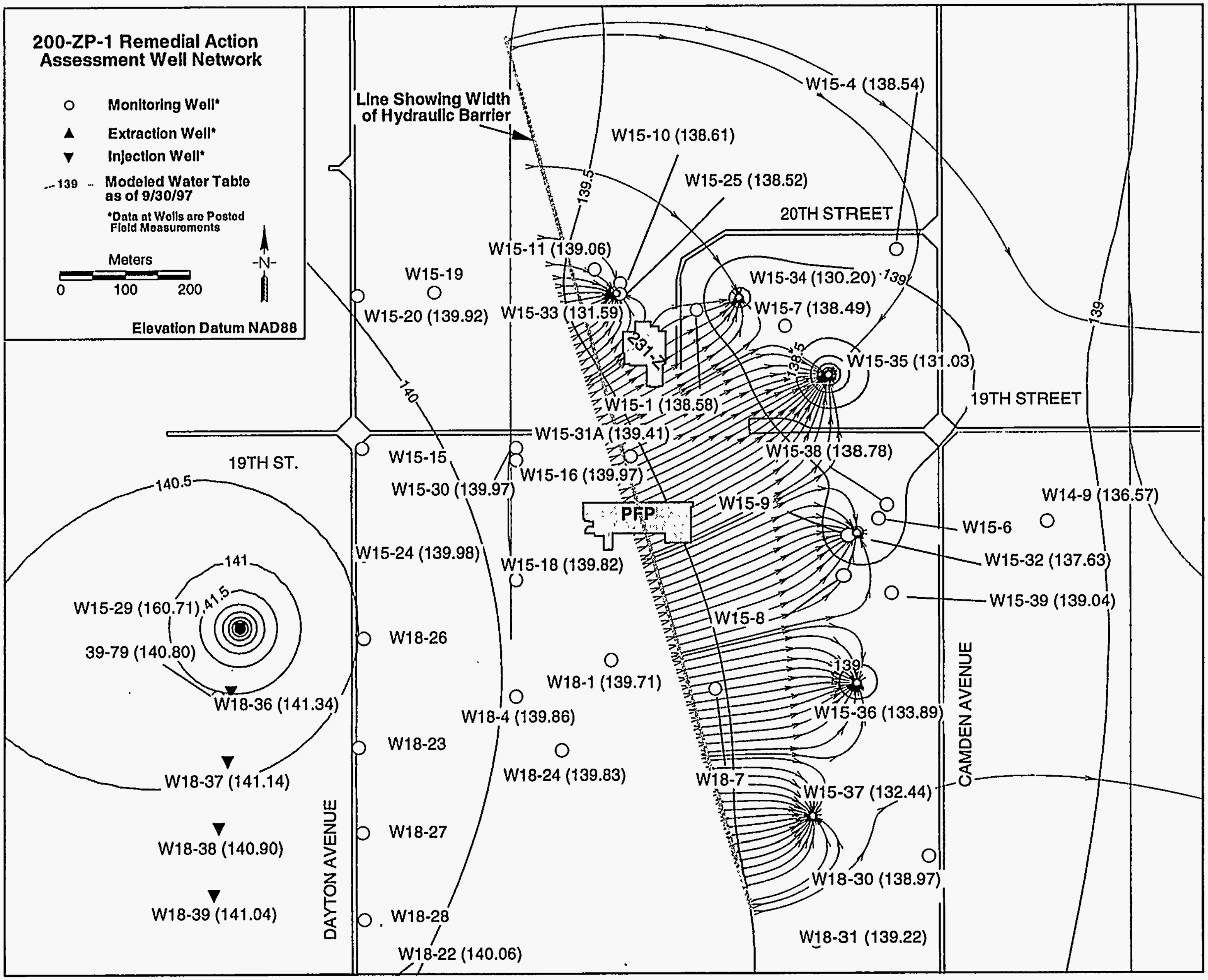
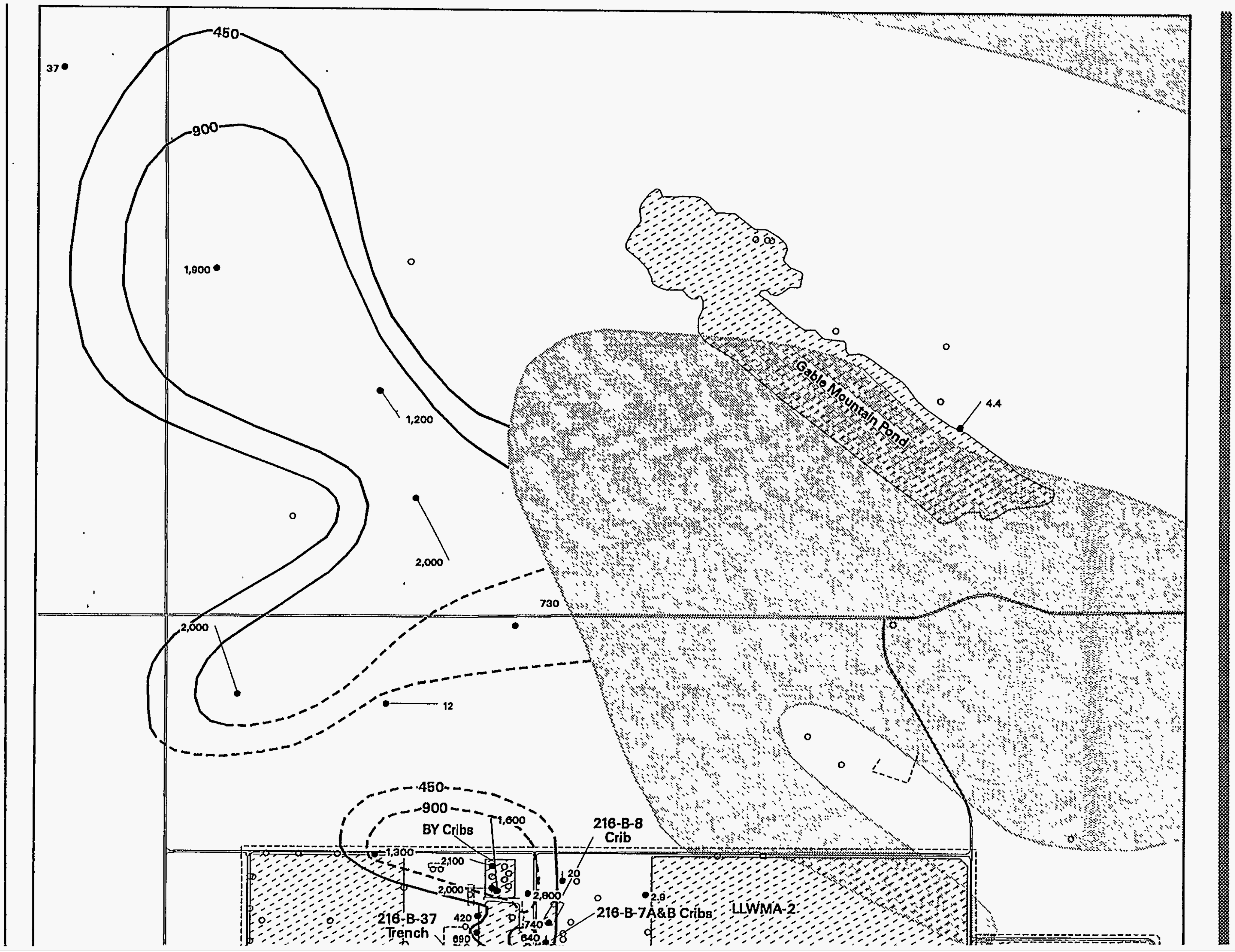


Figure 5.9-23. 200-ZP-1 Operable Unit Pump-and-Treat Capture-Zone Analysis (from BHI-01126)


450
900
37
1,900
1,200
2,000
730
2,000
12
Gable Mountain Pond
4.4
450
900
1,600
BY Cribs
216-B-8
Crib
1,300
2,100
2,000
20
2,800
2.9
216-B-37
Trench
420
690
740
640
216-B-7A&B Cribs
LLWMA-2

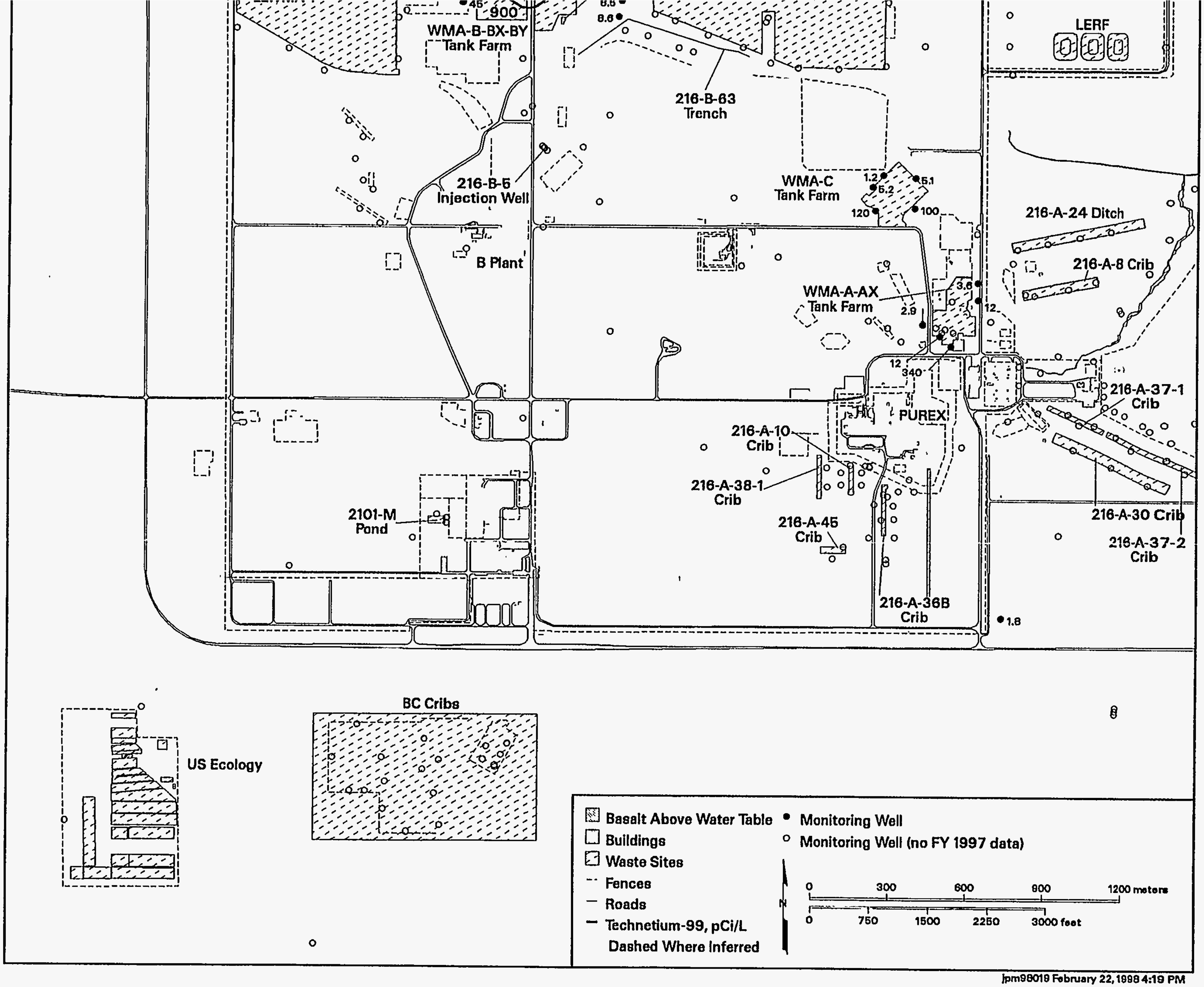


Figure 5.10-1. Average Fiscal Year 1997 Technetium-99 Concentrations in 200-East Area

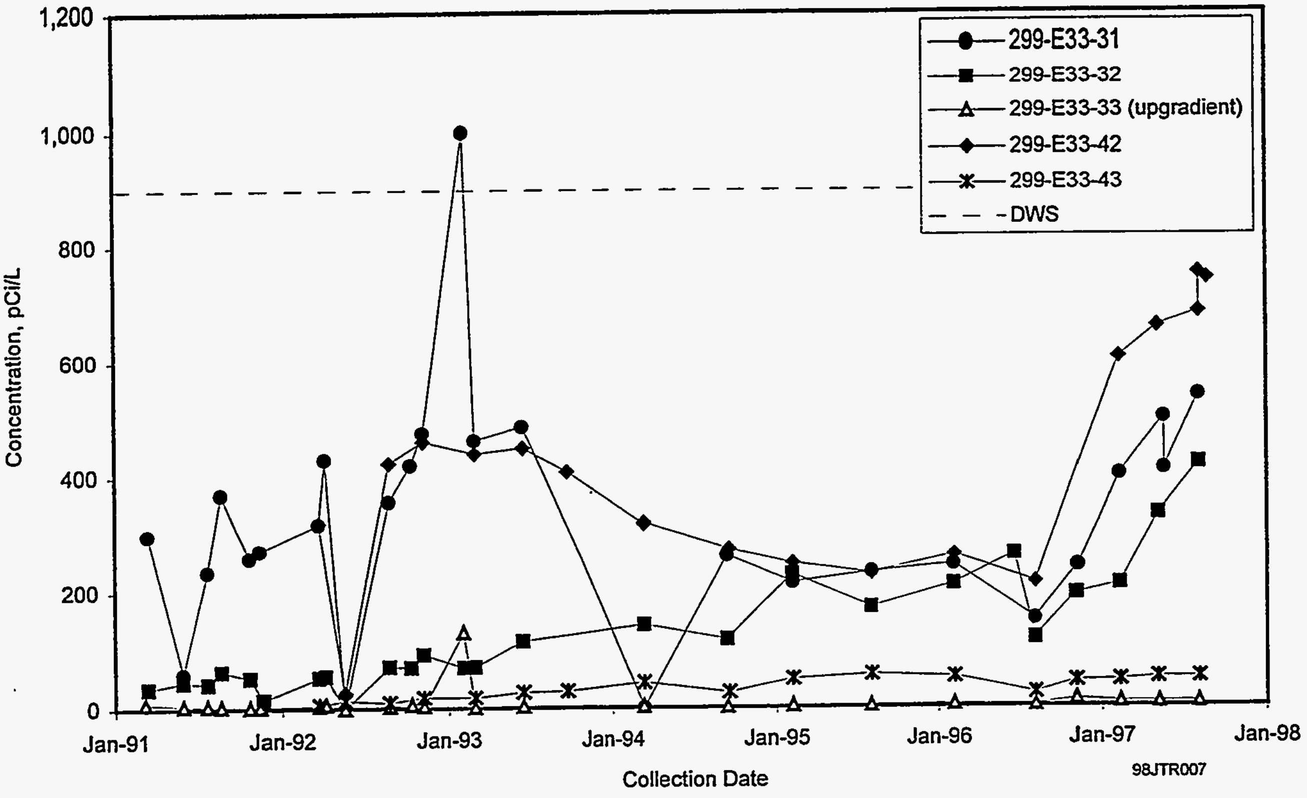


Figure 5.10-2. Technetium-99 Concentrations in Selected Wells Monitoring WMA B-BX-BY

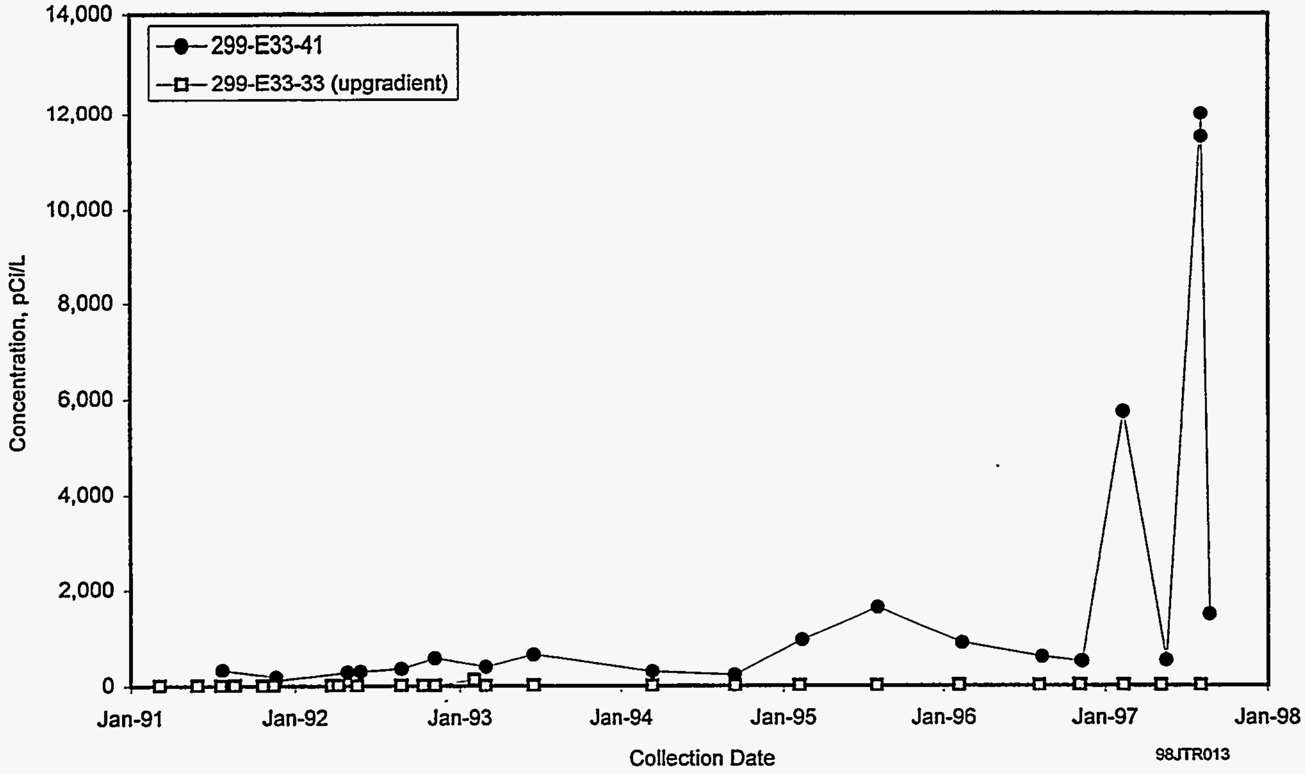


Figure 5.10-3. Technetium-99 Concentrations in Well 299-E33-41 Compared to Upgradient Well 299-E33-33

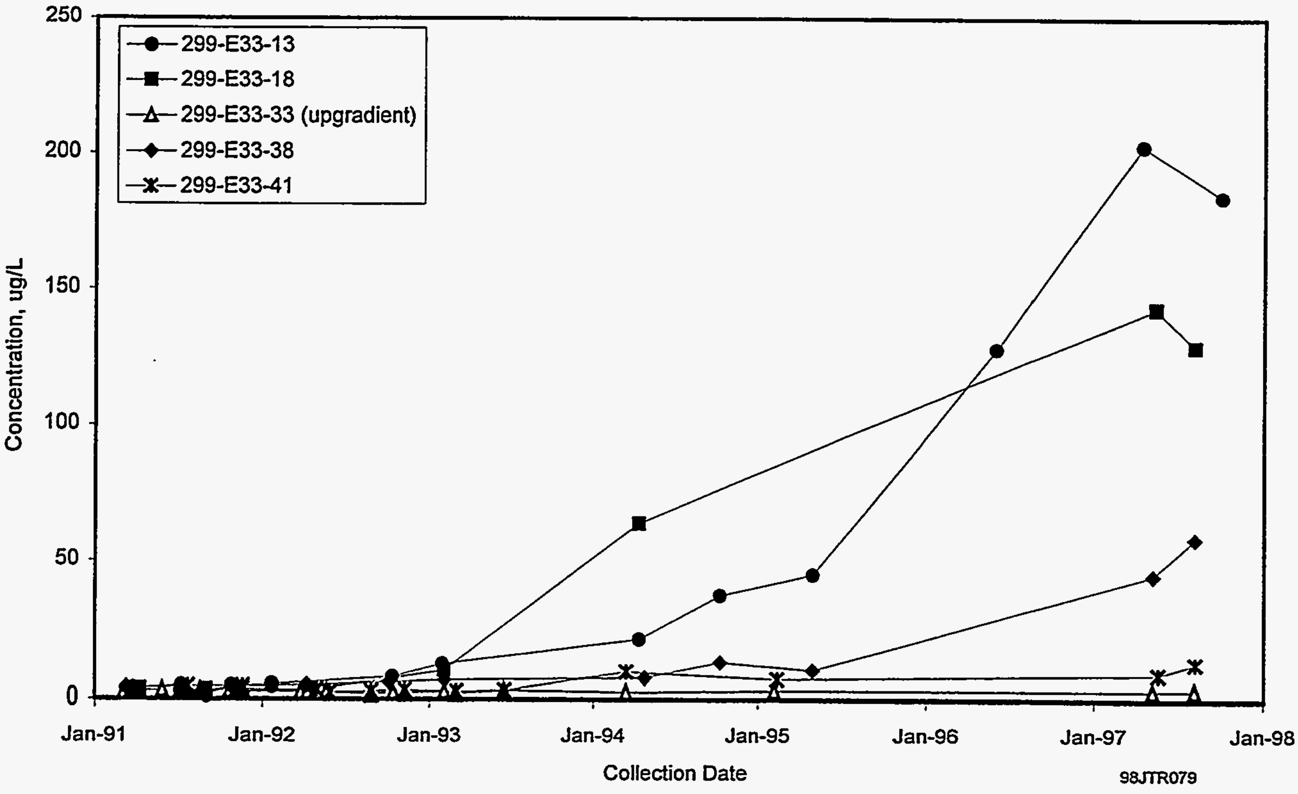
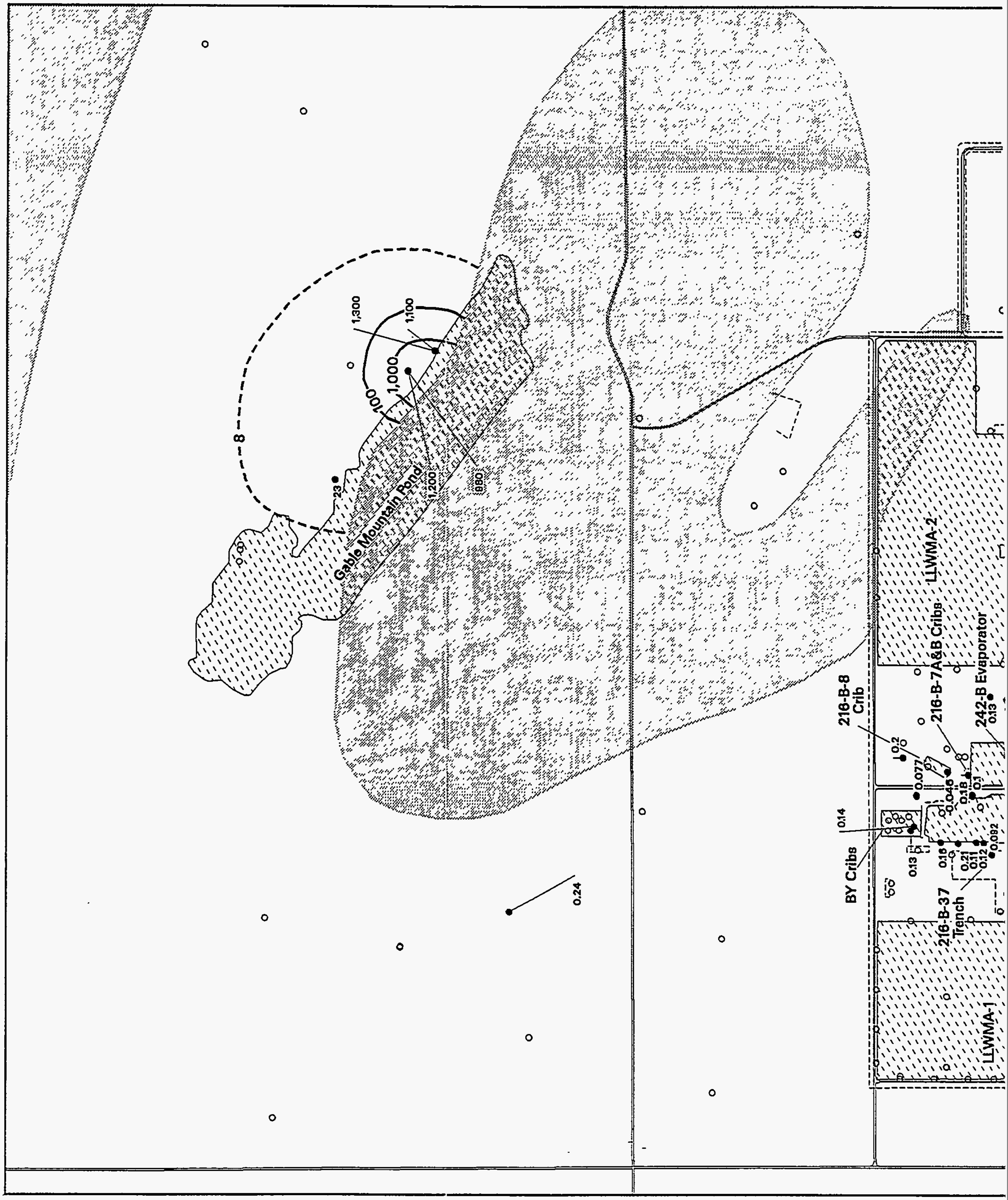


Figure 5.10-4. Uranium Concentrations in Wells in Vicinity of WMA B-BX-BY


Gable Mountain Pond
1,300
1,100
1,000
100
8
23
1,200
980
LLWMA-2
216-B-7A&B Cribs
242-B Evaporator
0.13
216-B-8 Crib
0.2
0.077
0.046
0.18
0.1
0.14
BY Cribs
0.13
0.18
0.21
0.11
0.12
0.092
216-B-37 Trench
0.24
LLWMA-1

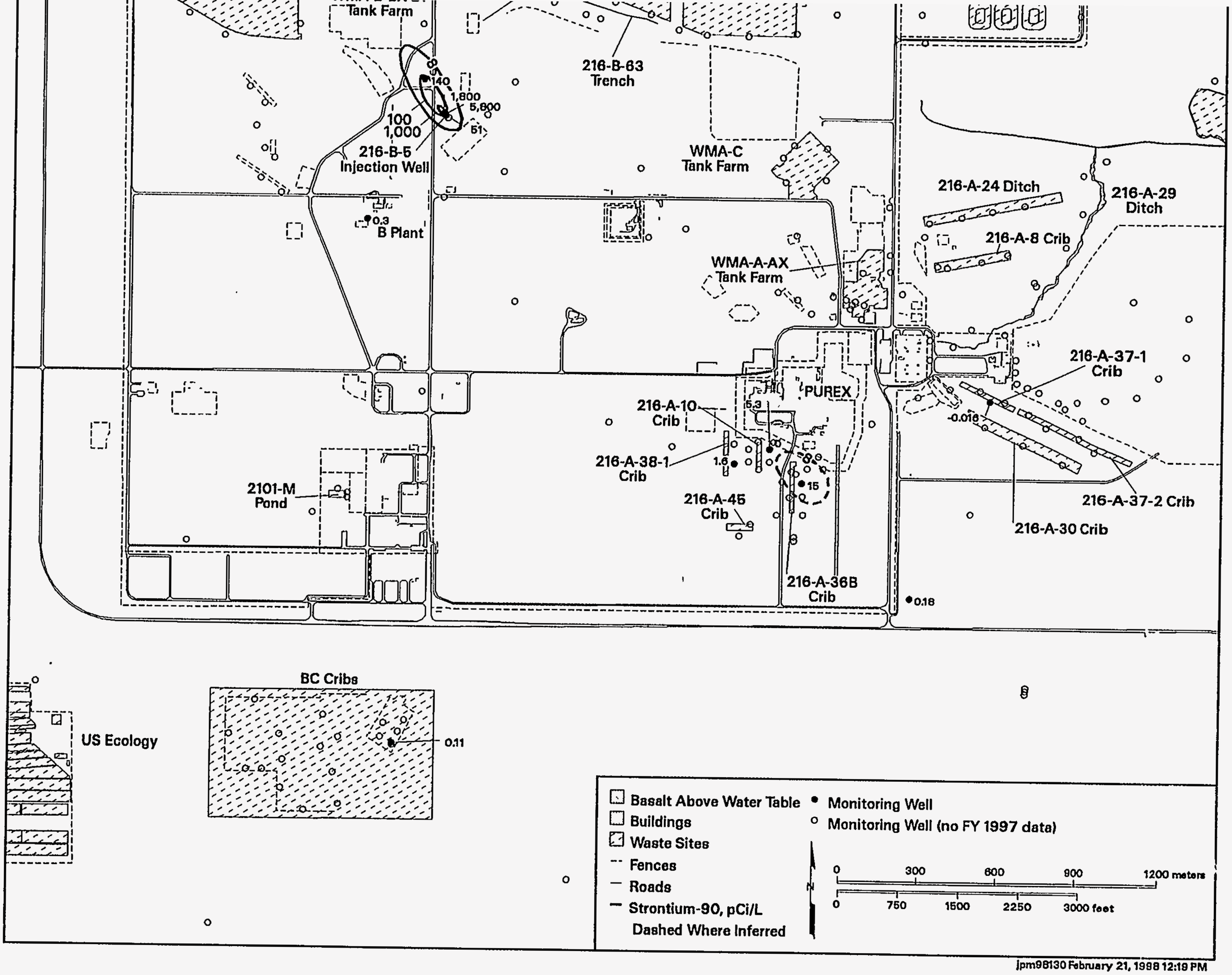


Figure 5.10-5. Average Fiscal Year 1997 Strontium-90 Concentrations in 200-East Area

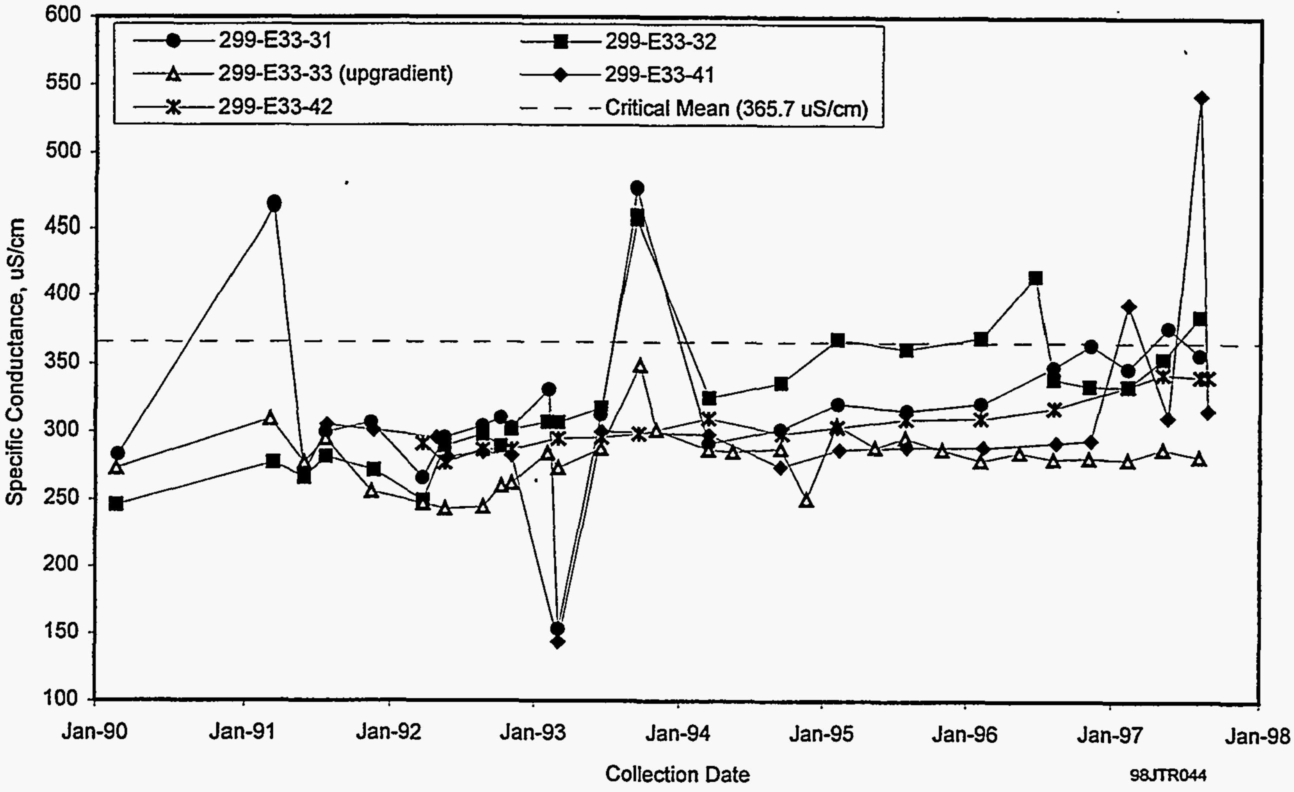
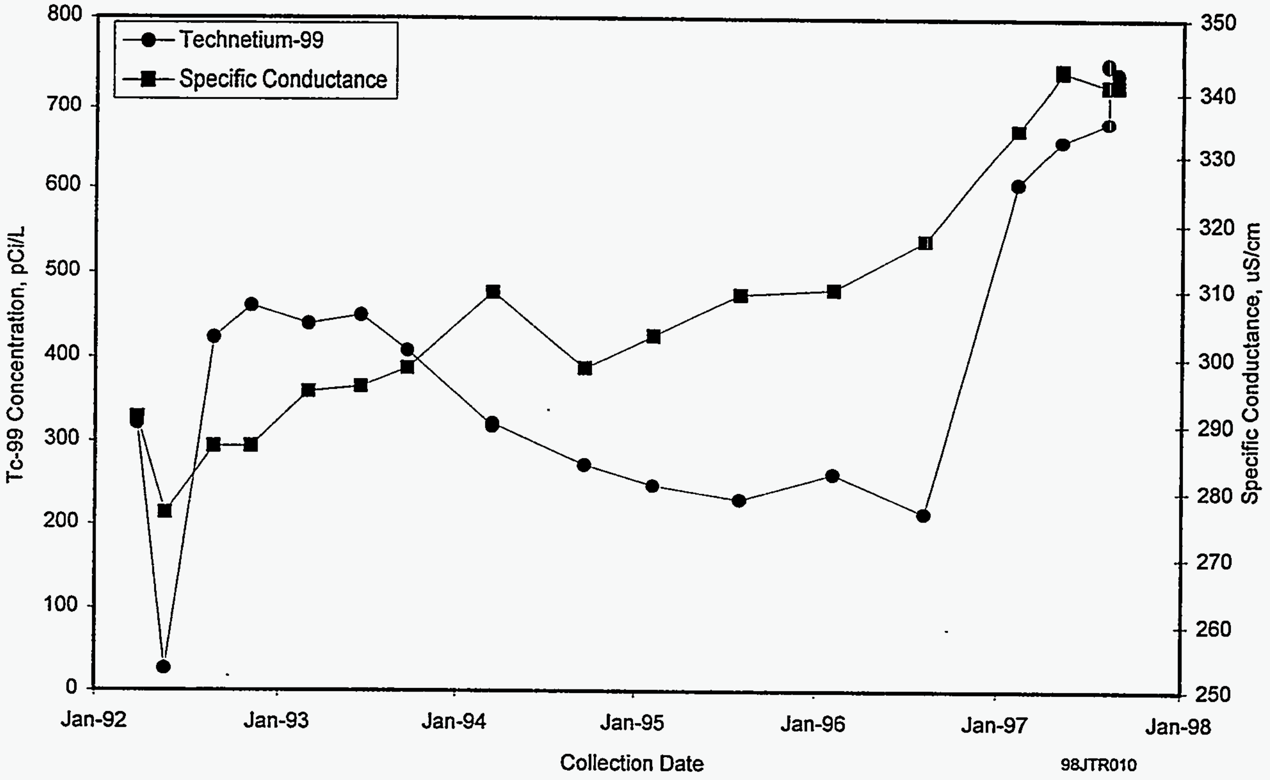


Figure 5.10-6. Specific Conductance in RCRA Wells Monitoring WMA B-BX-BY



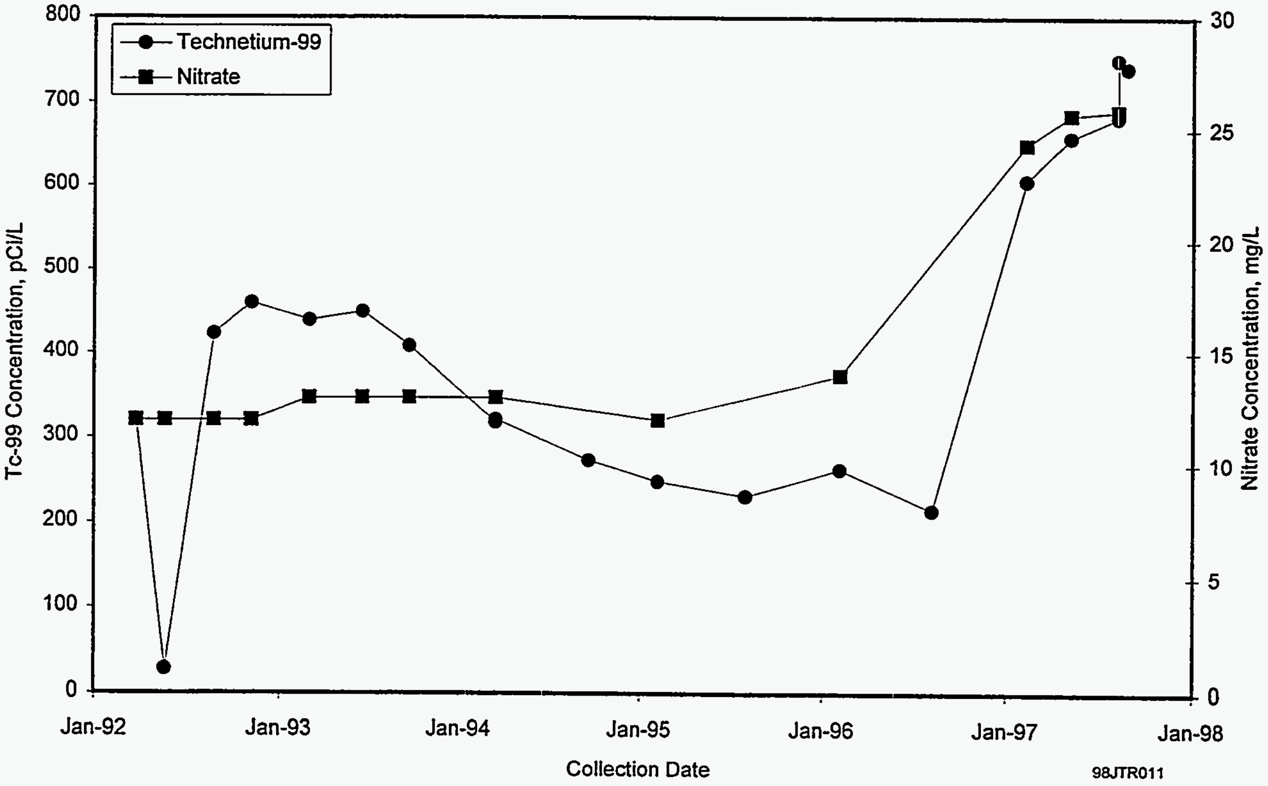


Figure 5.10-7. Specific Conductance and Nitrate Compared to Technetium-99 in Well 299-E33-42

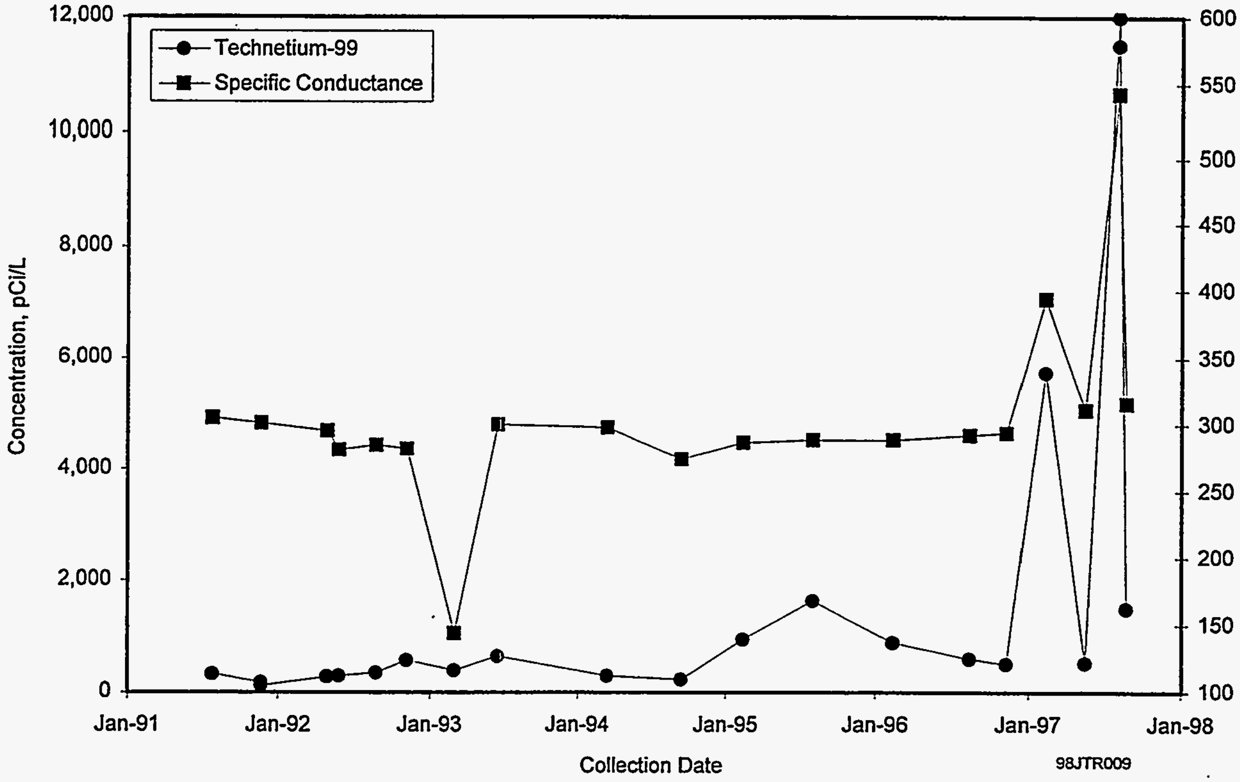


Figure 5.10-8. Specific Conductance and Technetium-99 Concentrations in Well 299-E33-41

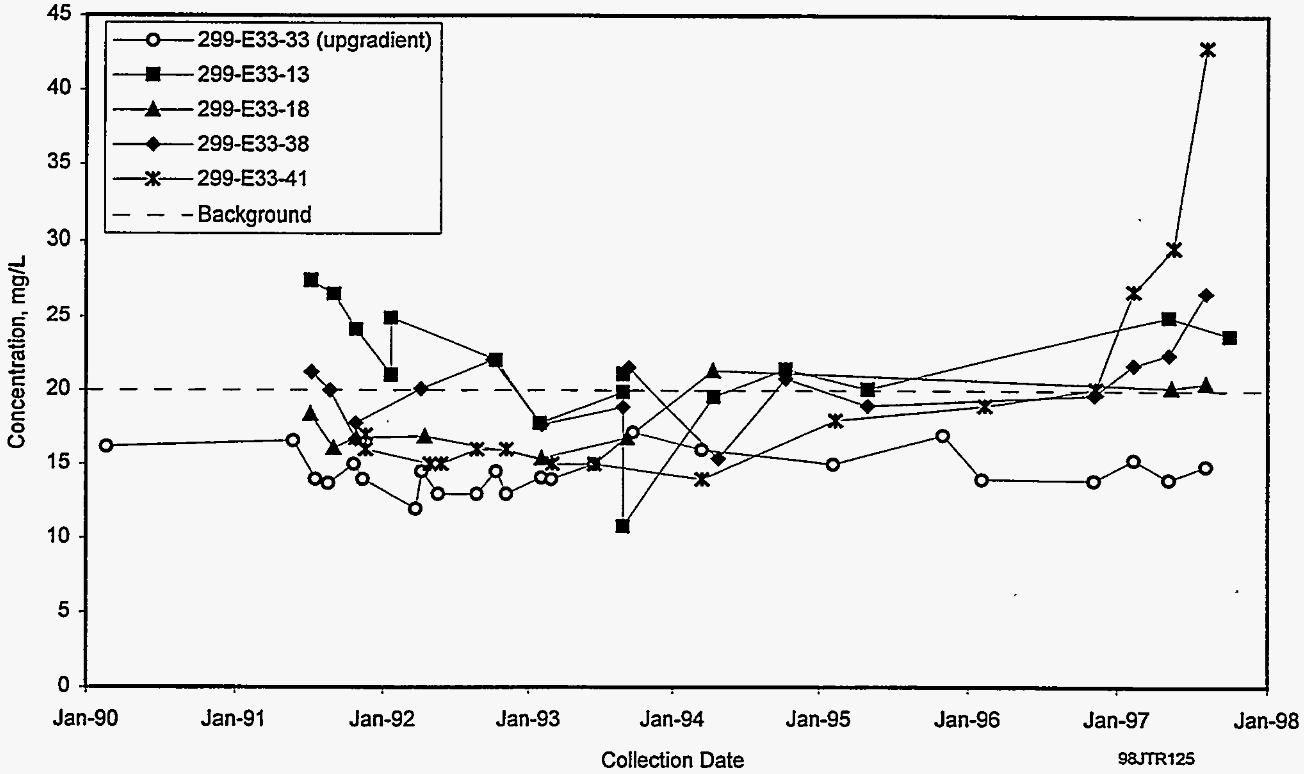


Figure 5.10-9. Filtered Sodium Concentrations in Wells Monitoring WMA B-BX-BY

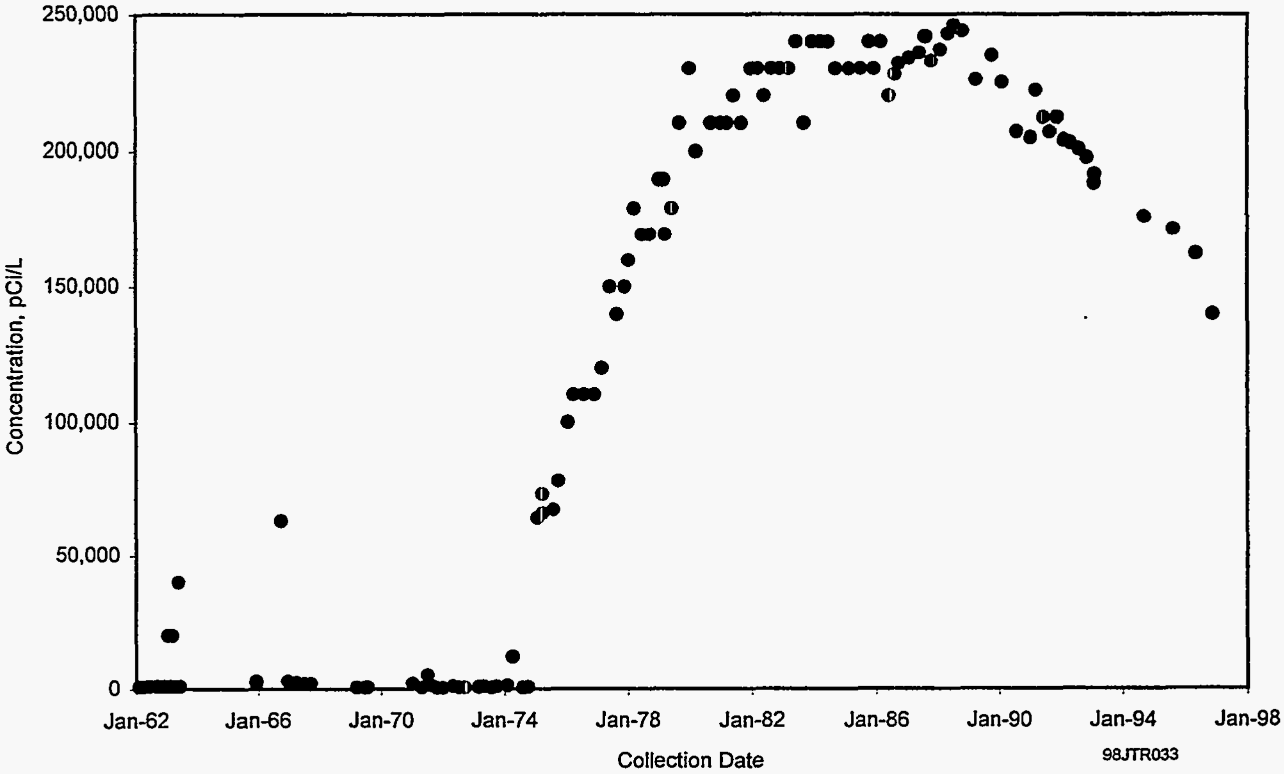


Figure 5.10-10. Tritium Concentrations in Well 699-40-1

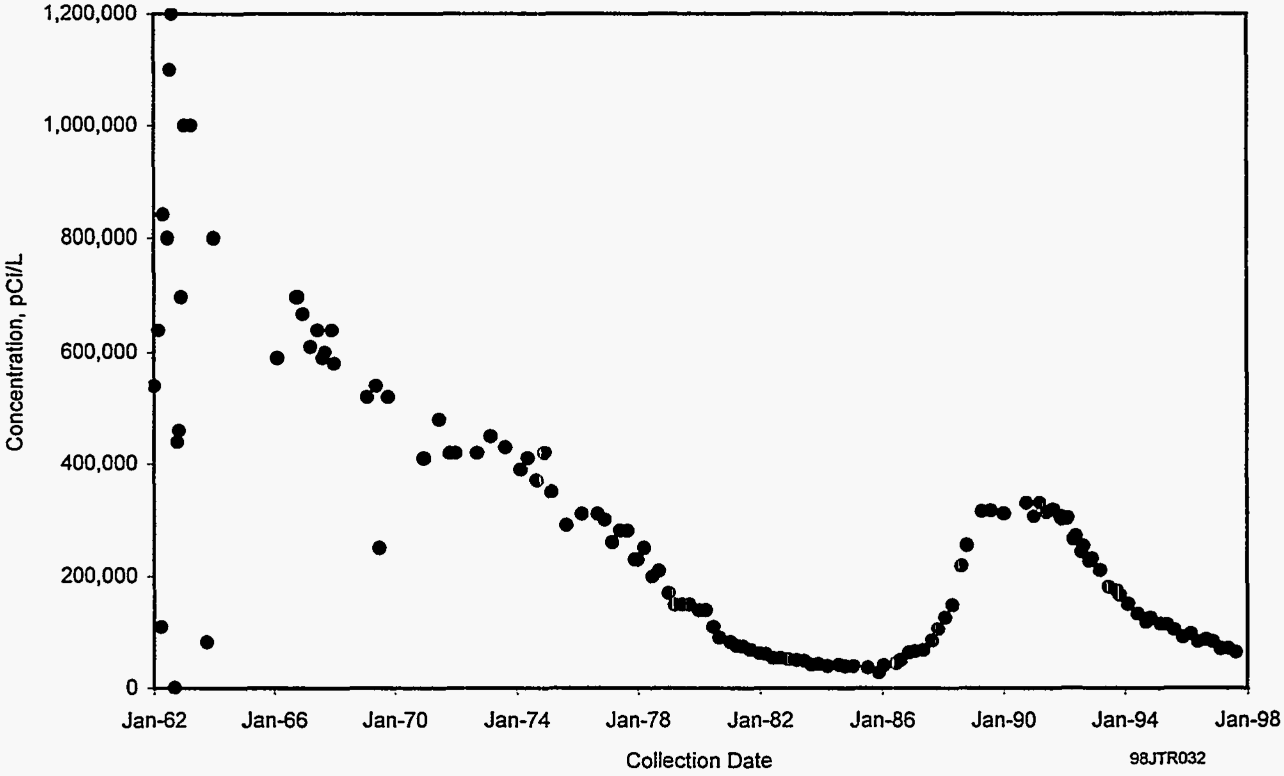


Figure 5.10-11. Tritium Concentrations in Well 699-24-33

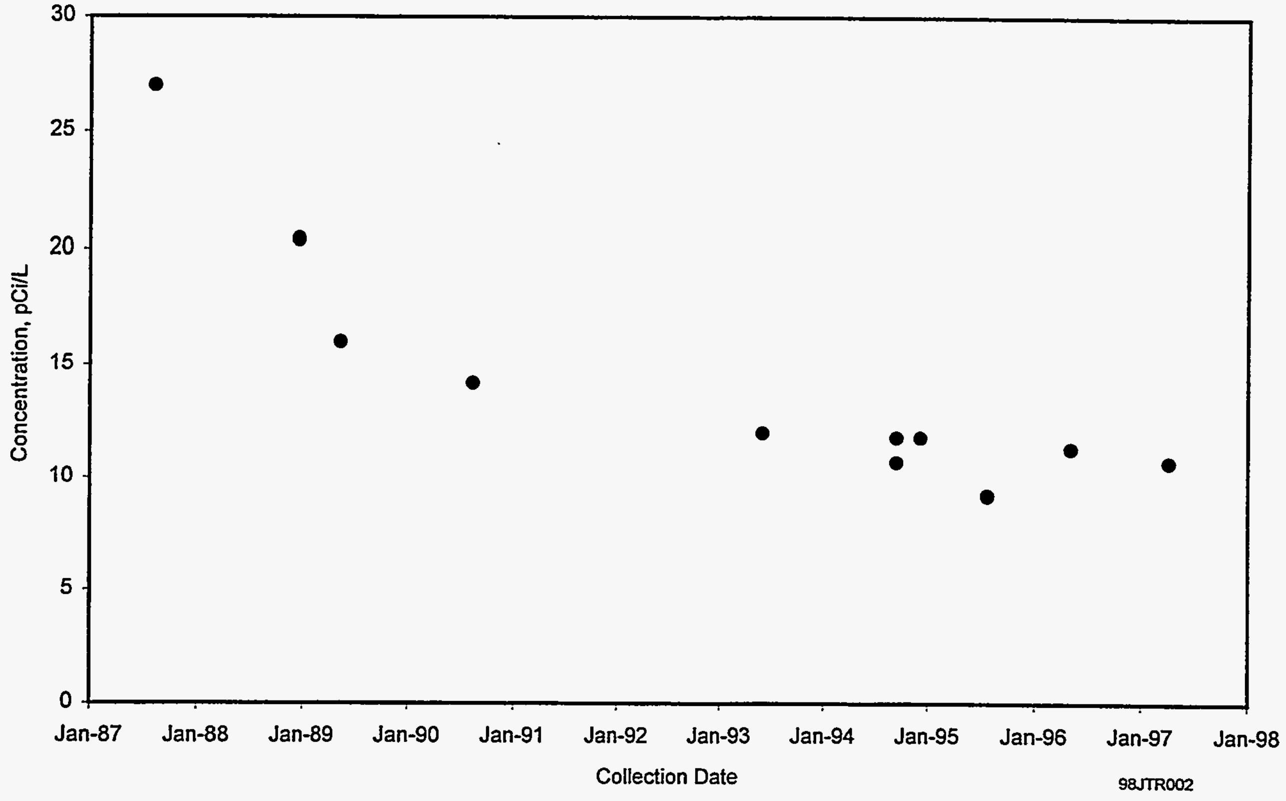


Figure 5.10-12. Iodine-129 Concentrations in Well 299-E17-9

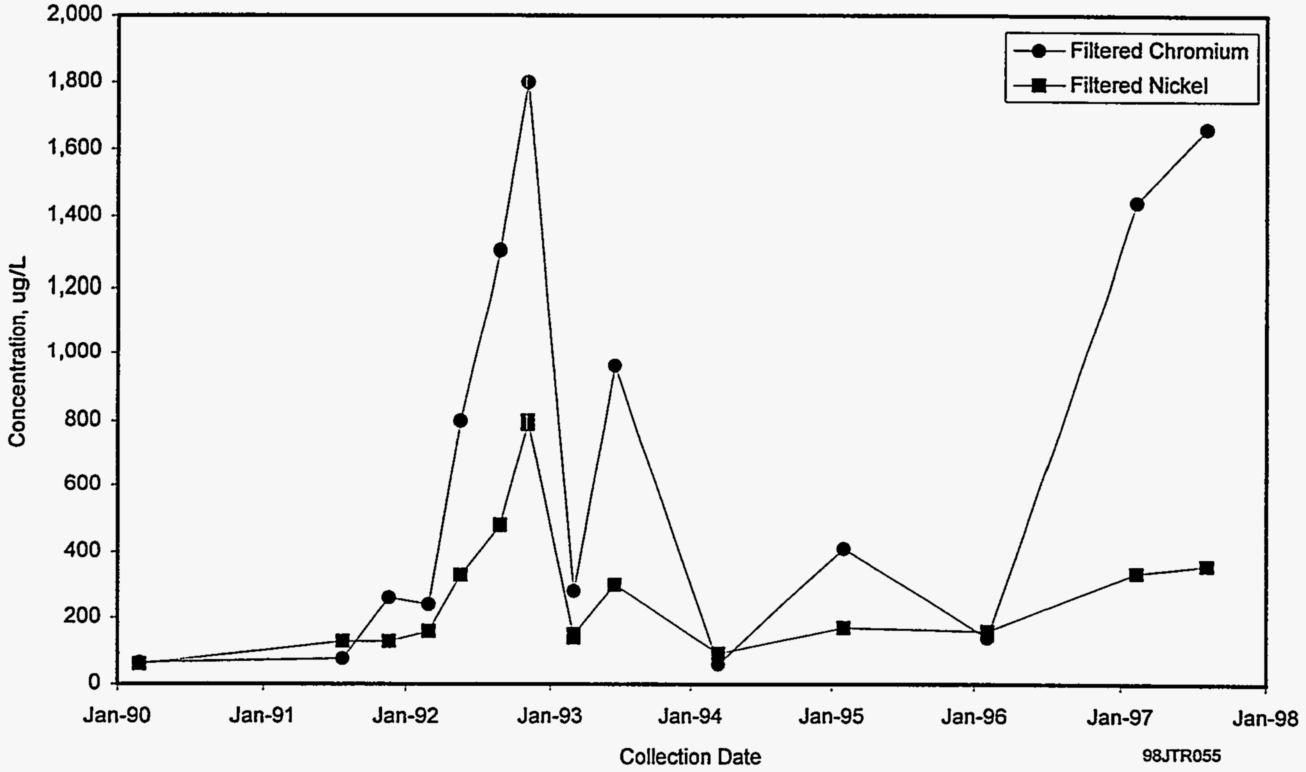


Figure 5.10-13. Filtered Chromium and Nickel Concentrations in Well 299-E24-19

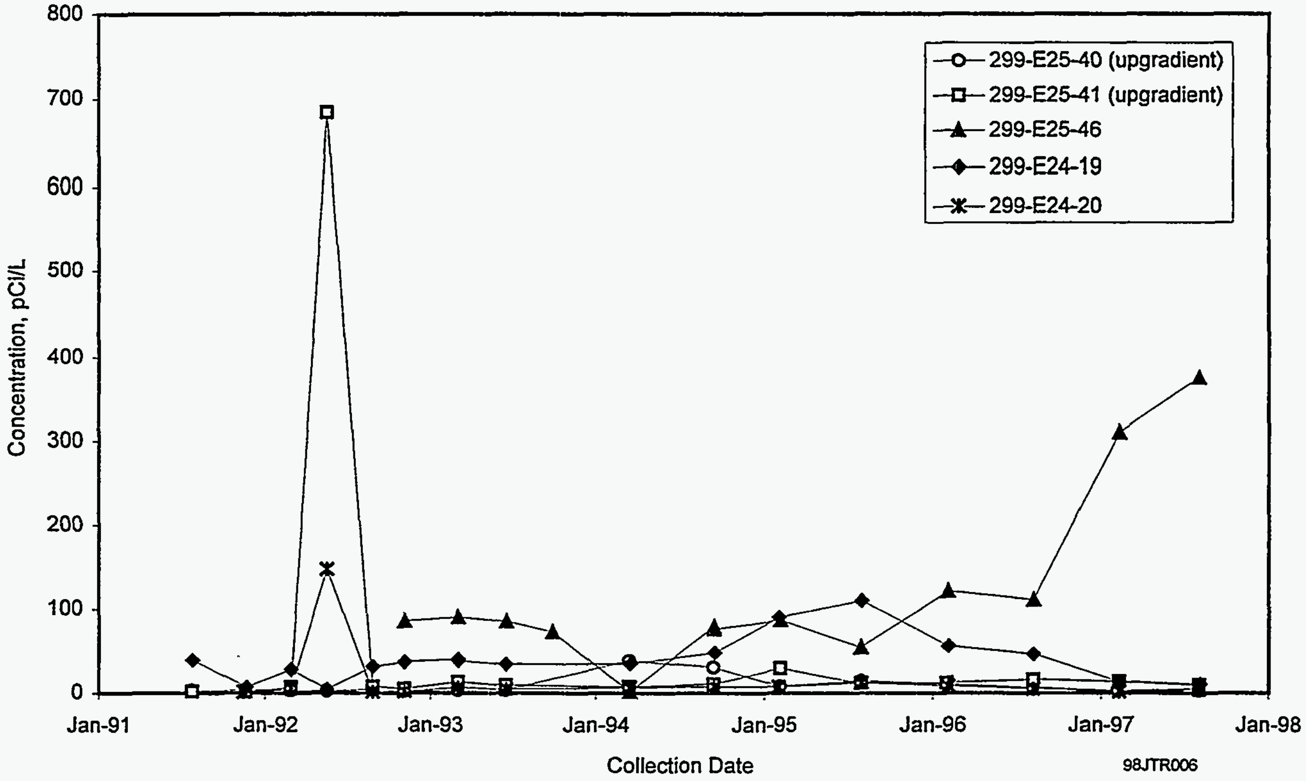


Figure 5.10-14. Technetium-99 Concentrations in Wells Monitoring WMA A-AX

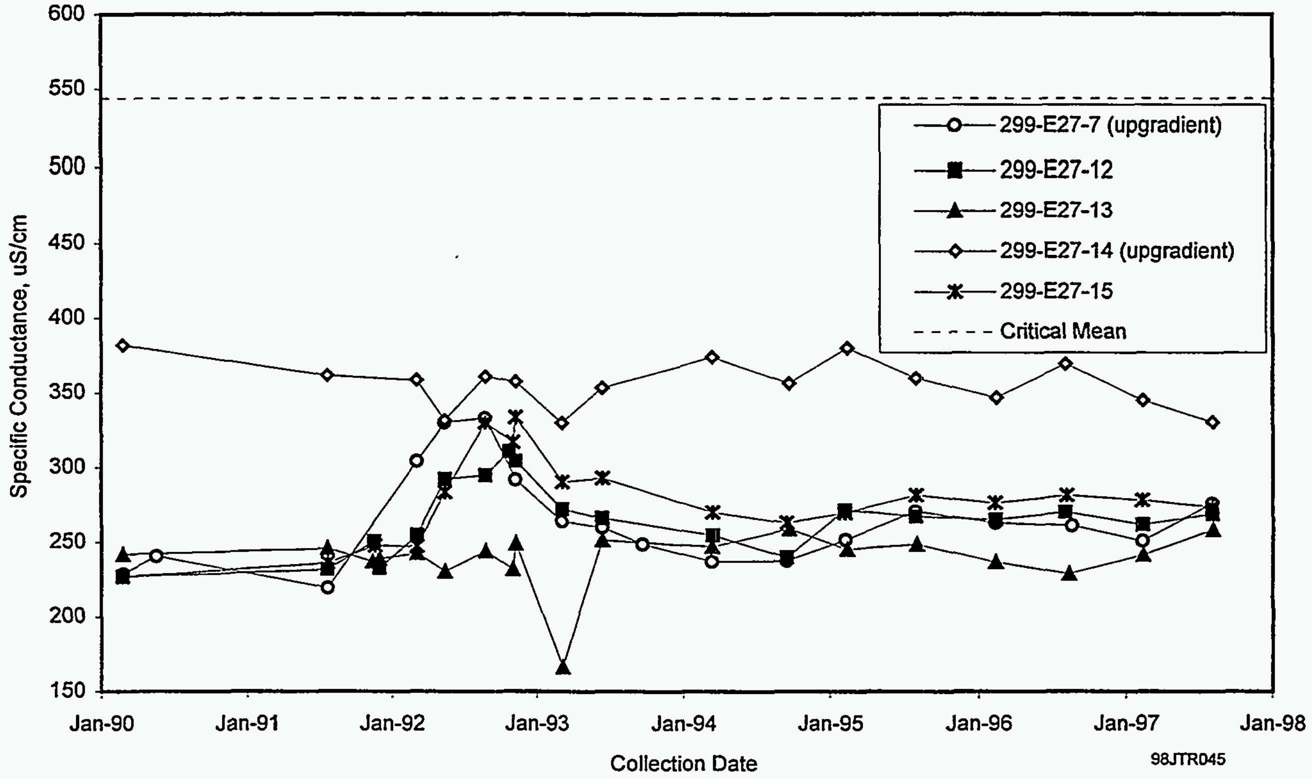


Figure 5.10-15. Specific Conductance in Wells Monitoring WMA C

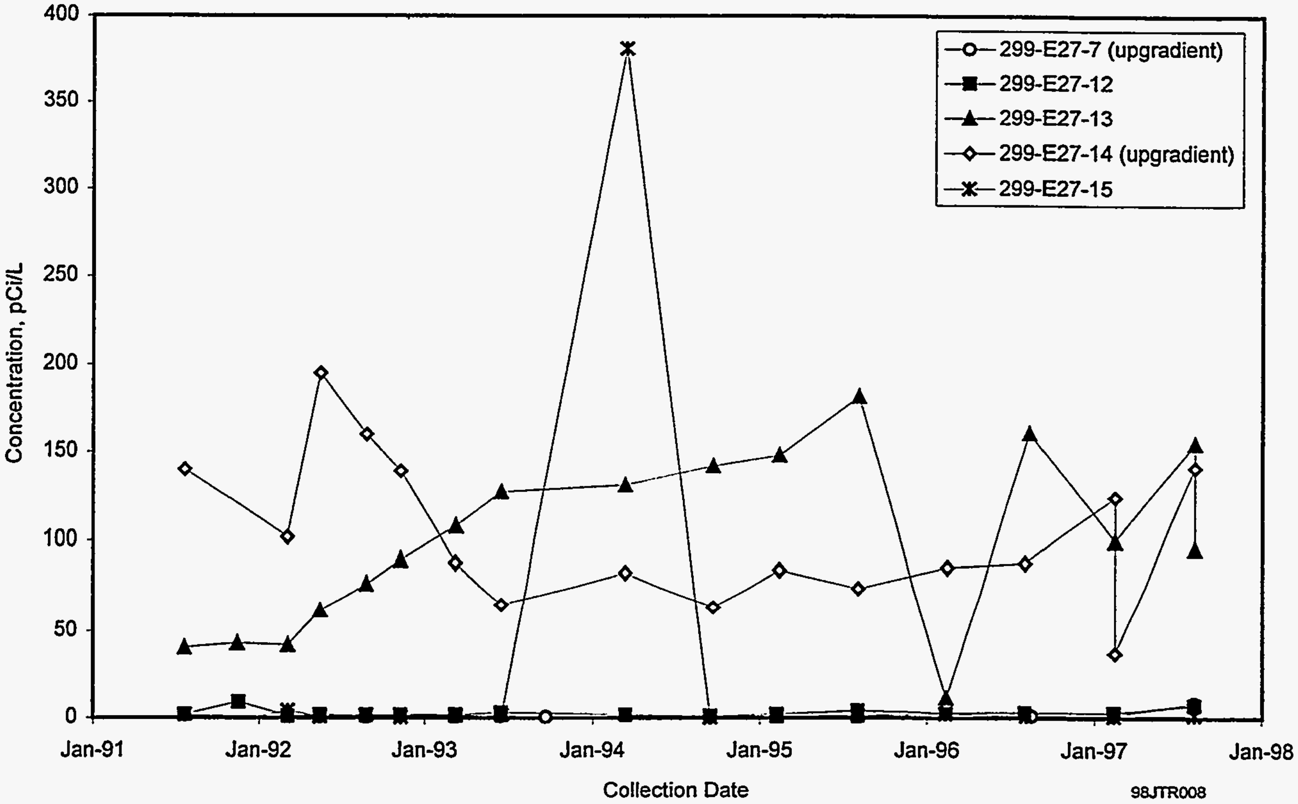


Figure 5.10-16. Technetium-99 Concentrations in Wells Monitoring WMA C

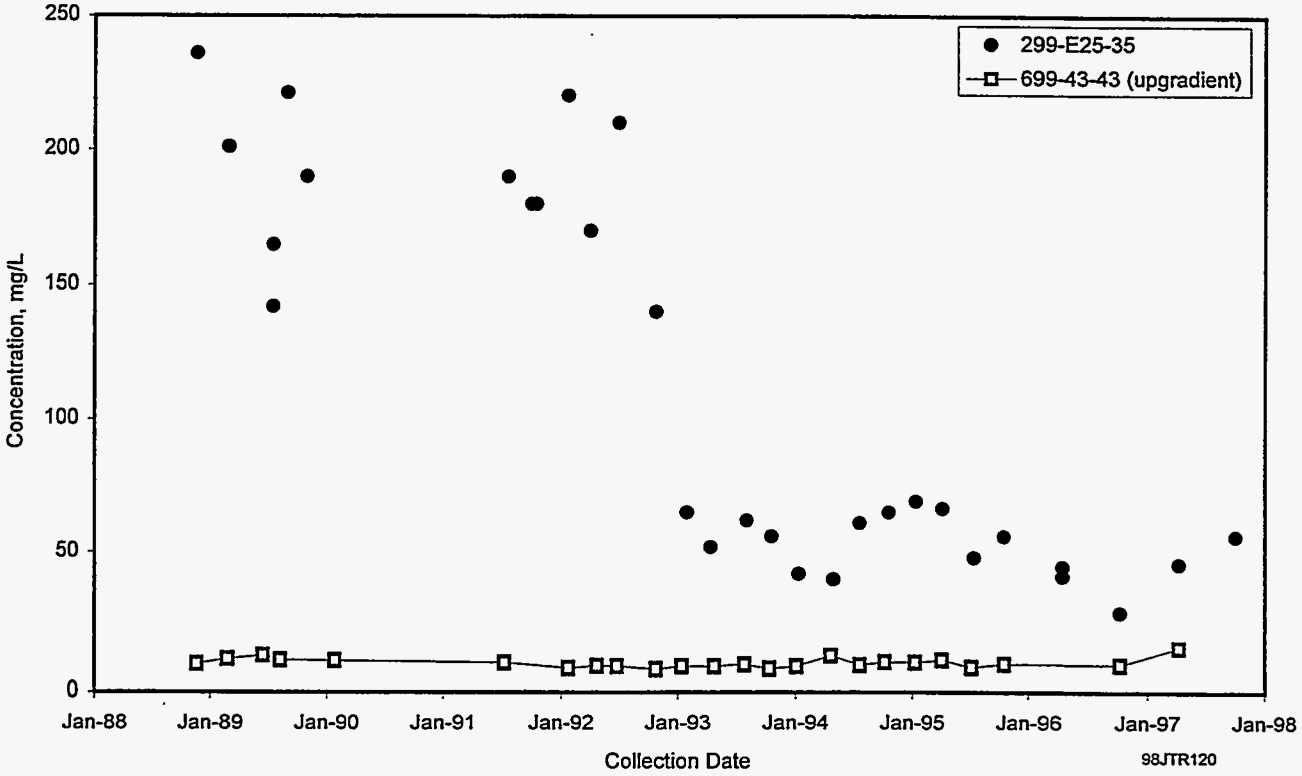


Figure 5.10-17. Sulfate Concentrations in Selected Wells Monitoring 216-A-29 Ditch

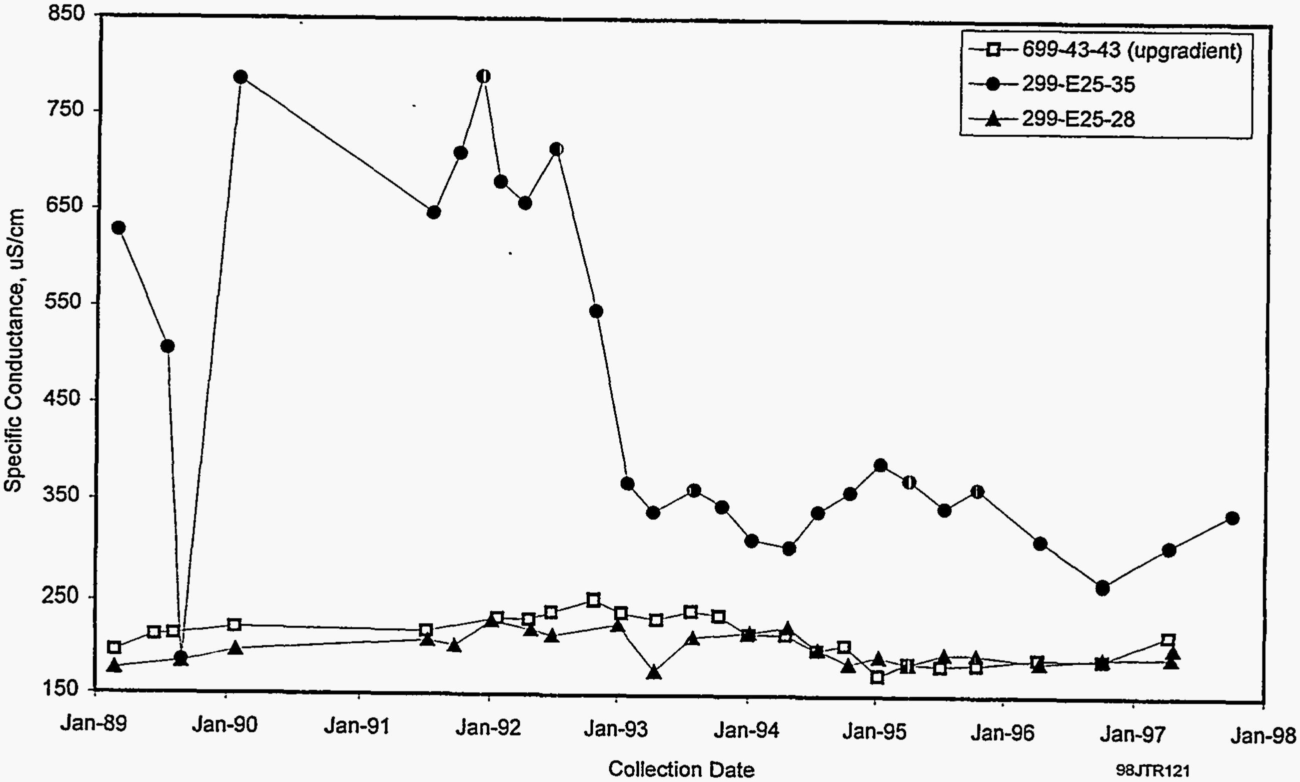
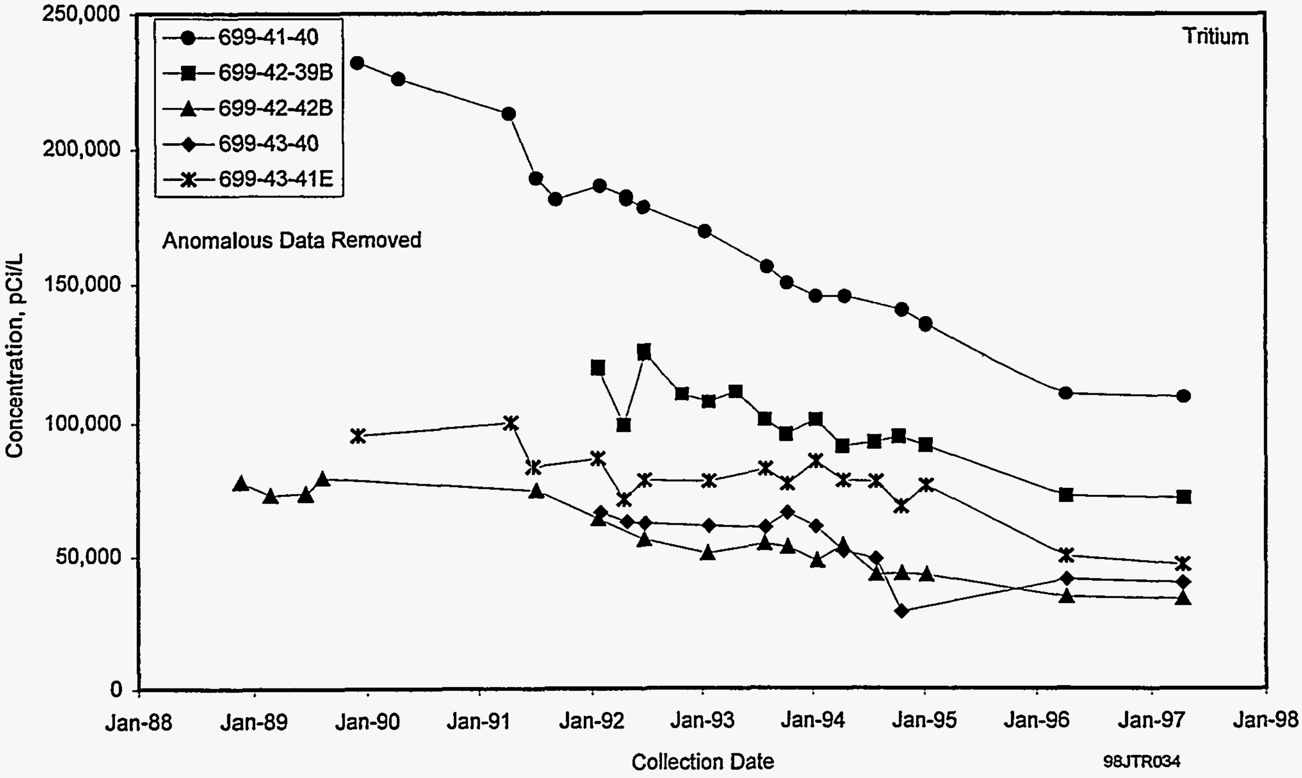


Figure 5.10-18. Specific Conductance in Selected Wells Monitoring 216-A-29 Ditch



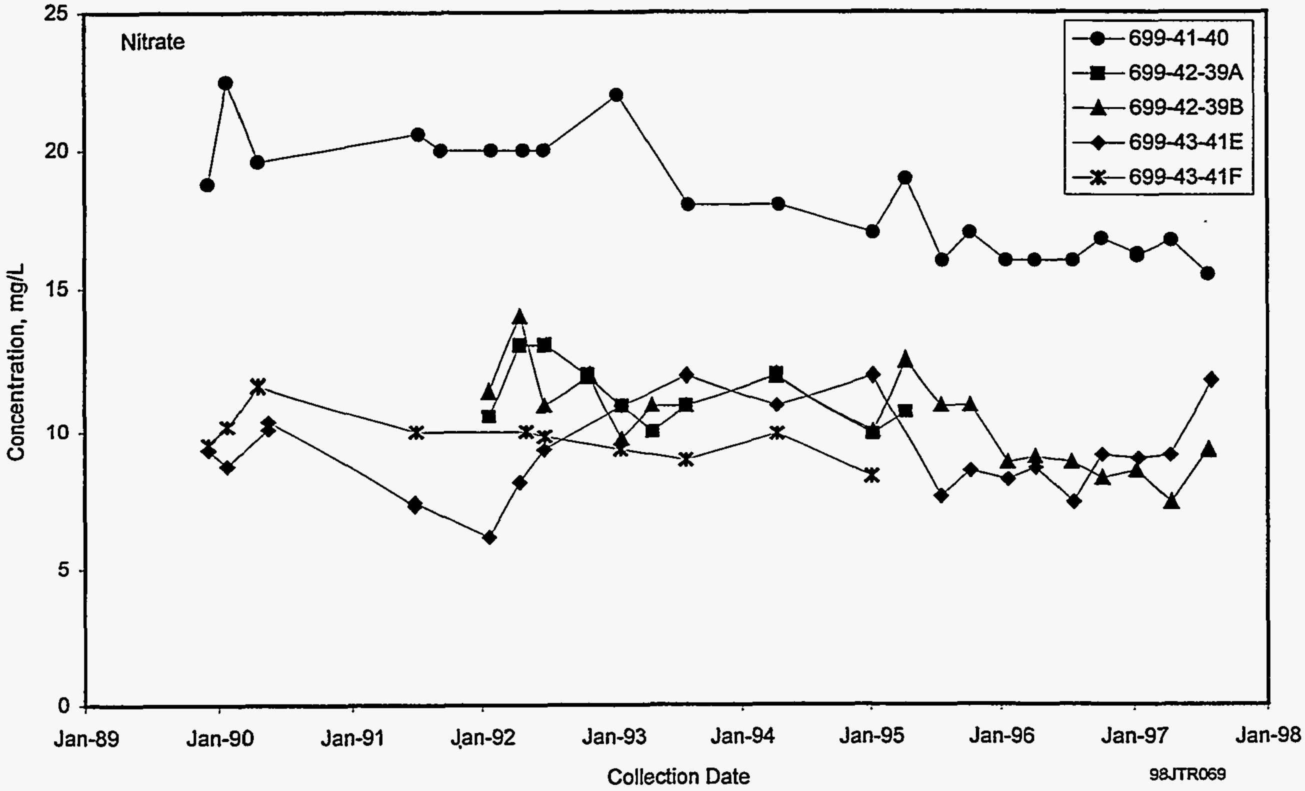


Figure 5.10-19. Tritium and Nitrate Concentrations in Selected Wells Monitoring 216-B-3 Pond

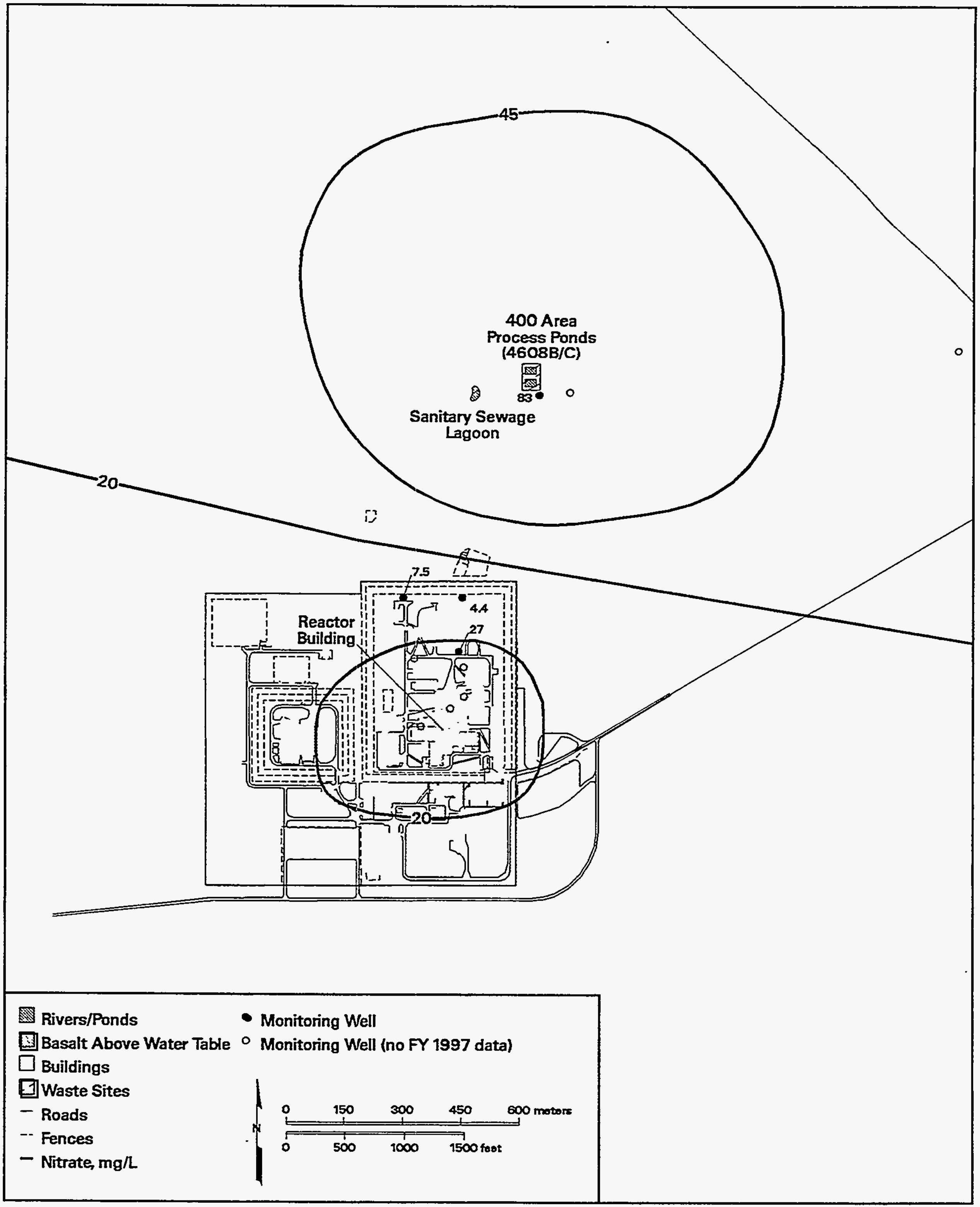


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Figure 5.11-1. Average Fiscal Year 1997 Nitrate Concentrations in 400 Area Wells

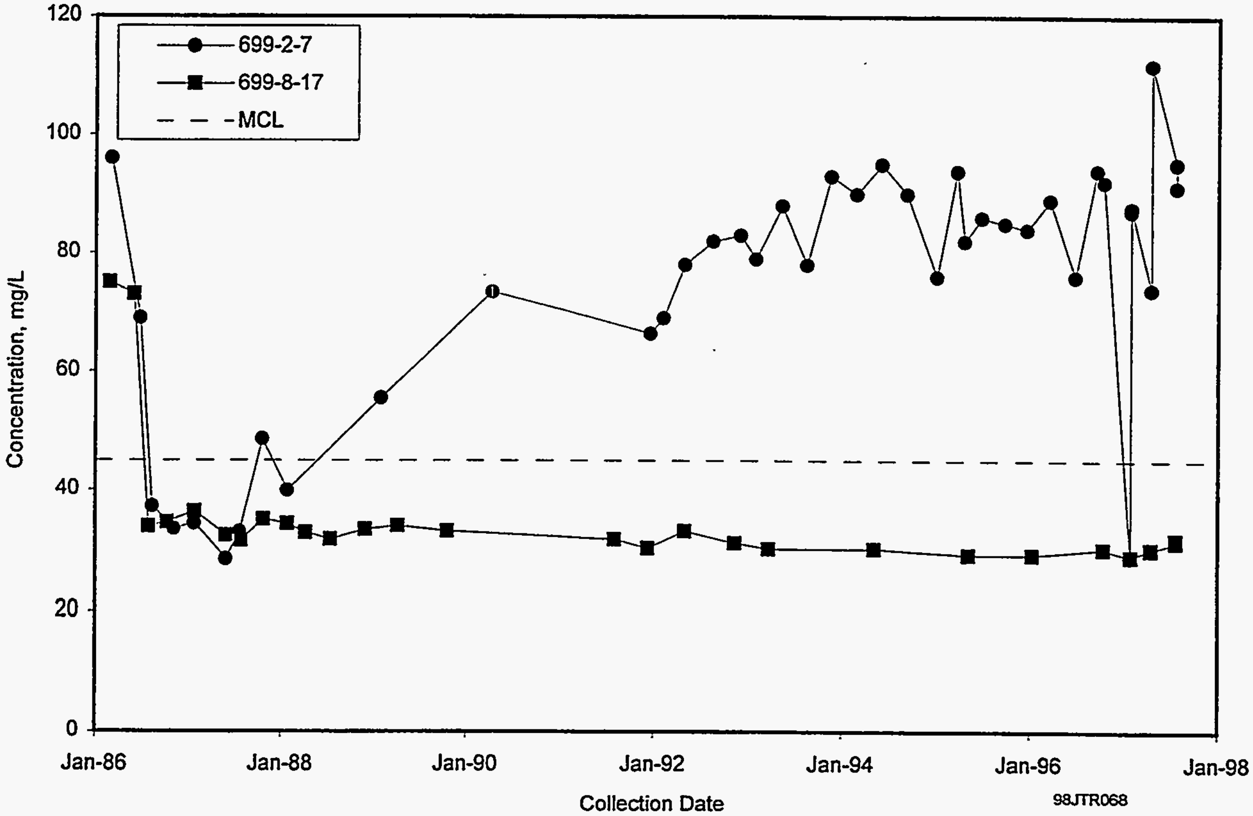


Figure 5.11-2. Nitrate Concentrations in 600 Area Wells Near 400 Area

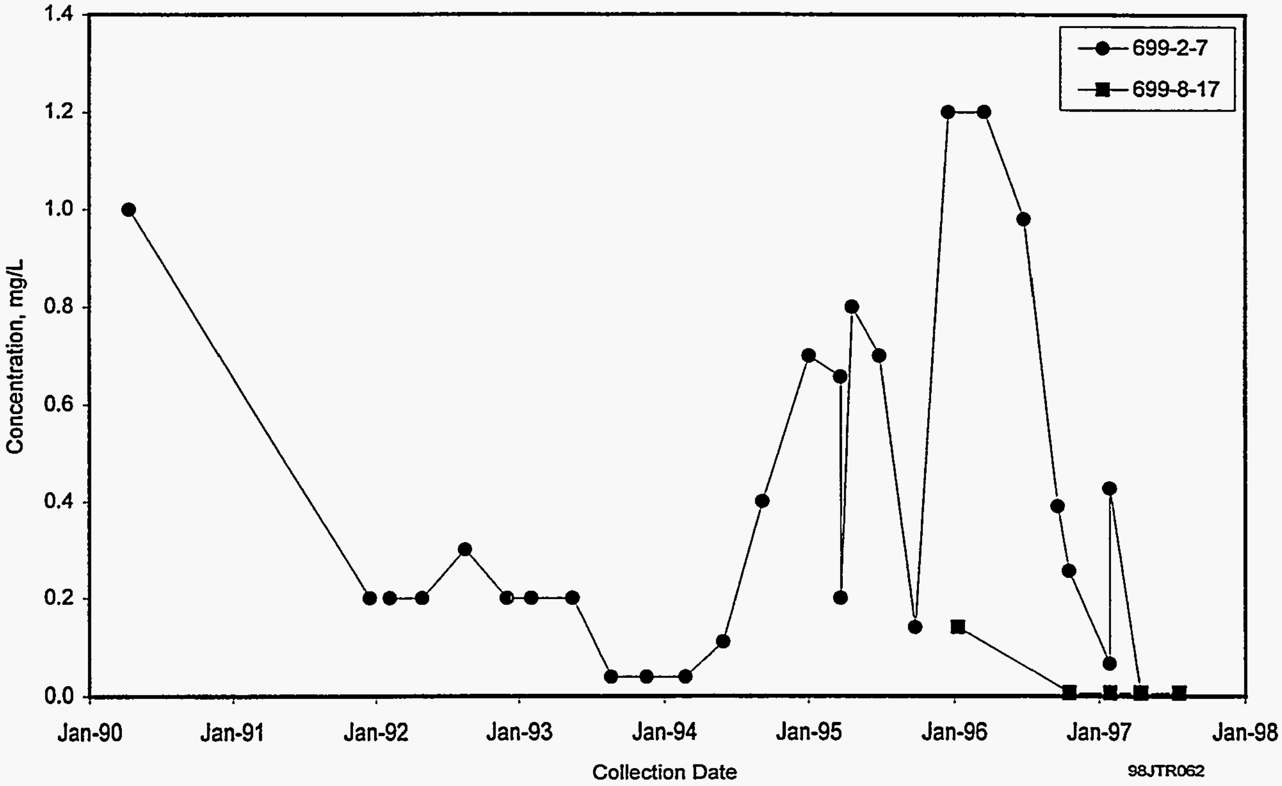


Figure 5.11-3. Nitrite Concentrations in 600 Area Wells Near 400 Area

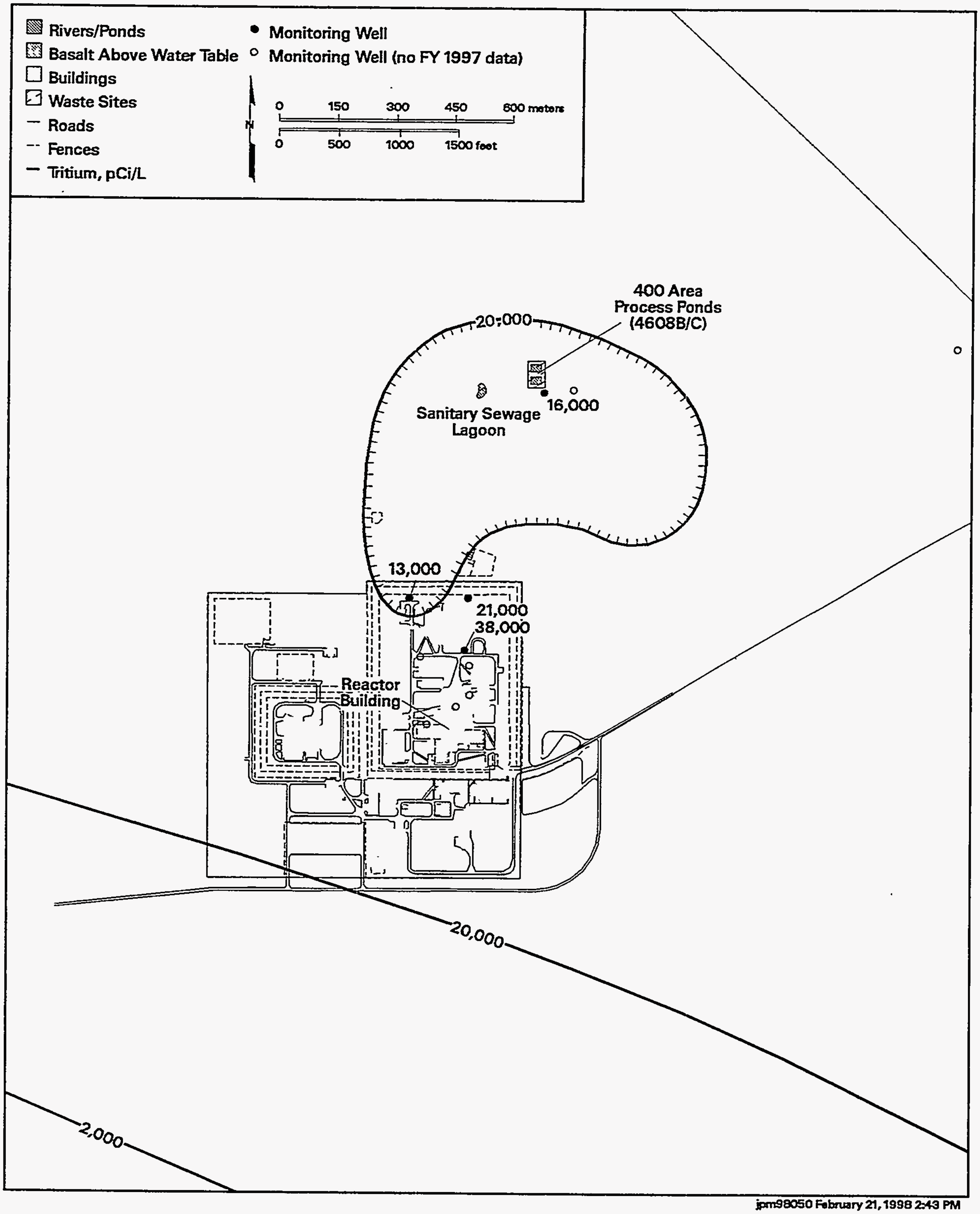
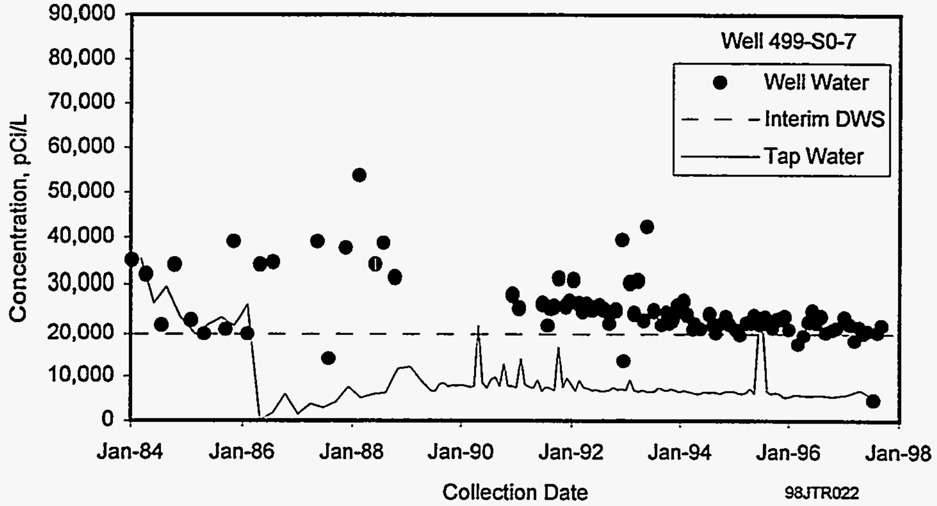
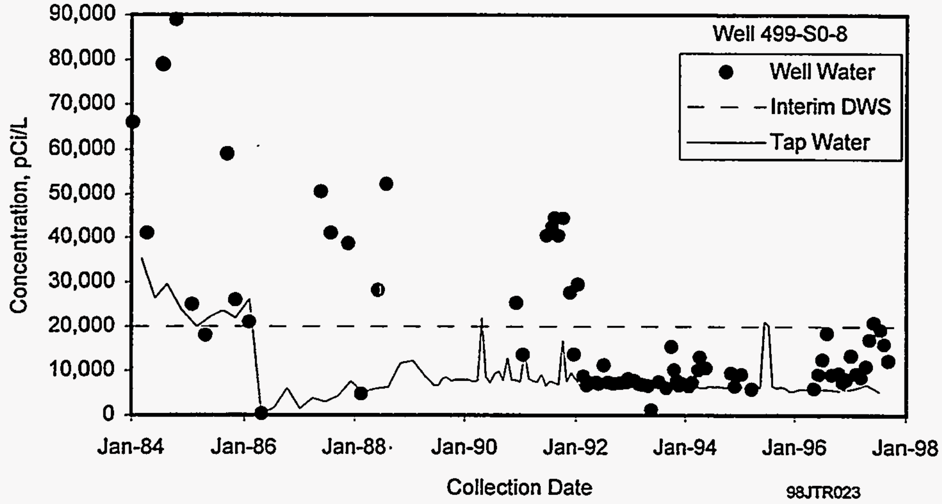


Figure 5.11-4. Average Fiscal Year 1997 Tritium Concentrations in 400 Area Wells





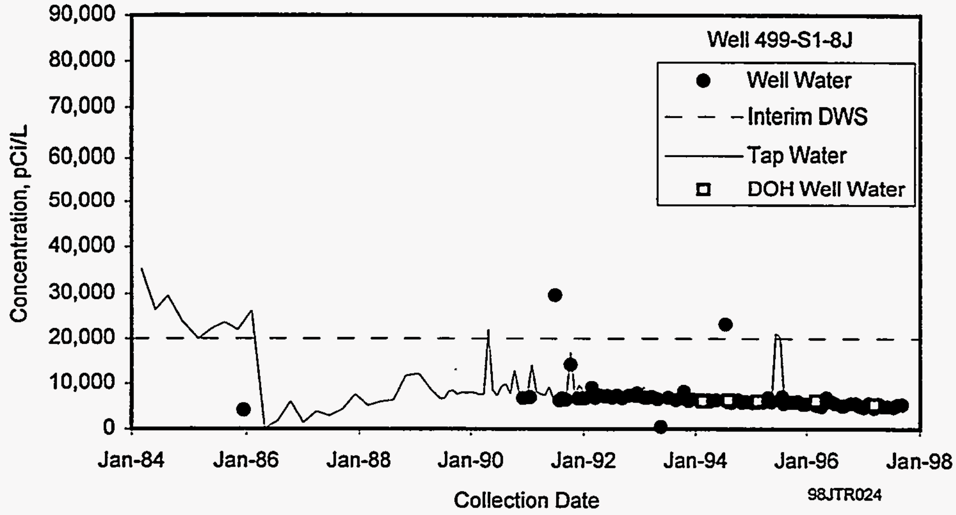


Figure 5.11-5. Comparison of Tritium Trends in 400 Area Drinking Water System

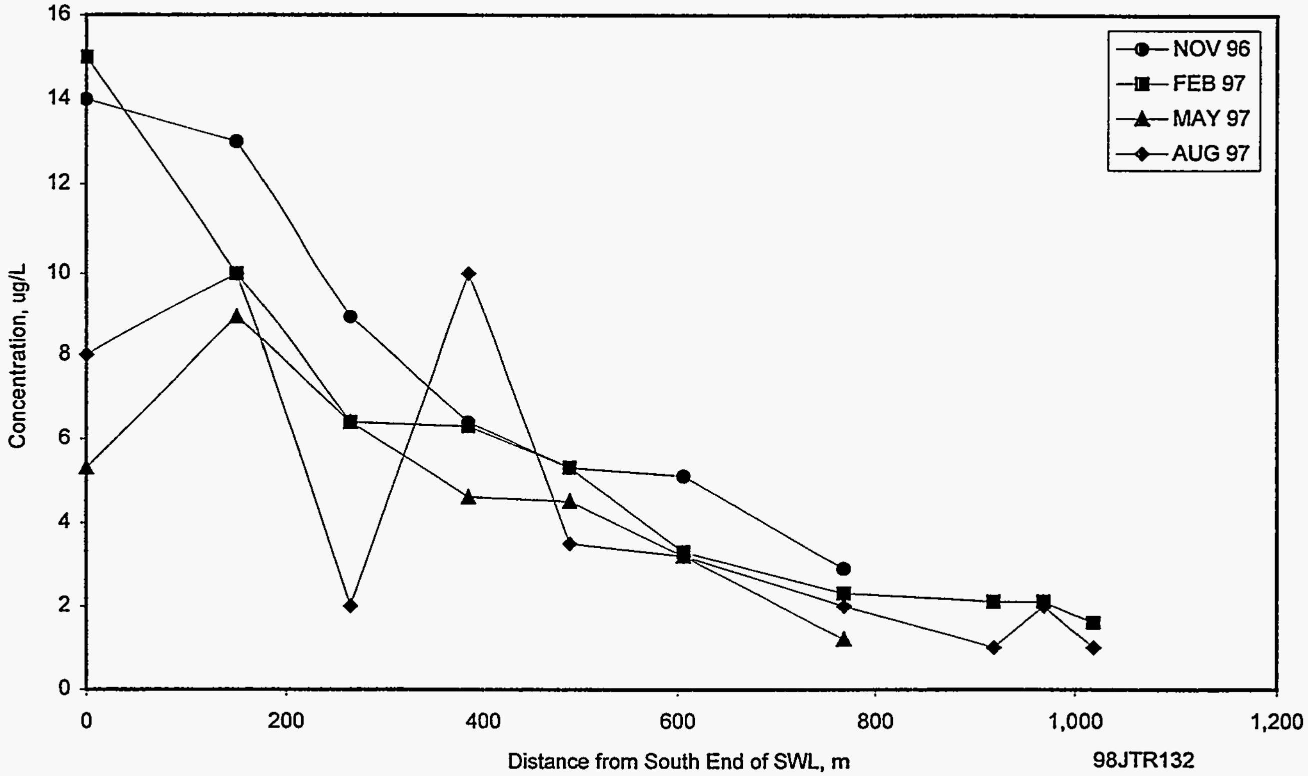
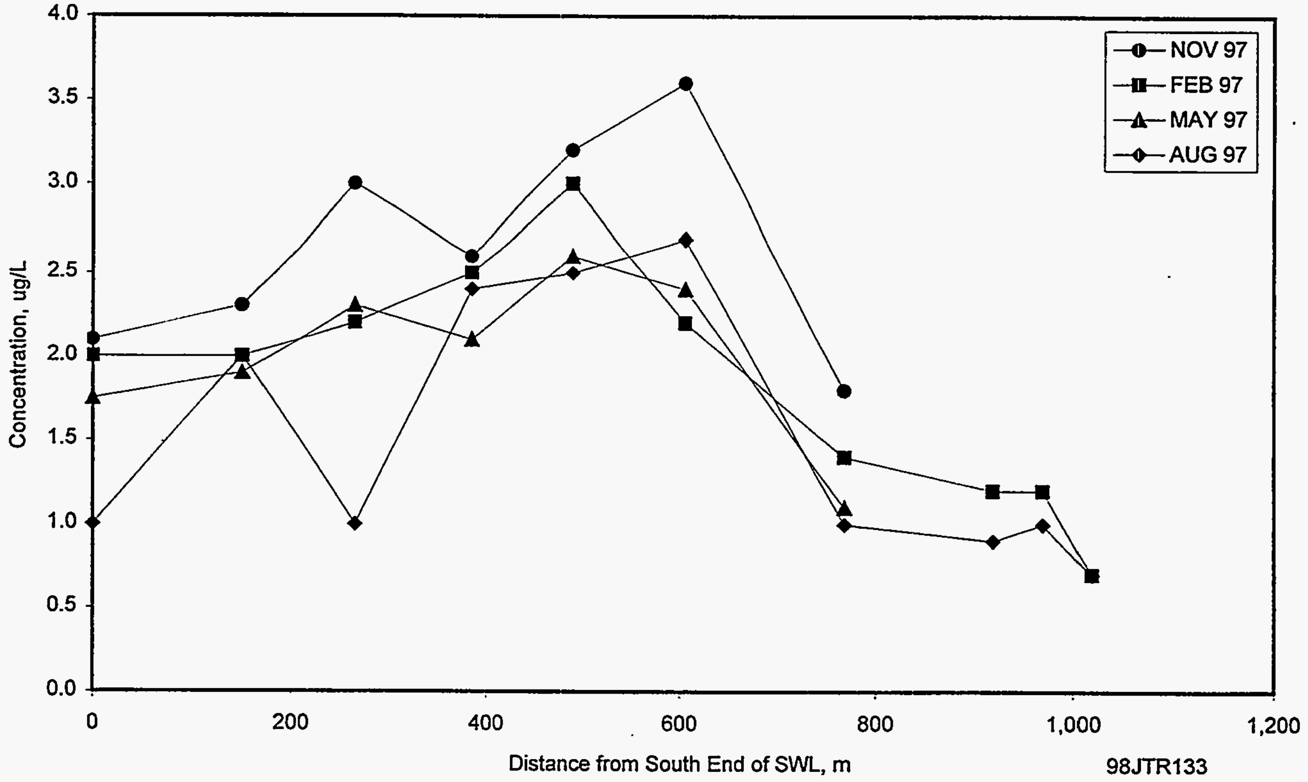


Figure 5.12-1. 1,1,1-Trichloroethane Concentrations in Wells Monitoring Solid Waste Landfill



- **Figure 5.12-2.** Tetrachloroethylene Concentrations in Wells Monitoring Solid Waste Landfill

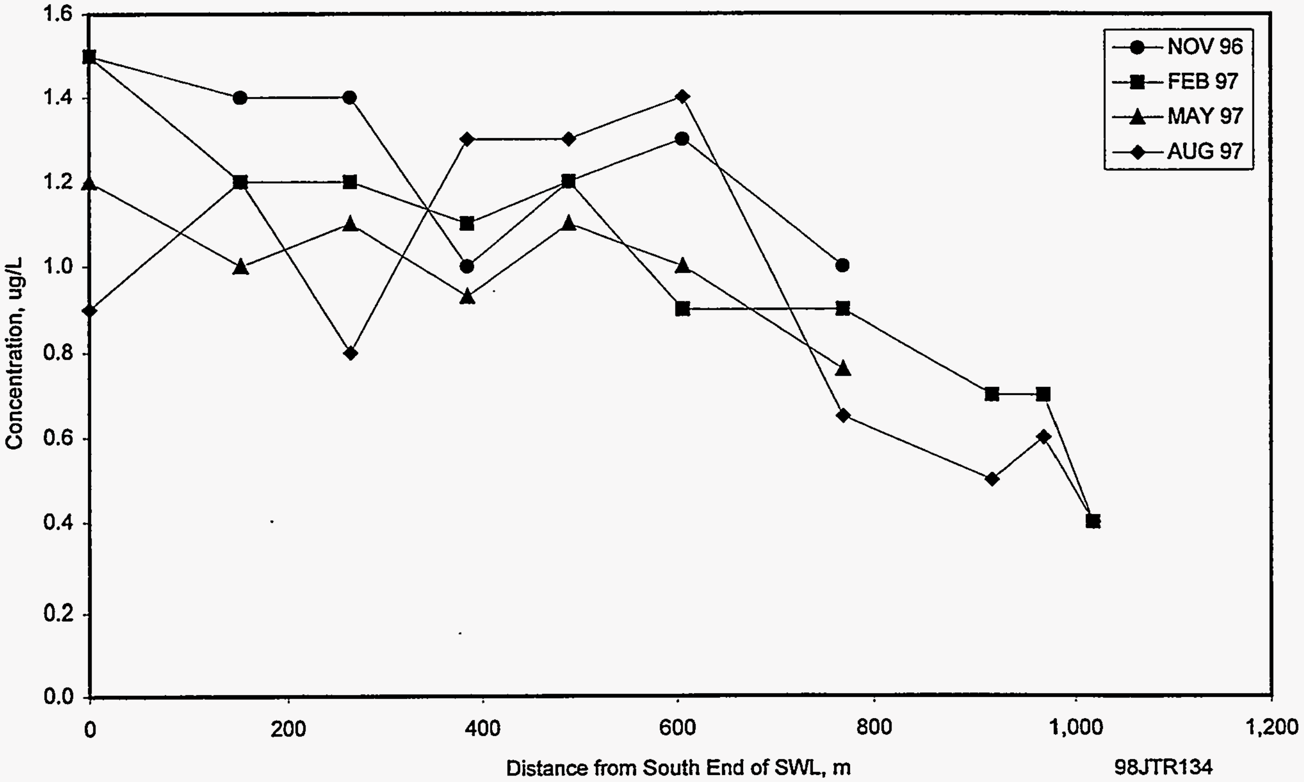


Figure 5.12-3. Trichloroethylene Concentrations in Wells Monitoring Solid Waste Landfill

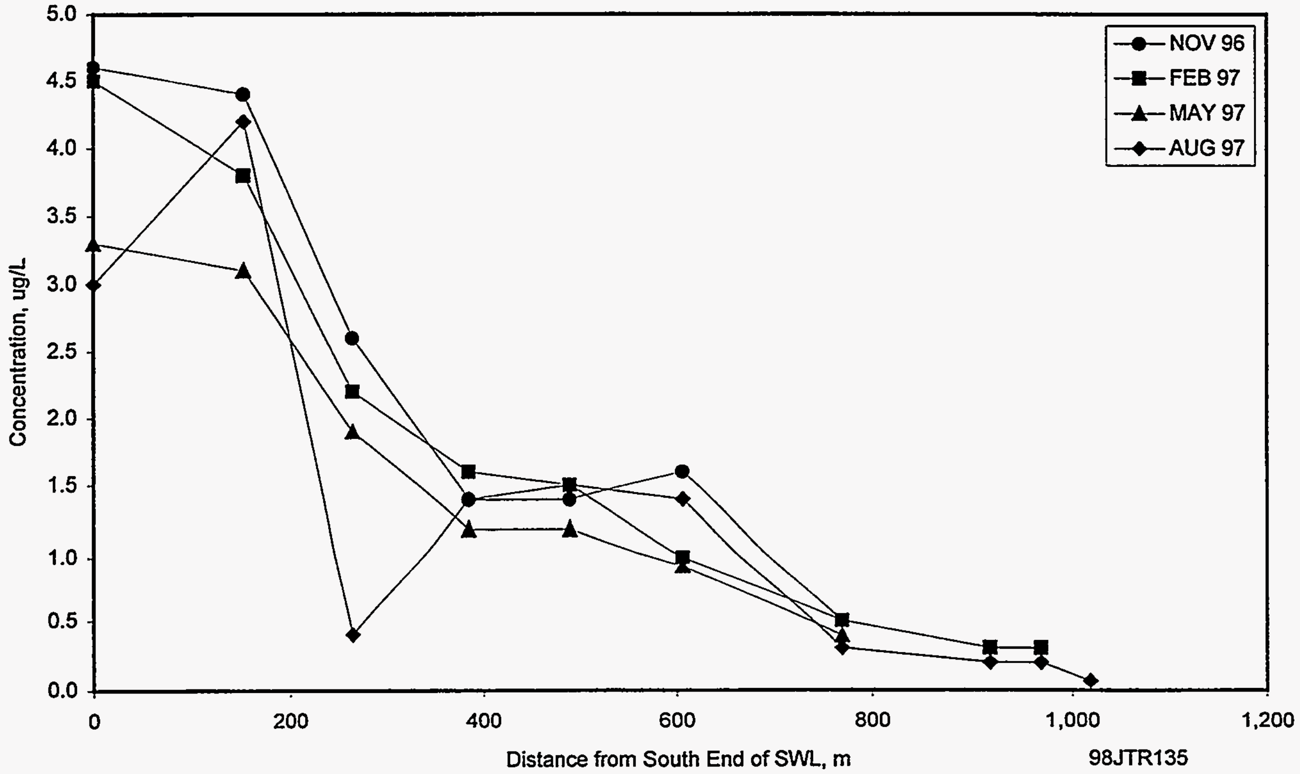


Figure 5.12-4. 1,1-Dichloroethane Concentrations in Wells Monitoring Solid Waste Landfill

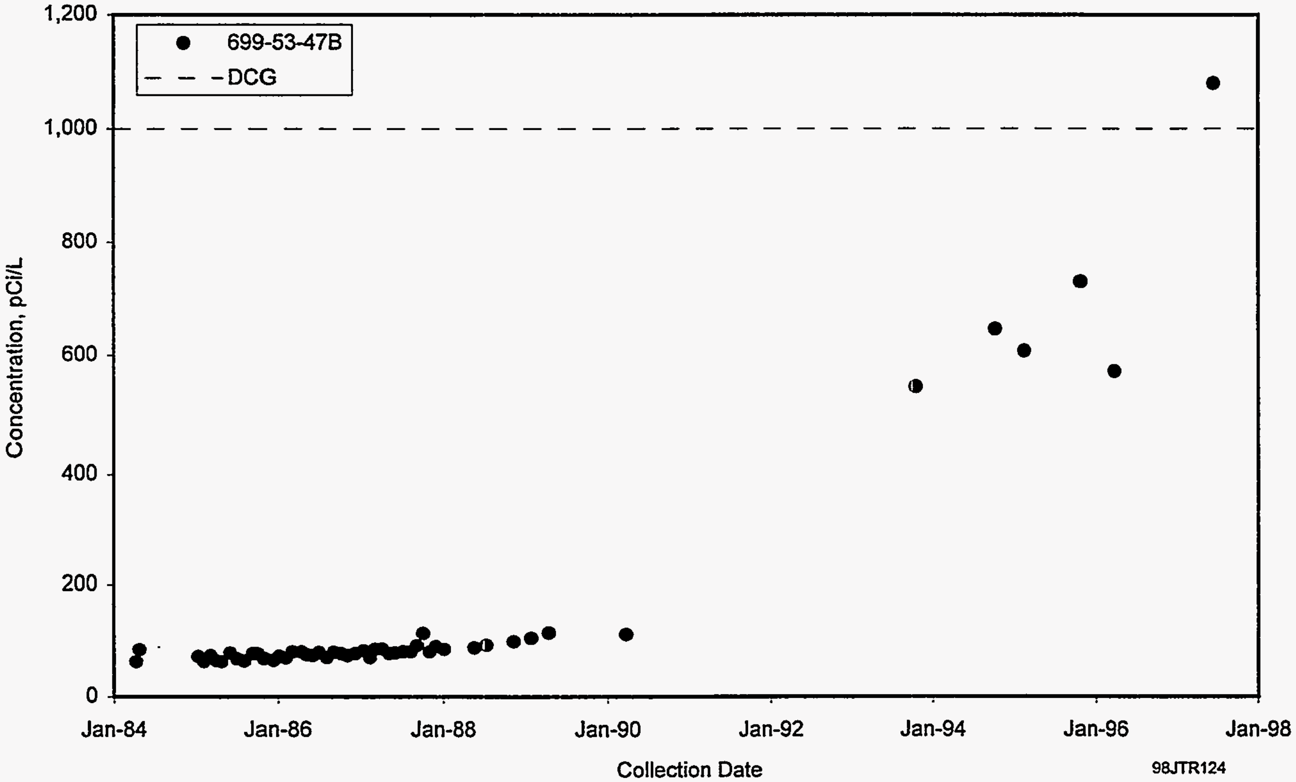


Figure 5.12-5. Strontium-90 Concentrations in Well 699-53-47B

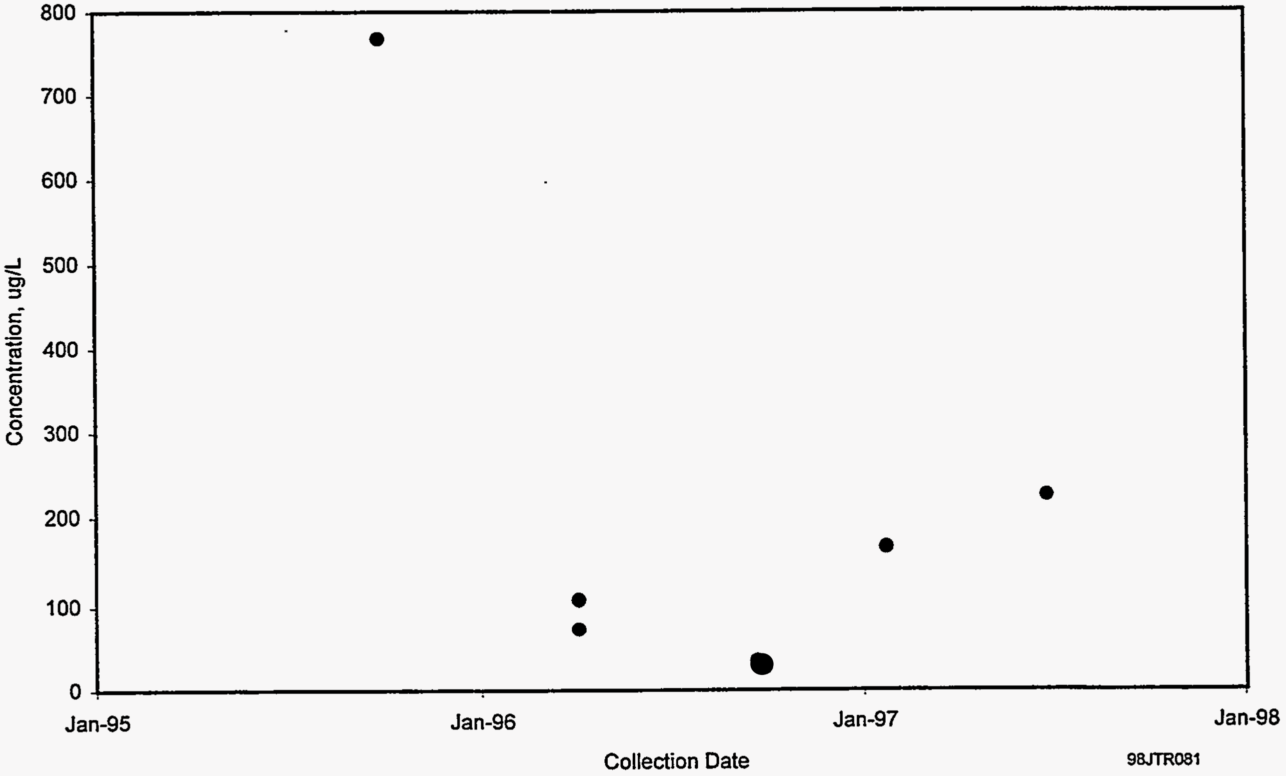


Figure 5.12-6. Uranium Concentrations in Well 699-S6-E4A

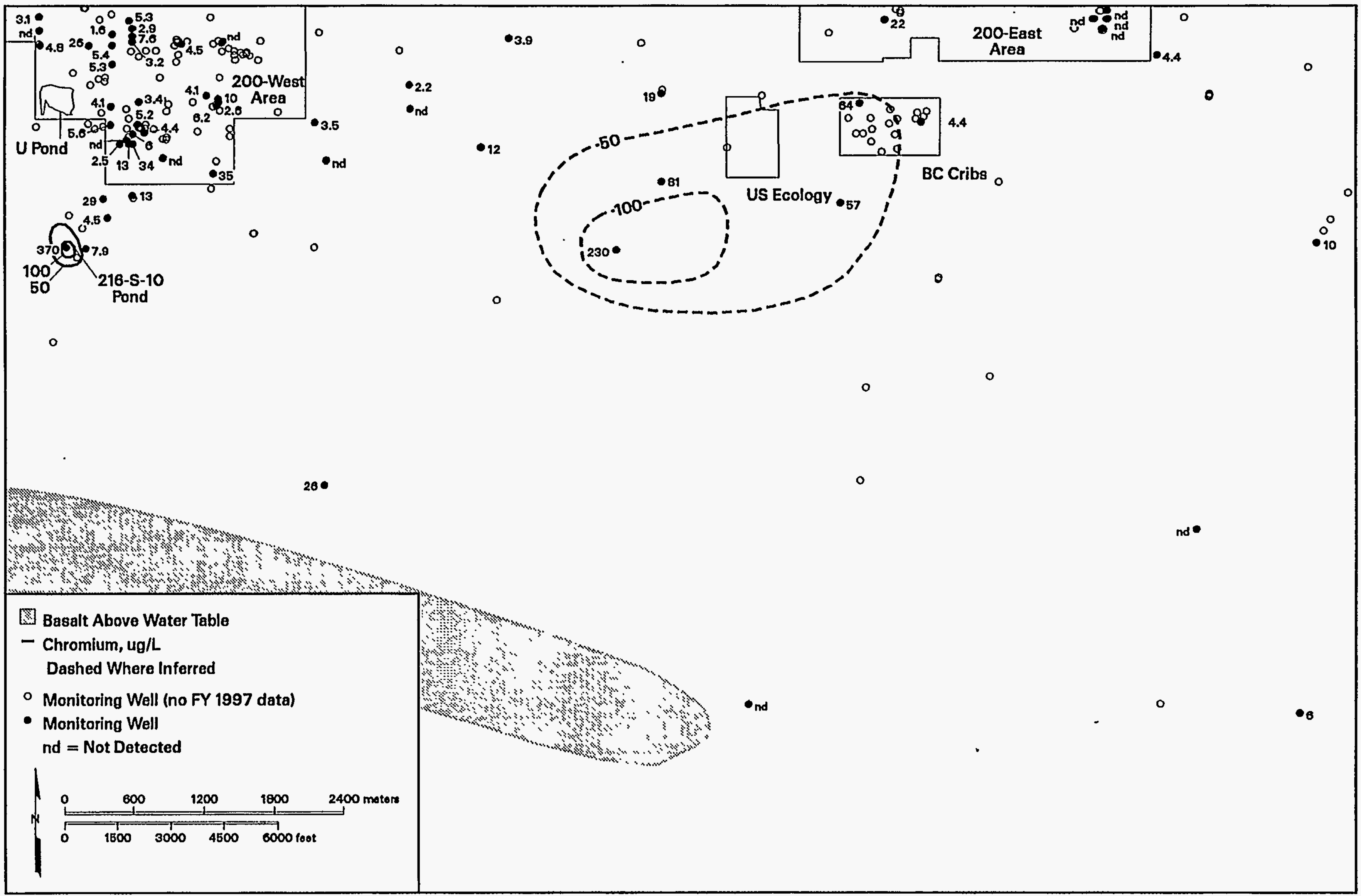


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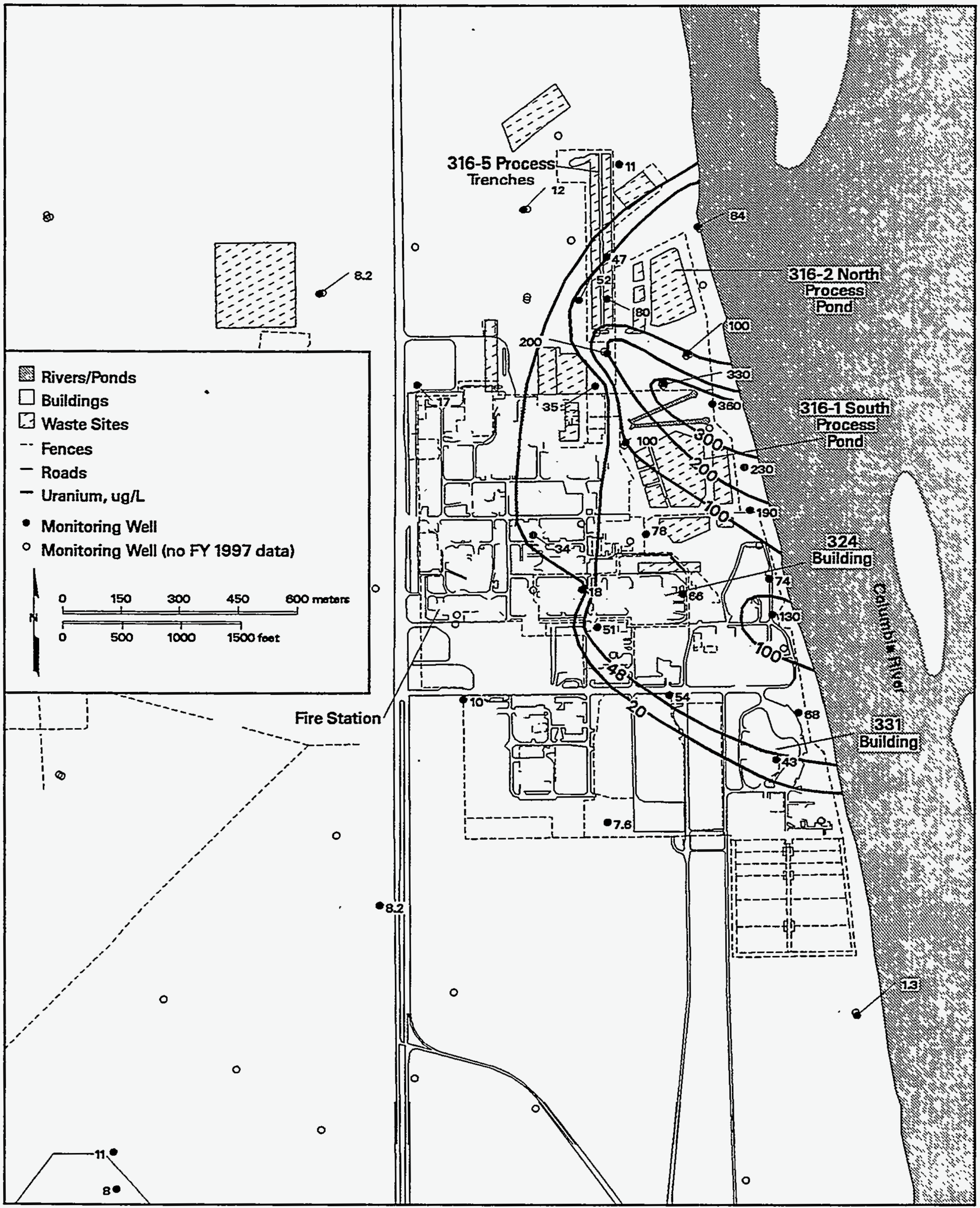
Figure 5.12-7. Average Fiscal Year 1997 Filtered Chromium Concentrations in Central Plateau South of 200-East Area



jpm98020 February 21, 1998 2:59 PM

Figure 5.13-1. Average Fiscal Year 1997 Uranium Concentrations in 300 Area

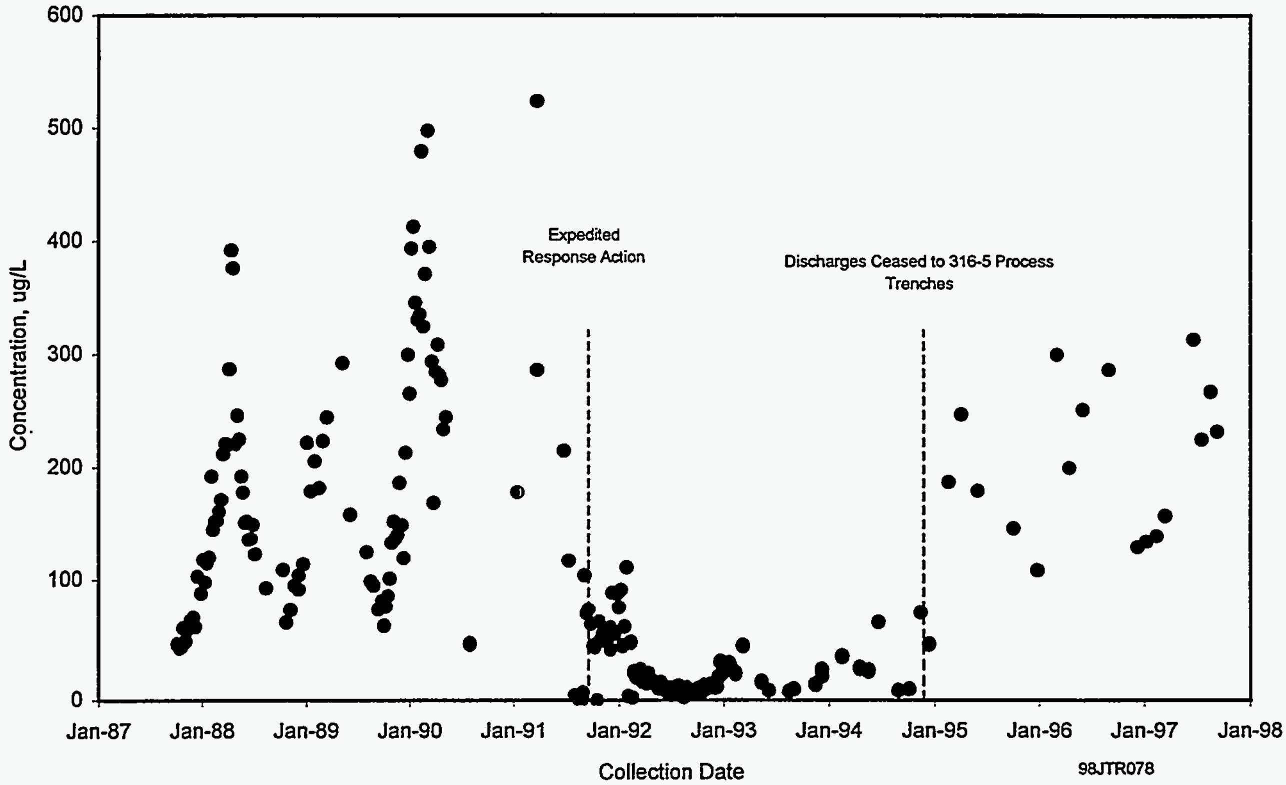


Figure 5.13-2. Uranium Concentrations in Well 399-1-17A

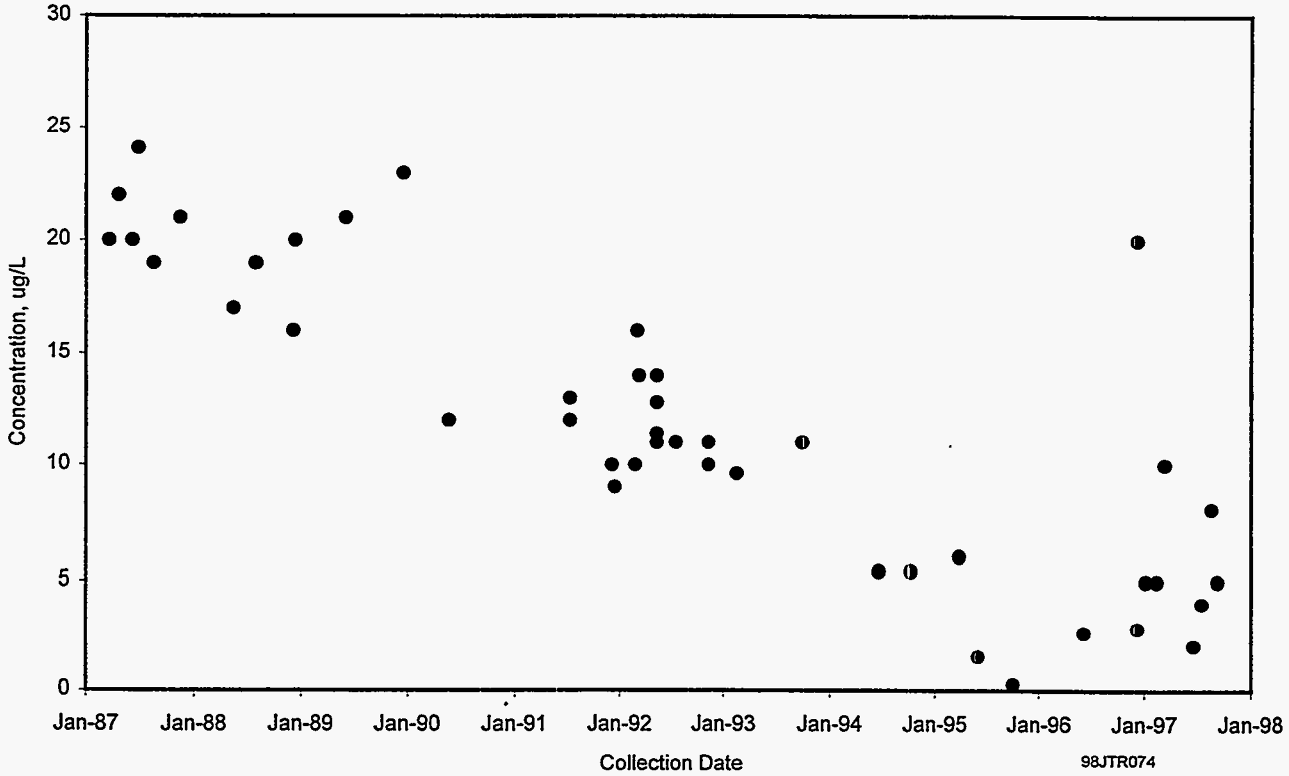


Figure 5.13-3. Trichloroethylene Concentrations in Well 399-1-16B

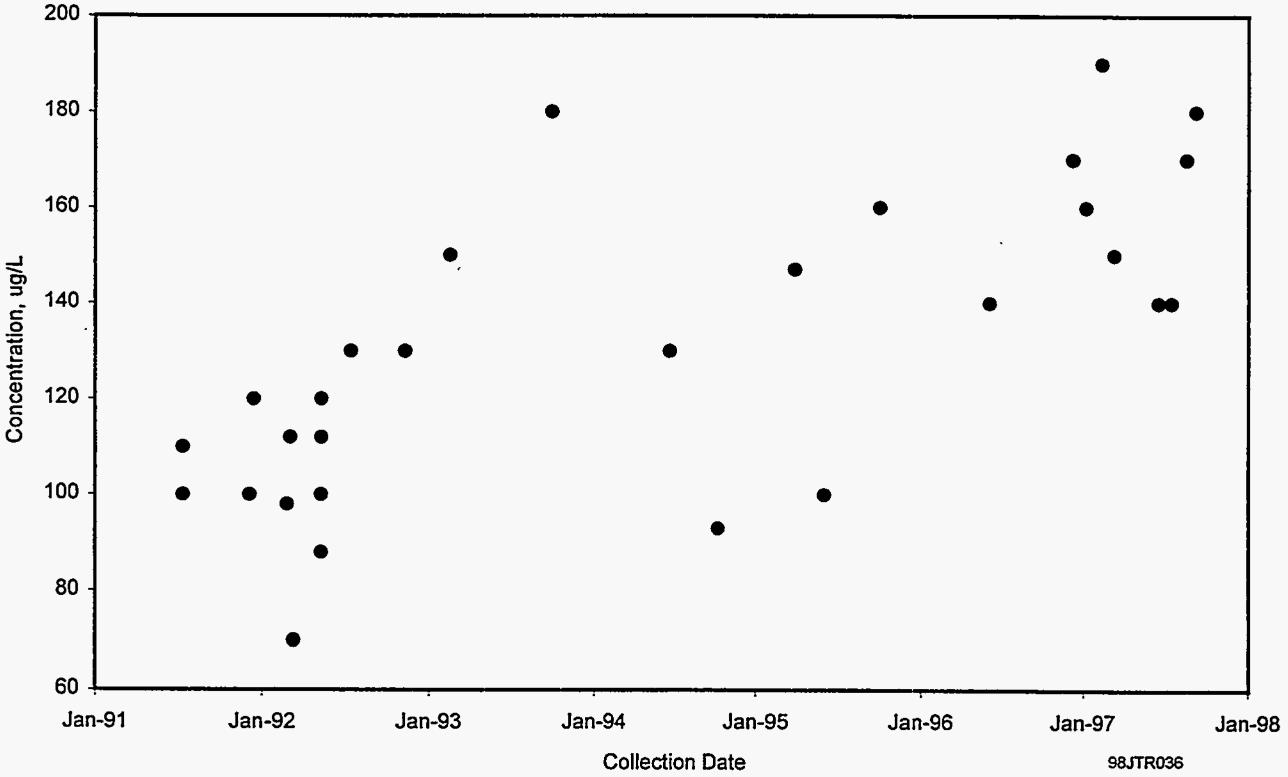
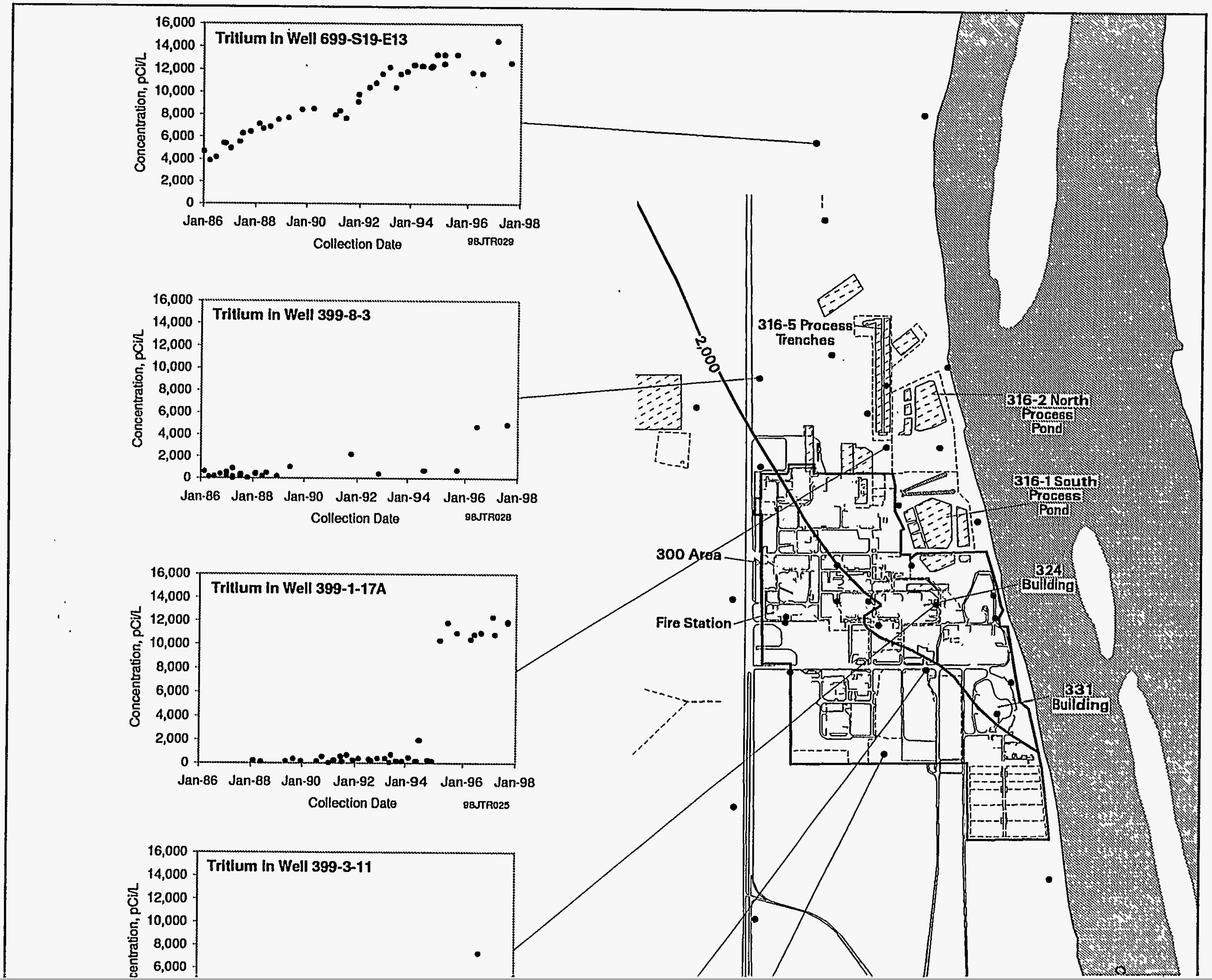


Figure 5.13-4. cis-1,2-Dichloroethylene Concentrations in Well 399-1-16B


Tritium in Well 699-S19-E13
Concentration, pCi/L
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Collection Date
98JTR029
Tritium in Well 399-8-3
Concentration, pCi/L
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Collection Date
98JTR028
Tritium in Well 399-1-17A
Concentration, pCi/L
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-86
Jan-88
Jan-90
Jan-92
Jan-94
Jan-96
Jan-98
Collection Date
98JTR025
Tritium in Well 399-3-11
centration, pCi/L
16,000
14,000
12,000
10,000
8,000
6,000
2,000
316-5 Process Trenches
316-2 North Process Pond
316-1 South Process Pond
300 Area
Fire Station
324 Building
331 Building

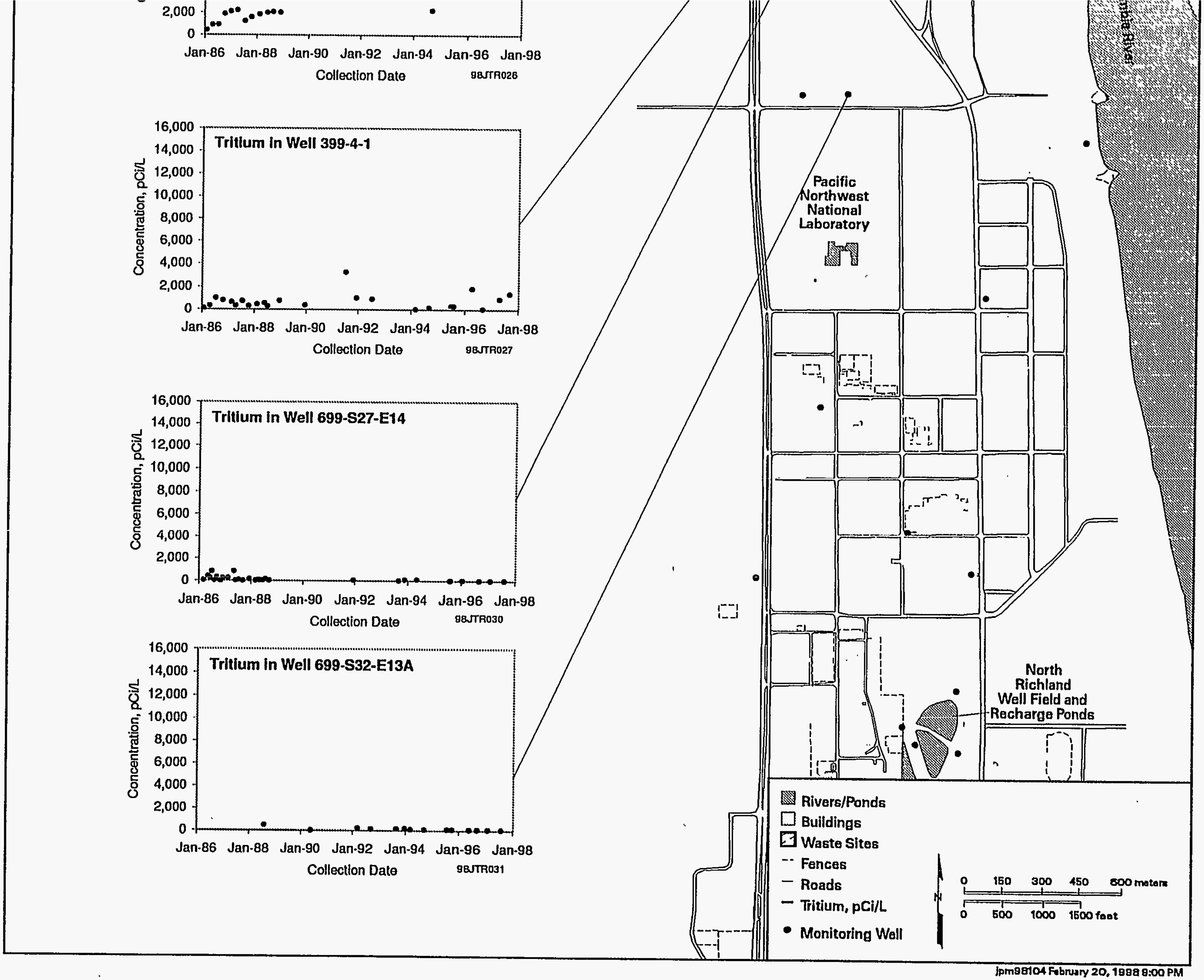


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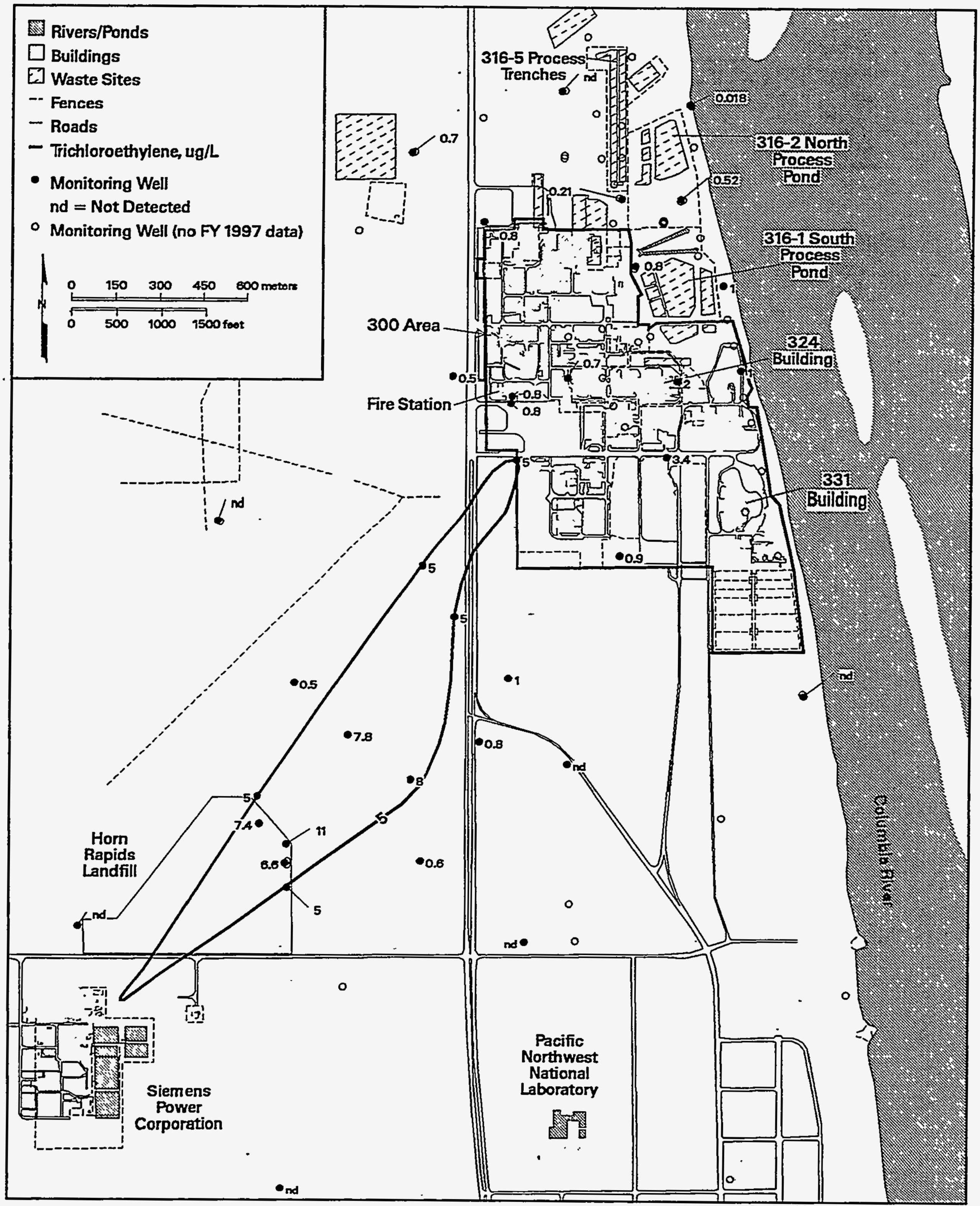
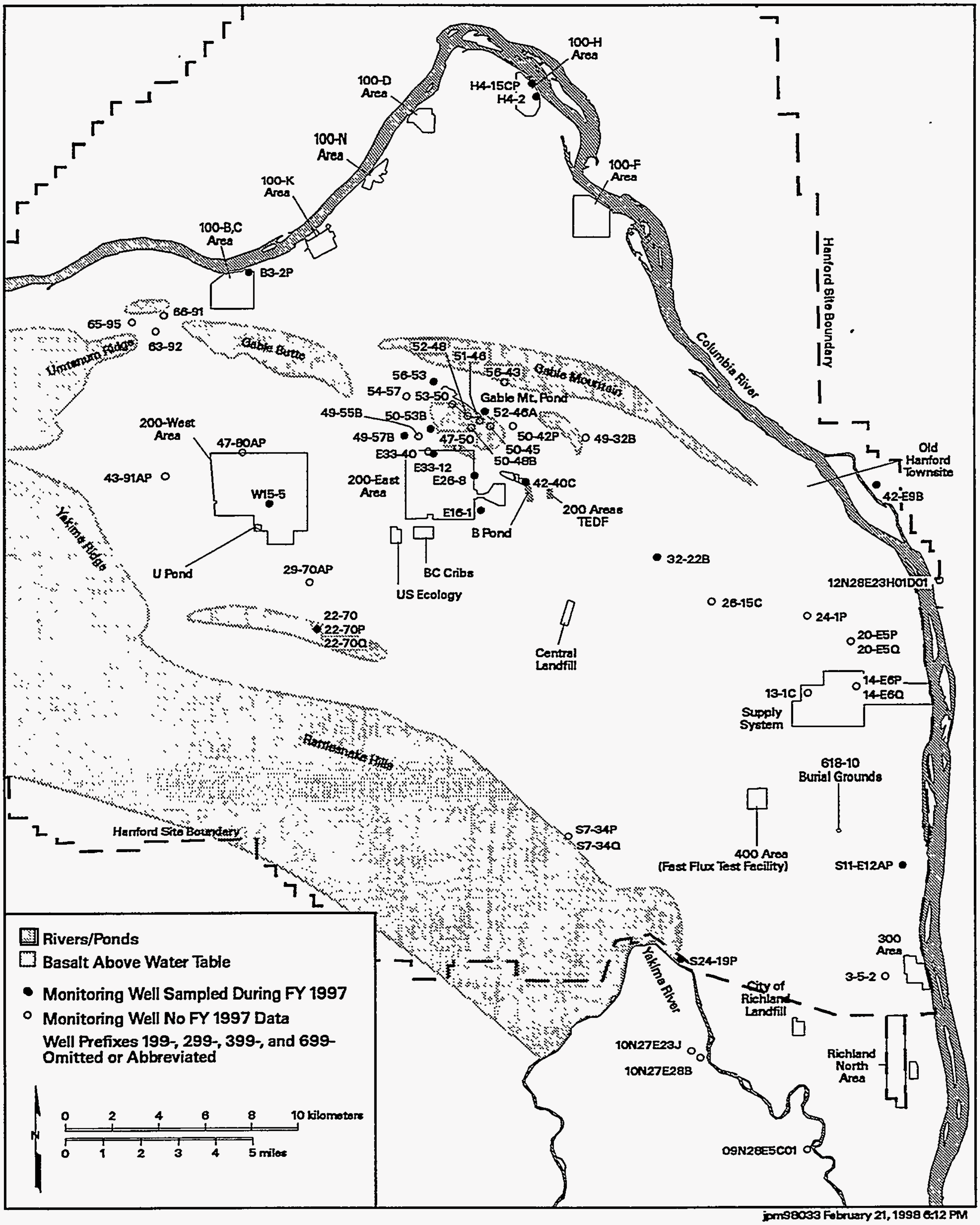
Figure 5.14-1. Tritium Concentrations in Unconfined Aquifer-Monitoring Wells in 300 and Richland North Areas



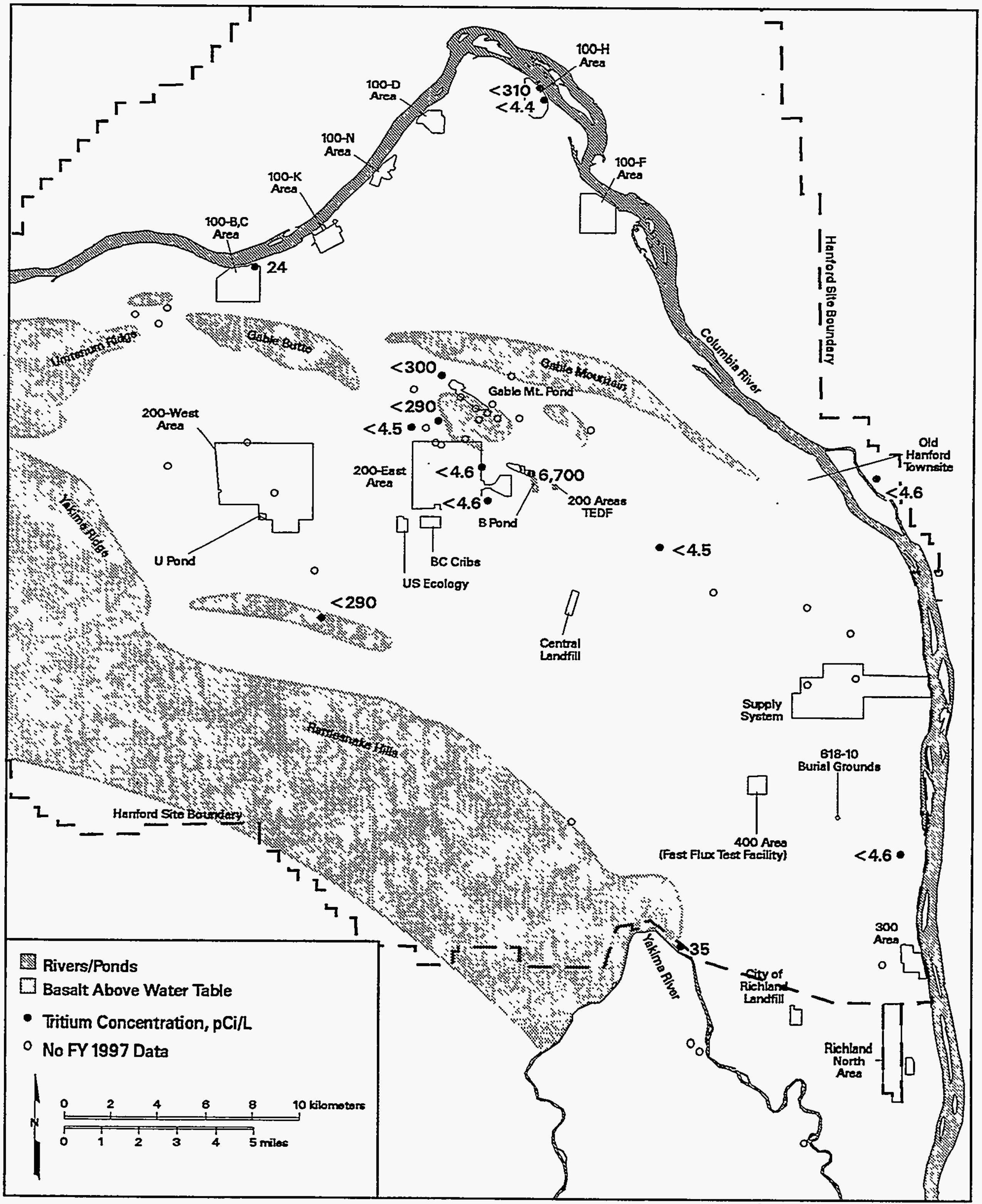
jpm98032 February 21, 1998 3:25 PM

Figure 5.14-2. Average Fiscal Year 1997 Trichloroethylene Concentrations in 300 and Richland North Areas



jpm98033 February 21, 1998 6:12 PM

Figure 5.15-1. Hanford Site Map Showing Upper Basalt-Confined Aquifer Wells



jpm98093 February 21, 1998 7:43 PM

Figure 5.15-2. Fiscal Year 1997 Tritium Results for Upper Basalt-Confined Aquifer Wells

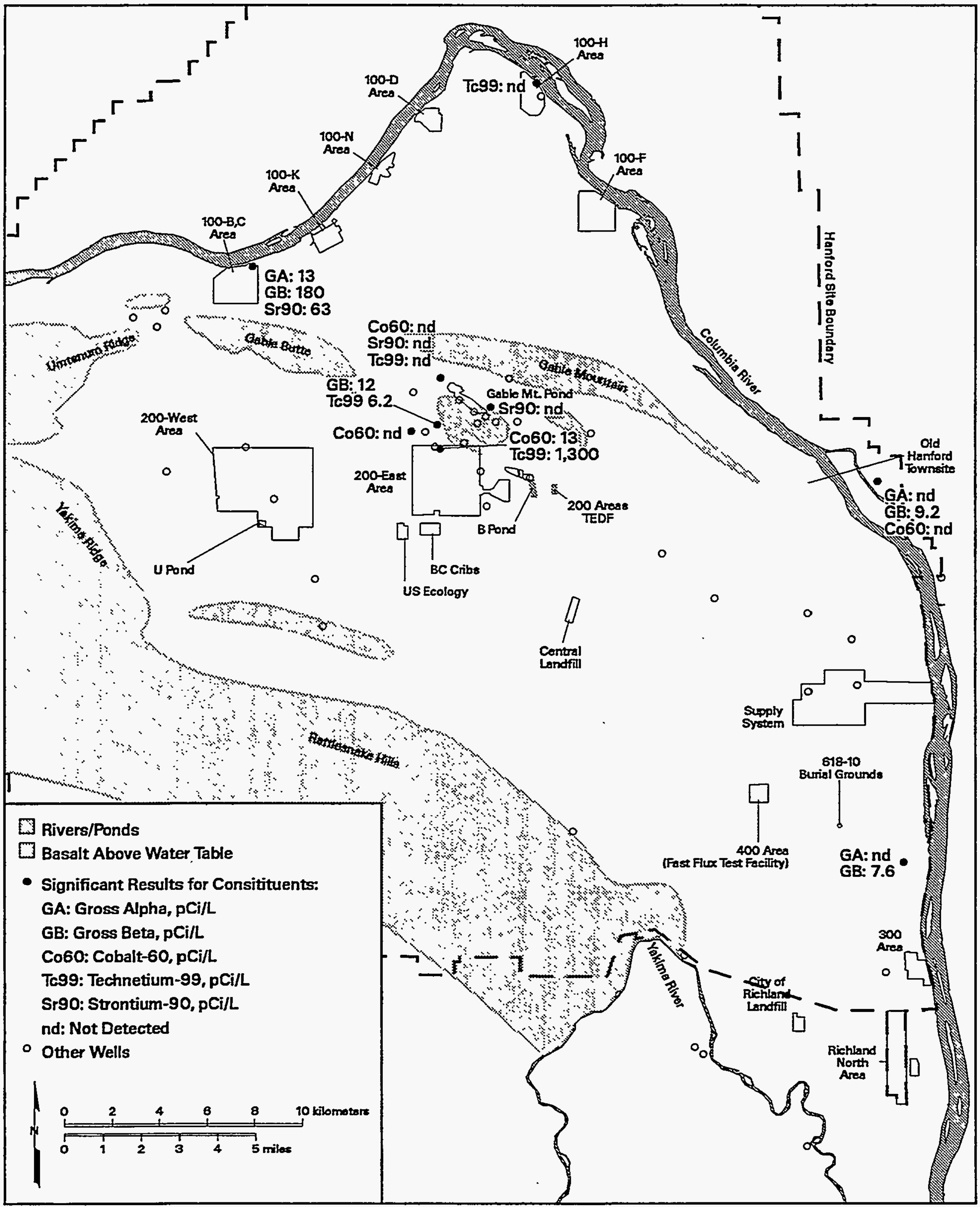


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Figure 5.15-3. Fiscal Year 1997 Selected Radionuclide Results for Upper Basalt-Confined Aquifer Wells

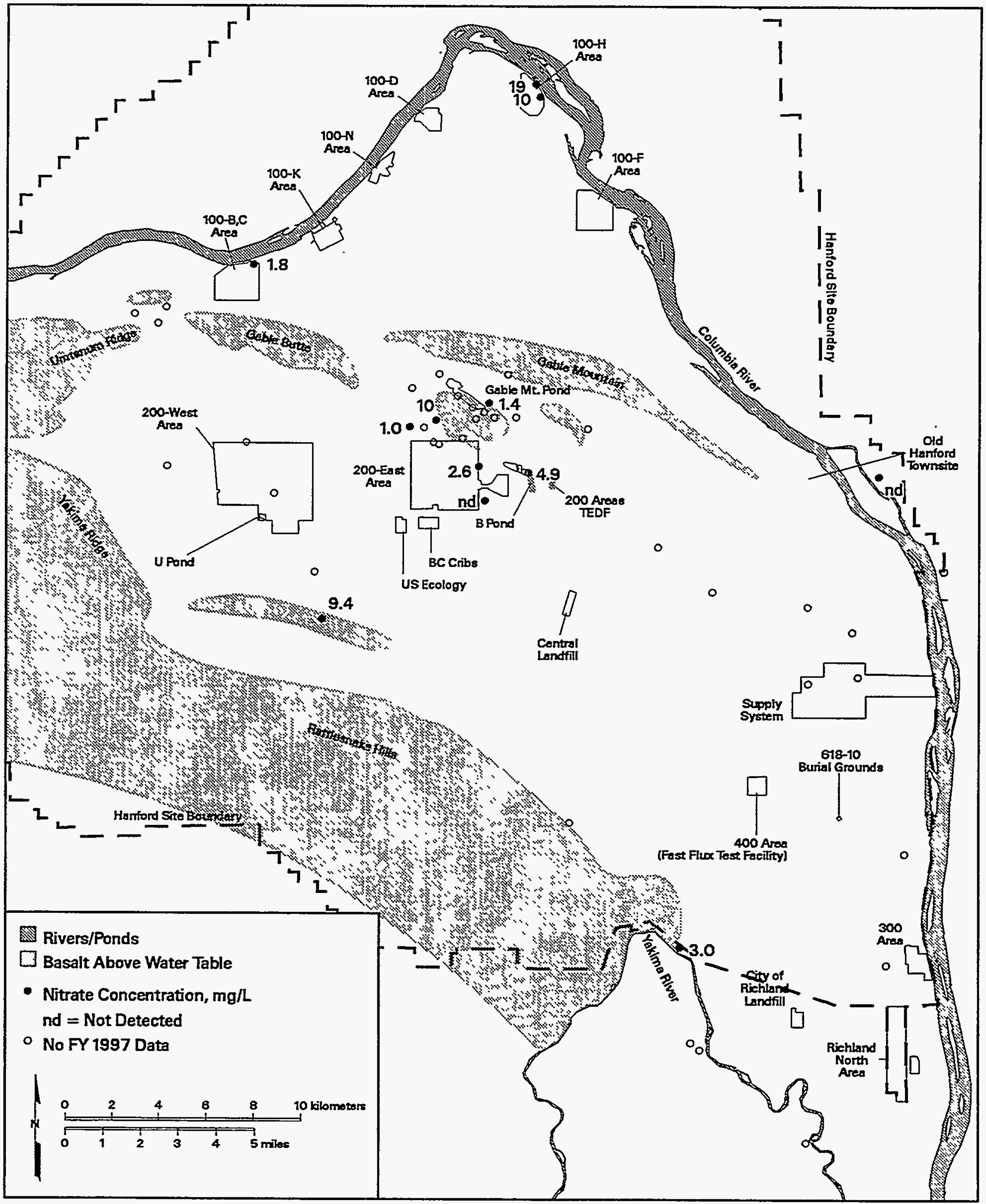

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Figure 5.15-4. Fiscal Year 1997 Nitrate Results for Upper Basalt-Confined Aquifer Wells

6.0 Groundwater Modeling

Groundwater-flow and contaminant-transport models are used to simulate future groundwater-flow conditions and predict the migration of contaminants through the groundwater pathway. During the past several years, a three-dimensional flow and transport model has been under development by Pacific Northwest National Laboratory's (PNNL's) Groundwater Monitoring Project. This model was used during fiscal year (FY) 1997 to simulate future transport of selected contaminant plumes in the unconfined aquifer system. A groundwater-flow model was also applied to illustrate the interaction between the unconfined aquifer and the Columbia River in the vicinity of the100-N Area. The objective of that model is to better understand the release of strontium-90 from the aquifer into the river. Other models were used in the design and evaluation of pump-and-treat activities aimed at remediation of contaminated groundwater in the 200-West Area. These models were used to describe the capture and injection zones for the extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat operations at different times. A recent multiyear modeling effort conducted to support development of the *Hanford Site Groundwater Remediation Strategy* (DOE/RL-94-95, Rev. 1) was completed during FY 1996 and was described in Bechtel Hanford, Inc. (BHI-) 00469 and Section 7.2 of PNNL-11470.

6.1 Three-Dimensional Sitewide Groundwater-Flow and -Transport Model

P. D. Thorne, S. K. Wurstner

A three-dimensional numerical model of groundwater flow and transport for the Hanford Site unconfined aquifer system has been developed over the past several years. The model uses the Coupled, Fluid, Energy, and Solute Transport (CFEST) code (BMI/ONWI-660) and was developed to support the Groundwater Monitoring Project. The objectives of the three-dimensional sitewide model are to increase the understanding of groundwater flow and contaminant transport at the Hanford Site, to predict future groundwater-flow conditions, and to provide better forecasts of the migration of contaminant plumes being monitored by the project.

Recent modeling efforts have focused on continued refinement of an initial version of the three-dimensional model developed in 1995 and its application to simulate future transport of selected contaminant plumes. Initial development of the model is described in PNL-10886. The model includes nine layers above the top of basalt to represent the major hydrogeologic units within the unconfined aquifer system. During FY 1997, the model was updated to a new version of the CFEST code, CFEST-96. The updated model was used to simulate groundwater-flow conditions through the year 2500 under assumed future recharge scenarios. The movements of existing tritium, iodine-129, technetium-99, uranium, and strontium-90 plumes originating from the 200 Areas plateau were also predicted for this time period. Each of the transport simulations was based on predicted future transient flow conditions. Details of the recent modeling effort and complete results are available in PNNL-11801.

6.1.1 Hydrogeologic Framework

To support development of the three-dimensional model, the lithofacies described in BHI-00184 (see Section 3.1) were regrouped into nine hydrogeologic units based on similarity in expected groundwater-flow properties. Flow properties generally correlate to texture, sorting, and degree of cementation. Other geologic factors such as depositional environment, lithologic composition, and time of deposition were not considered in defining hydrogeologic units for the model. Therefore, the grouping of lithofacies was similar but not identical to that in BHI-00184.

Hydrogeologic units used in the model were designated by numbers and are briefly described in Table 6.1. The units corresponding to BHI-00184 are shown in parentheses. More detailed descriptions of the sediments were presented in Section 3.1, and a graphic comparison of the model units against the stratigraphic column was shown in Figure 3.1-2. Odd-numbered Ringold units are predominantly coarse-grained sediments. Even-numbered Ringold units are predominantly fine-grained sediments with low permeability. The Hanford formation combined with the pre-Missoula gravel deposits were designated as model Unit 1. Units 2 and 3 correspond to the early Palouse soil and Plio-Pleistocene unit, respectively. The predominantly mud facies of BHI-00184's upper Ringold were designated as Unit 4. However, a difference in the definition of model units is that the lower, predominantly sand, portion of BHI-00184's upper Ringold was grouped with Unit 5 and also includes Ringold gravel Units E and C. Part of BHI-00184's lower mud unit was designated as Unit 6. However, sandy portions of the lower mud unit were assigned to Unit 7, which also includes BHI-00184's gravel Units B and D. Portions of the lower mud that occur below Unit 7 were designated as Unit 8. Gravels of BHI-00184's Unit A were designated as Unit 9 for the model, and the underlying basalt was designated as Unit 10. However, the basalt was assigned a very low hydraulic conductivity and was essentially impermeable in the model.

The lateral extent and thickness distribution of each hydrogeologic unit were defined based on information from well driller's logs, geophysical logs, and an understanding of the geologic environment. These interpreted areal distributions and thicknesses were then integrated into EarthVision™ (Dynamic Graphics, Inc., Alameda, California), a three-dimensional visualization software package that was used to construct a database of the three-dimensional hydrogeologic framework.

6.1.2 Recharge and Flow-System Boundaries

Both natural and artificial recharge to the aquifer were incorporated in the model. Natural recharge to the unconfined aquifer system occurs from infiltration of 1) runoff from elevated regions along the western boundary of the Hanford Site, 2) spring discharges originating from the basalt-confined aquifer system, and 3) precipitation falling across the site. Some recharge also occurs along the Yakima River in the southern portion of the site. Natural recharge from runoff and irrigation in Cold Creek Valley, upgradient of the site, also provides a source of groundwater inflow. As discussed in Section 3.2.1, areal recharge from precipitation on the site is highly variable, both spatially and temporally, and depends on local climate, soil type, and vegetation. The recharge map developed in PNL-10285 for 1979 (see Figure 3.2-1) was applied in the model.

The other source of recharge to the unconfined aquifer is wastewater disposal. As discussed in Section 3.2, the large volume of artificial recharge from wastewater discharged to disposal facilities on the Hanford Site over the past 50 years has significantly impacted groundwater flow and contaminant transport in the unconfined aquifer system. The volume of artificial recharge decreased significantly during the past 10 years, as shown in Figure 3.3-3.

Peripheral boundaries defined for the three-dimensional model are shown in Figure 6.1 together with the three-dimensional flow-model grid. The flow system is bounded by the Columbia River on the north and east and by the Yakima River and basalt ridges on the south and west. The Columbia River represents a point of regional discharge for the unconfined aquifer system. The amount of groundwater discharging to the river is a function of local hydraulic gradient between the groundwater elevation adjacent to the river and the river-stage elevation. This hydraulic gradient is highly variable because the river stage is affected by releases from upstream dams. To approximate the long-term effect of the Columbia River on the unconfined aquifer system in the three-dimensional model, the Columbia River was represented as a constant-head boundary over the entire thickness of the aquifer. The CHARIMA river-simulation model (PNWD-2225 HEDR) was used to generate long-term average river-stage elevations for the Columbia River based on 1979 conditions. The previous Columbia River boundary was extended from the left edge of the river to the middle of the river channel to more accurately reflect the hydraulic interaction of the unconfined aquifer and the river. The Yakima River was also represented as a specified-head boundary over the entire thickness of the aquifer.

At Cold Creek and Dry Creek Valleys, the unconfined aquifer system extends westward beyond the boundary of the model. To approximate the groundwater flux entering the modeled area from these valleys, both constant-head and constant-flux boundary conditions were defined. A constant-head boundary condition was specified for Cold Creek Valley for the steady-state model calibration runs. Once calibrated, the steady-state model was used to calculate the flux condition that was then used in the transient simulations. The constant-flux boundary was used because it better represents the response of the boundary to a declining water table than a constant-head boundary. Discharges from Dry Creek Valley in the model area, resulting from infiltration of precipitation and spring discharges, are approximated with a prescribed-flux boundary condition.

The basalt underlying the unconfined aquifer sediments represents a lower boundary to the unconfined aquifer system. The potential for interflow (recharge and discharge) between the basalt-confined aquifer system and the unconfined aquifer system is largely unquantified but is postulated to be small relative to the other flow components estimated for the unconfined aquifer system. Therefore, interflow with underlying basalt units was not included in the current three-dimensional model. The basalt was defined in the model as an essentially impermeable unit underlying the sediments.

6.1.3 Hydraulic and Transport Properties

To model groundwater flow, hydraulic properties, including both horizontal and vertical hydraulic conductivity, storativity, and specific yield, were needed for each hydrogeologic unit defined in the model. In addition, to simulate movement of contaminant plumes, transport properties were needed, including contaminant-specific distribution coefficients, bulk density, effective porosity, and longitudinal and transverse dispersivities.

Hydraulic properties of the Hanford Site unconfined aquifer were discussed in Section 3.2.2. For the two-dimensional model, measured values of aquifer transmissivity were used with an inverse model calibration procedure to determine the transmissivity distribution. Hydraulic conditions for 1979 were used in the inverse calibration because measured hydraulic heads were relatively stable at that time. Details concerning the updated calibration of the two-dimensional model are provided in PNNL-11801. The resulting transmissivity distribution for the unconfined aquifer system was shown in Figure 3.2-2.

Hydraulic conductivities were assigned to the three-dimensional model units so that the total aquifer transmissivity was preserved at every location. Hydrogeologic units below the unit containing the 1979 water table were assigned a constant hydraulic conductivity, while the hydrogeologic unit containing the 1979 water table was assigned a variable hydraulic conductivity that would preserve the total transmissivity from the inverse calibration. Hydraulic property values associated with the units below the water table were given in Table 6.1. The 1979 water table occurs in either Units 1 or 5 over most of the Hanford Site.

Information on transport properties used in past modeling studies at the Hanford Site is provided in PNL-10886. Values used in the three-dimensional transport model for simulating the movement of existing plumes are given in Table 6.2. The applied values were the same for all units.

6.1.4 Three-Dimensional Transient Flow Model

After a reasonable steady-state solution was generated for the three-dimensional model, the model was calibrated to match past changes in wastewater discharges. A number of calibration simulations were performed to evaluate the specific yield value that results in the best overall match. Specific yield largely controls how well the model responds to changes in flux. Three-dimensional transient simulations were conducted for the 1980 to 1995 time frame and used specific yields ranging from 0.1 and 0.35. The best fit to the observed data was achieved when a specific yield of 0.1 was used for the Ringold Formation and a specific yield of 0.25 for the Hanford formation. A comparison of predicted with observed conditions for 1996 using this combination of specific yields is shown in Figure 6.2.

The model was then used to simulate groundwater-flow conditions through the year 4000 and assumed that no large-scale irrigation would take place on the Hanford Site. Therefore, the projections mainly reflect the cessation of wastewater discharges associated with the Hanford Site. Water-table elevations estimated for the years 2000 and 2350 are shown in Figures 6.3 and 6.4. An overall decline in the water table and hydraulic gradient occurs across the entire modeled region. In the 200-East Area, the water table is predicted to decline by as much as 10 m before 2350. In the 200-West Area, a maximum decline of ~11 m is predicted during this same period. Additional details of the transient groundwater-flow simulations are provided in PNNL-11801, including responses predicted for individual well locations and a comparison of the predicted future water table with that estimated for 1944.

Flow-modeling results suggested that the water table may decline enough in the future that the aquifer will dry out in the area south of Gable Mountain along the eastern extension of the Gable Butte anticline. This could limit groundwater flow between the areas north and south of the Gable Butte anticline. The overall water table, including groundwater mounds near the 200 Areas, will decline. Groundwater movement from the 200 Areas plateau will shift to a more west-to-east pattern with discharge to the Columbia River occurring between the Old Hanford Townsite and the 300 Area.

6.1.5 Transport Modeling

The three-dimensional model was used to predict movement of the existing tritium, iodine-129, technetium-99, uranium, and strontium-90 plumes originating from the 200 Areas plateau. Each of the transport simulations was based on predicted future transient flow conditions. The finite-element grid for the 200 Areas plateau was refined to add horizontal and vertical discretization of the hydrogeologic units.

This was done to 1) represent the areal variations of initial contaminant concentrations, 2) more accurately represent flow paths, 3) minimize numerical dispersion, and 4) allow for appropriate specification of the initial vertical distribution of contaminants. The refined finite-element grid shown in Figure 6.5 has 3,108 surface nodes and a total of 23,668 nodes. The initial (1979) plume concentrations were assigned to model nodes found within the upper 25 m of the aquifer at initial water-table conditions. Where the aquifer was <25 m thick, the initial concentrations were assigned to the entire aquifer thickness.

6.1.5.1 Tritium Simulations

Simulations of tritium plume movement predicted that the 200-East Area plume will primarily migrate to discharge areas along the Columbia River between the Old Hanford Townsite and the 300 Area over a period of ~90 to 100 years. A smaller amount will migrate northward to the Columbia River. The plume from the 200-West Area was predicted to migrate beneath the 200-East Area. The contaminant concentration in the plume is reduced over time by dispersion and decay (half-life = 12.26 years). Predicted plumes for the year 2050 are shown in Figure 6.6.

6.1.5.2 Iodine-129 Simulations

Predictions of the iodine-129 plume beneath the 200-East Area indicated that it will migrate toward and discharge into the Columbia River over a period of ~570 years. During this period, concentrations predicted to discharge into the river will decline slightly by the process of dispersion. However, concentrations will not fall significantly below current levels because of the long half-life (1.6×10^7 years) of this isotope. The plume from the 200-West Area was predicted to migrate toward the 200-East Area, its concentration being reduced by dispersion. Figure 6.7 shows the distribution predicted for the year 2049.

6.1.5.3 Technetium-99 Simulations

Transport modeling of the technetium-99 plume indicated that the existing plumes in the 200-East and 200-West Areas will continue to migrate slowly from source locations in the 200 Areas toward the Columbia River. The 200-West Area plumes were predicted to migrate eastward toward the 200-East Area. The plume from the northern part of the 200-East Area was predicted to continue migrating northward through the gap between Gable Butte and Gable Mountain toward the Columbia River. Concentration levels of the simulated plumes decline to below regulatory limits over a period of 50 years because of dilution by infiltration and plume dispersion. Radioactive decay has little effect because of the long half-life (2.13×10^5 years) of this isotope. Figure 6.8 shows the distribution predicted for the year 2049.

6.1.5.4 Uranium Simulations

Simulations of the uranium plumes in the 200 Areas indicated that they will not migrate significantly from current source locations because uranium is sorbed by sediments (distribution coefficient = 0.6 mL/g). Concentration levels in the 200 Areas were predicted to decline to below regulatory limits during the next 50 years because of dilution by infiltration and plume dispersion. The primary isotope is uranium-238, having a half-life of 4.47×10^9 years. Therefore, predicted concentrations were not significantly affected by radioactive decay. The predicted distribution of the 200 Areas' plumes for the year 2049 is shown in Figure 6.9.

6.1.5.5 Strontium-90 Simulations

Transport modeling predicted that the strontium-90 plume in the 200-East Area will not migrate far from its current location because strontium-90 is sorbed by sediments (distribution coefficient = 20 mL/g). The strontium-90 plume was predicted to remain largely within the 200 Areas plateau. Figure 6.10 shows the plume configuration predicted for the 200-East Area for the year 2049. Concentrations were predicted to decline over the next 100 years to below regulatory limits because of radioactive decay (half-life = 28.8 years) and plume dispersion. However, predicted concentrations of strontium-90 associated with the deactivated Gable Mountain pond north of the 200-East Area may not be accurate. Current concentrations in this area reach a maximum of ~1,500 pCi/L. Radioactive decay will reduce this to ~350 pCi/L by 2049. However, because the unconfined aquifer is so thin at this location it is expected to be dewatered; that is why Figure 6.10 shows a maximum concentration of <8 pCi/L near the Gable Mountain pond site.

6.1.5.6 Model Results Discussion

Results of the transport analyses of tritium, iodine-129, technetium-99, and uranium with the three-dimensional model were generally in agreement with past sitewide modeling results (BHI-00469) in support of the *Hanford Site Groundwater Remediation Strategy* (DOE/RL-94-95, Rev. 1). The models predicted the same direction of movement and shape for each of the simulated plumes. However, the current three-dimensional model resulted in estimates of higher peak concentrations at shallow depths and less vertical migration than predicted in BHI-00469. These differences are attributable to assumptions about the hydrogeologic framework and the horizontal and vertical discretizations used in each model.

Projected future levels of tritium suggest that water supply wells in the 400 Area and emergency water supply wells in the 200-East Area will continue to be impacted by the tritium plume originating from the 200-East Area for the next 10 to 20 years. Tritium levels in the upper part of the unconfined aquifer system in the 400 Area and the 200-East Area are expected to remain above 20,000 pCi/L until sometime between 2010 and 2020. Model results predicted that tritium now found in the 300 Area in excess of 2,000 pCi/L will not reach the City of Richland's North Well Field recharge basins.

6.2 Modeling to Support Permeable Barrier Technology Testing

M. P. Connelly

In FY 1996, one of the remedial alternatives being considered for the strontium-90 plume at the 100-N Area was the installation of an in situ clinoptilolite treatment zone. The treatment zone was to be placed close to the shore of the Columbia River to capture any strontium-90 that may be moving from the aquifer into the river. One of the uncertainties associated with this technology and other proposed remediation technologies at the 100-N Area is the effect of river-stage fluctuations on groundwater movement near the river and, hence, on the effectiveness of the in situ treatment zone. The river-stage fluctuations are caused by use of Priest Rapids Dam, located upstream from the 100-N Area, as a peaking power facility, which causes the water level in the Columbia River to vary by as much as 2.6 m in a single day (Figure 6.11). In FY 1997, the U.S. Department of Energy's (DOE's) Office of Science and Technology (EM-50) funded a modeling study to analyze the hourly interaction between the Columbia River and the unconfined aquifer. A synopsis of the modeling study is presented here.

The modeling study used the Subsurface Transport Over Multiple Phases (STOMP) model (PNNL-11217) because of its ability to handle seepage face boundaries. The scope of the study was limited to modeling groundwater flow for a period of 4 weeks because of the vast data processing required to analyze the groundwater flow on an hourly basis. The principal functions of the model were the following:

- determine total water flux entering the aquifer from the river
- determine total water flux leaving the aquifer
- determine maximum and average water velocities within ~30 m of the Columbia River
- determine path of a massless water particle starting 20 m inland to the Columbia River
- compare and contrast results of the transient model to the steady-state model.

The first two functions were used to estimate how bank storage might affect the strontium-90 release to the Columbia River, while the next two functions could be used for possible in situ treatment remediation scenarios. As the river rises, water travels into the aquifer. When the river level drops, water that entered the aquifer when the river was high now flows back into the river. This is known as bank storage. Bank-storage water can have an impact on how contaminants are released from the groundwater to the river. The last function is to show whether a steady-state model is appropriate for near-river conditions.

6.2.1 Model Setup

The model simulated groundwater flow in a two-dimensional cross-section that extended northwest from well 199-N-67 for 403 m. Figure 6.12 shows this cross-section along with the finite-difference grid used in the modeling. The cross-section passes through well 199-N-8S and extends ~140 m into the Columbia River (left boundary). In the vertical direction, the base of the model is the impermeable Ringold mud unit at an elevation of 107 m (above mean sea level [MSL]), while the top of the model is at an elevation of 125 m MSL. The model was extended ~7 m above the water table, so the capillary fringe directly above the water table could be simulated. The grid used for the simulation consisted of 10,286 finite-difference cells. Of the 10,286 cells, 3,585 lie above the riverbed and/or land surface. These cells were declared inactive. A variable grid spacing was used to accommodate the large pressure gradients close to the Columbia River. The grid spacing is fine (0.5 x 0.5 m) where a vadose-zone seepage face is expected but is coarse away from the expected seepage faces (3.0 m [horizontal] x 0.5 m [vertical]). The upper vadose zone was not modeled.

6.2.2 Boundary Conditions

The lower boundary condition was set at no flow because of the presence of a relatively thick section of the Ringold mud unit. This unit has a hydraulic conductivity several orders of magnitude less than Ringold gravel unit E, which makes a no-flow boundary appropriate for this model. The upper boundary was set to natural recharge (2 cm/yr estimated for this area). The right boundary was set at no flow in the vadose zone, and a time-dependent constant-head boundary was set for the unconfined aquifer. The time-dependent constant-head boundary was set on an hourly basis from the real-time water-level data recorded for well 199-N-67. The left boundary was set at no flow for reasons of symmetry. The nodes on the riverbed were set to a time-dependent constant-head boundary. The head values applied to these nodes are from the real-time 100-N Area river-stage-monitoring station.

6.2.3 Model Calibration

Calibration of the groundwater-flow model established the degree to which the model simulated observed aquifer conditions. The calibration process involved iterative adjustments of selected model parameters (e.g., hydraulic conductivity, porosity) to improve the correlation between measured and simulated water levels in observed wells along the section (199-N-8) and to wells 199-N-2 and 199-N-3 that are near the section. The iterative process started with the Hanford formation having a horizontal hydraulic conductivity of 100 m/d and ending with 182 m/d, while the Ringold Formation started with a hydraulic conductivity of 10 m/d and ending with 15.2 m/d. The results of the model calibration are given in Figure 6.13. It should be noted that wells 199-N-2 and 199-N-3 are projected to the section. Well 199-N-3 is projected from the upstream side of the section and its water levels should be higher than those predicted by the model, while well 199-N-2 is projected from the downstream side of the section and its water levels should be lower than predicted by the model.

6.2.4 Model Results

Because of arrangements with Native Americans, Priest Rapids Dam daytime outflow rates are restricted to below 1,700 m^3/s during the months of October and November. This forces the salmon in the Hanford Reach of the Columbia River to stay within the low-water channel during spawning season. Because salmon do not spawn at night, the dam operators are allowed to raise the river's water level during the night to make up for lost power generation during the day. The model simulated the interaction between the Columbia River and the unconfined aquifer in 1-hour time steps for 4 weeks in October and early November 1995 (see Figure 6.11). Therefore, these 4 weeks were chosen because the daily river fluctuations were greatest during this period.

The results for each time step contained the following information: pressure head, hydraulic head, moisture content, percentage saturation, and pore velocities in the horizontal and vertical directions. The size of the file containing each week's simulation results was ~70 megabytes. The modeling results are given in three parts: 1) as a time-series animation for the duration of the simulation, 2) results of travel-time calculations for massless water particle in the riverbank and a comparison to those same water particles for a steady-state simulation, and 3) results of water-flux calculations to and from the Columbia River resulting from both bank storage and regional groundwater gradients.

6.2.5 Water-Particle Tracks

This section compares and contrasts the movement of water particles located close to the river's edge between a transient simulation in which the river level constantly changes and a steady-state simulation in which the river level remains constant through the course of the simulation. These simulations show the steady-state assumption is inappropriate for near-river conditions. The transient conditions for the water-particle travel path are much longer with higher groundwater velocities than those predicted by the steady-state conditions. Therefore, any permeable barrier placed close to the river's edge must take into account these higher groundwater velocities and longer and more tortuous travel paths.

For this comparison, four water-particle tracks were started ~25 m inland of the river to examine how a water particle would move from the riverbank to the river or, conversely, farther into the aquifer. Figure 6.14 shows each of the four water-particle tracks in a separate plot for the first 21 days of the simulation. Included in these plots are the stream traces from the initial-condition, steady-state simulation. All four transient particles travel a more circuitous and longer path than the steady-state particles. In the transient simulation, water particles moved both toward and away from the river. For the steady-state simulation, water particles moved only toward the river and at a much slower rate than under transient conditions. Table 6.3 gives the location of the uppermost water particle at the end of each day, the daily length of the particle path, the average particle velocity during the day, and the maximum daily particle velocity for the transient simulation. For comparison purposes, the same parameters (except maximum water-particle velocity) are also given for the steady-state simulation.

The uppermost water particle started in the Hanford formation (at an elevation of 116.25 m MSL) and traveled the 20 m to the Columbia River in 21 days in the transient simulation. Although it was only 20 m to the Columbia River, the particle actually traveled over 139 m before reaching the river because of the circuitous path along which it traveled. In contrast, a particle started from the same locations for the steady-state simulation were predicted to move along a noncircuitous path to the river that covered only 10.9 m. Water velocities for this Hanford formation particle in the transient simulation ranged from 6.67 to 22.05 m/d. The steady-state model for this particle predicted much lower water velocities, ranging between 0.5 to 0.57 m/d.

6.2.6 Water Flux

One of the primary purposes of the simulation was to estimate the volume of water that enters and leaves the river. STOMP has an option to calculate the instantaneous volume of water moving across a vertical or horizontal plane. If the water entered the aquifer, the water flux was positive; if the water left the aquifer, the water flux was negative. Forty-one surface-flux planes were used to define the flux surface along the riverbed. These 41 planes were placed into 2 groups: one within the Hanford formation and the other within the Ringold Formation. Table 6.4 gives the results of the water-flux calculations for the two groups, as wells as for the steady-state simulation. The average daily flux to the river or to the aquifer is given at the bottom of the table. This number was obtained by dividing the total cumulative flux given in the box for day 28 by 28.

An analysis of the water-flux results from the steady-state and 28-day transient simulations indicates that groundwater flow leaving the 100-N Area unconfined aquifer is a small fraction of the water flux associated with the bank-storage process. In the transient case, water moved in and out of the aquifer as the river level rose and fell. During the course of this transient simulation, an average 4.86 m^3/d of water flowed from the aquifer into the river when the river level was falling and an average 4.89 m^3/d of water flowed from the river into the aquifer when the river level rose for this 1-m-wide cross-sectional model. For the steady-state case, water only flowed from the aquifer to the river at a rate of ~0.5 m^3/d. A comparison of these two flow rates indicates that net flow from the aquifer to the river is only ~10% of the average volume that flows back and forth because of bank storage.

6.2.7 Bank-Storage Conclusions

The results from this simulation clearly demonstrate that the Columbia River's water-level variations have an impact on the near-river unconfined aquifer. The particle tracks show the differences in movement between using a transient boundary for the Columbia River and a steady-state boundary. Even though the water particles for the transient case had a more tortuous route and traveled a much greater distance, they also moved closer to the river in a shorter period of time than did the steady-state particles. The overall, average, daily, transient particle velocity was ~6 to 20 times that of the steady-state particles, and their maximum daily velocities could be up to 50 times that of the steady-state particles. Additionally, if the transient particle path was essentially a straight line toward the river, such as those observed between days 9 and 10, the particle velocities within the Hanford formation were ~10 m/d. This simulation has now provided some design criteria that remediation technologies will have to address.

The water-flux calculations indicate that bank storage is an important consideration when calculating total water movement from the aquifer into the river. The amount of water entering the river from the aquifer as a result of bank storage is an order of magnitude greater than the net volume of groundwater leaving the aquifer. This has both positive and negative effects concerning contaminants at the river's edge. For unretarded contaminants such as tritium and hexavalent chromium, the water entering the aquifer from the river will dilute the concentration of these contaminants before flowing back into the river. The same total mass of contaminant will be released but at lower concentrations. However, for contaminants that are adsorbed onto the sediments, the large bank-storage flow rates would remove sorbed contaminants from the near-river sediments faster than predicted from steady-state aquifer-flow rates unless the kinetics of the desorption process are too slow. For example, the clean water flowing into the aquifer when the river is high will equilibrate with the adsorbed contaminants and become contaminated. When this water flows back into the river (i.e., when the river level drops), a larger total amount of the adsorbed contaminant will be released and it would then contain the mass of the dissolved contaminants that were present in the groundwater plus any mass that desorbed from the sediments. However, it should also be pointed out that when the river level changes quickly, the pore-water velocities are high, and the clean water from the river may not have time to equilibrate with the contaminants adsorbed onto the soil.

6.3 Modeling 200-West Area Pump-and-Treat Operations

L. C. Swanson

Groundwater models for the 200-UP-1 and 200-ZP-1 Operable Units in the 200-West Area were constructed to assess the performance of the groundwater pump-and-treat systems. The models were used to predict system performance, including different extraction and injection well configurations, capture zones, and zones of hydraulic influence for the extraction and injection wells.

Modeling was conducted using the Micro-FEM© finite-element code (C. J. Hemker, Amsterdam, The Netherlands). Included in the modeling package are mesh-generating programs, a calculation module, and a postprocessing program. The mesh-generating programs allow the user to construct irregularly shaped and variably spaced triangular finite-element meshes. This feature allows for high resolution of the finite-element mesh near pumping or injection centers. The calculation module supports either a transient or steady-state solution. The postprocessing program enables the user to export the results of the simulations for presentation. The Micro-FEM© package was chosen because the finite-element, mesh-generating, and output capabilities make it easy to change the configuration of pumping and injection wells and quickly examine the results.

Groundwater modeling of the plume in the 200-UP-1 Operable Unit indicates that most of the targeted plume will be captured under the current well configuration (see Figure 5.9-21). Modeling of the pump-and-treat operation in the 200-ZP-1 Operable Unit shows that the high concentration area of the plume will be captured and a recirculation cell will be established. Descriptions of the pump-and-treat systems and results for FY 1997 are provided in Section 5.9.4.

Table 6.1. Major Hydrogeologic Units Used in Sitewide Three-Dimensional Model (after PNNL-11801)

Unit Number	Hydrogeologic Unit	Lithologic Description	Assumed Hydraulic Conductivity, m/d	Assumed Specific Yield
1	Hanford formation	Glaciofluvial gravels and sands (catastrophic flood deposits)	500	0.25
2	Palouse soil	Fine-grained sediments and eolian silts	1×10^{-4}	0.1
3	Plio-Pleistocene unit	Buried soil horizon containing caliche and basaltic gravels	350	0.1
4	Upper Ringold mud	Fine-grained fluvial and lacustrine sediments	5×10^{-2}	0.1
5	Middle Ringold (Units E and C)(a)	Semi-indurated coarse-grained fluvial sediments	8	0.1
6	Lower Ringold mud	Fine-grained fluvial and lacustrine sediments with some interbedded coarse-grained sediments	1×10^{-2}	0.1
7	Middle Ringold (Units B and D)(b)	Coarse-grained fluvial sediments	1	0.1
8	Lower Ringold mud	Fine-grained fluvial and lacustrine sediments	1×10^{-5}	0.1
9	Basal Ringold (Unit A)	Fluvial sand and gravel	1	0.1
10	Columbia River Basalt Group	Basalt	NA	NA

(a) Includes the predominantly sand portion of the upper Ringold described in BHI-00184.
(b) Includes the predominantly sand portion of the lower Ringold mud described in BHI-00184.
NA = Not applicable.

Table 6.2. Transport Properties Used in Simulations of Existing Plumes

Plume Constituent	Distribution Coefficient (K_d), mL/g	Bulk Density, g/mL	Effective Porosity	Dispersivity	
				Longitudinal, m	Transverse, m
Tritium	0	1.9	0.25	90	9
Iodine-129	0.5	1.9	0.25	90	9
Technetium-99	0	1.9	0.25	90	9
Uranium	3	1.9	0.25	90	9
Strontium-90	20	1.9	0.25	90	9

Table 6.3. Summary of Particle Track Movement

Particle Track Starting at Location Horizontal Distance = 160 m; Vertical Elevation = 116.25

Day	X-Location, m		Y-Location, m		Total Distance Traveled, m		Average Daily Velocity, m/d		Maximum Daily Velocity, m/d
	Transient	Steady St	Transient	Steady St	Transient	Steady St	Transient	Steady St	Transient
0	160.00	160.00	116.25	116.25	0.00	0.00	0.00	0.00	0.00
1	160.75	159.50	116.30	116.25	4.29	0.50	4.29	0.50	8.33
2	159.64	158.97	116.15	116.25	8.19	1.03	3.90	0.53	7.13
3	159.25	158.47	116.14	116.25	13.45	1.53	5.26	0.50	11.15
4	163.26	157.94	116.41	116.25	20.36	2.06	6.91	0.53	11.89
5	160.00	157.44	116.00	116.25	25.54	2.56	5.19	0.50	11.01
6	159.56	156.91	116.17	116.25	28.76	3.09	3.22	0.53	8.54
7	167.99	156.41	116.59	116.25	37.20	3.59	8.44	0.50	11.17
8	170.60	155.88	116.54	116.25	40.40	4.12	3.20	0.53	6.67
9	167.31	155.38	116.21	116.25	44.69	4.62	4.29	0.50	9.88
10	157.92	154.85	115.62	116.25	54.10	5.15	9.41	0.53	13.11
11	158.54	154.35	115.83	116.25	63.25	5.65	9.15	0.50	22.05
12	159.05	153.83	115.68	116.25	72.94	6.17	9.69	0.53	18.70
13	158.96	153.33	115.47	116.25	83.72	6.67	10.77	0.50	16.33
14	158.33	152.80	115.24	116.25	93.04	7.20	9.33	0.53	15.32
15	155.99	152.30	115.00	116.25	100.96	7.70	7.92	0.50	13.66
16	153.99	151.76	114.75	116.26	108.43	8.24	7.47	0.54	12.52
17	149.93	151.26	114.37	116.26	116.85	8.74	8.42	0.50	16.09
18	148.13	150.71	114.26	116.27	122.72	9.29	5.86	0.55	8.98
19	146.08	150.19	114.17	116.28	129.17	9.81	6.46	0.53	10.10
20	142.98	149.62	114.24	116.29	134.98	10.38	5.81	0.57	11.74
21	140.74	149.07	114.42	116.30	139.49	10.93	4.51	0.55	10.11

Table 6.4. Cumulative Total Volume of Water Entering or Leaving the Aquifer at End of Each Day

	Hanford Formation, m^3			Ringold Formation, m^3			Total, m^3			Steady State, m^3
Day	To River	To Aquifer	Net	To River	To Aquifer	Net	To River	To Aquifer	Net	To River
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	-3.10	3.68	0.59	-0.09	0.05	-0.03	-3.18	3.74	0.55	-0.49
2	-7.19	5.91	-1.28	-0.21	0.09	-0.12	-7.39	5.99	-1.40	-0.99
3	-10.97	9.14	-1.83	-0.32	0.13	-0.19	-11.29	9.28	-2.02	-1.48
4	-12.42	16.13	3.71	-0.36	0.23	-0.14	-12.79	16.36	3.58	-1.97
5	-18.71	17.61	-1.11	-0.55	0.25	-0.30	-19.26	17.86	-1.40	-2.46
6	-20.46	21.39	0.94	-0.59	0.29	-0.30	-21.05	21.69	0.64	-2.96
7	-20.46	32.22	11.77	-0.59	0.43	-0.16	-21.05	32.65	11.61	-3.45
8	-21.93	34.68	12.76	-0.61	0.47	-0.14	-22.53	35.16	12.62	-3.94
9	-28.32	35.86	7.54	-0.73	0.48	-0.24	-29.04	36.34	7.30	-4.44
10	-37.88	35.86	-2.01	-1.13	0.48	-0.65	-39.01	36.34	-2.66	-4.93
11	-40.49	42.07	1.58	-1.26	0.57	-0.70	-41.75	42.64	0.88	-5.42
12	-45.45	48.96	3.51	-1.42	0.65	-0.77	-46.88	49.61	2.73	-5.91
13	-51.32	56.39	5.07	-1.60	0.74	-0.86	-52.92	57.13	4.21	-6.41
14	-57.02	61.68	4.66	-1.73	0.80	-0.93	-58.75	62.48	3.73	-6.90
15	-62.41	65.48	3.08	-1.86	0.85	-1.01	-64.26	66.33	2.07	-7.39
16	-67.38	69.45	2.06	-1.98	0.90	-1.08	-69.36	70.35	0.98	-7.89
17	-73.27	73.05	-0.22	-2.18	0.95	-1.23	-75.45	73.99	-1.45	-8.38
18	-77.08	77.11	0.03	-2.27	1.00	-1.27	-79.35	78.11	-1.25	-8.87
19	-81.47	82.55	1.07	-2.38	1.06	-1.31	-83.85	83.61	-0.24	-9.36
20	-86.62	88.54	1.92	-2.50	1.14	-1.37	-89.12	89.68	0.56	-9.86
21	-91.89	95.63	3.74	-2.62	1.22	-1.41	-94.51	96.84	2.33	-10.35
22	-99.06	100.38	1.32	-2.78	1.27	-1.51	-101.84	101.65	-0.18	-10.84
23	-106.31	103.84	-2.47	-2.96	1.31	-1.66	-109.28	105.15	-4.13	-11.34
24	-111.02	111.69	0.67	-3.14	1.40	-1.74	-114.15	113.09	-1.07	-11.83
25	-116.46	117.97	1.50	-3.26	1.47	-1.79	-119.73	119.44	-0.29	-12.32
26	-121.25	124.39	3.14	-3.36	1.55	-1.81	-124.61	125.93	1.33	-12.81
27	-126.95	129.98	3.03	-3.48	1.61	-1.87	-130.43	131.59	1.16	-13.31
28	-132.52	135.17	2.65	-3.60	1.67	-1.93	-136.12	136.84	0.72	-13.80
Daily average	-4.73	4.83	0.10	-0.13	0.06	-0.07	-4.86	4.89	0.03	-0.49

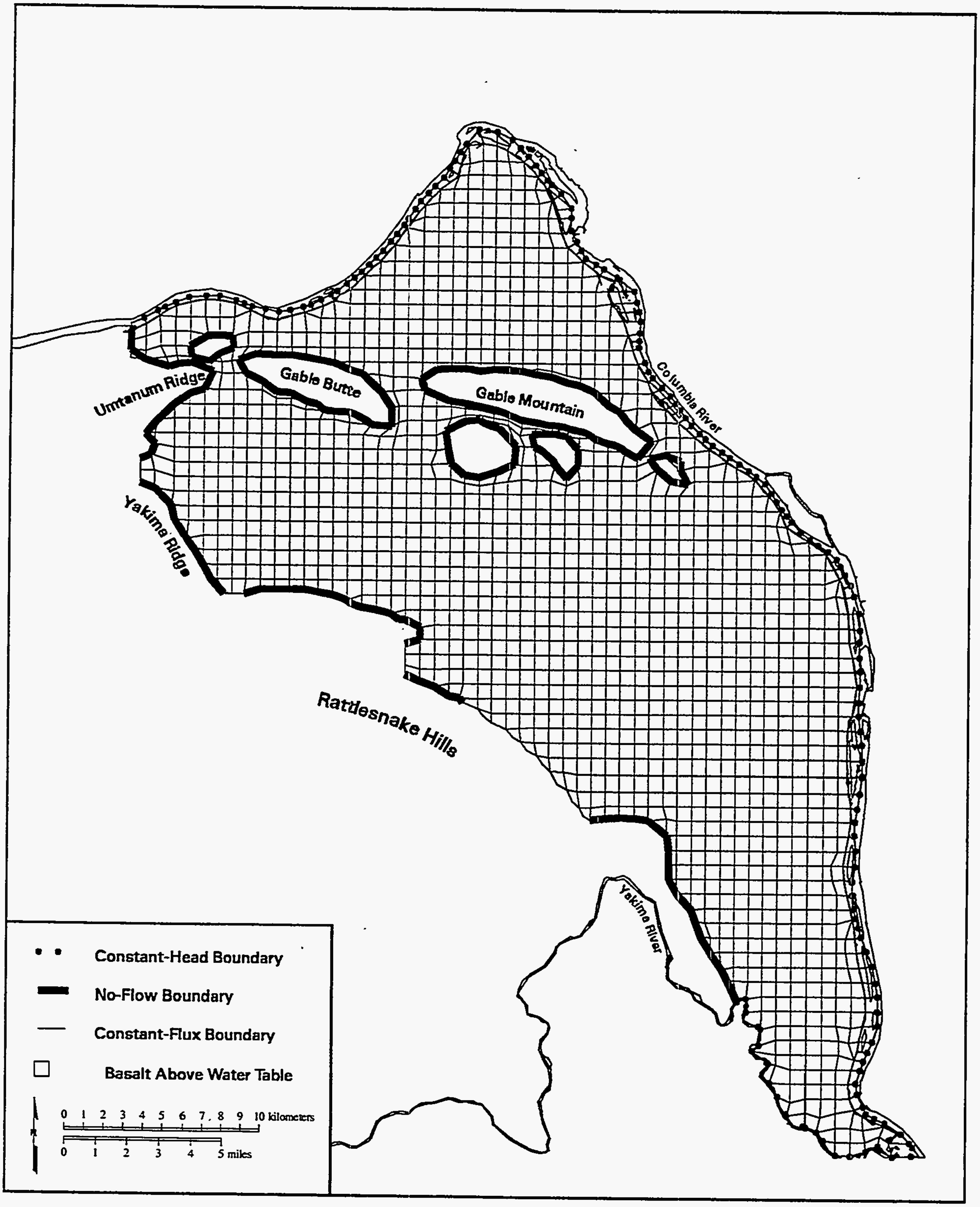

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Figure 6.1. Numerical Model Grid and Boundary Conditions

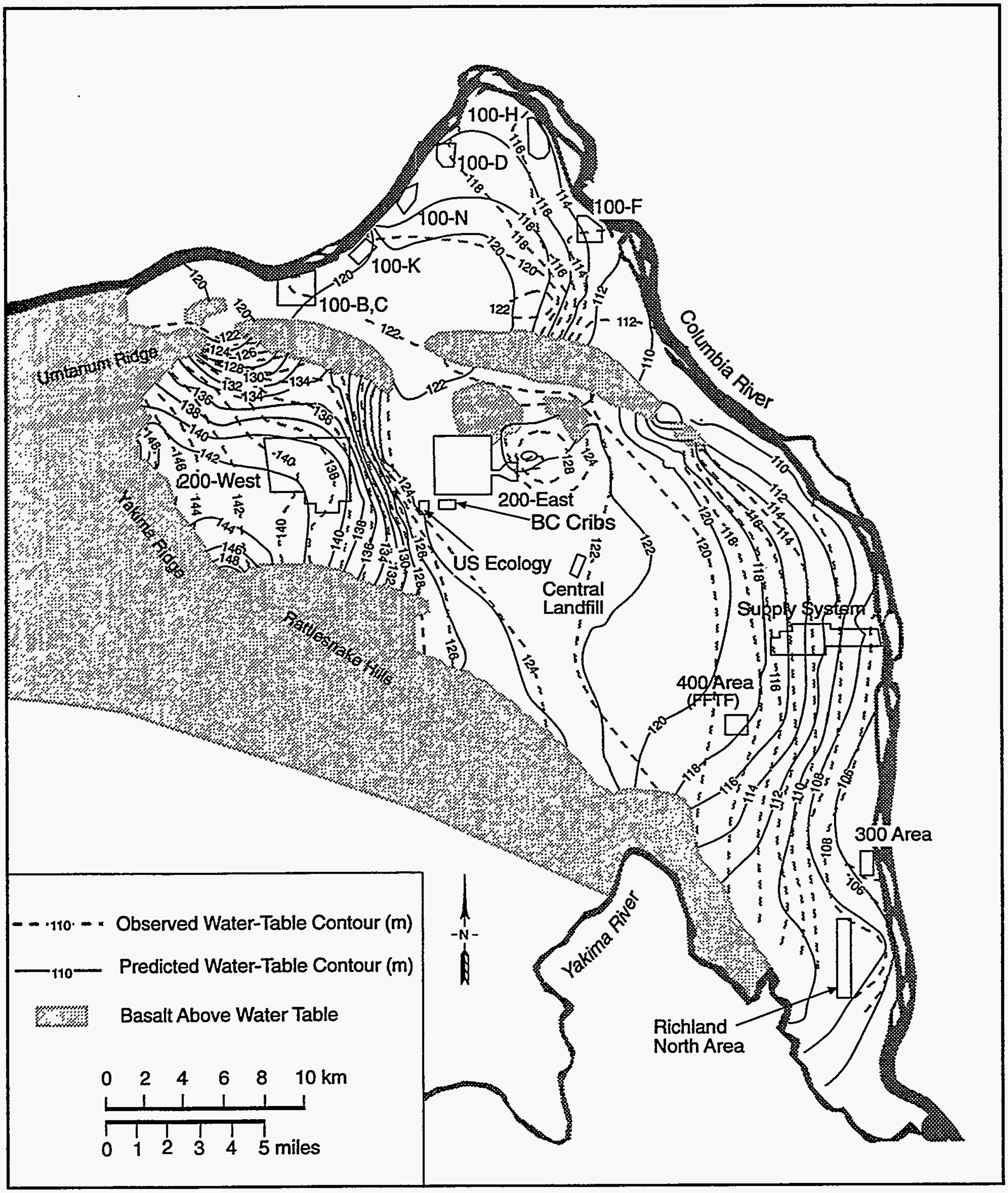

Figure 6.2. CFEST-Predicted Water Table for 1996 Compared to Observed Water Table

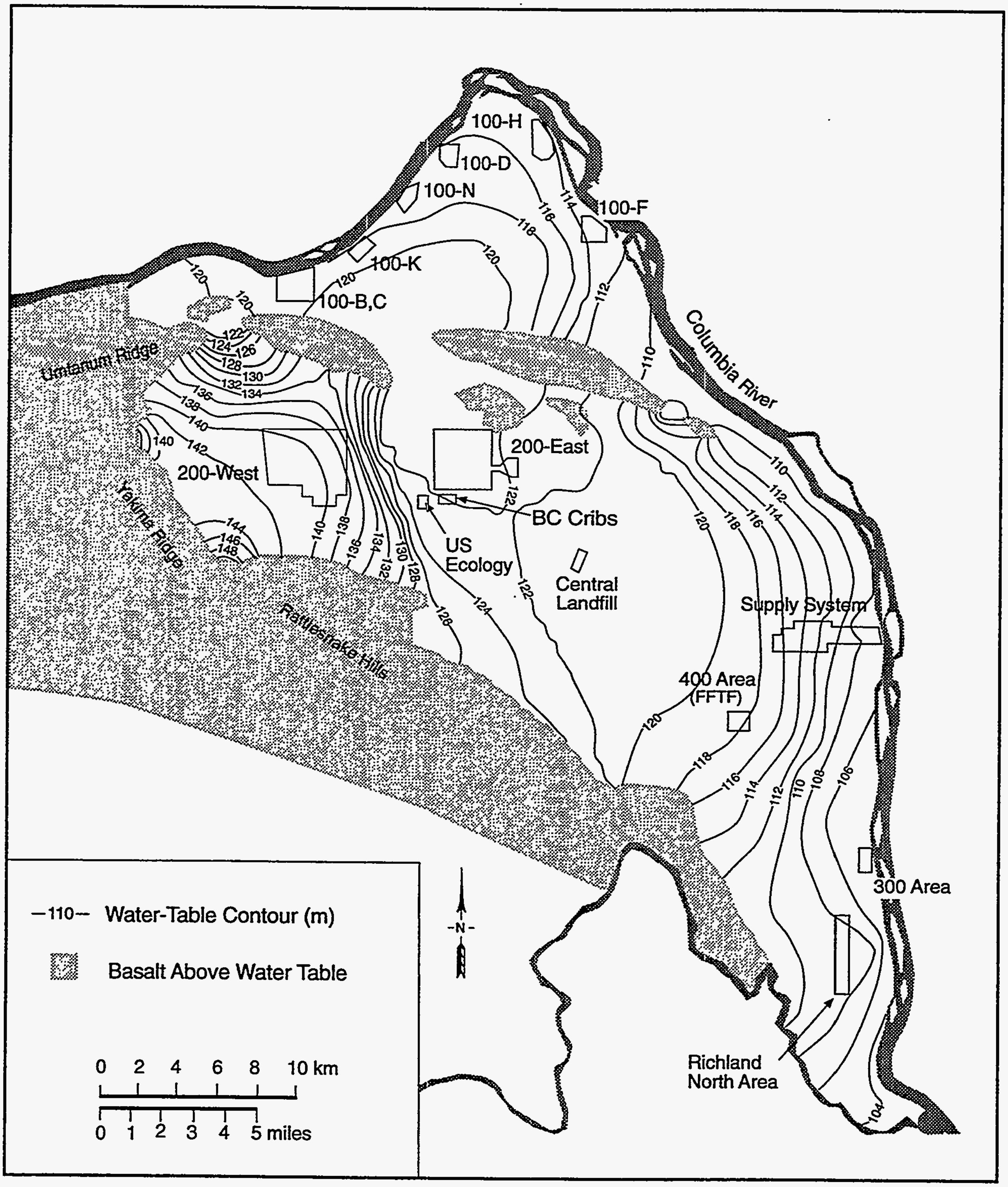

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Figure 6.3. Water Table for 2000 Predicted with Three-Dimensional CFEST Model

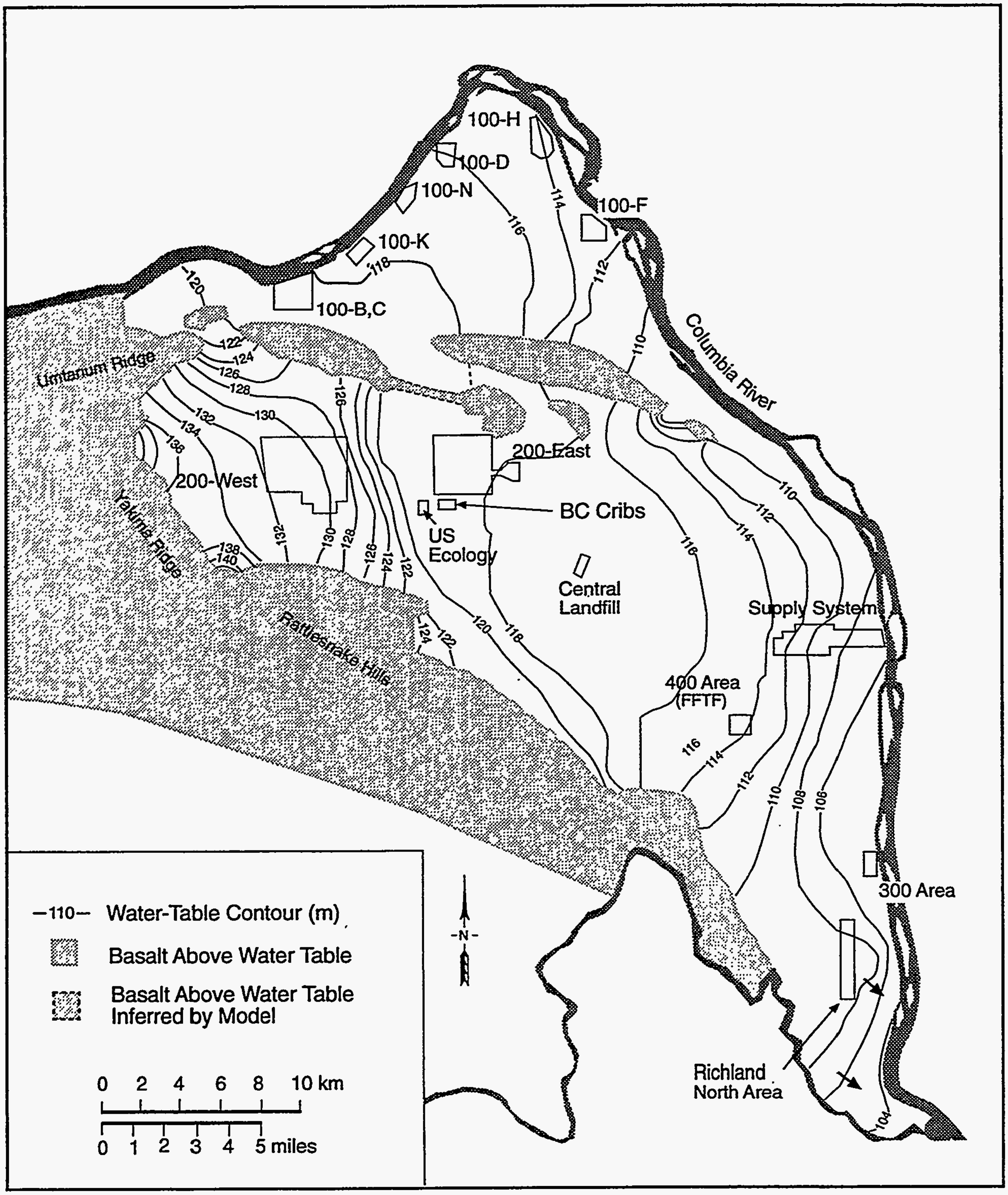

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Figure 6.4. Water Table for 2350 Predicted with Three-Dimensional CFEST Model

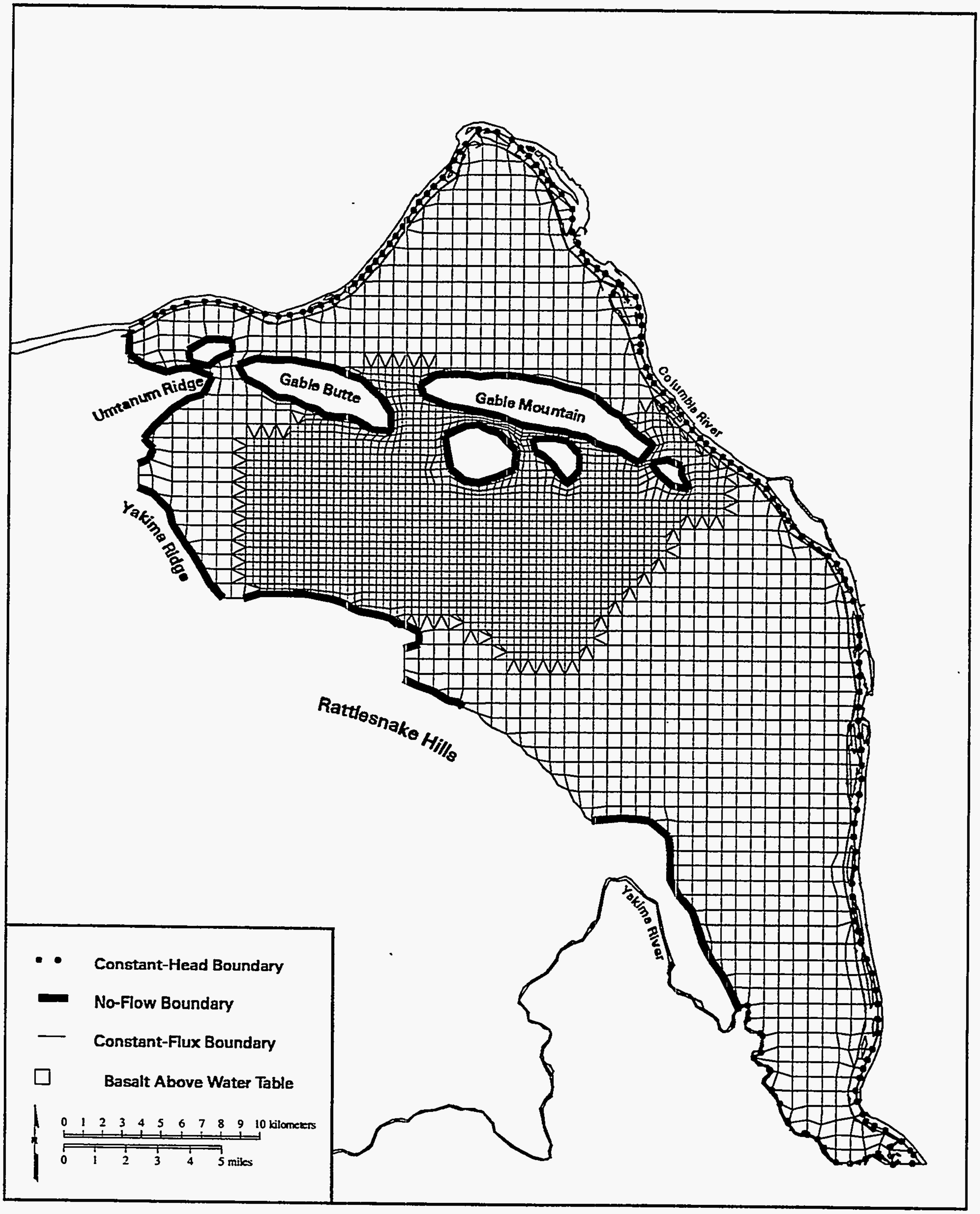

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Figure 6.5. Refined Grid

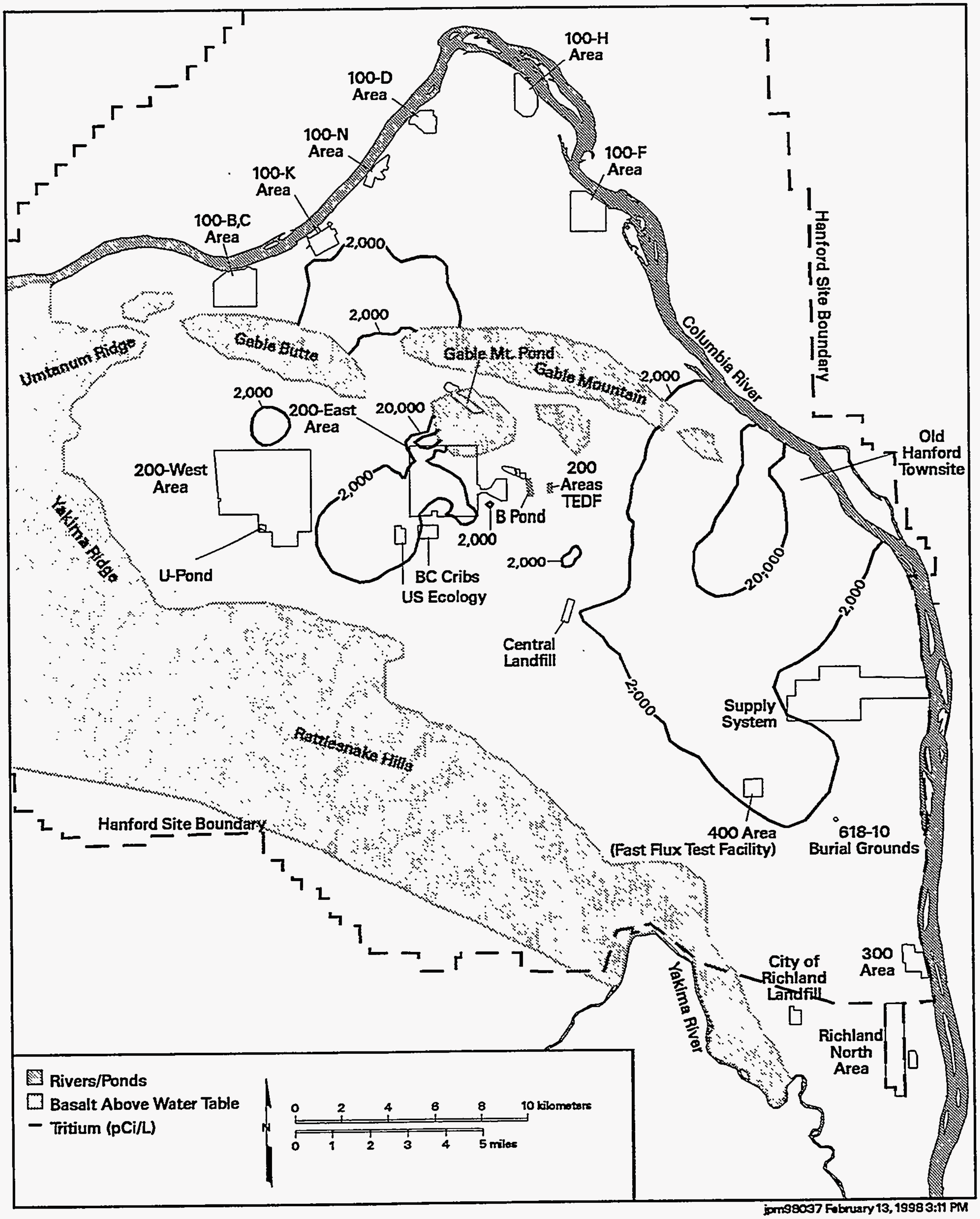

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Figure 6.6. Predicted Tritium Plumes from 200 Areas for 2050

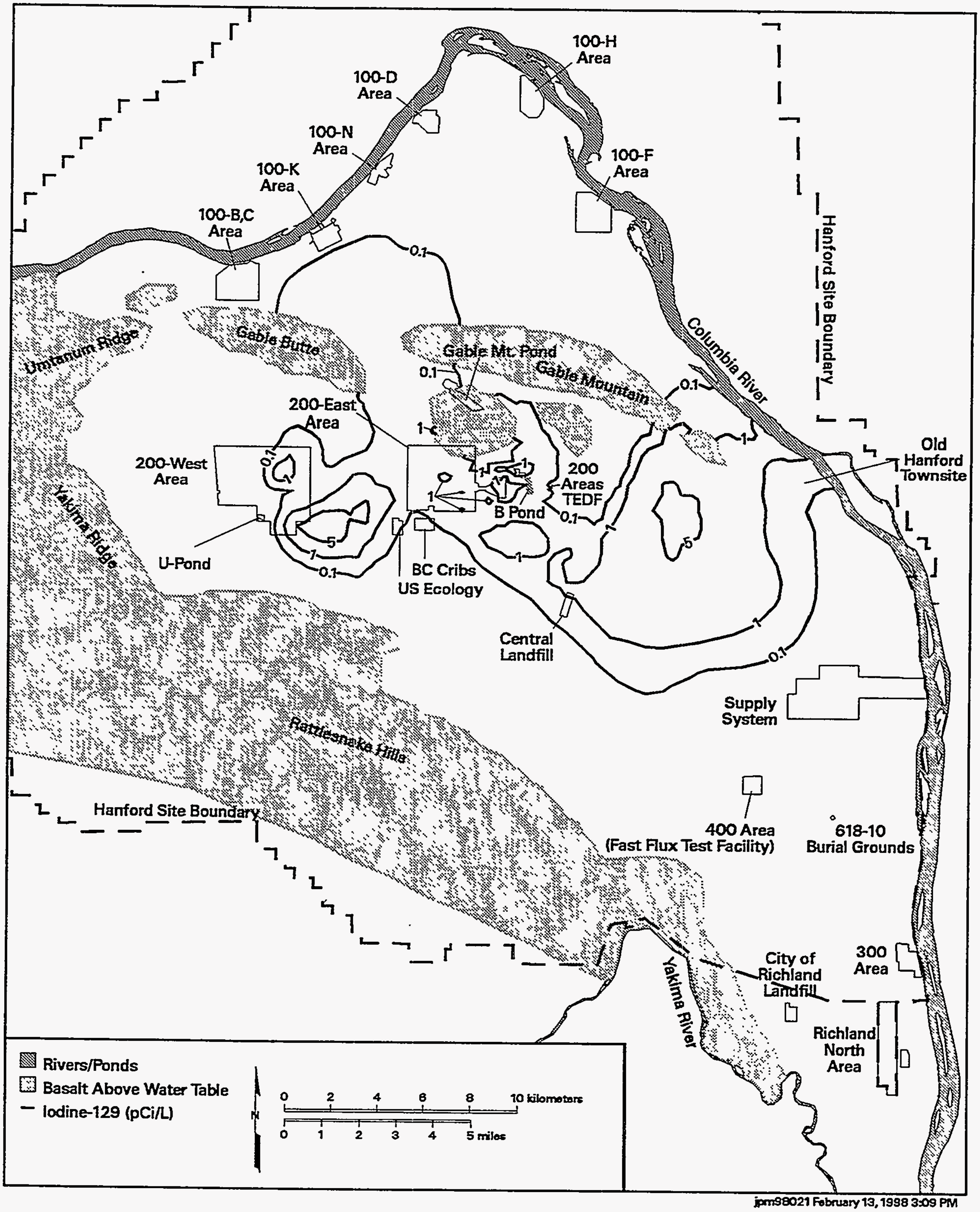

Figure 6.7. Predicted Iodine-129 Plumes from 200 Areas for 2049

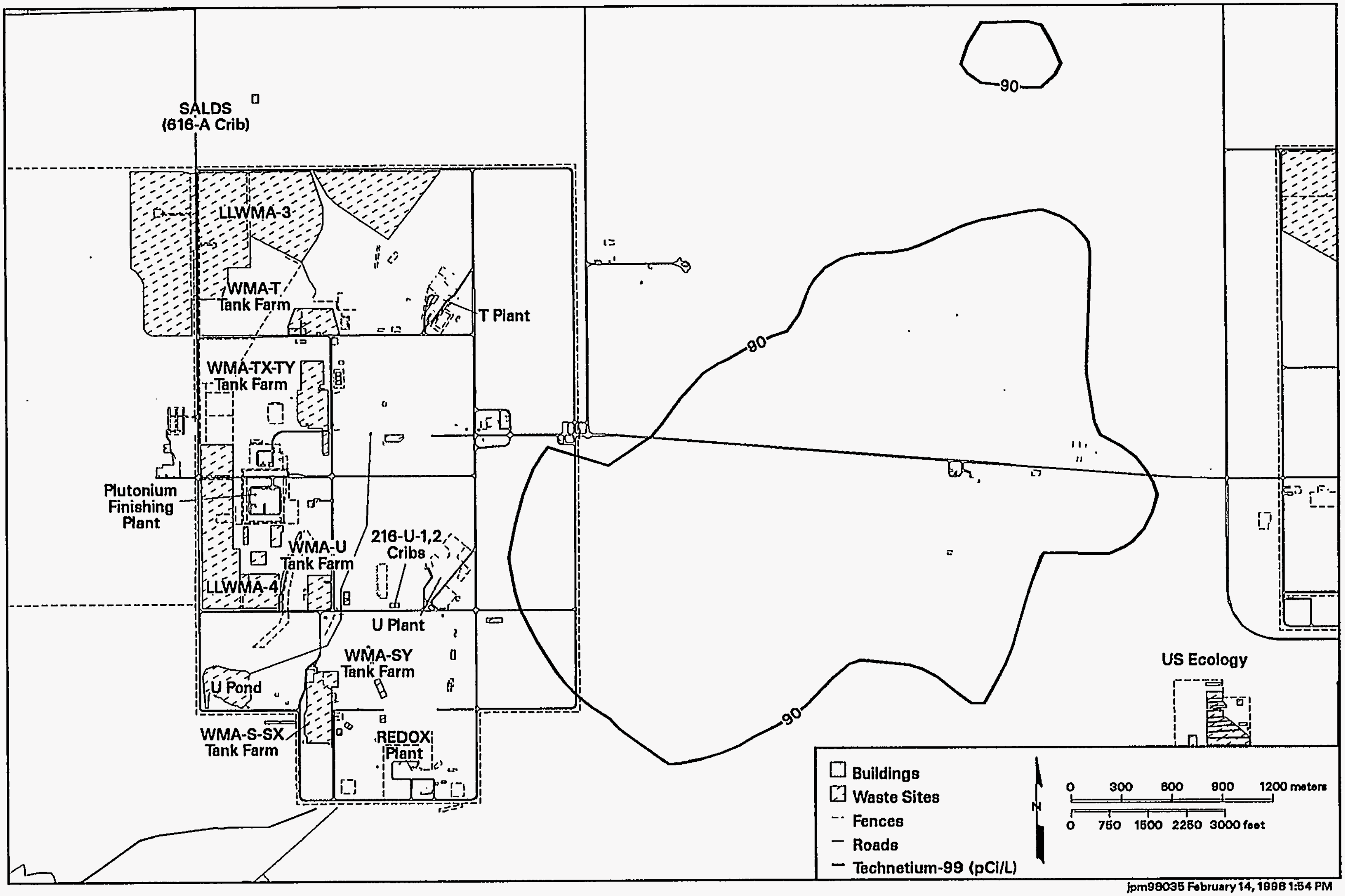

Figure 6.8. Predicted Technetium-99 Plume from 200-West Area for 2049

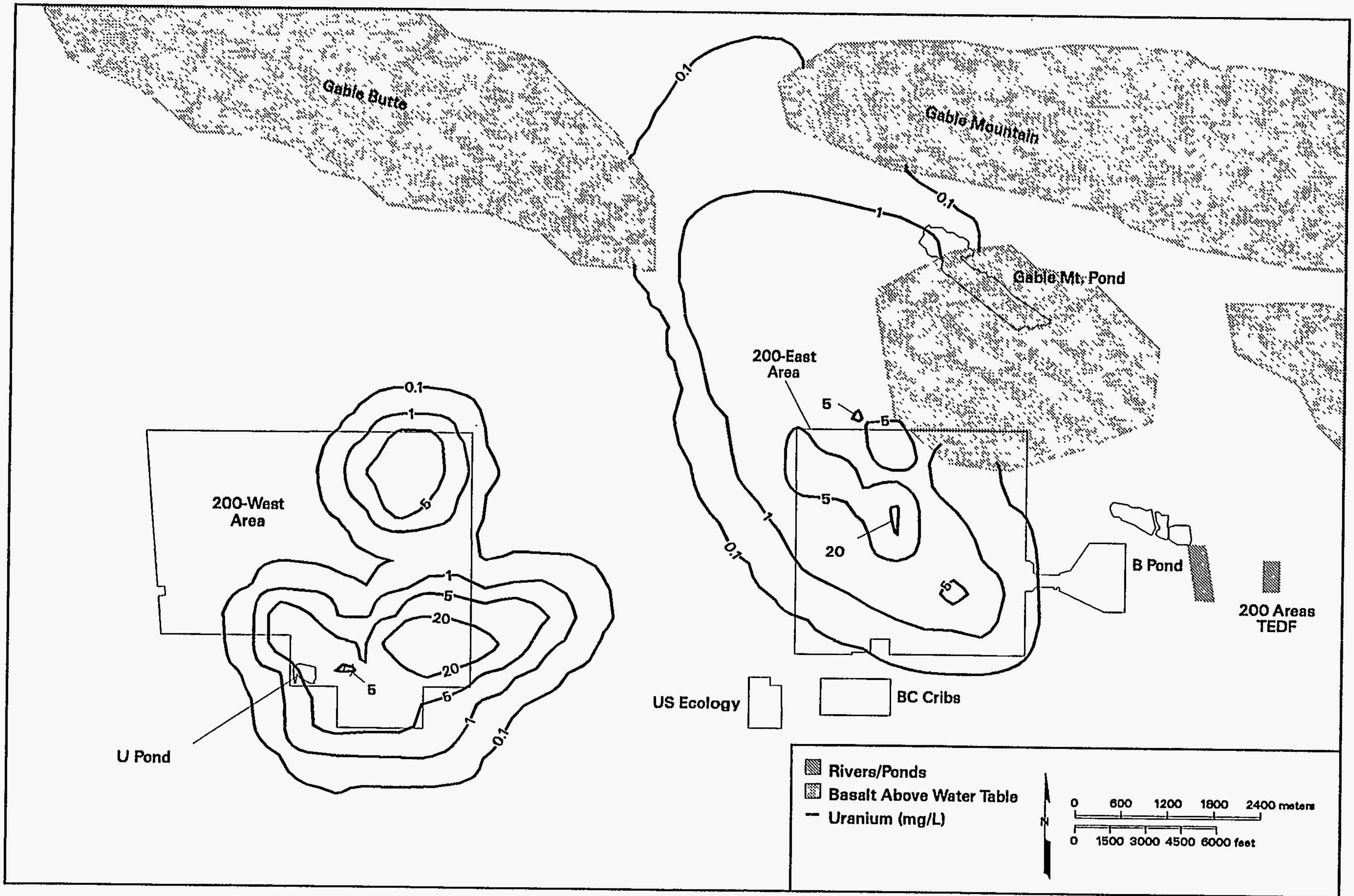

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Figure 6.9. Predicted Uranium Plumes from 200 Areas for 2049

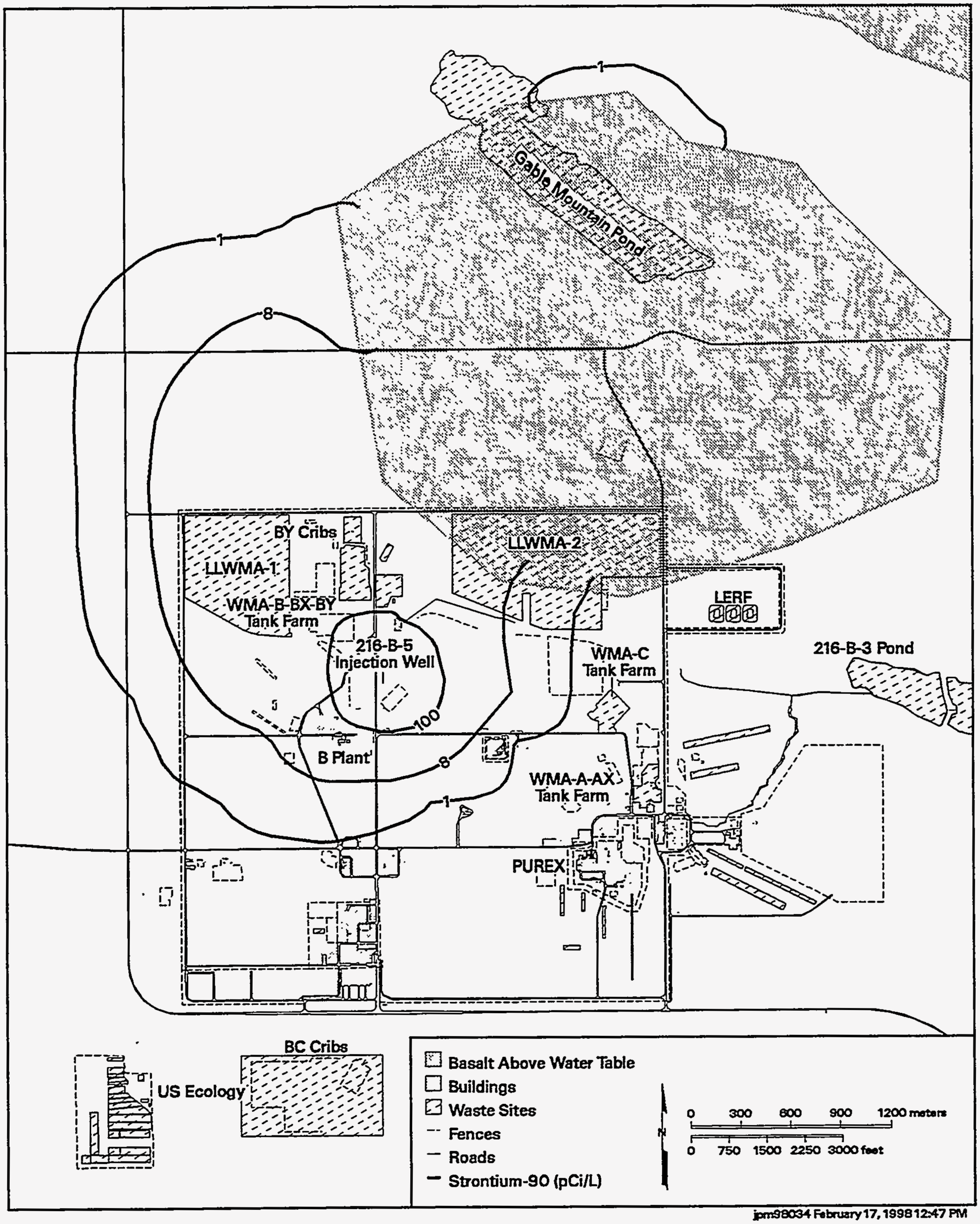

Figure 6.10. Predicted Strontium-90 Plumes from 200-East Area for 2049

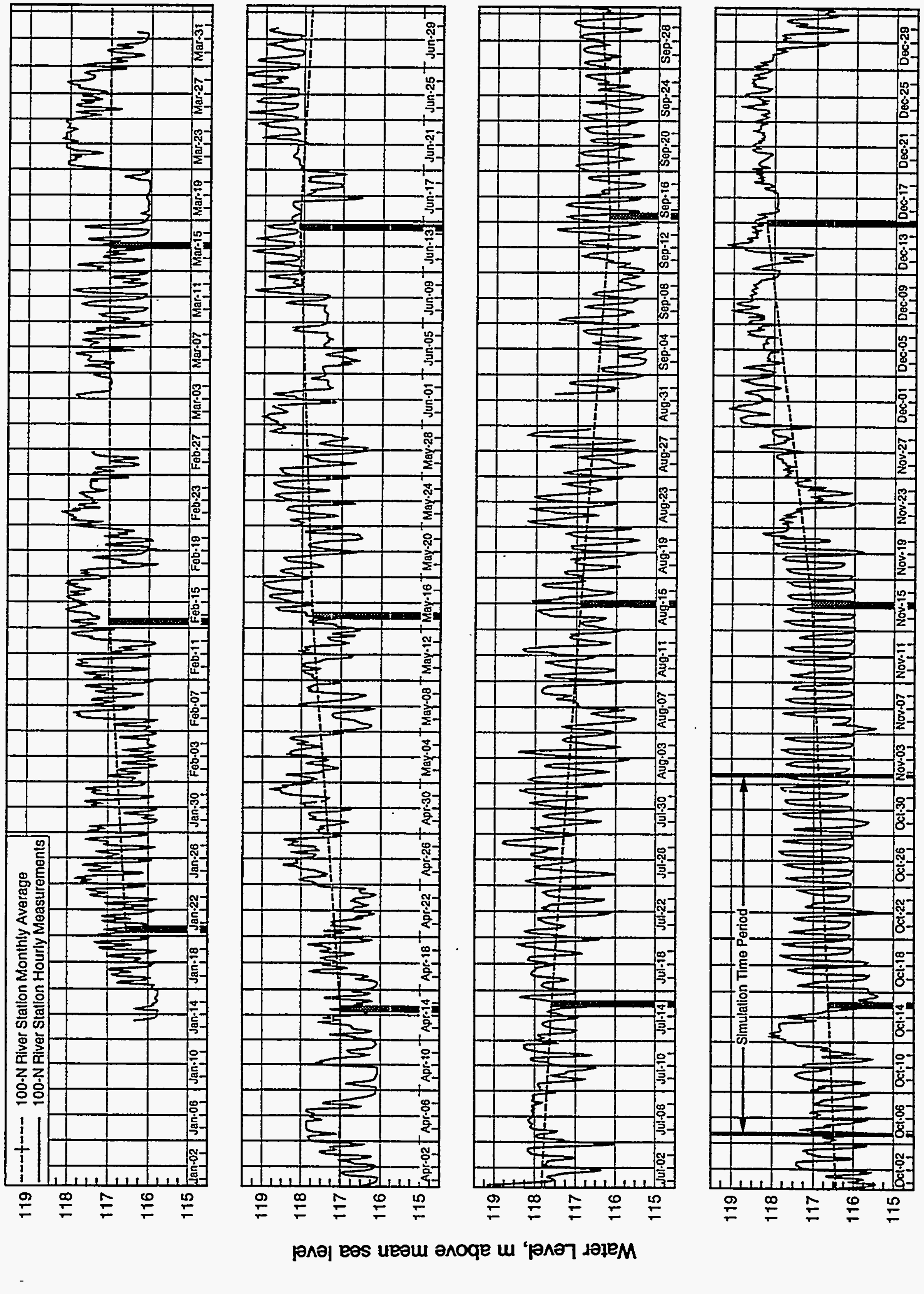

Figure 6.11. Columbia River Stage Measured at 100-N Area from January 14, 1995 to December 31, 1995

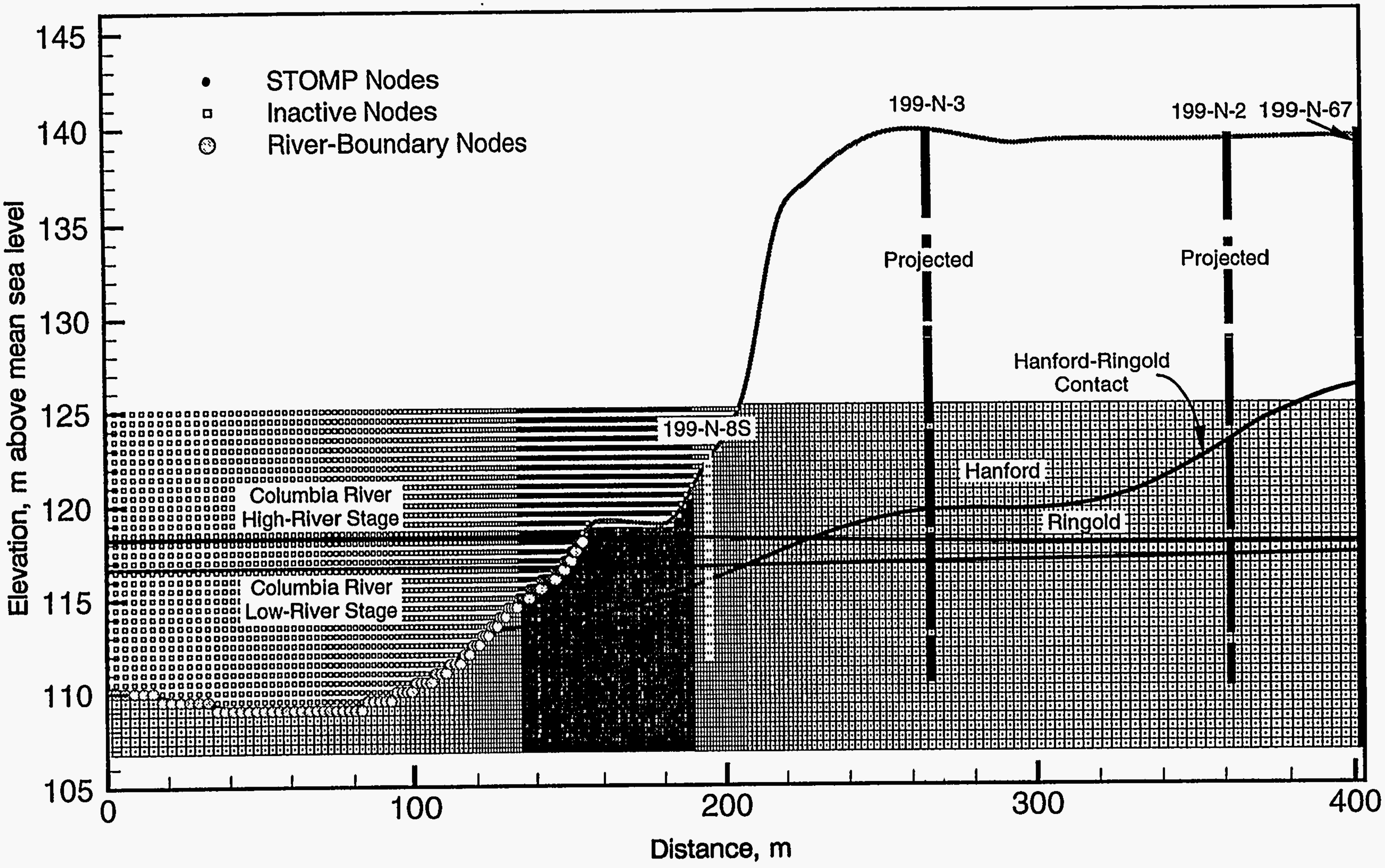

Figure 6.12. Two-Dimensional Cross-Section and Finite-Difference Grid

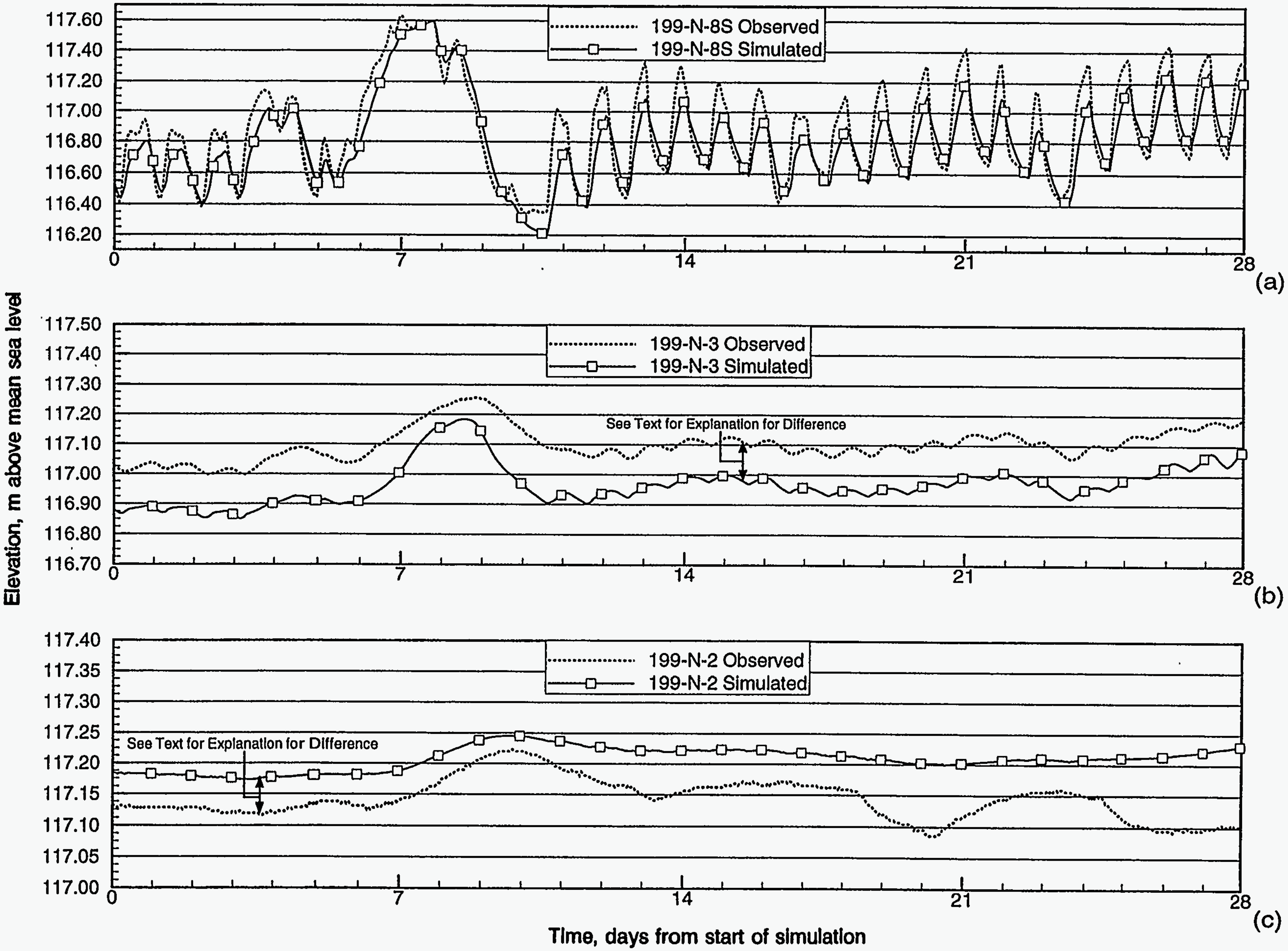

Figure 6.13. Comparison of Observed and Simulated Water Levels at Wells 199-N-8S, 199-N-3, and 199-N-2 for Final Model Calibration

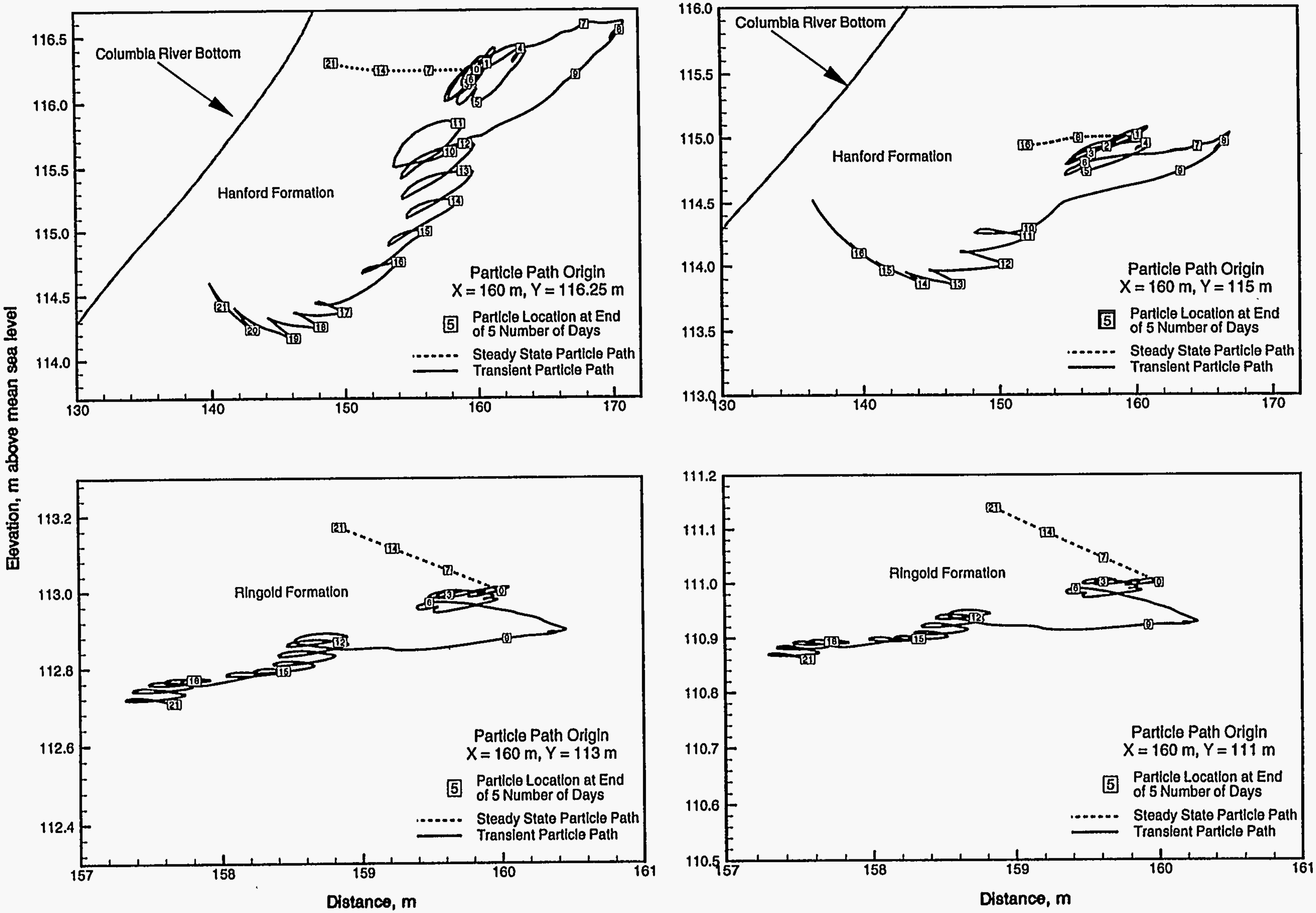

Figure 6.14. Comparison of Four Water-Particle Tracks Assuming Transient and Steady-State Flow Conditions

7.0 Well Maintenance, Remediation, and Decommissioning

B. H. Ford, W. D. Webber

This chapter describes well maintenance, remediation, and decommissioning activities conducted on the Hanford Site during fiscal year (FY) 1997.

7.1 Well Maintenance

Maintenance of groundwater wells is performed as part of a scheduled preventive maintenance cycle (routine) or in response to a problem identified in the field (nonroutine). Maintenance tasks are divided into two general categories: 1) surface tasks, which include conducting field inspections, well labeling, maintenance and replacement of locking well caps, casing repairs, diagnosis and repair of surface electrical and pump-discharge deficiencies, etc. and 2) subsurface tasks, which include repairing and replacing sampling pumps, performing camera surveys, brushing casing perforations, and developing wells to improve yield and sample quality, removal of sediment accumulation, etc.

Routine maintenance is performed on a 5-year cycle as a best management practice to maintain wells in a condition that helps improve the representativeness of groundwater samples and reduces the number of nonroutine activities. Routine maintenance involves, as needed, the following activities:

- perform field inspection and complete a field inspection report
- remove sample pumps and downhole equipment
- conduct downhole television camera survey
- brush and clean well casing
- remove debris and fill material with a sand pump and/or core barrel to restore well to original depth or to depth necessary to support sampling activities
- develop well using a bailer and/or an electric submersible pump
- install groundwater-sampling pump and/or downhole equipment.

Nonroutine tasks are performed in response to a problem identified in the field. Nonroutine maintenance tasks are varied and dependent on the specific problem, or set of problems, encountered at a well.

A summary of the number of maintenance activities by regulatory program, on which routine and nonroutine maintenance tasks were performed in FY 1997 is presented in Table 7.1.

7.2 Well Remediation

Well remediation involves activities that result in the modification of the physical configuration of a well. Remediation activities are considered when well condition deterioration is detected during maintenance activities or when the purpose of use for a well is changed. Remediation is performed in accordance with State of Washington Department of Ecology standards (WAC 173-160). If a well cannot be remediated to these standards or there is no longer an identified requirement to keep the well in service, the well is a candidate for decommissioning. A sitewide well remediation program was first instituted in FY 1993. No well remediation was performed during FY 1997.

7.3 Well Decommissioning

Decommissioning activities result in the permanent removal of a well from service. Well decommissioning is performed in accordance with State of Washington Department of Ecology standards (WAC 173-160). A well becomes a candidate for decommissioning if its use has been permanently discontinued; if its condition is so poor that its continued use is impractical; or it poses an environmental, safety, or public health hazard. A sitewide decommissioning program was first implemented in FY 1993. In FY 1997, the sitewide decommissioning strategy was revised to base schedule prioritization on 1) an evaluation of the risk of keeping a well in service (e.g., safety, public health, environmental) and 2) the need to be supportive of environmental cleanup priorities as defined in the Hanford Site long-range environmental restoration schedule (DOE/RL-96-105, Rev. 1).

Wells that present the risk of being immediate hazards to public health or safety are categorized as imminent hazard wells and receive the highest schedule priority for decommissioning. In FY 1997, there were no wells assigned to this category. Three risk categories (high, medium, and low) identify wells that have the potential to provide a pathway to allow the movement of contaminants into deeper zones in the subsurface environment. In FY 1997, a process for evaluating and categorizing wells was finalized. The two primary evaluation drivers are well construction and proximity to waste-disposal sites. During FY 1997, efforts began on applying the methodology in the 100 and 200 Areas. Well classifications are shown in Figure 7.1.

Once risk potential is assigned to wells, the decommissioning schedule is driven by the long-range environmental restoration schedule (DOE/RL-96-105, Rev. 1). In general, areas adjacent to the Columbia River are to be remediated first. Noncompliant wells in areas adjacent to the river have scheduling preference for decommissioning, in the order of risk, before wells toward the central portion of the Hanford Site. The strategy was applied during the second half of FY 1997 and will be continued in future decommissioning work.

During FY 1997, 109 Hanford Site wells were decommissioned. Of this total, one well (299-W15-5) is of particular note. This well was a high-risk well that had been scheduled for decommissioning for a number of years. Well 299-W15-5 had a high interest level because it was believed to have a high potential to provide a contaminant pathway for carbon tetrachloride to move into the confined aquifer system. Discussion of the results of sampling conducted during decommissioning of this well is provided in

Section 5.9.3.4. A listing of the wells decommissioned in FY 1997 is provided in Table 7.2. Wells decommissioned to date on the Hanford Site are illustrated in Figure 7.1.

Table 7.1. Well Maintenance Summary by Regulatory Program, Fiscal Year 1997

		Nonroutine	
	Routine[(a)]	Surface	Subsurface
RCRA	77	46	37
CERCLA	0	5	51
Sitewide	0	1	48
Total	77	52	136

(a) Routine maintenance activities include both surface and subsurface tasks.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

RCRA = Resource Conservation and Recovery Act of 1976.

Table 7.2. Wells Decommissioned During Fiscal Year 1997

			Decommission Dates	
Well Name	Well Identification	Location	Start	Finish
699-39-7C	B2603	600	03/03/97	03/05/97
699-38-8B	A8591	600	03/05/97	03/12/97
699-39-7D	B2604	600	03/03/97	03/19/97
CPT-19	B8062.	200-West	04/07/97	03/07/97
499-S1-8B	A8107	400	04/14/97	04/21/97
499-S1-8L	A8116	400	04/21/97	04/23/97
NA	B8063	600	04/30/97	04/30/97
699-36-E3	A8574	600	04/24/97	05/08/97
NA	B2616	600	05/09/97	05/13/97
NA	B8075	600	05/14/97	05/15/97
NA	B8076	600	05/15/97	05/15/97
699-39-7E	B2605	600	03/13/97	05/22/97
199-H5-1B	A9809	100-H	06/09/97	06/09/97
699-91-46B	A9810	600	06/02/97	06/04/97
699-93-48B	A9811	600	06/04/97	06/05/97
699-16-E4D	A8352	600	07/16/97	07/21/97
699-16-E4E	A8353	600	07/16/97	07/21/97
699-16-E3B	A8348	600	07/16/97	07/24/97

Table 7.2. (contd)

Well Name	Well Identification	Location	Decommission Dates Start	Decommission Dates Finish
699-15-E3B	A8334	600	07/16/97	07/28/97
NA	B2845	600	07/16/97	07/28/97
699-16-E4C	A8351	600	07/29/97	07/29/97
NA	B2843	600	07/29/97	07/29/97
NA	B2844	600	07/29/97	07/29/97
699-16-E5	A8354	600	07/30/97	08/04/97
699-17-E5	A8374	600	07/30/97	08/04/97
NA	B2846	600	07/30/97	08/04/97
NA	B2847	600	07/30/97	08/04/97
NA	B2848	600	07/30/97	08/04/97
699-18-E7	A8401	600	08/01/97	08/06/97
NA	B2849	600	08/01/97	08/06/97
NA	B2850	600	08/05/97	08/06/97
NA	B2855	600	08/05/97	08/06/97
NA	B2853	600	08/05/97	08/06/97
699-18-E8	A8402	600	08/07/97	08/07/97
NA	B2851	600	08/07/97	08/07/97
NA	B2852	600	08/07/97	08/07/97
NA	B2862	600	08/07/97	08/11/97
699-19-E9	A8417	600	08/07/97	08/11/97
NA	B8163	600	08/11/97	08/12/97
NA	B8164	600	08/11/97	08/12/97
699-18-E8B	A8403	600	08/12/97	08/12/97
699-20-E10	A8435	600	08/12/97	08/12/97
NA	B8198	600	08/12/97	08/12/97
699-20-E11	A8436	600	08/12/97	08/12/97
NA	B2865	600	08/14/97	08/15/97
699-16-E4B	A8350	600	08/14/97	08/18/97
699-17-E3B	A8373	600	08/14/97	09/02/97
699-17-E3A	A8372	600	08/14/97	09/02/97
NA	B2861	600	08/14/97	08/19/97
NA	B2872	600	08/14/97	08/19/97
NA	B2873	600	08/14/97	08/19/97
NA	B8199	600	08/14/97	08/19/97
NA	B2879	600	08/14/97	08/19/97
NA	B2885	600	08/14/97	08/20/97
NA	B8200	600	08/15/97	08/19/97

Table 7.2. (contd)

Well Name	Well Identification	Location	Decommission Dates	
			Start	Finish
NA	B2878	600	08/15/97	08/20/97
NA	B2894	600	08/15/97	08/20/97
699-16-E1	A8346	600	08/18/97	08/18/97
699-15-0	A8315	600	08/18/97	08/18/97
NA	B8414	600	08/20/97	08/20/97
NA	B8413	600	08/20/97	08/20/97
NA	B8412	600	08/20/97	08/20/97
299-W15-5	A4930	200-West	06/23/97	08/28/97
699-17-E6	A8375	600	09/22/97	09/29/97
699-14-E1B	A8301	600	08/21/97	08/25/97
699-14-E1C	A8302	600	08/21/97	08/25/97
NA	B2864	600	08/21/97	08/25/97
699-14-E1A	A8300	600	08/21/97	08/25/97
699-14-1A	A8290	600	08/21/97	08/25/97
699-14-1B	A8291	600	08/21/97	08/25/97
NA	B8437	600	08/26/97	08/26/97
NA	B8438	600	08/21/97	08/26/97
NA	B8439	600	08/21/97	08/26/97
NA	B8440	600	08/21/97	08/26/97
NA	B8441	600	08/26/97	08/26/97
NA	B8442	600	08/26/97	08/26/97
699-13-0	A8258	600	08/27/97	09/02/97
699-18-E3C	A8400	600	08/27/97	09/03/97
699-18-E3A	A8398	600	08/27/97	09/03/97
699-18-E3B	A8399	600	08/27/97	09/03/97
699-20-E2	A8426	600	08/27/97	09/03/97
NA	B2863	600	08/27/97	09/03/97
NA	B8443	600	08/27/97	09/02/97
699-21-E2	A8441	600	08/28/97	09/15/97
NA	B2866	600	08/28/97	09/09/97
NA	B2867	600	08/28/97	09/09/97
NA	B2868	600	08/28/97	09/09/97
NA	B2869	600	08/28/97	09/09/97
699-22-E2	A8447	600	08/28/97	09/10/97
NA	B2858	600	08/29/97	09/10/97
NA	B2860	600	08/29/97	09/17/97
NA	B8452	600	08/29/97	09/10/97

Table 7.2. (contd)

Well Name	Well Identification	Location	Decommission Dates	
			Start	Finish
NA	B2859	600	08/29/97	09/17/97
699-23-E2	A8451	600	09/04/97	09/12/97
NA	B8453	600	09/04/97	09/12/97
NA	B8454	600	09/04/97	09/12/97
NA	B8455	600	09/04/97	09/12/97
NA	B8456	600	09/04/97	09/16/97
NA	B8457	600	09/04/97	09/16/97
NA	B8461	600	09/08/97	09/15/97
NA	B8462	600	09/08/97	09/15/97
NA	B8463	600	09/08/97	09/16/97
NA	B8458	600	08/29/97	09/11/97
NA	B8450	600	08/27/97	09/15/97
NA	B8451	600	08/27/97	09/16/97
299-W15-96(a)	A7395	200-West	09/16/96	01/10/97
199-K-10	A5738	100-K	09/24/97	09/25/97
199-K-12	A5739	100-K	09/24/97	09/25/97
199-F5-2	A4588	100-F	09/24/97	09/24/97

(a) This well could not be located in the TY tank farm. With agreement from the State of Washington Department of Ecology, it was designated as decommissioned and the appropriate completion reports were submitted to document its removal from the inventory.

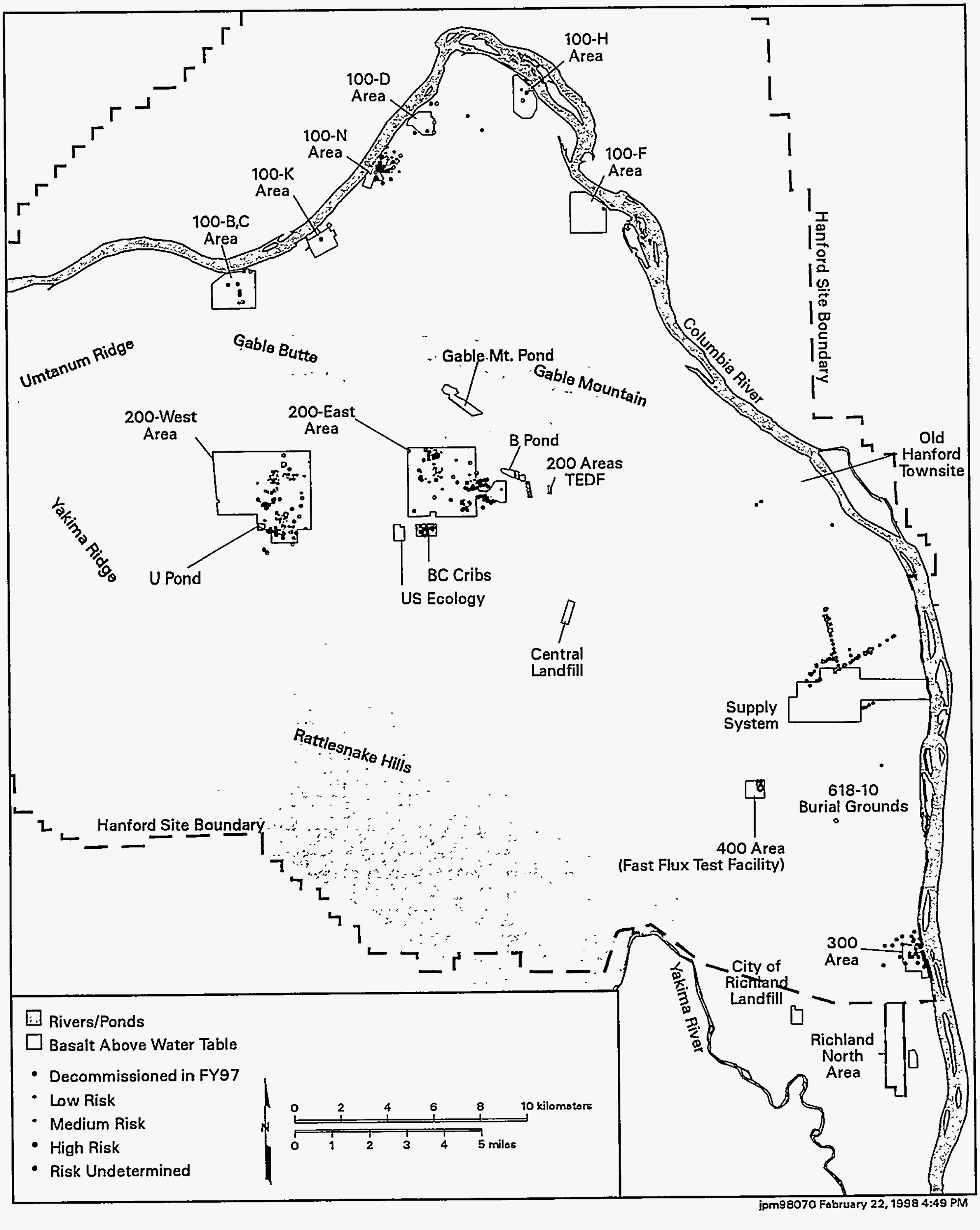

Figure 7.1. Classification of Wells for Decommissioning (coordinates lacking for 14 wells decommissioned in FY 1997 in 100, 200, and 400 Areas)

8.0 References

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Appendix A

Supporting Information for Regulated Units

Appendix A

Supporting Information for Regulated Units

M. J. Hartman

This appendix lists supplemental information for waste-disposal facilities on the Hanford Site requiring groundwater monitoring and regulated under the Washington Administrative Code (WAC). Most of these are *Resource Conservation and Recovery Act of 1976* (RCRA) facilities (WAC 173-303), on which this appendix is focused. Three treated effluent-disposal facilities (WAC 173-216) and one solid waste landfill (WAC 173-304) are also included for completeness.

Figure A-1 shows the locations of the WAC-regulated units on the Hanford Site. Figures A-2 through A-26 show well locations for each facility. Table A-1 is a matrix showing where in this report required RCRA elements may be found. Tables A-2 through A-26 are well and constituent lists for each WAC-regulated facility. The tables include references to the current monitoring plans or assessment plans. Wells that are cosampled with other RCRA units or to meet the requirements of other regulations or U.S. Department of Energy (DOE) orders are noted in the "other networks" column. Wells sampled for DOE Order 5400.1 are designated "operational" for near-field monitoring or "sitewide" for far-field monitoring. Designations of "CERCLA" or operable unit number (e.g., 100-HR-3) denote monitoring under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*. Well-location figures are interspersed with well lists in this appendix for the reader's convenience.

Table A-27 lists RCRA monitoring results for fiscal year 1997 that exceeded primary or secondary maximum contaminant levels or interim drinking water standards (see Table 5.1-1 in the main text for references to standards). Federal standards from 40 CFR 141 and 40 CFR 143 were applied for all constituents except two organic constituents for which there are no federal maximum contaminant levels. For those constituents, bis(2-ethylhexyl)phthalate and 1,1-dichloroethane, the standards of WAC 173-200 were applied. The groundwater database was queried for all wells sampled for RCRA with results greater than each constituent's drinking water standard between October 1, 1996 and September 30, 1997. Results were excluded from this table if the analyte was undetected and the drinking water standard was smaller than the detection limit (i.e., result was flagged with a U in the database). Results that are suspected to be erroneous are also excluded (results flagged with F, Y, or R in the database).

This table may be used to determine where constituents are consistently greater than the drinking water standards, as reflected by a high number of exceedances and/or exceedances in multiple wells. Results of upgradient wells are included, reflecting possible upgradient sources of contaminants. Interpretation of the most significant contaminants for each RCRA unit are included in Chapter 5.0 of the main text.

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Table A.1. Organizational Matrix for Required RCRA Elements in this Report

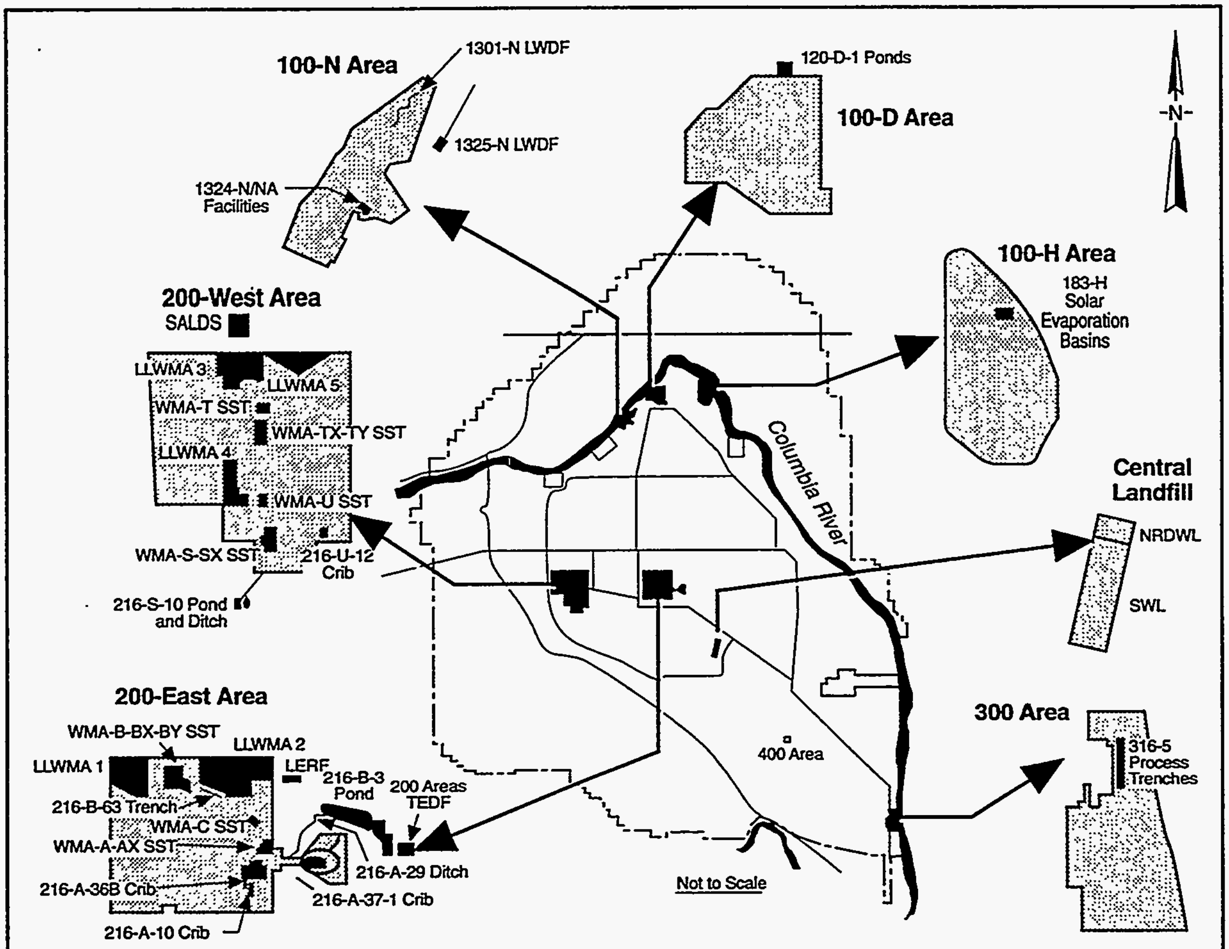
RCRA Site	Regulatory Status(a)	Facility Overview	Hydrogeology Flow Direction and Rate(b)	Well Network and Constituent List Table	Indicator Parameters and Statistics(c)	Elevated Constituents, Concentration Histories, Distribution	Evaluation of Monitoring Network
1301-N, 1324-N/NA, 1325-N	Indicator evaluation	5.5.1	3.5.3	A.2	5.5.2	5.5.3	5.5.2
120-D-1 ponds	Indicator evaluation	5.6.1	3.5.4	A.3	5.6.2	5.6.3	5.6.2
183-H solar evaporation basins	Compliance	5.7.1	3.5.5	A.4	NA	5.7.3	5.7.2
216-S-10 pond and ditch	Indicator evaluation	5.9.1	3.6.1	A.5	5.9.2	5.9.3	5.9.2
216-U-12 crib	Assessment	5.9.1	3.6.2	A.6	NA	5.9.3	5.9.2
216-B-3 pond	Assessment	5.10.1	3.6.7	A.7	NA	5.10.3	5.10.2
216-A-29 ditch	Indicator evaluation	5.10.1	3.6.6	A.8	5.10.2	5.10.3	5.10.2
PUREX cribs(d)	Assessment	5.10.1	3.6.5	A.9, A.10	NA	5.10.3	5.10.2
216-B-63 trench	Indicator evaluation	5.10.1	3.6.8	A.11	5.10.2	5.10.3	5.10.2
LERF	Indicator evaluation	5.10.1	3.6.11	A.12	5.10.2	5.10.3	5.10.2
LLWMA 1	Indicator evaluation	5.10.1	3.6.10	A.13	5.10.2	5.10.3	5.10.2
LLWMA 2	Indicator evaluation	5.10.1	3.6.10	A.14	5.10.2	5.10.3	5.10.2
LLWMA 3	Indicator evaluation	5.9.1	3.6.4	A.15	5.9.2	5.9.3	5.9.2
LLWMA 4	Indicator evaluation	5.9.1	3.6.4	A.16	5.9.2	5.9.3	5.9.2
WMA A-AX	Indicator evaluation	5.10.1	3.6.9	A.17	5.10.2	5.10.3	5.10.2
WMA B-BX-BY	Assessment	5.10.1	3.6.9	A.18	NA	5.10.3	5.10.2
WMA C	Indicator evaluation	5.10.1	3.6.9	A.17	5.10.2	5.10.3	5.10.2
WMA S-SX	Assessment	5.9.1	3.6.3	A.19	NA	5.9.3	5.10.2

Table A.1. (contd)

RCRA Site	Regulatory Status[a]	Facility Overview	Hydrogeology Flow Direction and Rate[b]	Well Network and Constituent List Table	Indicator Parameters and Statistics[c]	Elevated Constituents, Concentration Histories, Distribution	Evaluation of Monitoring Network
WMA T	Assessment	5.9.1	3.6.3	A.20a	NA	5.9.3	5.9.2
WMA TX-TY	Assessment	5.9.1	3.6.3	A.20b	NA	5.9.3	5.9.2
WMA U	Indicator evaluation	5.9.1	3.6.3	A.19	5.9.2	5.9.3	5.9.2
NRDWL	Indicator evaluation	5.12.1	3.7.2	A.21b	5.12.2	5.12.3	5.12.2
316-5 process trenches	Compliance	5.13.1	3.8.1	A.22, A.23	NA	5.13.3	5.13.2

(a) As of September 30, 1997; see also Chapter 2.0 in the main text.
(b) See also Table 3.5-1 in the main text.
(c) Indicator evaluation sites only; see also Appendix B.
(d) Plutonium-uranium extraction (PUREX) cribs are 216-A-10, 216-A-36B, and 216-A-37-1.

LERF = Liquid Effluent-Retention Facility.
LLWMA = Low-level waste management area.
NA = Not applicable.
NRDWL = Nonradioactive Dangerous Waste Landfill.
WMA = Waste management area.



LERF	Liquid Effluent-Retention Facility
LLWMA	Low-Level Waste-Management Area
LWDF	Liquid Waste-Disposal Facility
NRDWL	Nonradioactive Dangerous Waste Landfill
SALDS	State-Approved Land-Disposal Site
SST	Single-Shell Tank
SWL	Solid Waste Landfill
TEDF	Treated Effluent-Disposal Facility
WMA	Waste Management Area

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Figure A.1. RCRA Facilities on the Hanford Site Requiring Groundwater Monitoring

Table A.2. Monitoring Wells and Constituents for 100-N Area Units (adapted from WHC-SD-EN-AP-038, Rev. 2)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Networks
		1301-N Liquid Waste-Disposal Facility			
199-N-2^{64}	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2, ERA, Sitewide
199-N-3^{64}	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2, ERA, Sitewide
199-N-34^{83}	Top of unconfined	Semiannual	Semiannual	PRE	Sitewide
199-N-57^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	Sitewide
199-N-105A^{95}	Unconfined	Semiannual	--	RCRA(a)	ERA
		1324-N/NA Liquid Waste-Disposal Facilities			
199-N-59^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-N-71^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	Sitewide
199-N-72^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-N-73^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-N-77^{92}	Bottom of unconfined	Semiannual	Semiannual	RCRA	--
		1325-N Liquid Waste-Disposal Facility			
199-N-28$^{83(b)}$	Top of unconfined	Semiannual	Semiannual	PRE	Sitewide
199-N-32^{83}	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2
199-N-41^{84}	Top of unconfined	Semiannual	Semiannual	PRE	Sitewide
199-N-74^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	100-NR-2, Sitewide
199-N-81^{93}	Top of unconfined	Semiannual	Semiannual	RCRA	100-NR-2, Sitewide

Contamination Indicator Parameters	Other Parameters	
pH (field)	Alkalinity	ICP metals (filtered)
Specific conductance (field)	Anions	Turbidity
Total organic carbon		
Total organic halides		

(a) Extraction well; screened over entire thickness of aquifer.
(b) Used for supplemental information; no statistical evaluations.
Shading = Upgradient well.
Superscript = Year of installation.
ERA = Expedited response action.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

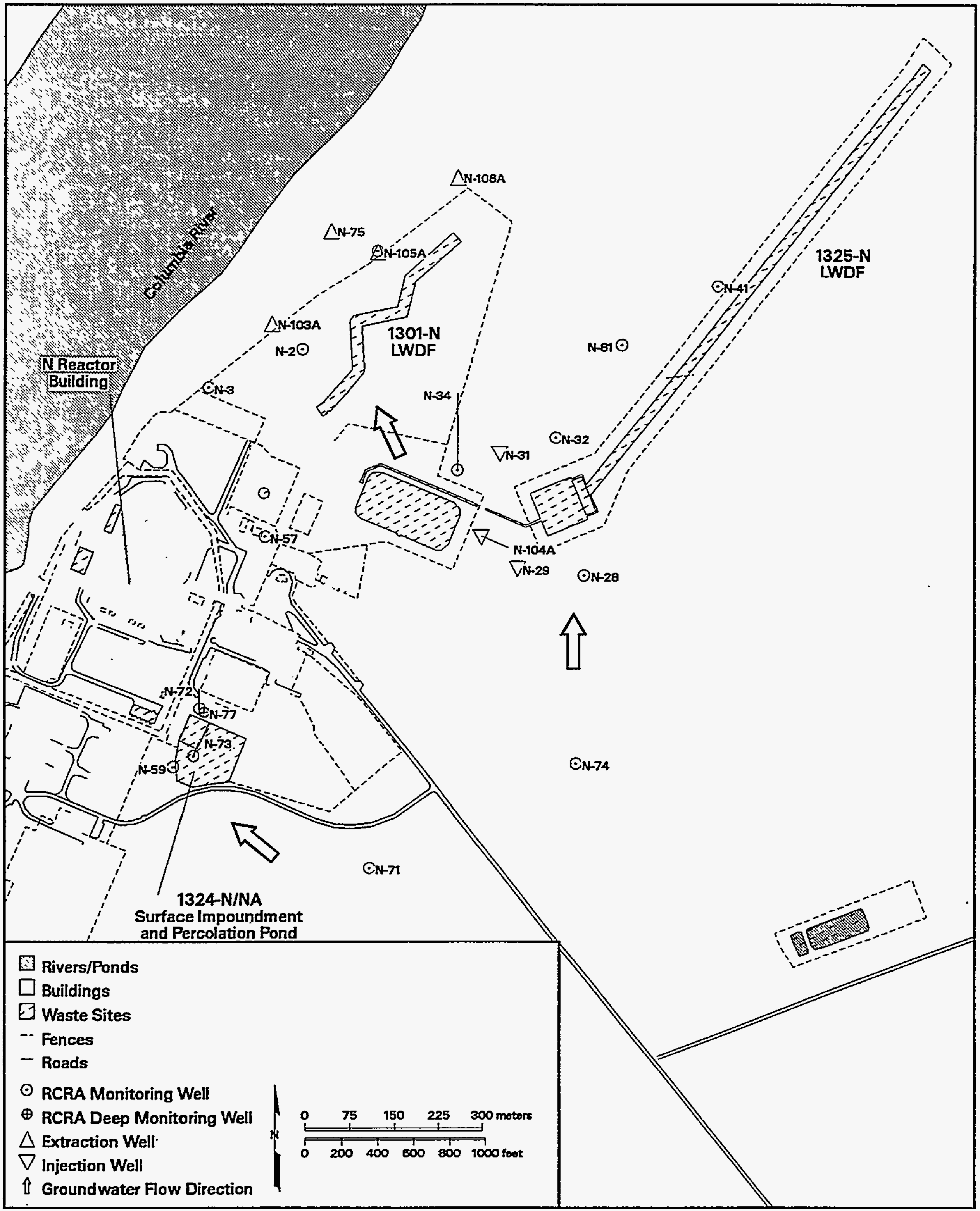

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Figure A.2. Monitoring Well Locations for 100-N Area RCRA Units

Table A.3. Monitoring Wells and Constituents for 120-D-1 Ponds (adapted from WHC-SD-EN-AP-048)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Network
199-D5-13[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-D8-4[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-D8-5[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-D8-6[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--

Contamination Indicator Parameters	Other Parameters	
pH (field)	Alkalinity	ICP metals (filtered)
Specific conductance (field)	Anions	Mercury (filtered)
Total organic carbon	Gross alpha	Tritium
Total organic halides	Gross beta	Turbidity (field)

Shading = Upgradient well.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

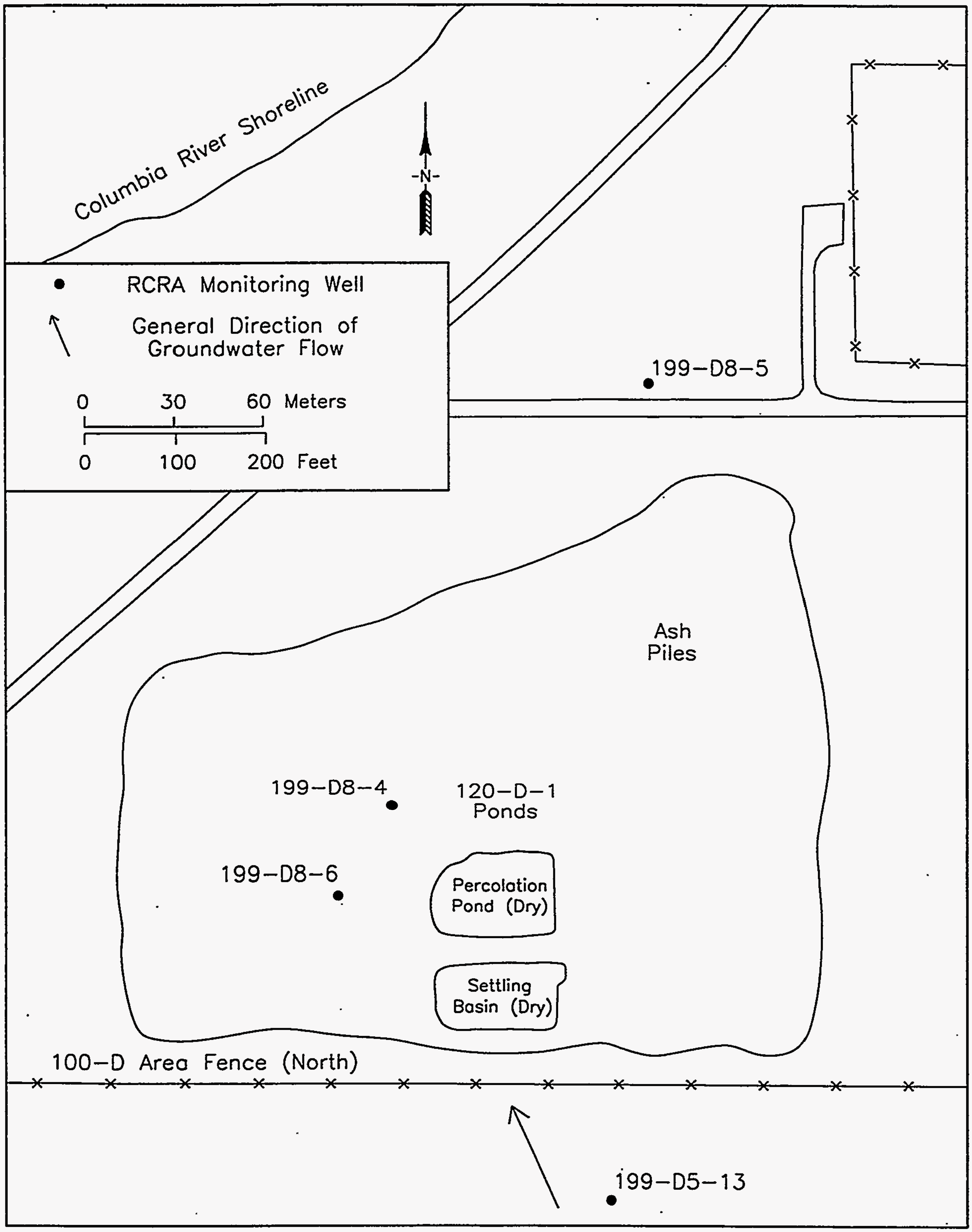

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Figure A.3. Monitoring Well Locations for 120-D-1 Ponds

Table A.4. Monitoring Wells and Constituents for 183-H Solar Evaporation Basins (adapted from WHC-SD-EN-AP-180)

Well	Hydrogeologic Unit Monitored	Sampling Frequency$^{(a)}$	Water-Level Measurement$^{(a)}$	Well Standards	Other Networks
199-H3-2A$^{86(a)}$	Top of unconfined	Semiannual	Semiannual	RCRA	IRA
199-H4-3^{74}	Top of unconfined	Semiannual	Semiannual	PRE	IRA
199-H4-4^{83}	Top of unconfined	Semiannual	Semiannual	PRE	100-HR-3
199-H4-6^{83}	Top of unconfined	Semiannual	Semiannual	PRE	IRA, Sitewide
199-H4-9^{86}	Top of unconfined	Semiannual	Semiannual	RCRA	IRA
199-H4-12A$^{86(a)}$	Top of unconfined	Semiannual	Semiannual	RCRA	IRA
199-H4-12C^{86}	Mid-depth unconfined	Semiannual	Semiannual	RCRA	IRA
199-H4-18^{86}	Top of unconfined	Semiannual	Semiannual	RCRA	IRA

Dangerous Constituents	Other Parameters	
Chromium (filtered)	Alkalinity	pH
Nitrate	Anions	Specific conductance
Technetium-99	ICP metals (filtered)	Turbidity
Uranium		

(a) Sampled and measured monthly for 4 months for each sampling period.
(b) Extraction well.
Shading = Upgradient well.
Superscript = Year of installation.
IRA = Interim Response Action.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

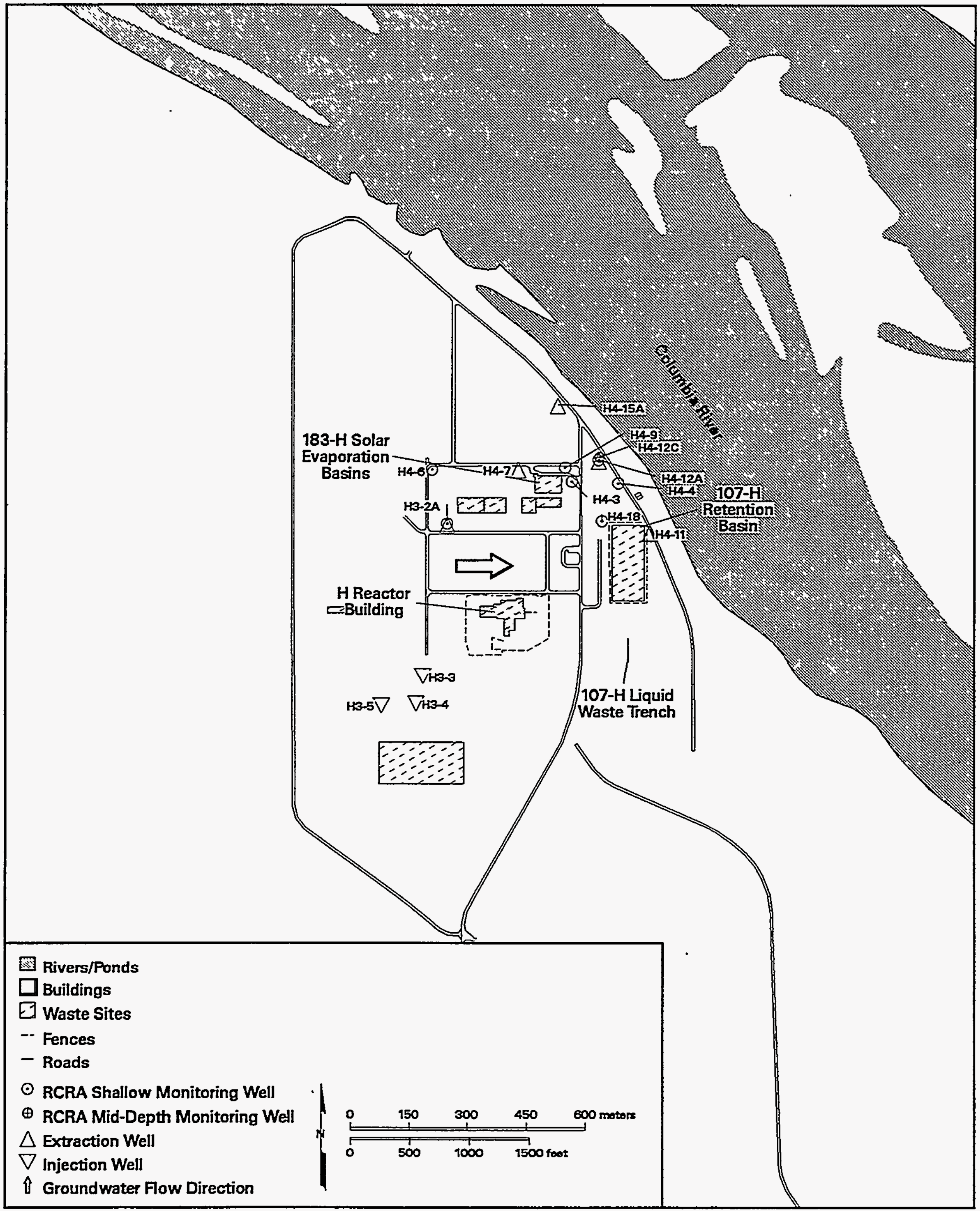

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Figure A.4. Monitoring Well Locations for 183-H Solar Evaporation Basins

Table A.5. Monitoring Wells and Constituents for 216-S-10 Pond and Ditch (adapted from WHC-SD-EN-AP-018)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurements	Well Standard	Other Network
299-W26-7^{91}	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-W26-8^{90}	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-W26-9^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W26-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W26-12^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W27-2^{92}	Base of unconfined	Semiannual	Semiannual	RCRA	--

Contamination Indicator Parameters

PH

Specific conductance

Total organic carbon

Total organic halides

Groundwater Quality Parameters

Chloride

Iron (filtered)

Manganese (filtered)

Phenols

Sodium (filtered)

Sulfate (filtered)

Drinking Water Parameters

Barium (filtered)

Cadmium (filtered)

Chromium (filtered)

Fluoride

Gross alpha

Gross beta

Nitrate

Silver (filtered)

Turbidity

Site-Specific Parameter

Alkalinity

(a) Upgradient wells sampled in March, June, September, and December 1997 to reestablish critical mean for total organic halides; sampled semiannually thereafter.

Shading = Upgradient well.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

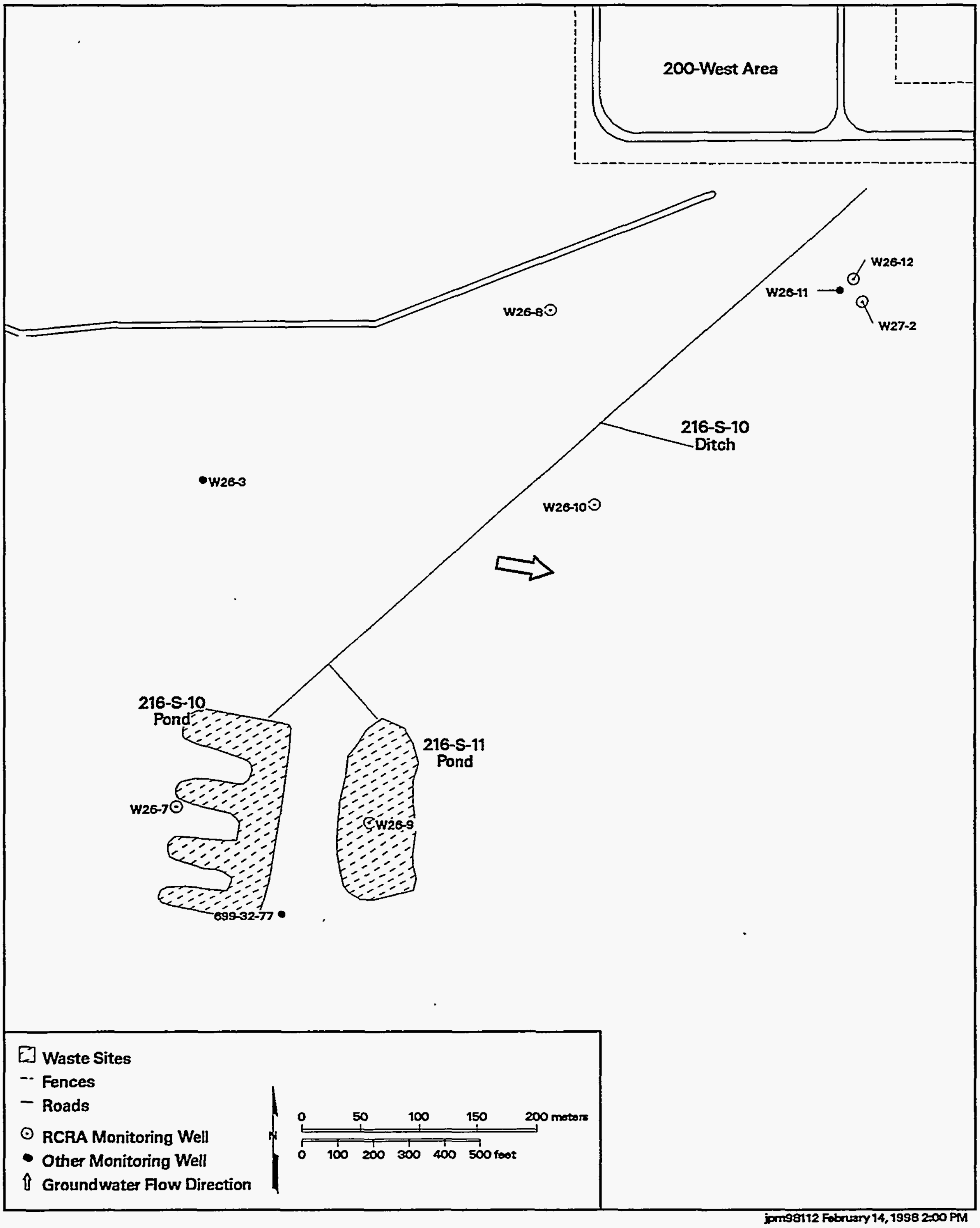

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Figure A.5. Monitoring Well Locations for 216-S-10 Pond and Ditch

Table A.6. Monitoring Wells and Constituents for 216-U-12 Crib (adapted from WHC-SD-EN-AP-019 and WHC-SD-EN-AP-103)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W22-40^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, Sitewide
299-W22-41^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, Sitewide
299-W22-42^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, Sitewide
299-W22-43^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, Sitewide
699-36-70A^{94}	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, CERCLA, Sitewide

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity[(a)]	Iodine-129
Specific conductance	Anions	Technetium-99
Total organic carbon	Gross alpha	Total dissolved solids
Total organic halides	Gross beta	Tritium
	ICP metals (filtered)	Turbidity

(a) Only analyzed in wells 299-W22-42, 299-W22-43, and 699-36-70A.
Shading = Upgradient well.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

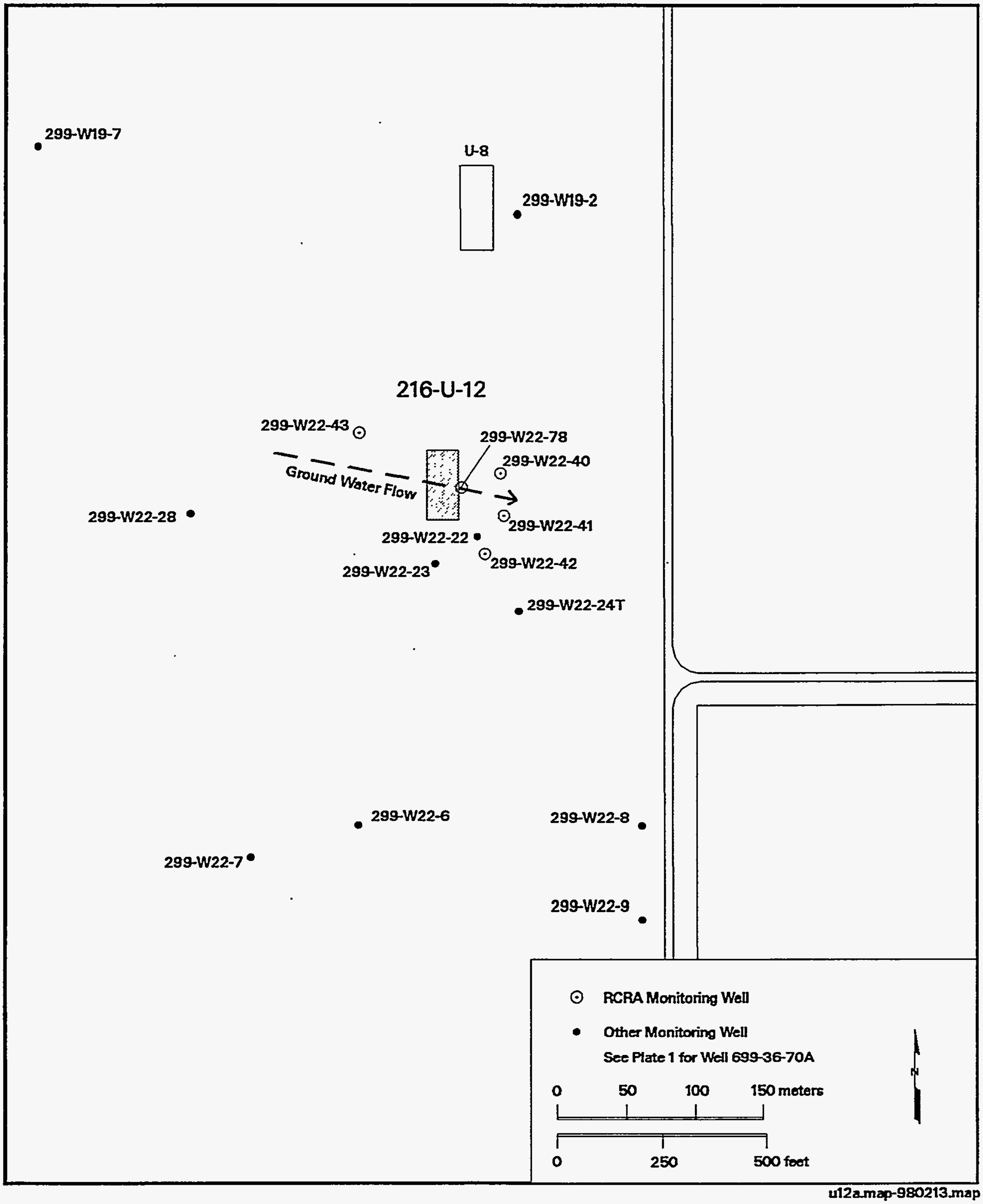

Figure A.6. Monitoring Well Locations for 216-U-12 Crib

Table A.7. Monitoring Wells and Constituents for 216-B-3 Pond (WHC-SD-EN-AP-013, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-level Measurement	Well Standard	Other Networks
299-E32-4^{87}	Top of uppermost	Quarterly	Quarterly	RCRA	LLWMA-2
699-40-40A^{91}	Lower uppermost	Quarterly	Quarterly	RCRA	--
699-41-40^{89}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-41-42^{92}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-42-39B^{91}	Lower uppermost	Quarterly	Quarterly	RCRA	--
699-42-41^{91}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-42-42B^{88}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-43-40^{91}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-43-41E^{89}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-43-41G^{91}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-43-45^{89}	Top of uppermost	Quarterly	Quarterly	RCRA	216-A-29 Ditch
699-44-39B^{92}	Top of uppermost	Quarterly	Quarterly	RCRA	--
699-44-43B^{89}	Top of uppermost	Quarterly	Quarterly	RCRA	--

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Alkalinity	Gross beta
Specific conductance	Anions	Turbidity
Total organic carbon	Gross alpha	
Total organic halides		

Shading = Upgradient wells.
Superscript = Year of installation.
LLWMA = Low-level waste management area.
RCRA = Well constructed to RCRA standards.

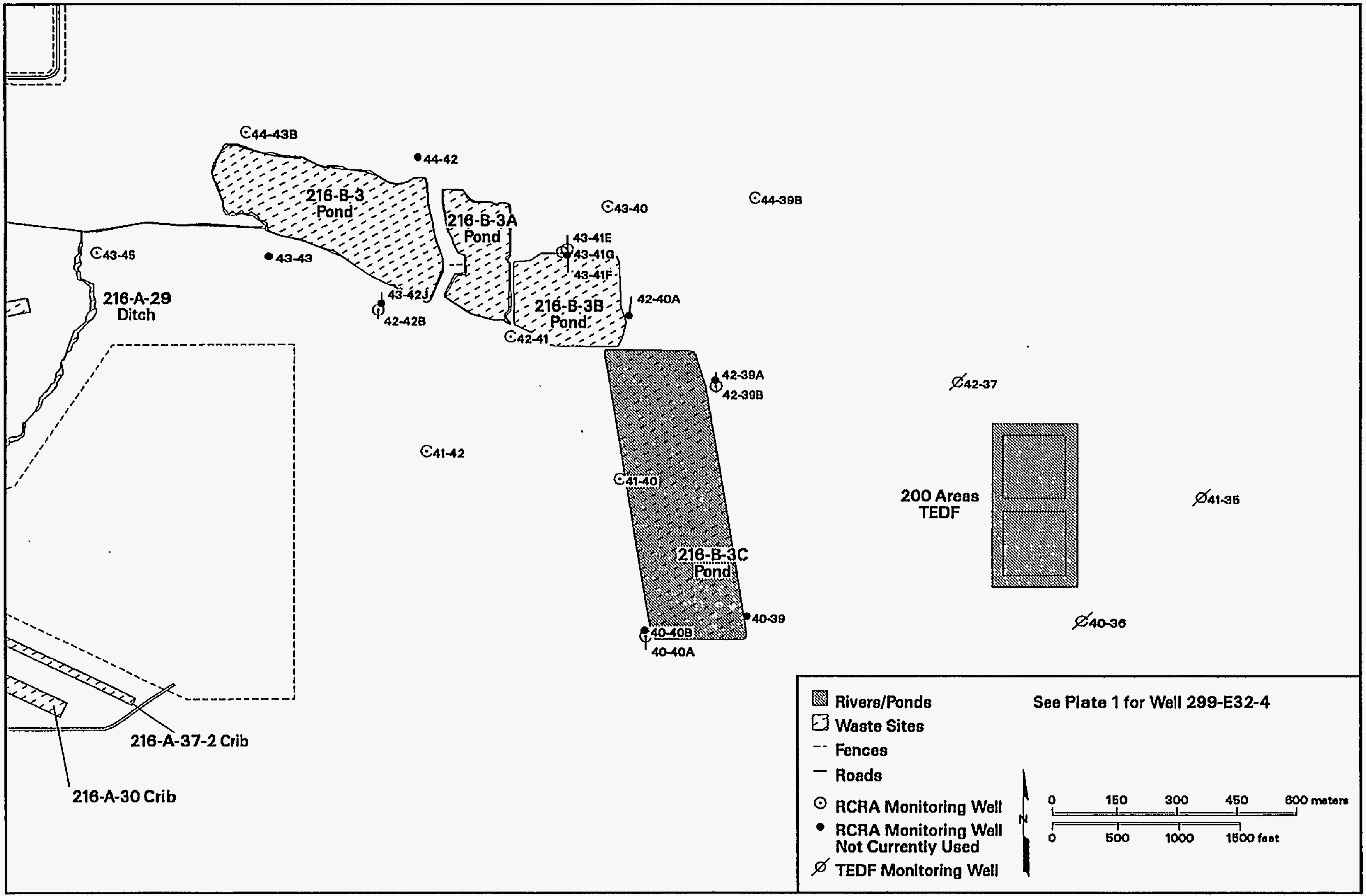

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Figure A.7. Monitoring Well Locations for 216-B-3 Pond

Table A.8. Monitoring Wells and Constituents for 216-A-29 Ditch (adapted from WHC-SD-EN-AP-045, Rev. 0-A)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E25-26[85]	Upper unconfined	Semiannual	Quarterly	RCRA	--
299-E25-28[86]	Deep unconfined	Semiannual	Quarterly	RCRA	--
299-E25-32P[88]	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-34[88]	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-35[88]	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-48[92]	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E26-12[91]	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E26-13[91]	Top of unconfined	Semiannual	Quarterly	RCRA	--
699-43-43[88]	Top of unconfined	Semiannual	Quarterly	RCRA	216-B-3 Pond
699-43-45[89]	Top of unconfined	Semiannual	Quarterly	RCRA	216-B-3 Pond

Contamination Indicator Parameters
PH
Specific conductance
Total organic carbon
Total organic halides

Groundwater Quality Parameters	
Chloride	Phenols
Iron (filtered)	Sodium (filtered)
Manganese (filtered)	Sulfate

Drinking Water Parameters		
2,4-D	Endrin	Methoxychlor
2,4,5-TP Silvex	Fluoride	Nitrate
Arsenic	Gross alpha	Radium
Barium	Gross beta	Selenium
Cadmium	Lead	Silver
Chromium	Lindane	Toxaphene
Coliform	Mercury	Turbidity

Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

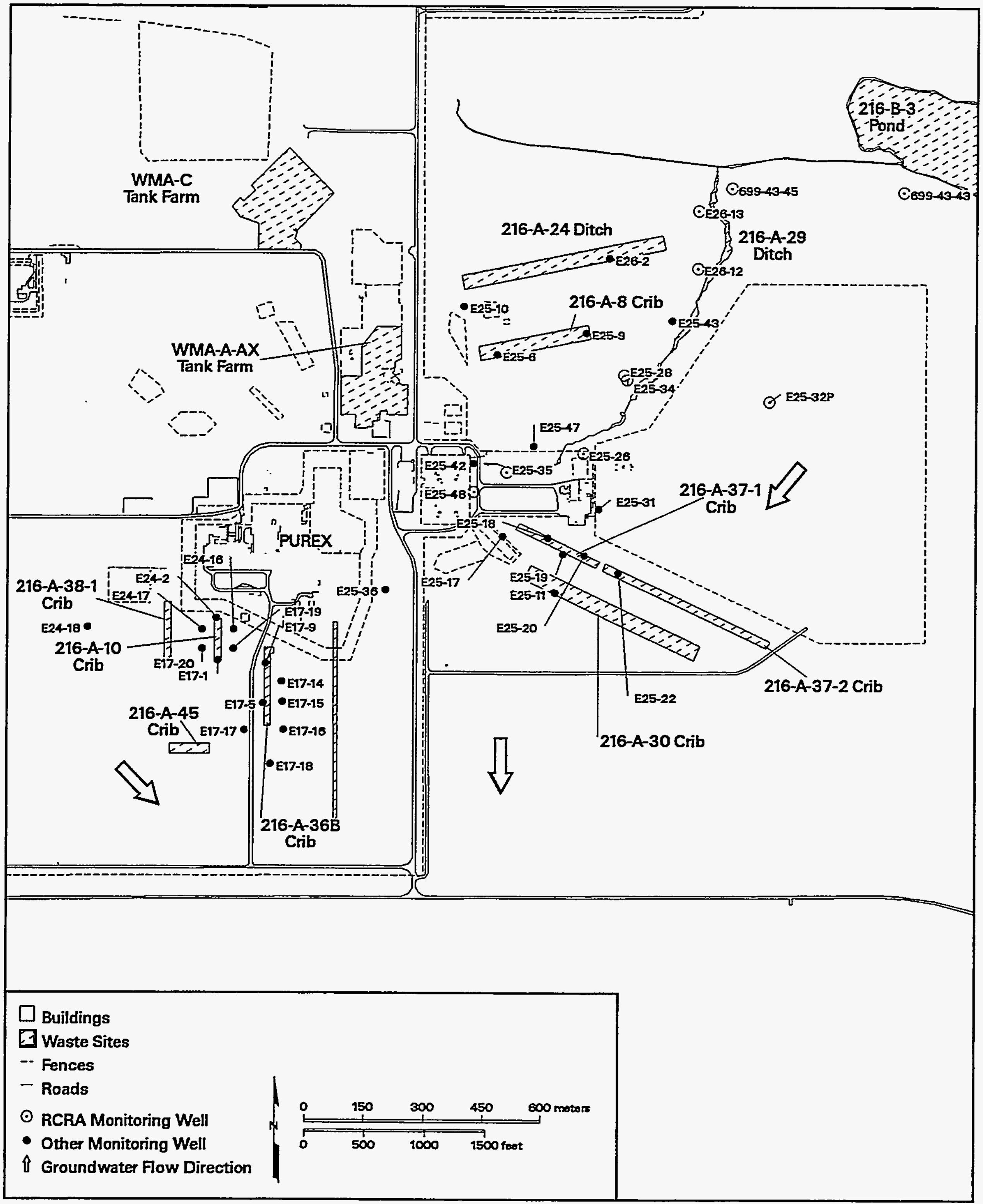

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Figure A.8. Monitoring Well Locations for 216-A-29 Ditch

Table A.9. Monitoring Wells and Constituents for 216-A-10 and 216-A-36B Cribs through June 30, 1997 (adapted from WHC-SD-EN-AP-170, Rev. 0-A)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurement	Well Standard	Other Networks
		216-A-10 Crib			
299-E17-1^{55}	Top of unconfined	Semiannual	Quarterly	PRE	--
299-E17-19^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E17-20^{88}	Top of unconfined	Quarterly	Quarterly	RCRA	216-A-29 Ditch
299-E24-2^{56}	Top of unconfined	Semiannual	Quarterly	PRE	--
299-E24-16^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E24-17^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E24-18^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	216-A-36B Crib
299-E25-36^{88}	Top of unconfined	Quarterly	Quarterly	RCRA	216-A-29 Ditch 216-A-36B Crib
		216-A-36B Crib			
299-E17-9^{68}	Top of unconfined	Semiannual	Quarterly	PRE	--
299-E17-5^{65}	Top of unconfined	Not sampled	Quarterly	PRE	--
299-E17-14^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E17-15^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E17-16^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E17-17^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E17-18^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E24-18^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	216-A-10 Crib
299-E25-36^{88}	Top of unconfined	Semiannual	Quarterly	RCRA	216-A-10 Crib 216-A-29 Ditch

Contamination Indicator Parameters	Other Constituents	
pH	Alkalinity	Iodine-129
Specific conductance	Anions	Phenols
Total organic carbon	Gross alpha	Tritium
Total organic halides	Gross beta	Turbidity
	ICP metals (filtered)	

Shading = Upgradient wells.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

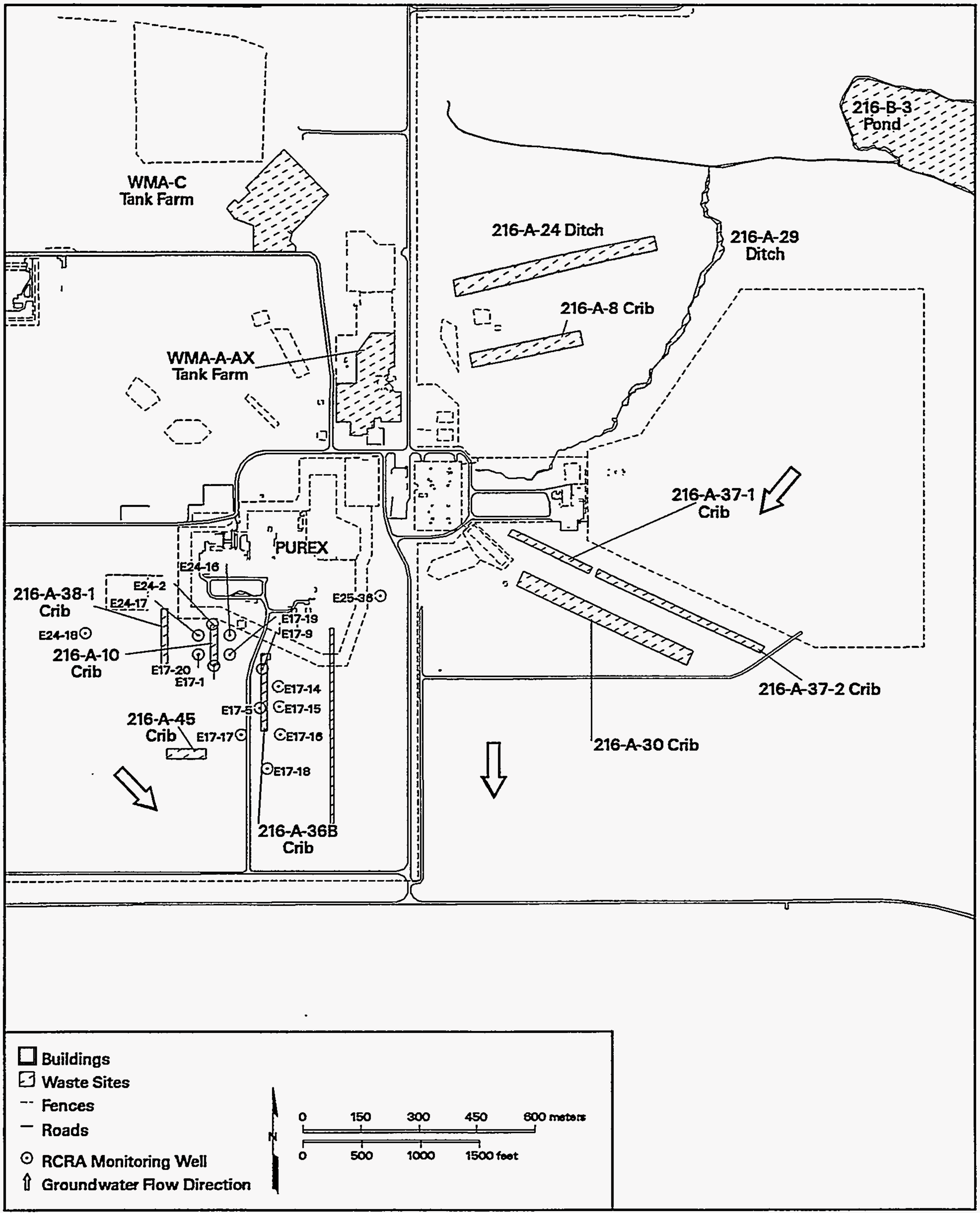

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Figure A.9. Monitoring Well Locations for 216-A-10 and 216-A-36B Cribs through June 30, 1997

Table A.10. Monitoring Wells and Constituents for PUREX Cribs (216-A-10, 216-A-36B, and 216-A-37-1), Beginning July 1, 1997 (adapted from PNNL-11523)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurements	Well Standards	Other Network
		Near-Field Wells – Upgradient			
299-E24-18^{88}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E25-31^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
		Near-Field Wells – 216-A-10 Crib			
299-E17-1^{55}	Top of unconfined	Semiannual	Semiannual	PRE	--
299-E17-19^{88}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E24-16^{88}	Top of unconfined	Quarterly	Quarterly	RCRA	--
		Near-Field Wells – 216-A-36B Crib			
299-E17-9^{68}	Top of unconfined	Semiannual	Semiannual	PRE	--
299-E17-14^{88}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-E17-17^{88}	Top of unconfined	Semiannual	Semiannual	RCRA	--
		Near-Field Wells – 216-A-37-1 Crib			
299-E25-17^{76}	Top of unconfined	Semiannual	Semiannual	PRE	--
299-E25-19^{76}	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-37-47A^{96}	Top of unconfined	Semiannual	Semiannual	RCRA	--
		Far-Field Wells			
57 wells	Unconfined	Annual	Annual	RCRA, PRE	Sitewide

Field-Analyzed Parameters

- pH(a)
- Specific conductance(a)
- Temperature(a)
- Turbidity(a)

Groundwater Quality Parameters

- Chloride
- Iron(b)
- Manganese(b)
- Phenols
- Sodium(b)
- Sulfate

Drinking Water Parameters

- Arsenic(b)
- Barium(b)
- Cadmium(b)
- Chromium(b)
- Coliform
- Fluoride
- Gross alpha
- Gross beta
- Lead(b)
- Mercury(b)
- Nitrate(a)
- Radium
- Selenium(b)
- Silver(b)

Site-Specific Parameters

- Alkalinity
- Ammonium ion
- Iodine-129(a)
- Strontium-90
- Tritium(a)

(a) Far-field wells analyzed for these constituents only.
(b) Filtered samples.

Shading = Upgradient wells.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

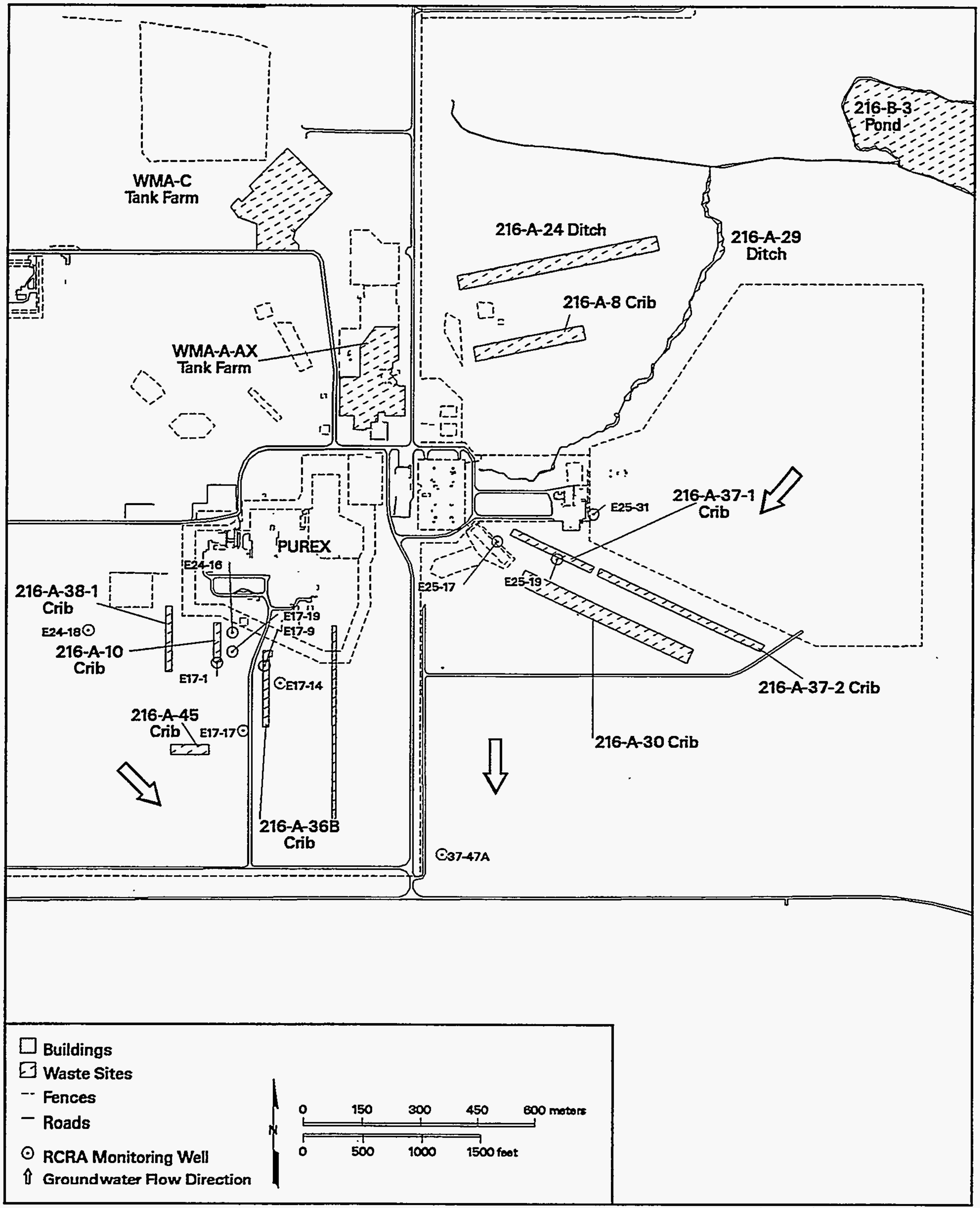

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Figure A.10. Monitoring Well Locations for PUREX Cribs (216-A-10, 216-A-36B, and 216-A-37-1), Beginning July 1, 1997

Table A.11. Monitoring Wells and Constituents for 216-B-63 Trench (adapted from WHC-SD-EN-AP-165)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E27-8^{87}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2
299-E27-9^{87}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2
299-E27-11^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2
299-E27-16^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-17^{91}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2
299-E27-18^{92}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-19^{92}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E33-33^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	B-BX-BY SSTF
299-E33-36^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E33-37^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E34-8^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2
299-E34-10^{91}	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA-2

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Groundwater Quality Parameters

Chloride
Iron (filtered)
Manganese (filtered)
Phenols
Sodium (filtered)
Sulfate

Site-Specific Parameters

Alkalinity
Gross alpha
Gross beta
Turbidity

Shading = Upgradient wells.
Superscript = Year of installation.
LLWMA = Low-level waste management area.
RCRA = Well constructed to RCRA standards.
SSTF = Single-shell tank farms.

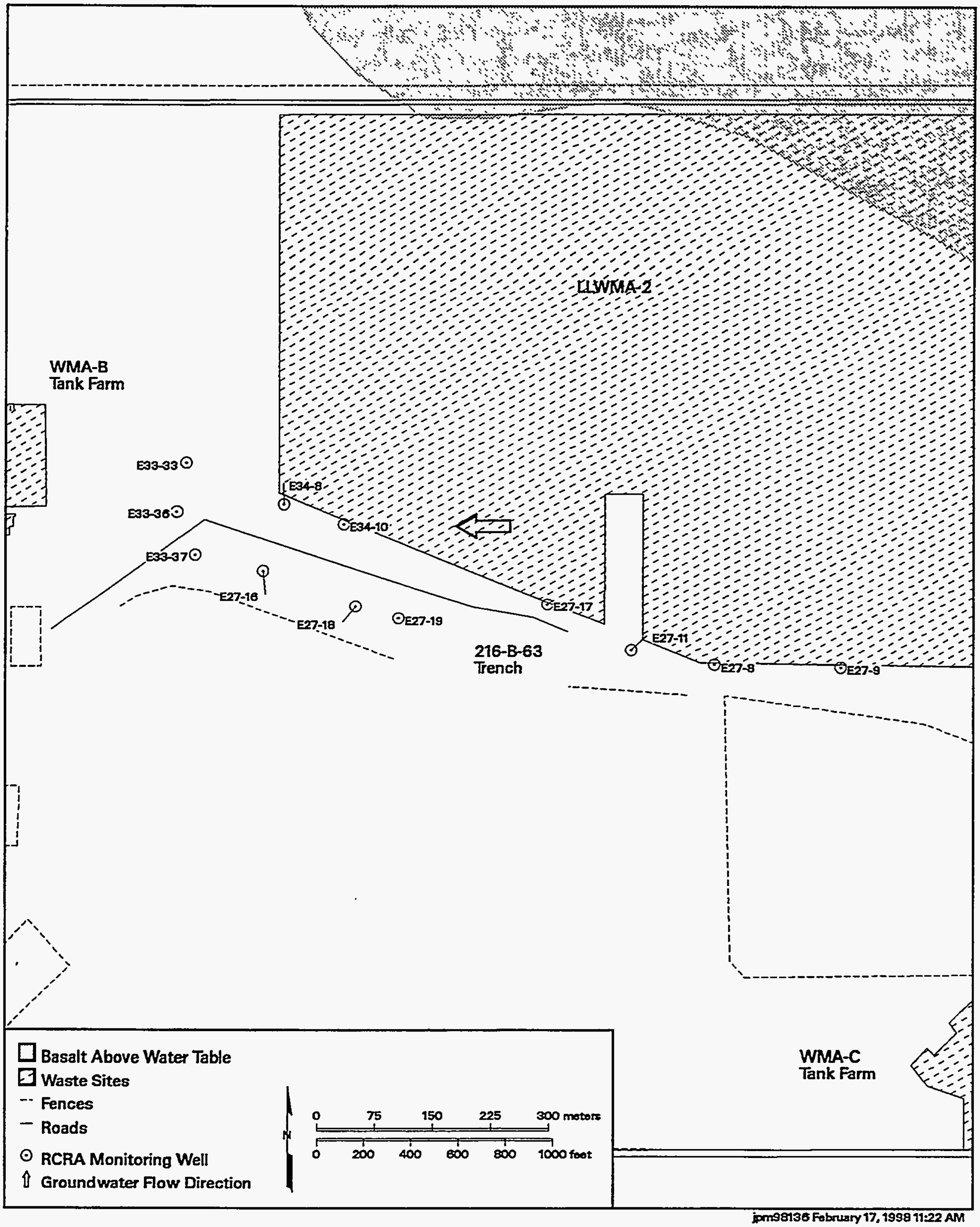

Figure A.11. Monitoring Well Locations for 216-B-63 Trench

Table A.12. Monitoring Wells and Constituents for Liquid Effluent-Retention Facility (adapted from WHC-SD-EN-AP-024)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Network
299-E26-11^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E26-10^{90}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E26-9^{87}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E35-2^{87}	Top of unconfined	Semiannual	Quarterly	RCRA	--

Contamination Indicator Parameters	Other Parameters	
PH	Alkalinity	ICP metals (filtered)
Specific conductance	Anions	Temperature
Total organic carbon	Gross alpha	Tritium
Total organic halides	Gross beta	Turbidity

Shading = Upgradient well.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

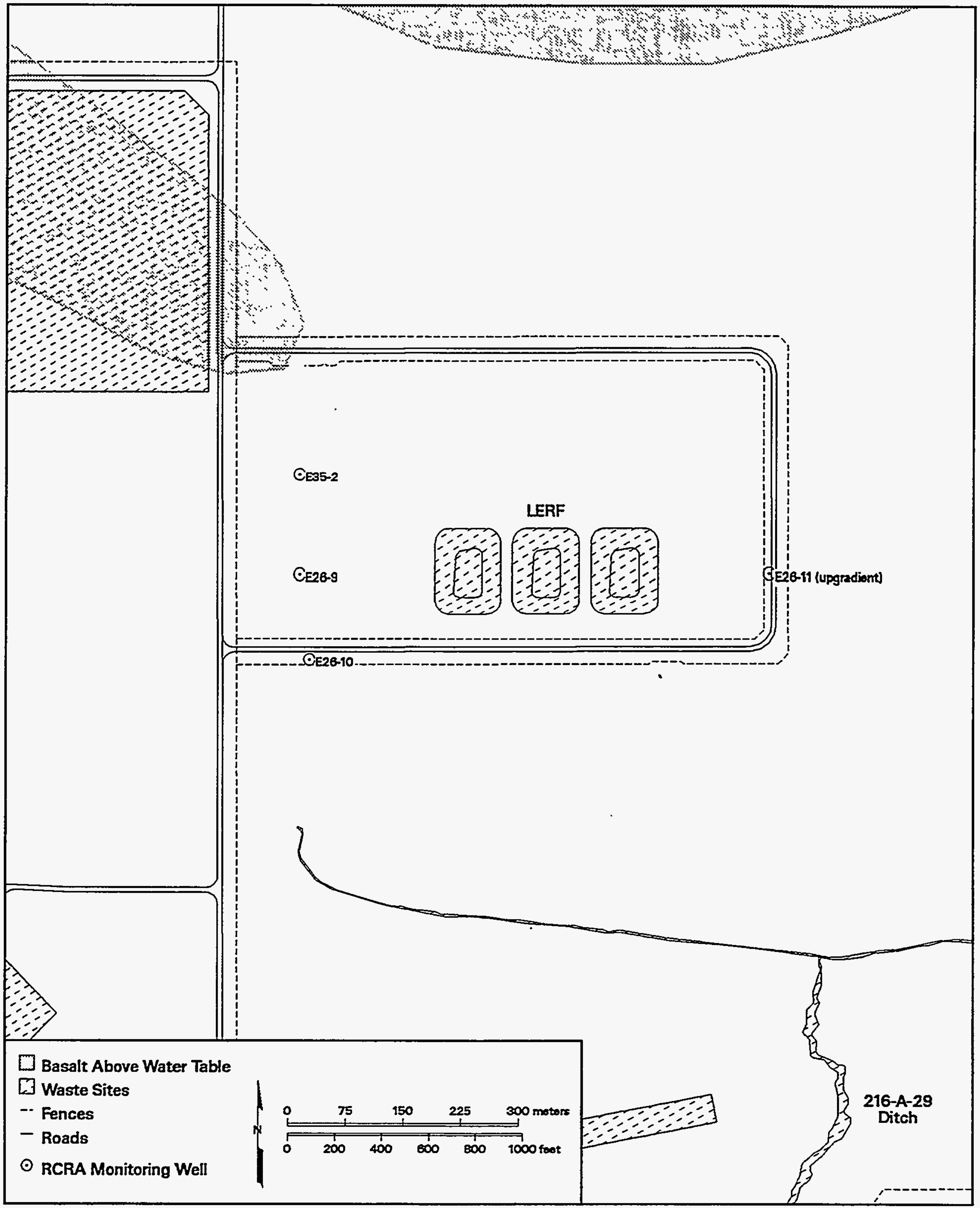

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Figure A.12. Monitoring Well Locations for the Liquid Effluent-Retention Facility

Table A.13. Monitoring Wells and Constituents for Low-Level Waste Management Area 1 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Network
299-E28-26^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E28-27^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E28-28^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-3 Pond
299-E32-5^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-6^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-7^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-8^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-10^{92}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-28^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-29^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-30^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-34^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-35^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--

Contamination Indicator Parameters	Other Constituents	
PH	Alkalinity	Lead (filtered)
Specific conductance	Gross alpha	Mercury (filtered)
Total organic carbon	Gross beta	Phenols
Total organic halides	ICP metals (filtered)	Tritium

Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

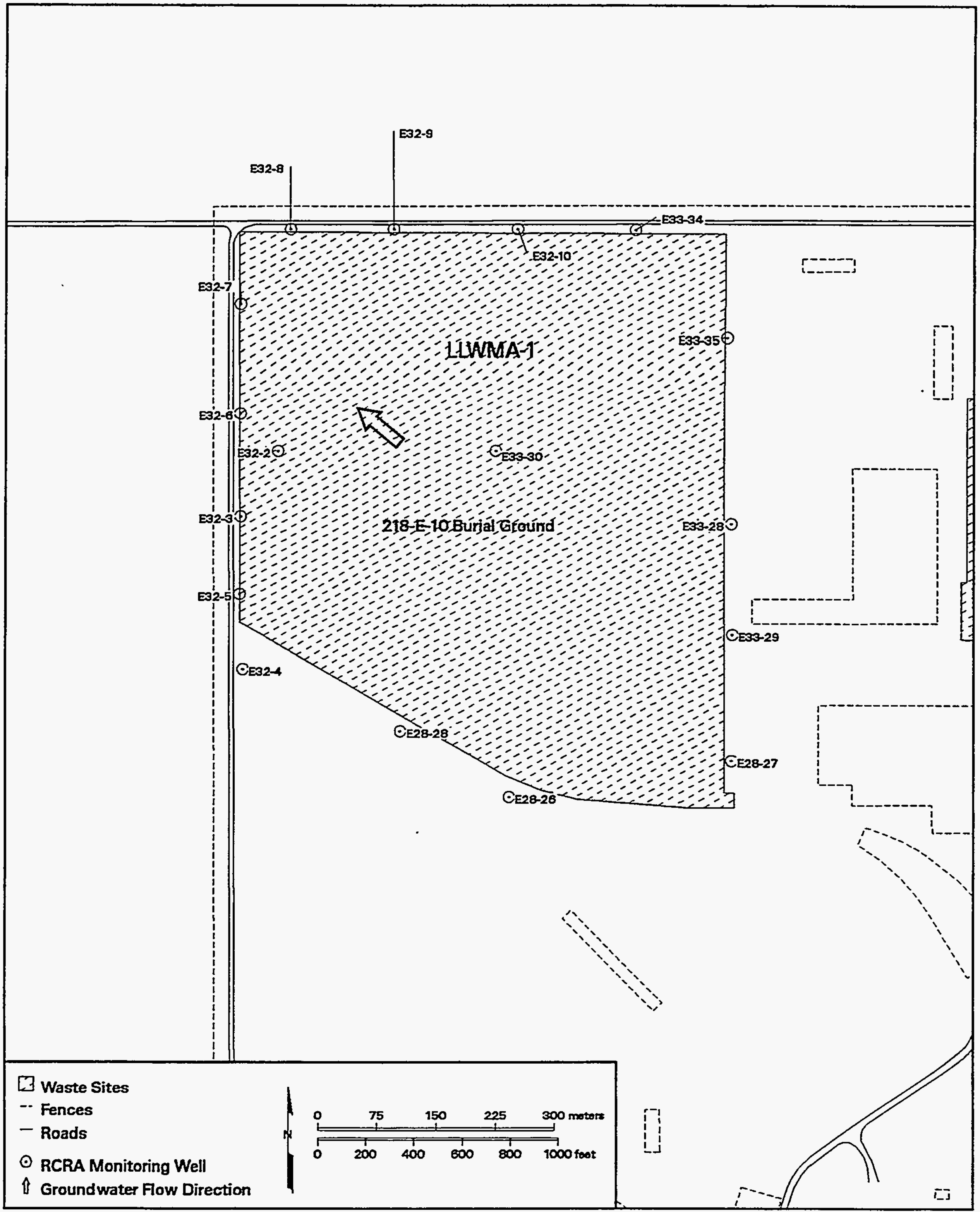

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Figure A.13. Monitoring Well Locations for Low-Level Waste Management Area 1

Table A.14. Monitoring Wells and Constituents for Low-Level Waste Management Area 2 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E27-8^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 Trench
299-E27-9^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 Trench
299-E27-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E27-11^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 Trench
299-E27-17^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 Trench
299-E34-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-3^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-4^{87}	Top of unconfined	Dry	Dry	RCRA	--
299-E34-5^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-6^{87}	Top of unconfined	Dry	Dry	RCRA	--
299-E34-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-9^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-10^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 Trench
299-E34-11^{92}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E34-12^{92}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E35-1^{89}	Top of unconfined	Dry	Dry	RCRA	--

Contamination Indicator Parameters	Other Constituents	
PH	Alkalinity	Lead (filtered)
Specific conductance	Gross alpha	Mercury (filtered)
Total organic carbon	Gross beta	Phenols
Total organic halides	ICP metals (filtered)	Polychlorinated biphenyls
		Tritium

Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

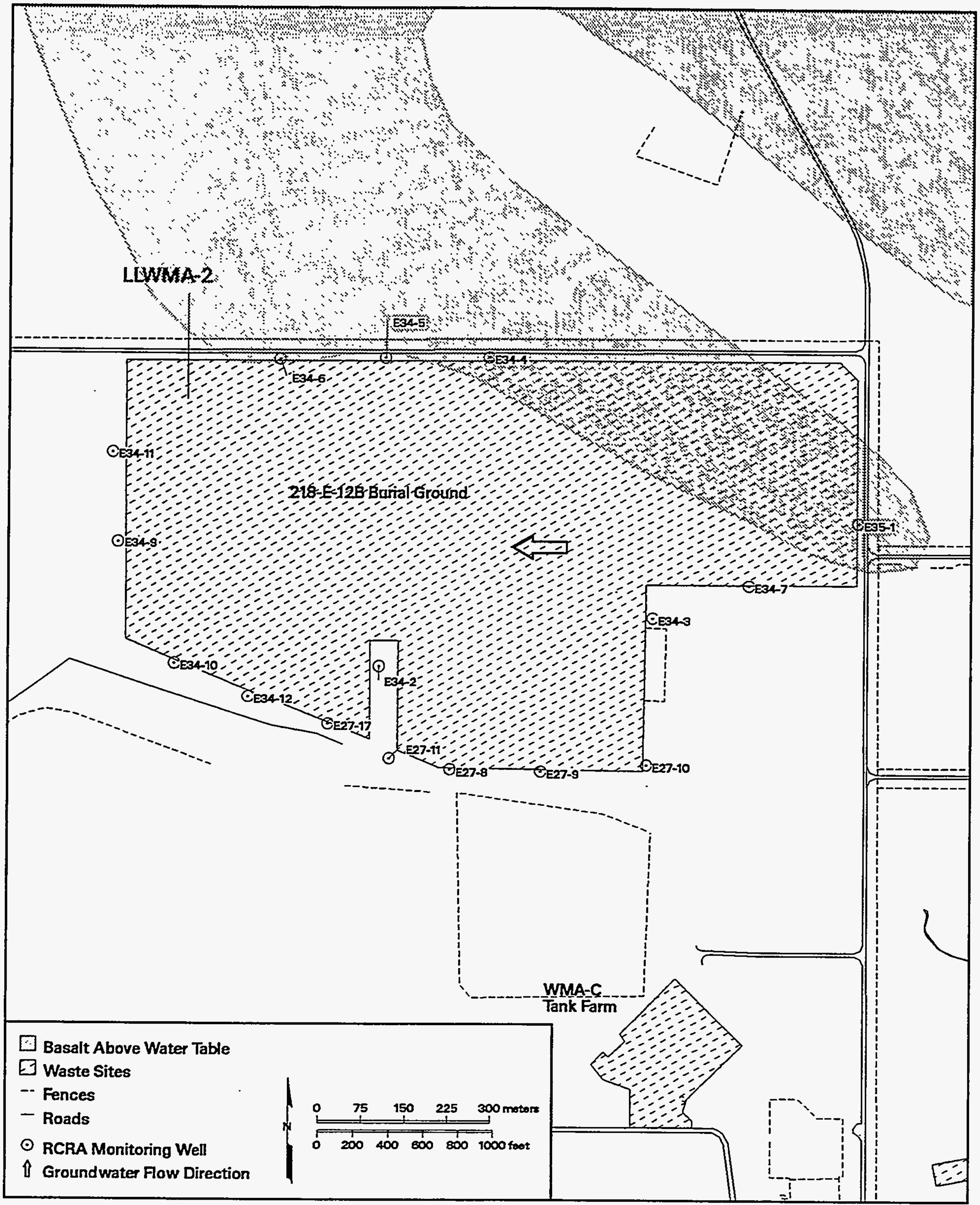

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Figure A.14. Monitoring Well Locations for Low-Level Waste Management Area 2

Table A.15. Monitoring Wells and Constituents for Low-Level Waste Management Area 3 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W6-2^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	SSTF
299-W7-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-2^{87}	Top of unconfined	Dry	Dry	RCRA	--
299-W7-3^{87}	Deep unconfined	Semiannual	Semiannual	RCRA	--
299-W7-4^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-5^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-6^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-7^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-8^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-9^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-10^{90}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-11^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-12^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W8-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS
299-W9-1^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W10-13^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W10-14^{87}	Deep unconfined	Semiannual	Semiannual	RCRA	--
299-W10-19^{92}	Top of unconfined	Semiannual	Semiannual	RCRA	SSTF
299-W10-20^{93}	Top of unconfined	Semiannual	Semiannual	RCRA	SSTF
299-W10-21^{93}	Top of unconfined	Semiannual	Semiannual	RCRA	SSTF

Contamination Indicator Parameters	Other Constituents	
PH	Alkalinity	Mercury (filtered)
Specific conductance	Gross alpha	Phenols
Total organic carbon	Gross beta	Tritium
Total organic halides	ICP metals (filtered)	Volatile organic compounds
	Lead (filtered)	

Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.
SALDS = State-Approved Land-Disposal Site.
SSTF = Single-shell tank farm.

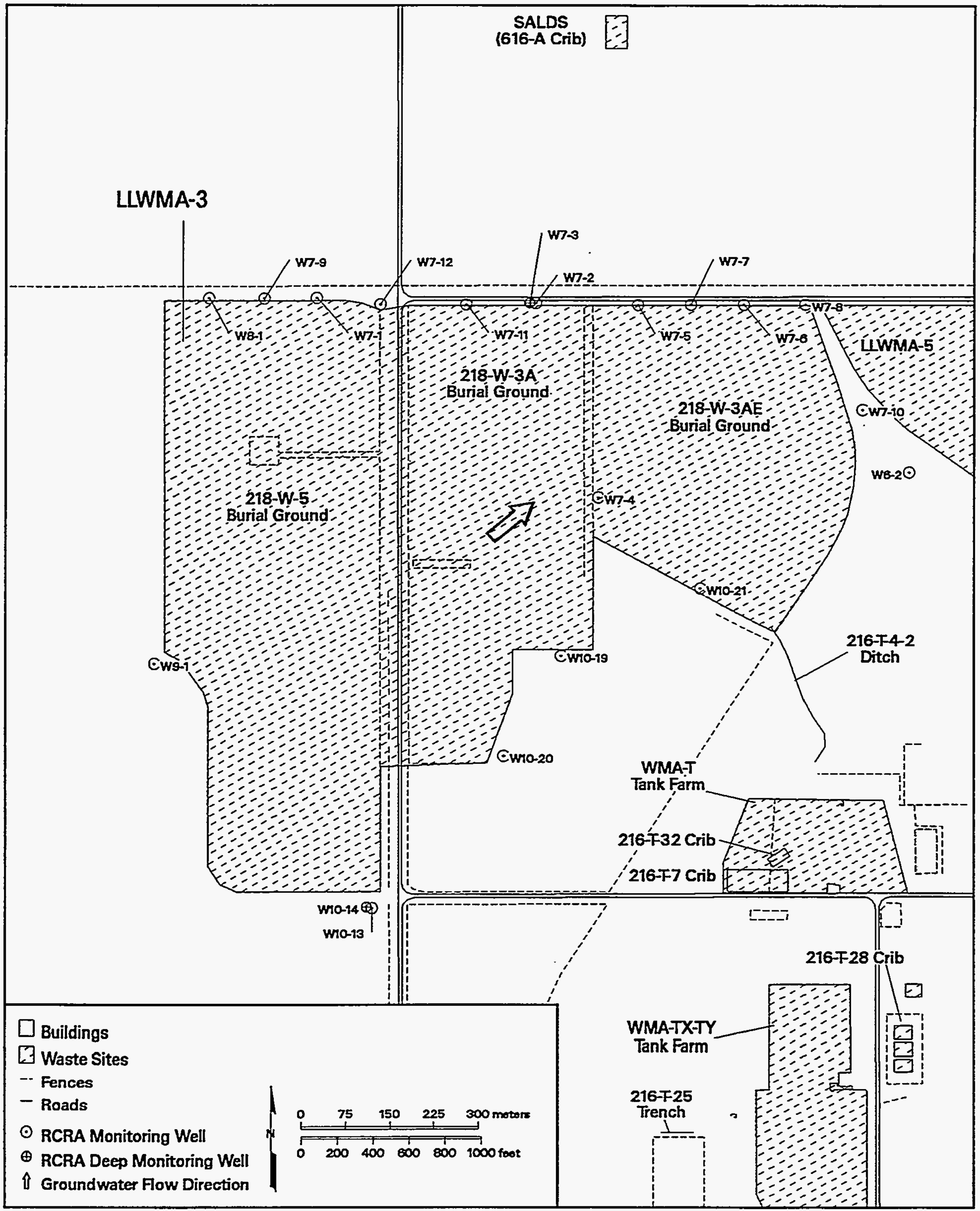

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Figure A.15. Monitoring Well Locations for Low-Level Waste Management Area 3

Table A.16. Monitoring Wells and Constituents for Low-Level Waste Management Area 4 (adapted from WHC-SD-EN-AP-015)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W15-15^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W15-16^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W15-17^{87}	Deep unconfined	Semiannual	Semiannual	RCRA	--
299-W15-18^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W15-19^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W15-20^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W15-23^{90}	Top of unconfined	Dry	Dry	RCRA	--
299-W15-24^{89}	Top of unconfined	Dry	Dry	RCRA	--
299-W18-21^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-22^{87}	Deep unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-23^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-24^{87}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-26^{89}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-27^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-28^{91}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-29^{91}	Perched zone	Dry	Dry	RCRA	--
299-W18-32^{92}	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1

Contamination Indicator Parameters	Other Constituents	
PH	Alkalinity	Mercury (filtered)
Specific conductance	Gross alpha	Phenols
Total organic carbon	Gross beta	Tritium
Total organic halides	ICP metals (filtered)	Volatile organic compounds
	Lead (filtered)	

NOTE: Gradient is changing because of 200-ZP-1 Operable Unit pump-and-treat system. Upgradient and downgradient wells no longer identified.

Superscript = Year of installation.

RCRA = Well constructed to RCRA standards.

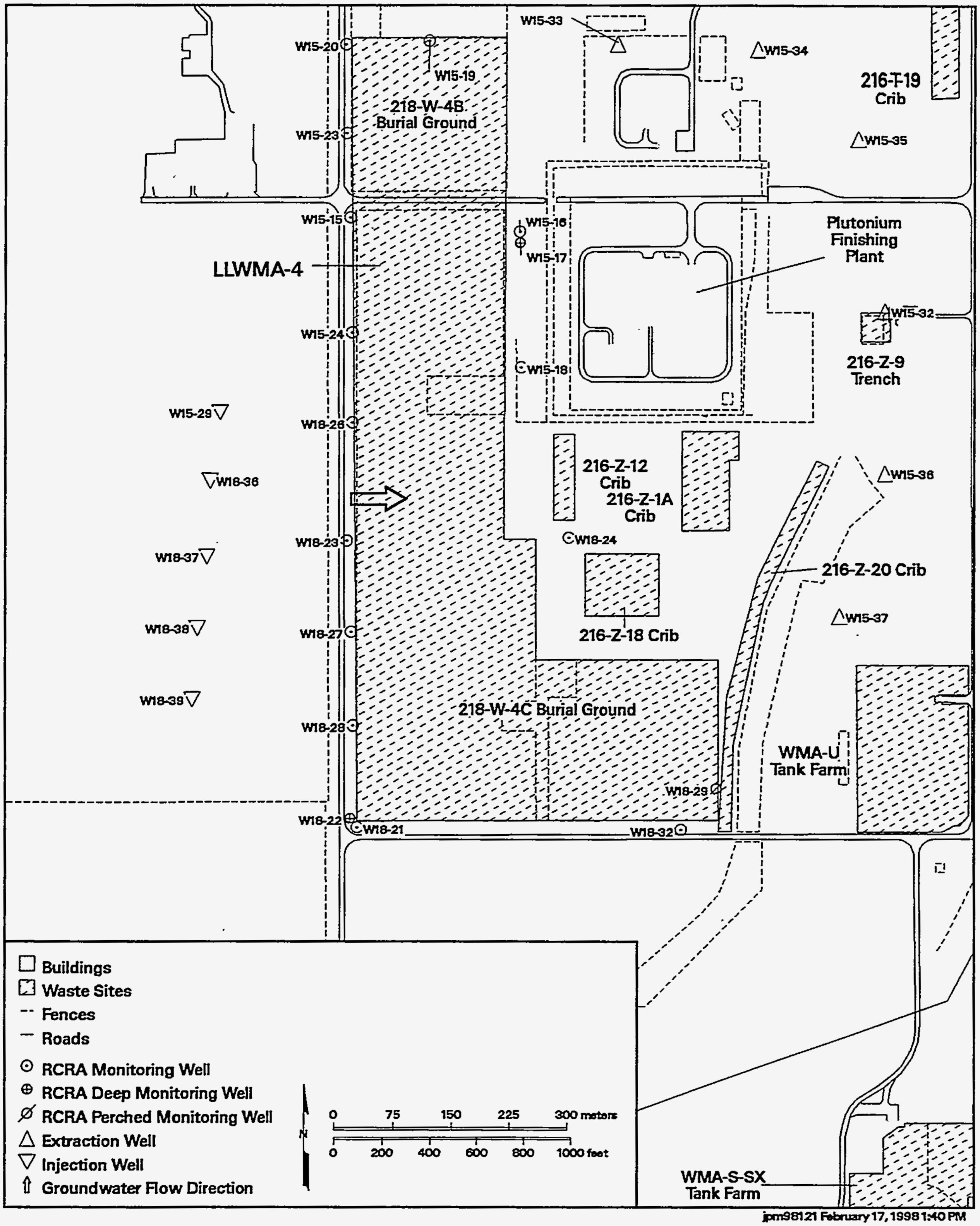


Figure A.16. Monitoring Well Locations for Low-Level Waste Management Area 4

Table A.17. Monitoring Wells and Constituents for Waste Management Areas A-AX and C (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Network
	A-AX Single-Shell Tank Farms				
299-E24-19^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E24-20^{91}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-2^{55}	Top of unconfined	--	Quarterly	PRE	--
299-E25-40^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-41^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-46^{92}	Top of unconfined	Semiannual	Quarterly	RCRA	--
	C Single-Shell Tank Farms				
299-E27-7^{82}	Top of unconfined	Semiannual[a]	Quarterly	PRE	--
299-E27-12^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-13^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-14^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-15^{89}	Top of unconfined	Semiannual	Quarterly	RCRA	--

Contamination Indicator Parameters

pH

Specific conductance

Total organic carbon

Total organic halides

Groundwater Quality Parameters

Chloride

Iron (filtered)

Manganese (filtered)

Phenols

Sodium (filtered)

Sulfate

Drinking Water Parameters

Barium (filtered)

Cadmium (filtered)

Chromium (filtered)

Fluoride

Gross alpha

Gross beta

Nitrate

Silver (filtered)

Turbidity

Site-Specific Parameters

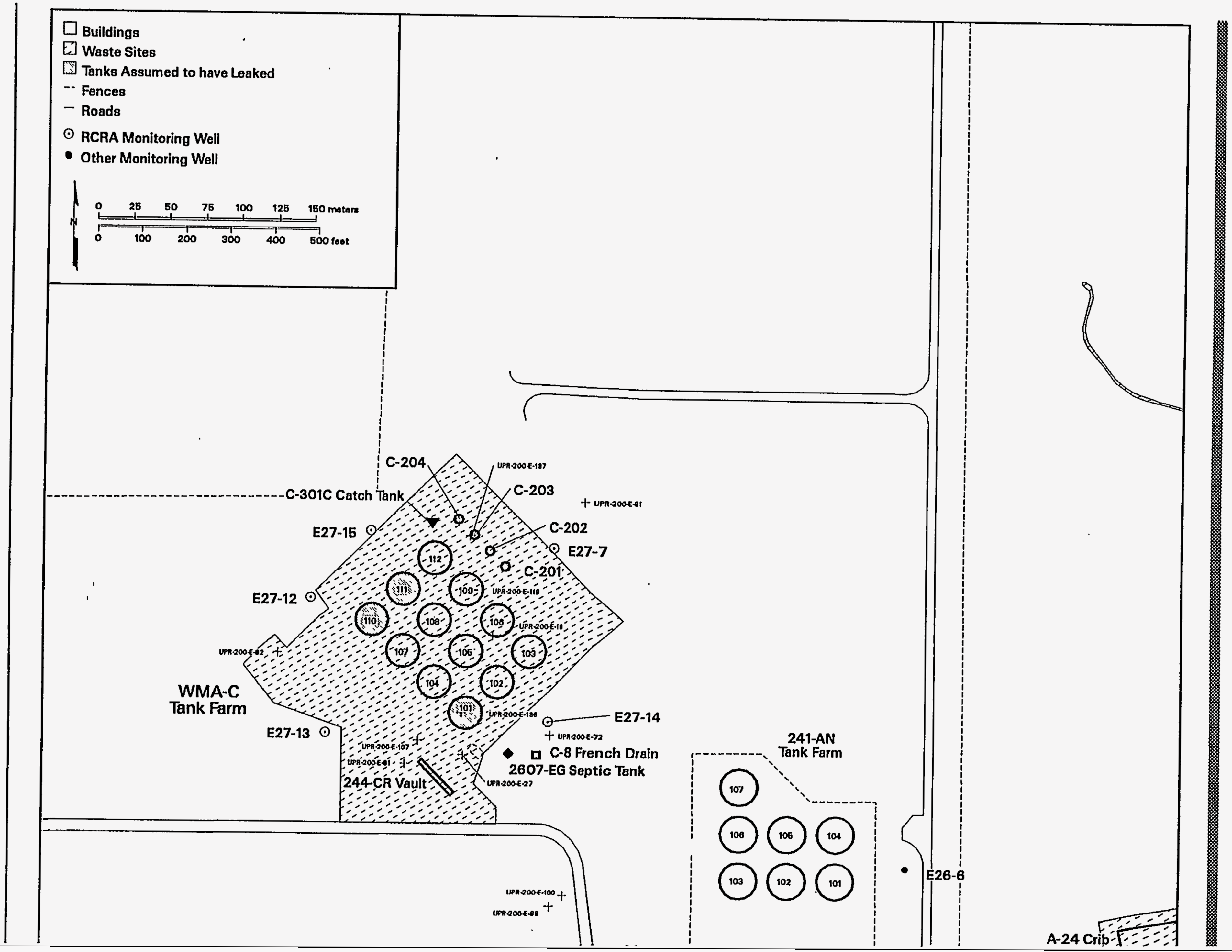
Ammonium

Iodine-129

Technetium-99

Tritium

Shading = Upgradient wells.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.


Buildings
Waste Sites
Tanks Assumed to have Leaked
Fences
Roads
RCRA Monitoring Well
Other Monitoring Well
N
0
25
50
75
100
125
150 meters
0
100
200
300
400
500 feet
C-204
UPR-200-E-187
C-301C Catch Tank
C-203
UPR-200-E-91
E27-15
C-202
E27-7
112
C-201
E27-12
111
100
UPR-200-E-118
110
108
106
UPR-200-E-18
UPR-200-E-82
107
105
103
104
102
WMA-C
Tank Farm
101
UPR-200-E-186
E27-14
E27-13
UPR-200-E-72
UPR-200-E-107
C-8 French Drain
UPR-200-E-81
2607-EG Septic Tank
244-CR Vault
UPR-200-E-27
241-AN
Tank Farm
107
106
105
104
E26-6
103
102
101
UPR-200-F-100
UPR-200-E-99
A-24 Crib

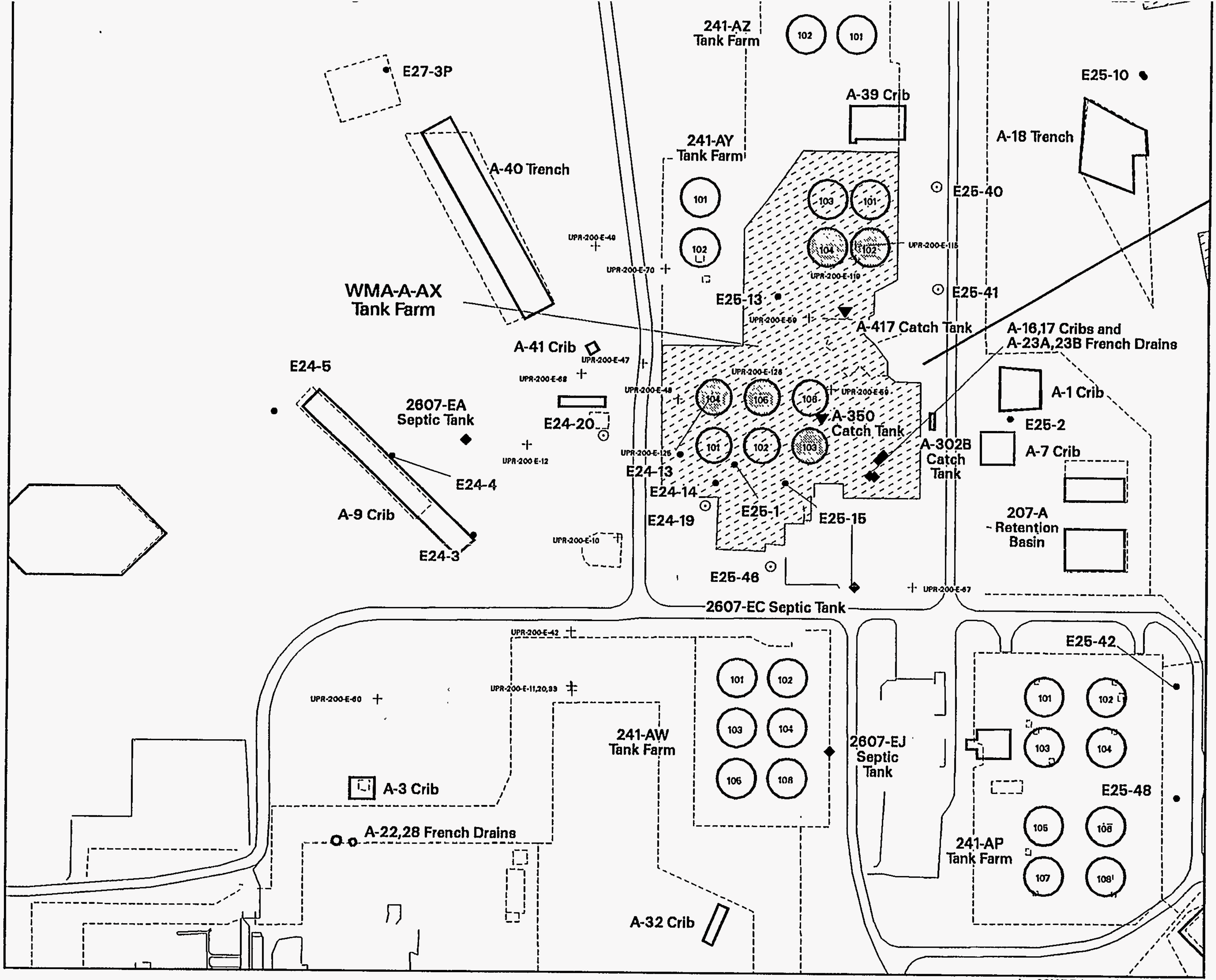


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Figure A.17. Monitoring Well Locations for Waste Management Areas A-AX and C

Table A.18. Monitoring Wells and Constituents for Waste Management Area B-BX-BY (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-ENV-AP-002)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Network
299-E33-5^{55}	Top of unconfined	--	Quarterly	PRE	--
299-E33-8^{53}	Top of unconfined	--	Quarterly	PRE	--
299-E33-13^{53}	Top of unconfined	Quarterly	Quarterly	PRE	
299-E33-15^{53}	Top of unconfined	Quarterly	Quarterly	PRE	
299-E33-16^{53}	Top of unconfined	Quarterly	Quarterly	PRE	
299-E33-18^{50}	Top of unconfined	--	Quarterly	PRE	--
299-E33-21^{57}	Top of unconfined	Quarterly	Quarterly	PRE	
299-E33-31^{89}	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-E33-32^{89}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-E33-33^{89}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-E33-36^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	216-B-63 Trench
299-E33-38^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-E33-39^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-E33-41^{91}	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-E33-42^{91}	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-E33-43^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--

Contamination Indicator Parameters

- pH
- Specific conductance
- Total organic carbon
- Total organic halides

Groundwater Quality Parameters

- Chloride
- Iron (filtered)
- Manganese (filtered)
- Sodium (filtered)
- Sulfate

Drinking Water Parameters

- Barium (filtered)
- Cadmium (filtered)
- Chromium (filtered)
- Fluoride
- Gross alpha
- Gross beta
- Nitrate
- Silver (filtered)
- Turbidity

Site-Specific Parameters

- Ammonium
- Iodine-129
- Low-level gamma
- Technetium-99
- Tritium
- Uranium

(a) Sampled monthly starting in August 1997.
Shading = Upgradient wells.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

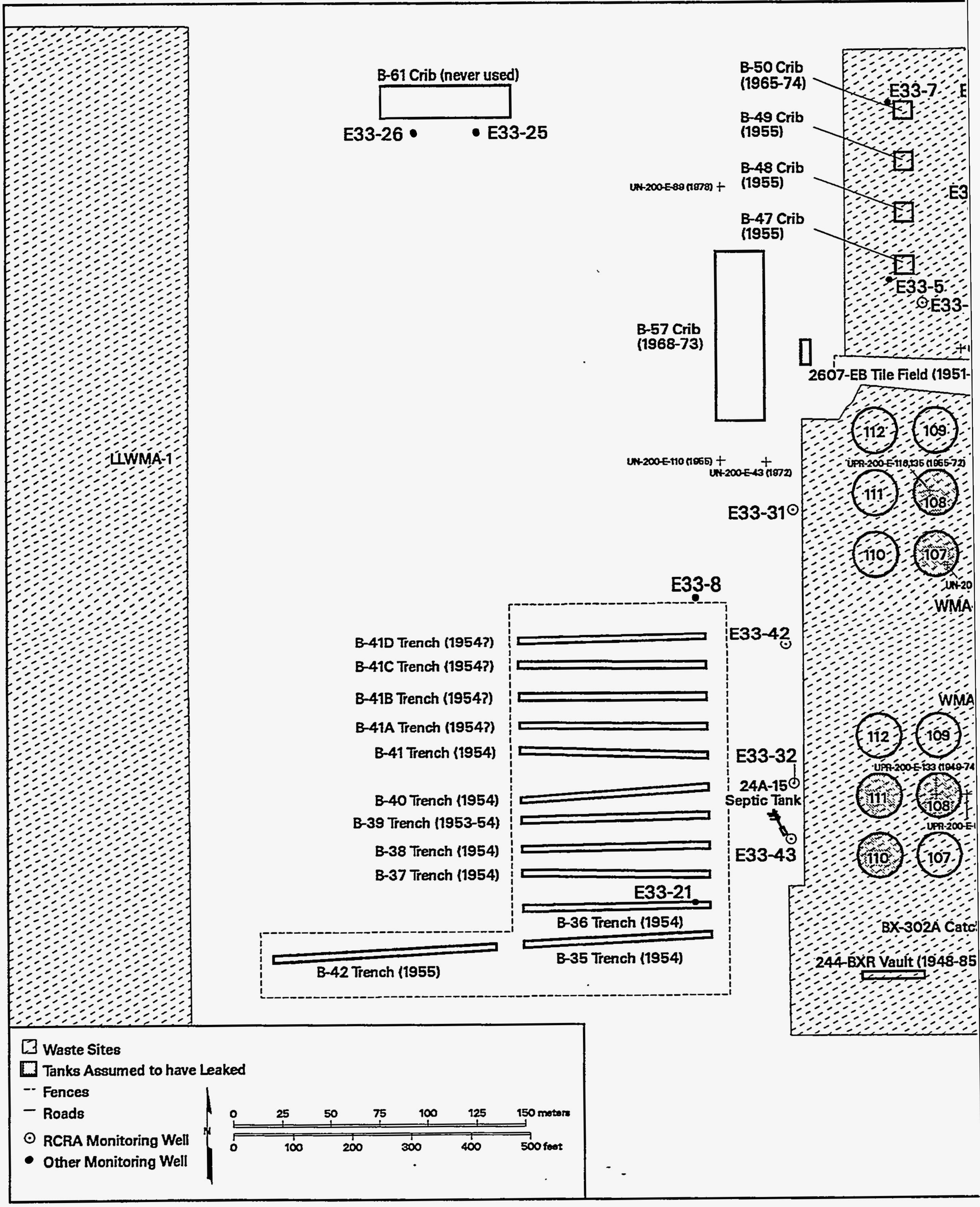
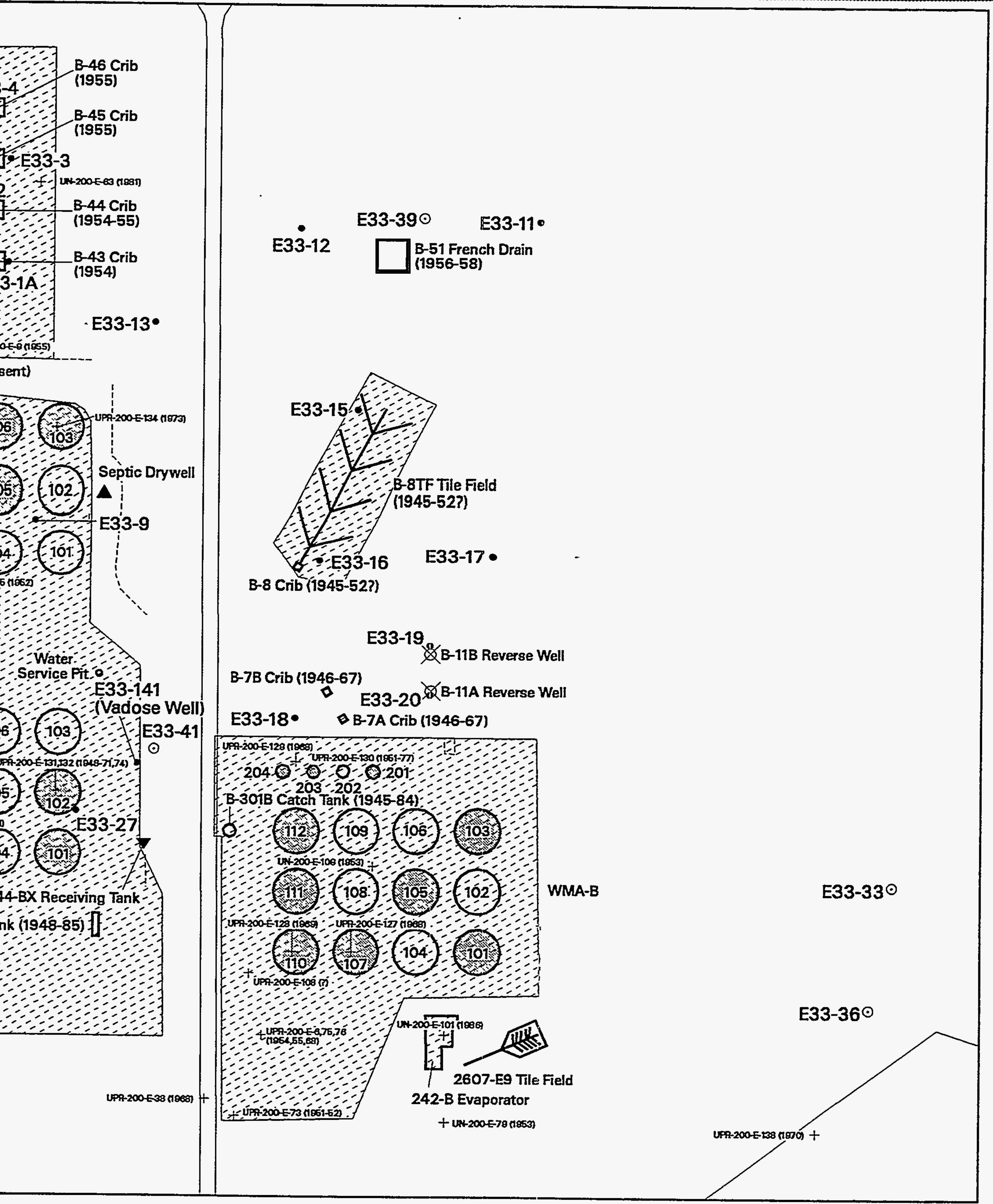


Figure A.18. Monitoring Well Locatio



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or Waste Management Area B-BX-BY

Table A.19. Monitoring Wells and Constituents for Waste Management Areas S-SX and U (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-AP-191)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurements	Well Standards	Other Network
	S-SX Single-Shell Tank Farm				
299-W22-39[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W22-44[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W22-45[92]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W22-46[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W23-7[69]	Top of unconfined	June 1996	Semiannual	PRE	--
299-W23-13[90]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W23-14[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W23-15[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
	U Single-Shell Tank Farm				
299-W18-25[90]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W18-30[91]	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W18-31[91]	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W19-31[90]	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--
299-W19-32[91]	Top of unconfined	Quarterly(a)	Quarterly	RCRA	--

Contamination Indicator Parameters		Groundwater Quality Parameters	
pH		Chloride	Phenols
Specific conductance		Iron (filtered)	Sodium (filtered)
Total organic carbon		Manganese (filtered)	Sulfate
Total organic halides			

Drinking Water Parameters		Site-Specific Parameters	
Barium (filtered)	Gross beta(b)	Technetium-99	Tritium
Cadmium (filtered)	Nitrate		
Chromium (filtered)	Silver (filtered)(b)		
Fluoride	Turbidity(b)		
Gross alpha(b)			

(a) Quarterly sampling for total organic halides only.
(b) For WMA U.
Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

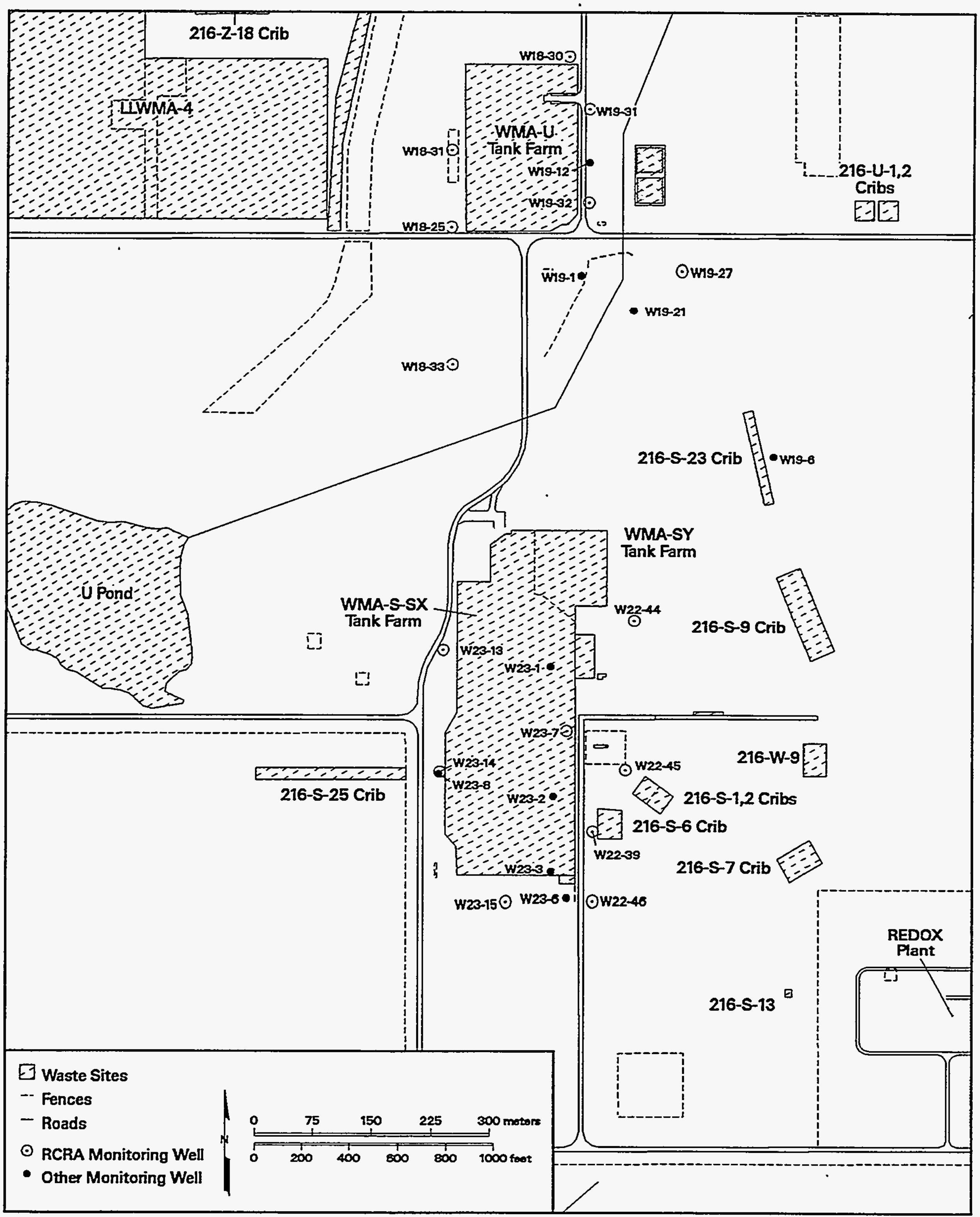

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Figure A.19. Monitoring Well Locations for Waste Management Areas S-SX and U

Table A.20a. Monitoring Wells and Constituents for Waste Management Area T (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-AP-132)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Networks
299-W6-2$^{87(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W6-4$^{91(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W6-6$^{91(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W6-9$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W10-8^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W10-9^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W10-11^{74}	Top of unconfined	--	Quarterly	PRE	--
299-W10-12^{74}	Top of unconfined	--	Quarterly	PRE	--
299-W10-15^{89}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W10-16^{89}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W10-19$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W10-20$^{93(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W10-21$^{93(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W11-23^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W11-24^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W11-27^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W11-28^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W11-31$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	--

Contamination Indicator Parameters

PH
Specific conductance
Total organic carbon
Total organic halides

Groundwater Quality Parameters

Chloride
Iron (filtered)
Manganese (filtered)
Phenols
Sodium (filtered)
Sulfate

Drinking Water Parameters

Barium (filtered)
Cadmium (filtered)
Chromium (filtered)
Fluoride
Gross alpha
Gross beta
Nitrate
Silver (filtered)
Turbidity

Site-Specific Parameters

Ammonium
Cesium-137
Cobalt-60
Gamma scan
Iodine-129
Technetium-99
Tritium

(a) Wells used for expanded assessment monitoring.
Shading = Upgradient well.
Superscript = Year of installation.
LLWMA = Low-level waste management area.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.20b. Monitoring Wells and Constituents for Waste Management Area TX-TY Single-Shell Tank Farms (adapted from WHC-SD-EN-AP-012, Rev. 1 and WHC-SD-EN-AP-132)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Networks
299-W10-17^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W10-18^{90}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W14-12^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W15-22^{91}	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W15-12^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W15-13^{73}	Top of unconfined	--	Quarterly	PRE	--
299-W6-2$^{87(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W6-4$^{91(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W6-6$^{91(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W6-9$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	--
299-W10-19$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W10-20$^{93(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W10-21$^{93(a)}$	Top of unconfined	Quarterly	--	RCRA	LLWMA-3
299-W11-31$^{92(a)}$	Top of unconfined	Quarterly	--	RCRA	--

Contamination Indicator Parameters
pH
Specific conductance
Total organic carbon
Total organic halides

Groundwater Quality Parameters	
Chloride	Phenols
Iron (filtered)	Sodium (filtered)
Manganese (filtered)	Sulfate

Drinking Water Parameters	
Barium (filtered)	Gross beta
Cadmium (filtered)	Nitrate
Chromium (filtered	Silver (filtered)
Fluoride	Turbidity
Gross alpha	

Site-Specific Parameters	
Ammonium	Iodine-129
Cesium-137	Technetium-99
Cobalt-60	Tritium
Gamma scan	

(a) Wells used for expanded assessment monitoring.
Shading = Upgradient well.
Superscript = Year of installation.
LLWMA = Low-level waste management area.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

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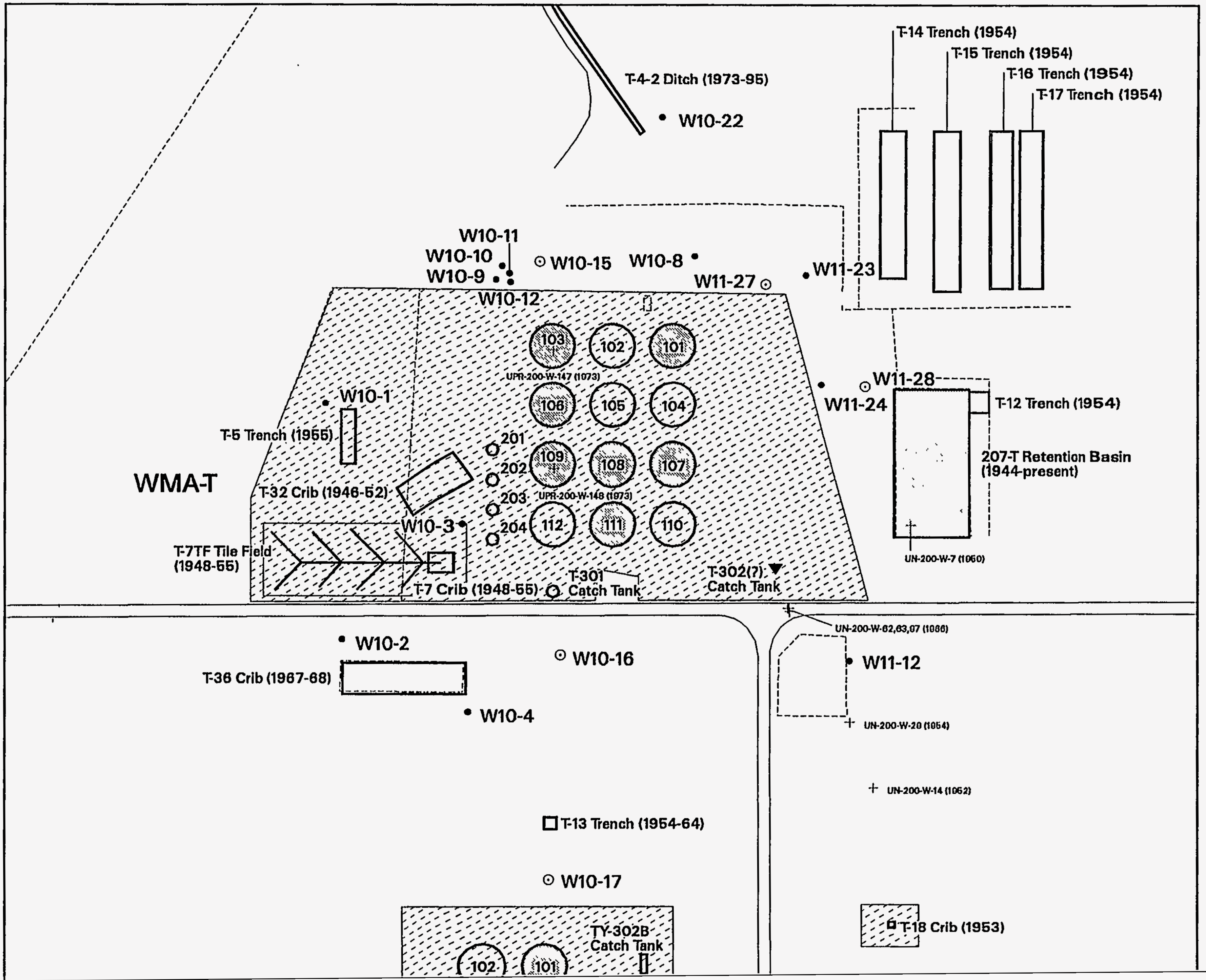
T-14 Trench (1954)
T-15 Trench (1954)
T-16 Trench (1954)
T-17 Trench (1954)
T-4-2 Ditch (1973-95)
W10-22
W10-11
W10-10
W10-9
W10-15
W10-8
W11-27
W11-23
W10-12
103
102
101
UPR-200-W-147 (1973)
106
105
104
109
108
107
UPR-200-W-148 (1973)
112
111
110
201
202
203
204
W11-28
W11-24
T-12 Trench (1954)
207-T Retention Basin
(1944-present)
UN-200-W-7 (1960)
W10-1
T-5 Trench (1955)
WMA-T
T-32 Crib (1946-52)
W10-3
T-7TF Tile Field
(1948-55)
T-7 Crib (1948-55)
T-301
Catch Tank
T-302(?)
Catch Tank
UN-200-W-62,63,07 (1986)
W10-2
T-36 Crib (1967-68)
W10-16
W10-4
W11-12
UN-200-W-20 (1954)
UN-200-W-14 (1952)
T-13 Trench (1954-64)
W10-17
TY-302B
Catch Tank
102
101
T-18 Crib (1953)

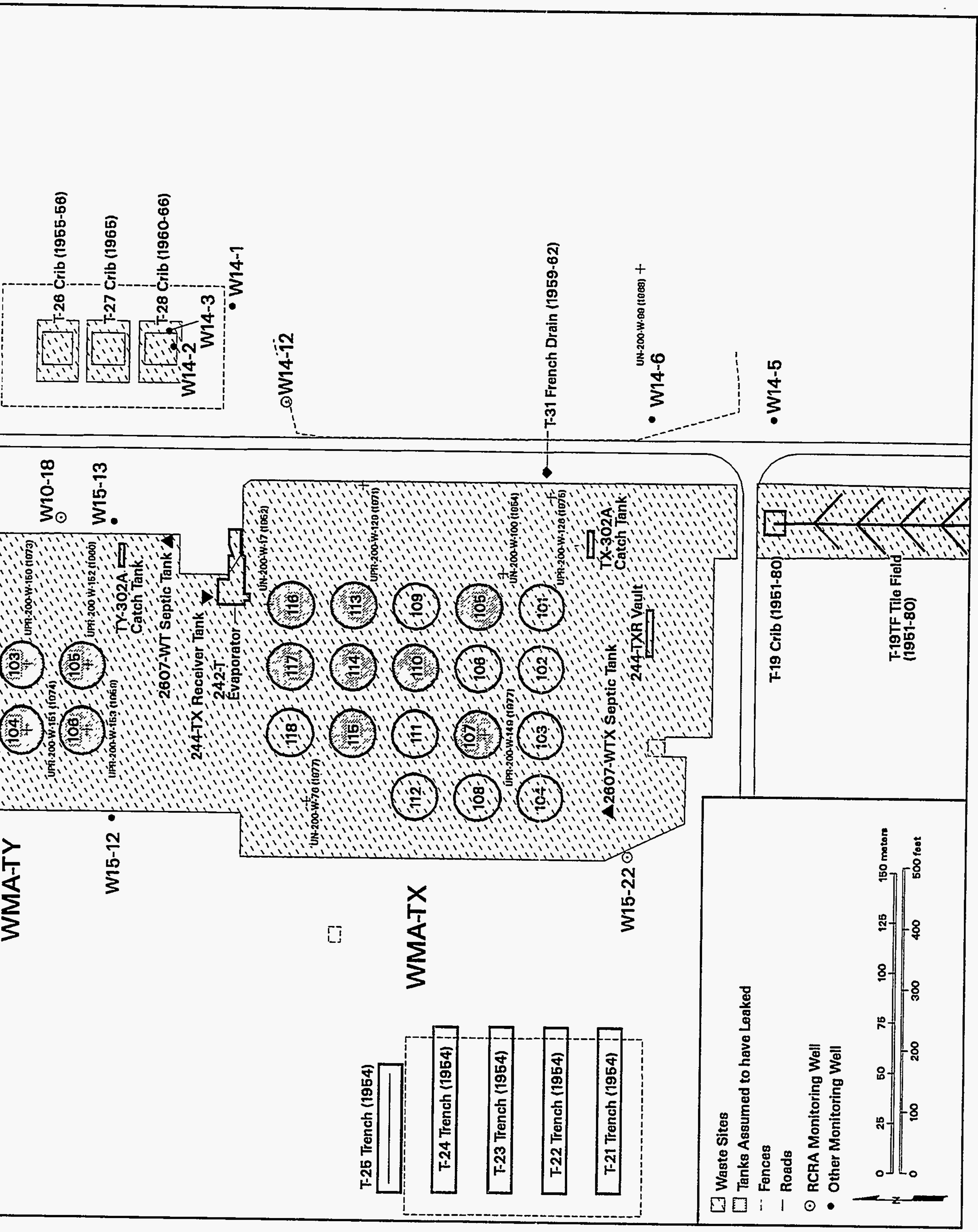

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Figure A.20. Monitoring Well Locations for Waste Management Areas T and TX-TY

Table A-21a. Monitoring Wells and Constituents for Solid Waste Landfill (adapted from WHC-SD-EN-AP-043)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standards	Other Networks
699-22-35[93]	Top of unconfined	Quarterly	--	RCRA	--
699-23-34A[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-23-34B[93]	Top of unconfined	Quarterly	--	RCRA	--
699-24-33[48]	Top of unconfined	Quarterly[(a)]	Monthly	PRE	Sitewide
699-24-34A[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-24-34B[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-24-34C[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-24-35[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-25-34C[87]	Top of unconfined	Quarterly	Monthly	RCRA	--
699-26-35A[86]	Top of unconfined	Quarterly	Monthly	RCRA	NRDWL

Parameters/Constituents Required by WAC 173-304-490		Site-Specific Constituents	
Ammonia as nitrogen	Nitrate	Total organic halides	Trichloroethylene
Chemical oxygen demand	Nitrite	1,1,1-Trichloroethane	Tritium
Chloride	pH		
Specific conductance	Sulfate		
Dissolved iron	Temperature		
Dissolved zinc	Total coliform		
Manganese	Total organic carbon		

(a) Well sampled for supporting data.
Shading = Upgradient wells.
Superscript = Year of installation.
NRDWL = Nonradioactive Dangerous Waste Landfill.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

Table A.21b. Monitoring Wells and Constituents for Nonradioactive Dangerous Waste Landfill (adapted from WHC-SD-EN-AP-026)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurement	Well Standard	Other Network
699-25-33A^{87}	Top of LPU(a)	Semiannual	Monthly	RCRA	--
699-25-34A^{86}	Top of unconfined	Semiannual	Monthly	RCRA	--
699-25-34B^{86}	Top of unconfined	Semiannual	Monthly	RCRA	--
699-25-34D^{92}	Top of unconfined	Quarterly	Monthly	RCRA	--
699-26-33^{86}	Top of unconfined	Semiannual	Monthly	RCRA	--
699-26-34A^{92}	Top of unconfined	Semiannual	Monthly	RCRA	--
699-26-34B^{92}	Top of unconfined	Quarterly	Monthly	RCRA	--
699-26-35A^{86}	Top of unconfined	Semiannual	Monthly	RCRA	SWL
699-26-35C^{87}	Top of LPU(a)	Semiannual	Monthly	RCRA	--

Contamination Indicator Parameters

- pH
- Specific conductance
- Total organic carbon
- Total organic halides

Groundwater Quality Parameters

- Chloride
- Iron (filtered)
- Manganese (filtered)
- Phenols
- Sodium (filtered)
- Sulfate

Drinking Water Parameters

- Barium
- Cadmium (filtered)
- Chromium (filtered)
- Coliform bacteria
- Fluoride
- Gross alpha
- Gross beta
- Nitrate
- Silver (filtered)
- Turbidity

Site-Specific Parameters

- Tritium
- Volatile chlorinated hydrocarbons

(a) Low-permeability unit in upper Ringold Formation.
Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.
SWL = Solid Waste Landfill.

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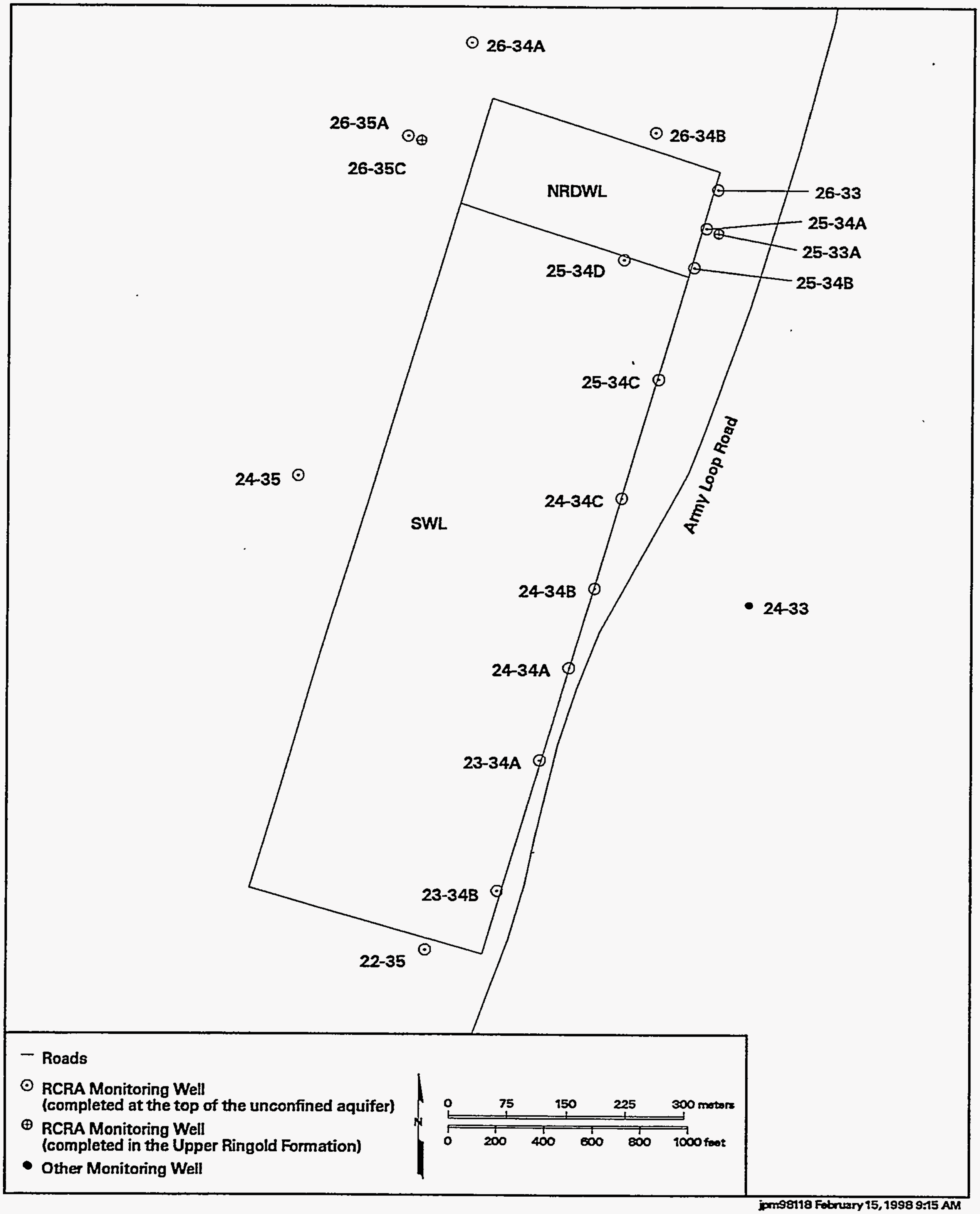

Figure A.21. Monitoring Well Locations for Solid Waste Landfill and Nonradioactive Dangerous Waste Landfill

Table A.22. Monitoring Wells and Constituents for 316-5 Process Trenches through November 30, 1996 (adapted from PNL-6671)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Water-Level Measurement	Well Standards	Other Network
399-1-10A[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-1-11[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-1-12[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-1-14A[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-1-16A[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-1-16B[87]	Bottom of unconfined	Semiannual	Quarterly	RCRA	--
399-1-17A[86]	Top of unconfined	Quarterly	Quarterly	RCRA	--
399-1-17B[86]	Bottom of unconfined	Semiannual	Quarterly	RCRA	--
399-1-18A[86]	Top of unconfined	Semiannual	Quarterly	RCRA	--
399-2-1[48]	Top of unconfined	Semiannual(a)	Quarterly	PRE	--
399-3-10[76]	Top of unconfined	Semiannual(a)	Quarterly	PRE	--

Contamination Indicator Parameters	Groundwater Quality Parameters	
PH	Chloride	Phenols
Specific conductance	Iron	Sodium
Total organic carbon	Manganese	Sulfate
Total organic halides		

Drinking Water Parameters		Site-Specific Parameters	
Arsenic (filtered)	Gross beta	Alkalinity	Phosphate
Barium (filtered)	Lead (filtered)	Bromide	Strontium-90
Cadmium (filtered)	Mercury (filtered)	Gamma scan	Tritium
Chromium (filtered)	Nitrate	ICP metals (filtered)	Uranium
Coliform	Radium	Isotopic uranium	Volatile organics
Fluoride	Selenium (filtered)	Nitrite	
Gross alpha	Silver (filtered)		

(a) Well sampled for supporting data.
Shading = Upgradient wells.
Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

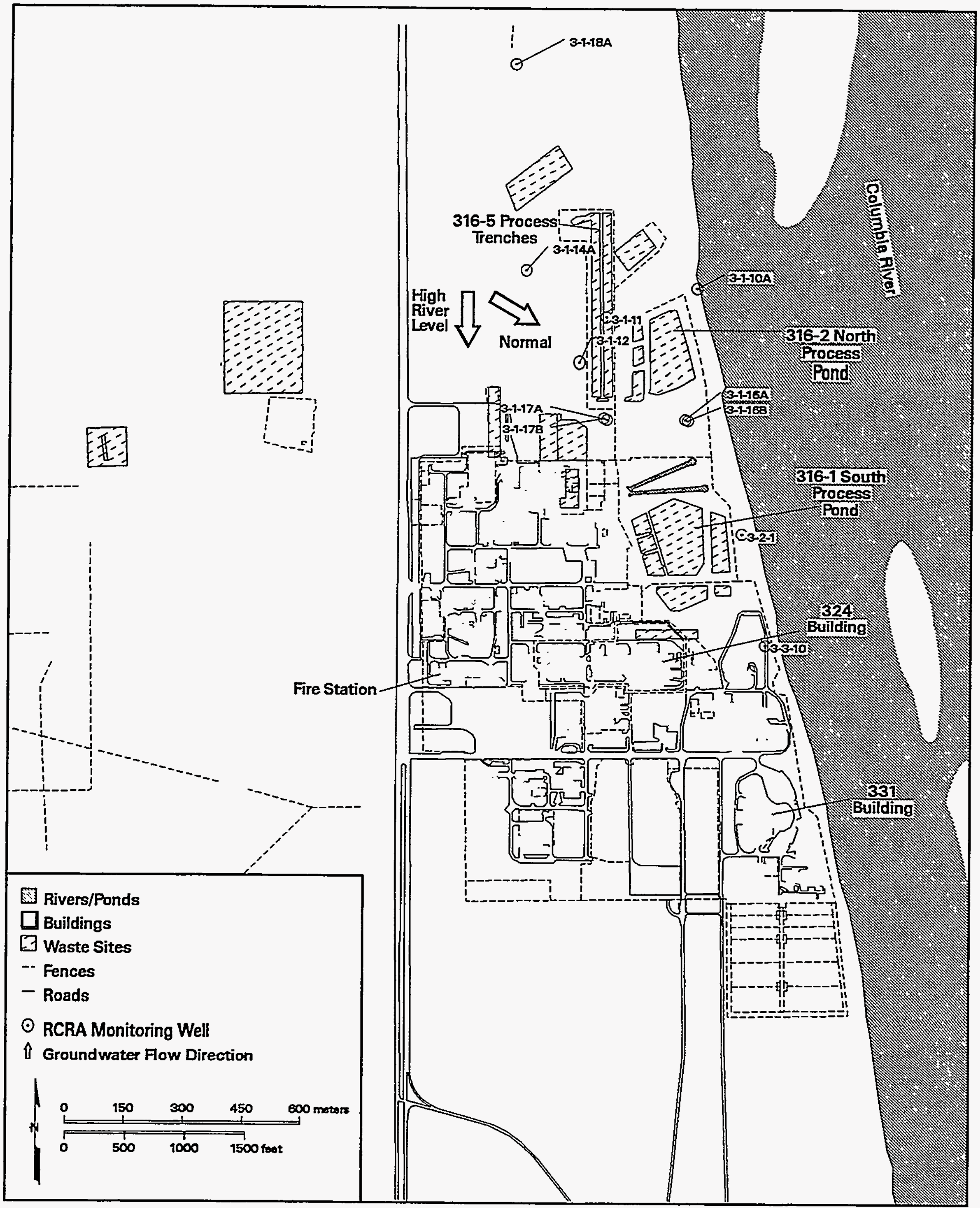

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Figure A.22. Monitoring Well Locations for 316-5 Process Trenches through November 30, 1996

Table A.23. Monitoring Wells and Constituents for 316-5 Process Trenches, Beginning December 1, 1996 (adapted from WHC-SD-EN-AP-185)

Well	Hydrogeologic Unit Monitored	Sampling Frequency(a)	Water-Level Measurement(a)	Well Standard	Other Networks
399-1-10A^{86}	Top of unconfined	Semiannual	Semiannually	RCRA	--
399-1-10B^{91}	Bottom of unconfined	Semiannual	Semiannually	RCRA	--
399-1-16A^{86}	Top of unconfined	Semiannual	Semiannually	RCRA	--
399-1-16B^{87}	Bottom of unconfined	Semiannual	Semiannually	RCRA	--
399-1-17A^{86}	Top of unconfined	Semiannual	Semiannually	RCRA	--
399-1-17B^{86}	Bottom of unconfined	Semiannual	Semiannually	RCRA	--
399-1-18A^{86}	Top of unconfined	Semiannual	Semiannually	RCRA	--
399-1-18B^{87}	Bottom of unconfined	Semiannual	Semiannually	RCRA	--

Field-Measured Parameters	Site-Specific Parameters	
pH	Benzo(A)Pyrene(b)	Manganese(c,d)
Specific conductance	Chrysene(b)	Polychlorinated biphenyls(b)
Temperature	cis-Dichloroethylene	Thallium(b)
Turbidity	Dissolved oxygen(c)	Trichloroethylene
	Eh(c)	Uranium
	Iron(c,d)	

(a) Sampled and measured monthly for 4 months for each semiannual sampling period.
(b) Analyzed first 2 years.
(c) Deep wells only for 2 sampling periods.
(d) Filtered samples.

Shading = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

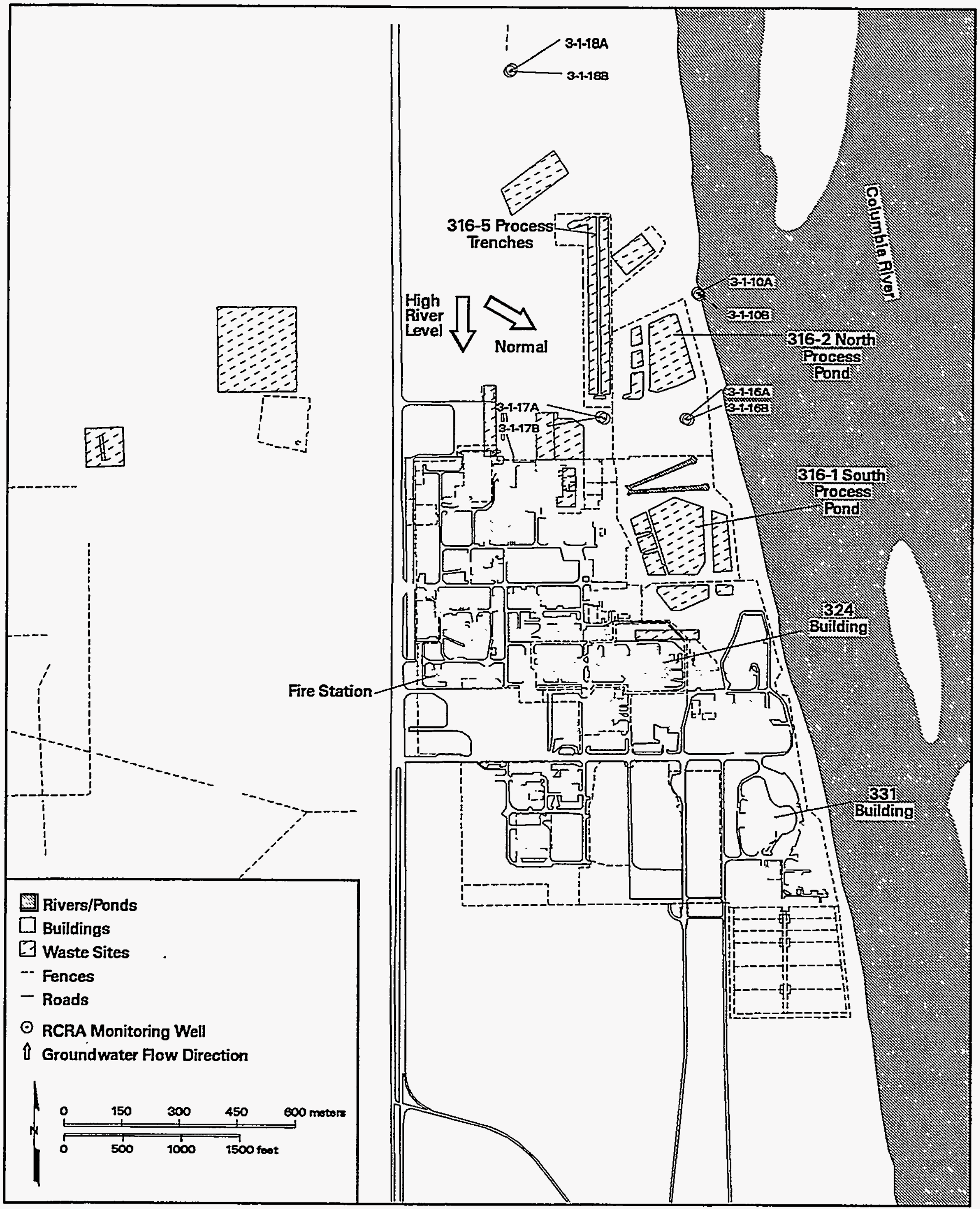

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Figure A.23. Monitoring Well Locations for 316-5 Process Trenches, Beginning December 1, 1996

Table A.24. Tritium Tracking Network for State-Approved Land-Disposal Site (adapted from WHC-SD-C018H-PLN-004, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequencies	Well Standards	Other Networks
299-W6-5	Top of unconfined	Semiannual	RCRA	--
299-W6-6	Top of unconfined	Semiannual	RCRA	T-TX-TY SSTF
299-W6-7	Top of unconfined	Semiannual	RCRA	--
299-W6-8	Top of unconfined	Semiannual	RCRA	--
299-W6-11	Top of unconfined	Semiannual	RCRA	--
299-W6-12	Top of unconfined	Semiannual	RCRA	--
299-W7-1	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-2	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-3	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-5	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-6	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-7	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-8	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-9	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-11	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W7-12	Top of unconfined	Semiannual	RCRA	LLWMA-3
299-W8-1	Top of unconfined	Semiannual	RCRA	LLWMA-3
699-48-71	Unconfined	Semiannual	PRE	--
699-48-77A	Confined Ringold Unit E; upper	Quarterly	RCRA	--
699-48-77C	Confined Ringold Unit E; mid-to-lower	Quarterly	RCRA	--
699-48-77D	Confined Ringold Unit E; upper	Quarterly	RCRA	--
699-49-79	Ringold	Annual	PRE	Sitewide
699-51-75	Confined Ringold (?)	Annual	PRE	

Shading = Upgradient wells.
LLWMA = Low-level waste management area.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.
SSTF = Single-shell tank farms.

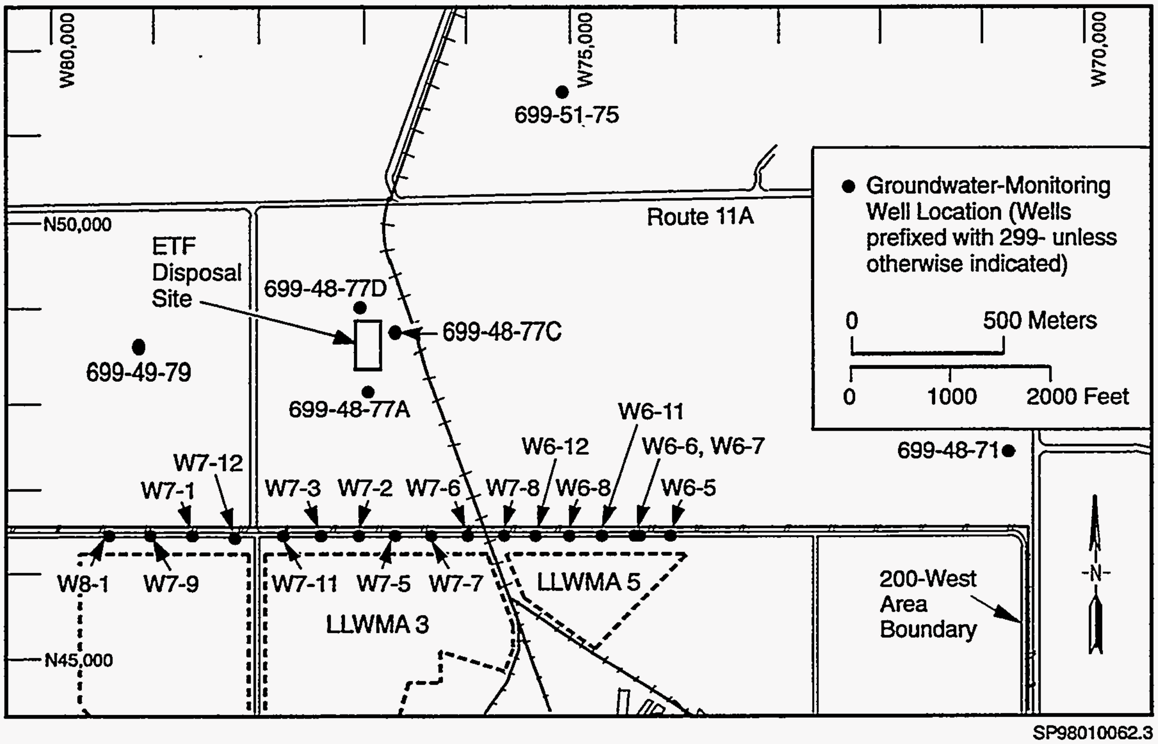

Figure A.24. Tritium Tracking Network for State-Approved Land-Disposal Site

Table A.25. Monitoring Wells for 200 Areas Treated Effluent-Disposal Facility (adapted from WHC-SD-EN-WP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Well Standard	Other Network
699-40-36	Confined Ringold	Quarterly	RCRA	--
699-41-35	Confined Ringold	Quarterly	RCRA	--
699-42-37	Confined Ringold	Quarterly	RCRA	--

RCRA = Well constructed to RCRA standards.

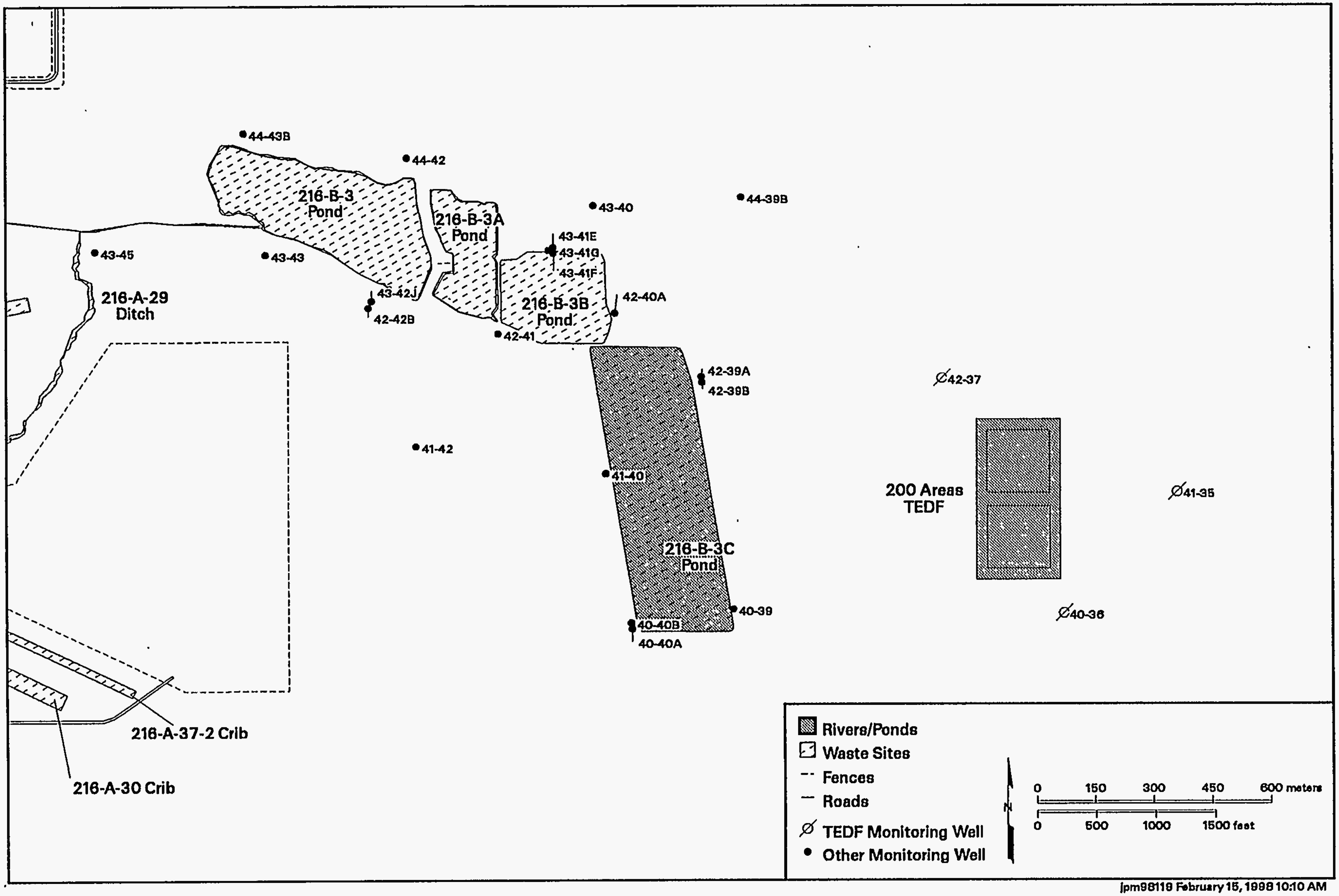

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Figure A.25. Monitoring Wells for 200 Areas Treated Effluent-Disposal Facility

Table A.26. Monitoring Wells and Constituents for 400 Area Process Ponds

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurements	Well Standards	Other Network
699-2-7^{78}	Unconfined aquifer	Quarterly	Annual	PRE	--
699-8-17^{50}	Unconfined aquifer	Quarterly	Semiannual	PRE	Sitewide
699-2-6A^{97}	Unconfined aquifer	Quarterly	Annual	RCRA	--

Field-Measured Parameters	Site-Specific Parameters	
pH	Alkalinity	Mercury (unfiltered)
Specific conductance	Cadmium (unfiltered)	pH
Temperature	Chromium (unfiltered)	Sulfate
Turbidity	Lead (unfiltered)	Total organic carbon

Superscript = Year of installation.
PRE = Well not constructed to RCRA standards.
RCRA = Well constructed to RCRA standards.

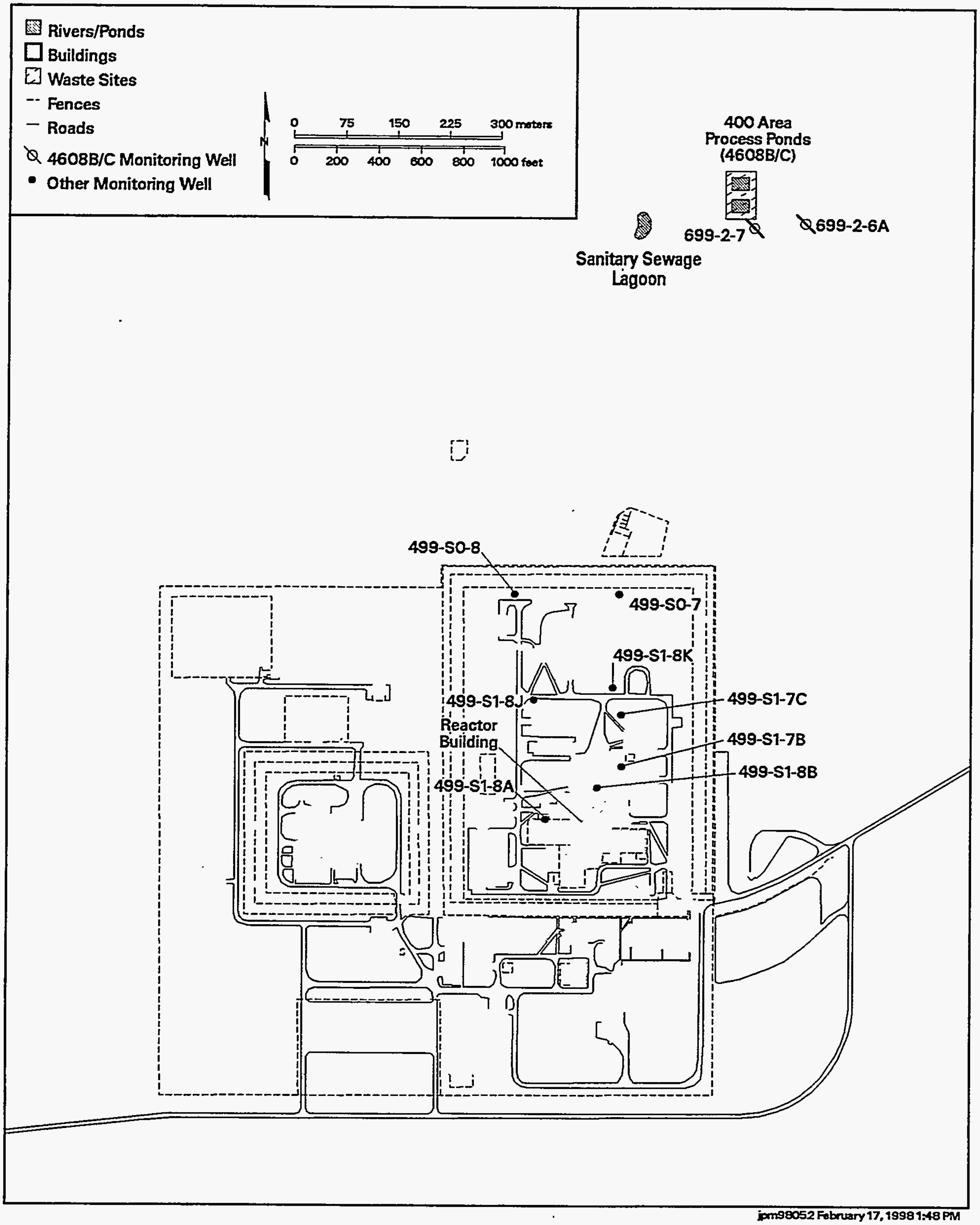

Figure A.26. Monitoring Wells for 400 Area Process Ponds

Table A.27. RCRA Monitoring Results Exceeding Maximum Contaminant Levels

Constituent	Filter(a)	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
100-N Area						
Antimony, µg/L	Y	199-N-41	Down	1	24	6
Gross beta, pCi/L	N	199-N-2	Down	1	4,500	50
	N	199-N-3	Down	2	3,210	50
	N	199-N-81	Down	1	4,470	50
Iron, µg/L	Y	199-N-28	Up	1	404	300
Manganese, µg/L	Y	199-N-3	Down	1	141	50
Nitrogen in nitrate, µg/L	N	199-N-105A	Down	1	24,900	10,000
	N	199-N-3	Down	1	11,600	10,000
	N	199-N-32	Down	1	15,600	10,000
Strontium-90, pCi/L	N	199-N-28	Up	1	77.5	8
	N	199-N-34	Up	1	57.8	8
	N	199-N-57	Up	2	25.8	8
	N	199-N-81	Down	1	886	8
Sulfate, µg/L	N	199-N-3	Down	3	269,000	250,000
	N	199-N-59	Down	1	282,000	250,000
	N	199-N-72	Down	1	320,000	250,000
	N	199-N-73	Down	1	358,000	250,000
Tritium, pCi/L	N	199-N-2	Down	1	21,400	20,000
	N	199-N-27	Down	1	29,500	20,000
	N	199-N-32	Down	2	95,600	20,000
	N	199-N-81	Down	1	20,900	20,000
100-D Area						
Aluminum, µg/L	Y	199-D8-4	Down	2	70.5	50
	Y	199-D8-6	Down	1	52.3	50
Chromium, µg/L	N	199-D5-13	Up	1	366	100
	Y	199-D5-13	Up	3	444	100
Nitrogen in nitrate, µg/L	N	199-D5-13	Up	2	16,100	10,000
	N	199-D8-4	Down	1	19,200	10,000
pH	N	199-D8-4	Down	9	8.94	8.5
	N	199-D8-6	Down	8	9.32	8.5
183-H Solar Evaporation Basins						
Antimony, µg/L	Y	199-H4-12A	Down	1	28.6	6
	Y	199-H4-18	Down	1	21.4	6
Chromium, µg/L	Y	199-H4-12C	Down	9	277	100
	N	199-H4-12C	Down	1	264	100
	Y	199-H4-18	Down	4	116	100
	Y	199-H4-3	Down	9	169	100
	N	199-H4-3	Down	1	160	100
	N	199-H4-4	Down	1	108	100
	Y	199-H4-4	Down	2	105	100
	N	199-H4-6	Up	1	103	100
	Y	199-H4-6	Up	1	105	100

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Gross alpha, pCi/L	N	199-H4-18	Down	1	16.3	15
	N	199-H4-3	Down	1	77.7	15
	N	199-H4-4	Down	2	56.4	15
Gross beta, pCi/L	N	199-H4-18	Down	1	85.2	50
	N	199-H4-3	Down	1	348	50
	N	199-H4-4	Down	2	722	50
Iron, µg/L	N	199-H4-3	Down	1	704	300
Nitrogen in nitrate, µg/L	N	199-H4-12A	Down	8	25,700	10,000
	N	199-H4-18	Down	9	50,700	10,000
	N	199-H4-3	Down	9	144,000	10,000
	N	199-H4-4	Down	5	118,000	10,000
	N	199-H4-9	Down	7	34,300	10,000
Technetium-99, pCi/L	N	199-H4-3	Down	8	2,080	900
	N	199-H4-4	Down	4	1,640	900
		<u>216-S-10 Pond and Ditch</u>				
Aluminum, µg/L	Y	299-W26-10	Down	1	61.5	50
	Y	299-W26-12	Down	1	65.5	50
pH	N	299-W26-8	Up	8	8.86	8.5
		<u>216-U-12 Crib</u>				
Aluminum, µg/L	Y	299-W22-42	Down	1	87.3	50
Carbon tetrachloride, µg/L	N	299-W22-42	Down	2	7	5
	N	699-36-70A	Down	2	7	5
Gross beta, pCi/L	N	299-W22-41	Down	1	55.8	50
Iodine-129, pCi/L	N	299-W22-42	Down	5	12	1
	N	699-36-70A	Down	3	15.5	1
Nitrogen in nitrate, µg/L	N	299-W22-41	Down	4	106,000	10,000
	N	299-W22-42	Down	5	48,300	10,000
	N	699-36-70A	Down	3	28,000	10,000
Tritium, pCi/L	N	299-W22-42	Down	4	54,500	20,000
		699-36-70A	Down	4	155,000	20,000
		<u>216-B-3 Pond</u>				
Iodine-129, pCi/L	N	699-41-40	Down	1	1.73	1
	N	699-42-42B	Down	1	4.17	1
	N	699-43-40	Down	1	2.83	1
	N	699-43-41E	Down	1	4.07	1
	N	699-43-45	Down	1	4.6	1
Pentachlorophenol, µg/L	N	299-E32-4	Up	1	4	1

Table A.27. (contd)

Constituent	Filter(a)	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
pH	N	699-41-40	Down	7	8.59	8.5
	N	699-41-42	Down	4	8.52	8.5
	N	699-41-41E	Down	8	8.73	8.5
	N	699-41-41G	Down	1	8.51	8.5
Tritium, pCi/L	N	699-41-40	Down	1	110,000	20,000
	N	699-42-39A	Down	1	50,500	20,000
	N	699-42-39B	Down	1	71,800	20,000
	N	699-42-42B	Down	1	33,800	20,000
	N	699-43-40	Down	1	40,000	20,000
	N	699-43-41E	Down	1	46,800	20,000
			<u>216-A-29 Ditch</u>			
Iodine-129, pCi/L	N	299-E25-28	Down	1	2	1
	N	699-43-45	Up	1	4.6	1
pH	N	299-E25-28	Down	9	8.83	8.5
	N	299-E25-35	Down	7	8.81	8.5
			<u>216-A-10 Crib</u>			
Aluminum, µg/L	Y	699-37-47A	Down	2	145	50
Arsenic, µg/L	Y	699-37-47A	Down	1	84.8(b)	50
Gross alpha, pCi/L	N	699-37-47A	Down	1	150(b)	15
Iodine-129, pCi/L	N	299-E17-20	Down	1	6.44	1
	N	299-E24-16	Down	2	18.1	1
	N	299-E24-17	Down	1	3.89	1
	N	299-E24-18	Up	1	3.06	1
	N	699-37-47A	Down	2	2.03	1
Iron, µg/L	Y	699-37-47A	Down	1	593(b)	300
Manganese, µg/L	Y	699-37-47A	Down	3	132(b)	50
Nitrogen in nitrate, µg/L	N	299-E17-1	Down	2	18,000	10,000
	N	299-E17-19	Down	1	12,700	10,000
	N	299-E17-20	Down	1	17,900	10,000
	N	299-E24-16	Down	2	16,100	10,000
pH	N	299-E17-20	Down	8	8.66	8.5
Tritium, pCi/L	N	299-E17-1	Down	3	1,370,000	20,000
	N	299-E17-19	Down	3	701,000	20,000
	N	299-E17-20	Down	2	1,130,000	20,000
	N	299-E24-16	Down	3	866,000	20,000
	N	299-E24-17	Down	2	565,000	20,000
	N	299-E24-18	Up	2	118,000	20,000
			<u>216-A-36B Crib</u>			
Aluminum, µg/L	Y	299-E25-36	Up	1	96.7	50
Gross beta, pCi/L	N	299-E17-14	Down	2	56.9	50
	N	299-E17-15	Down	1	66.1	50
	N	299-E17-16	Down	1	52.5	50

Table A.27. (contd)

Constituent	Filter(a)	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Iodine-129, pCi/L	N	299-E17-14	Down	3	11.6	1
	N	299-E17-15	Down	1	8.6	1
	N	299-E17-18	Down	1	5.65	1
	N	299-E17-9	Down	1	10.7	1
	N	299-E24-18	Up	1	3.06	1
Nitrogen in nitrate, µg/L	N	299-E17-14	Down	1	17,100	10,000
	N	299-E17-15	Down	1	25,600	10,000
	N	299-E17-9	Down	1	30,900	10,000
Strontium-90, pCi/L	N	299-E17-14	Down	3	15.7	8
Tritium, pCi/L	N	299-E17-14	Down	4	1,400,000	20,000
	N	299-E17-15	Down	2	1,010,000	20,000
	N	299-E17-16	Down	2	425,000	20,000
	N	299-E17-17	Up	2	726,000	20,000
	N	299-E17-18	Down	2	227,000	20,000
	N	299-E17-9	Down	2	3,070,000	20,000
	N	299-E24-18	Up	2	118,000	20,000
			216-A-37-1 Crib			
Aluminum, µg/L	Y	299-E25-17	Down	1	58.3	50
Iodine-129, pCi/L	N	299-E25-19	Down	1	1.53	1
Tritium, pCi/L	N	299-E25-19	Down	2	396,000	20,000
			216-B-63 Trench			
Iodine-129, pCi/L	N	299-E27-18	Down	1	3.1	1
	N	299-E33-33	Down	5	5.43	1
	N	299-E33-36	Down	5	5.26	1
	N	299-E34-10	Up	1	3.14	1
pH	N	299-E33-36	Down	4	8.58	8.5
			Liquid Effluent-Retention Facility			
Gross alpha, pCi/L	N	299-E26-9	Down	1	40.9	15
Gross beta, pCi/L	N	299-E26-9	Down	1	57.8	50
Methylene chloride, µg/L	N	299-E26-9	Down	1	38	5
			Low-Level Waste Management Area 1			
Aluminum, µg/L	Y	299-E32-5	Down	1	72.9	50
	Y	299-E32-6	Down	1	97.7	50
	Y	299-E33-30	Down	1	78.4	50
Gross beta, pCi/L	N	299-E32-10	Down	2	94.8	50
	N	299-E33-34	Down	2	356	50
	N	299-E33-35	Up	2	144	50
Iodine-129, pCi/L	N	299-E32-8	Down	1	4.76	1
	N	299-E33-29	Up	1	4.08	1
	N	299-E33-34	Down	1	5.68	1
Nitrogen in nitrate, µg/L	N	299-E33-34	Down	2	17,800	10,000

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Pentachlorophenol, µg/L	N	299-E32-4	Up	1	4	1
	N	299-E32-5	Down	1	2.6	1
	N	299-E33-29	Up	1	2.6	1
	N	299-E33-34	Down	1	2.2	1
Technetium-99, pCi/L	N	299-E33-34	Down	1	1,280	900
Tritium, pCi/L	N	299-E28-27	Up	2	49,400	20,000
	N	299-E32-2	Down	1	20,500	20,000
	N	299-E32-3	Down	2	27,000	20,000
	N	299-E32-5	Down	2	28,900	20,000
	N	299-E32-6	Down	2	24,900	20,000
	N	299-E32-7	Down	2	22,100	20,000
Low-Level Waste Management Area 2						
Aluminum, µg/L	Y	299-E34-7	Up	1	67	50
	Y	299-E34-9	Down	1	55.6	50
Iodine-129, pCi/L	N	299-E27-10	Up	1	4.73	1
	N	299-E27-10	Down	1	3.14	1
Nitrogen in nitrate, µg/L	N	299-E34-7	Up	1	11,400	10,000
Sulfate, µg/L	N	299-E34-7	Up	1	318,000	250,000
Low-Level Waste Management Area 3						
Aluminum, µg/L	Y	299-W10-19	Up	1	81.4	50
	Y	299-W10-21	Up	1	51.1	50
	Y	299-W7-5	Down	1	131	50
	Y	299-W7-7	Down	1	251	50
Carbon tetrachloride, µg/L	N	299-W10-13	Up	2	20	5
	N	299-W10-19	Up	2	1,600	5
	N	299-W10-20	Up	2	1,700	5
	N	299-W10-21	Up	2	630	5
	N	299-W6-2	Down	2	170	5
	N	299-W7-10	Down	2	11	5
	N	299-W7-4	Down	2	520	5
	N	299-W7-5	Down	2	140	5
	N	299-W8-1	Down	1	6	5
Chloroform, µg/L	N	299-W10-21	Up	1	200	100
Iron, µg/L	Y	299-W7-3	Down	1	469	300
Methylene chloride, µg/L	N	299-W10-19	Up	1	10	5
	N	299-W10-20	Up	1	220	5
	N	299-W10-21	Up	1	22	5
	N	299-W7-4	Down	1	18	5
	N	299-W7-5	Down	1	13	5
Nitrogen in nitrate, µg/L	N	299-W10-19	Up	4	30,400	10,000
	N	299-W10-20	Up	5	34,900	10,000
	N	299-W10-21	Up	5	34,700	10,000
	N	299-W6-2	Down	4	11,800	10,000
	N	299-W7-4	Down	2	23,800	10,000
	N	299-W7-5	Down	2	14,400	10,000
pH	N	299-W7-9	Down	4	8.61	8.5

Table A.27. (contd)

Constituent	Filter(a)	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Total dissolved solids, µg/L	N	299-W10-19	Up	1	510,000	500,000
Trichloroethylene, µg/L	N	299-W10-19	Up	1	12	5
Low-Level Waste Management Area 4						
Aluminum, µg/L	Y	299-W15-17	(c)	1	53.6	50
	Y	299-W18-21	(c)	1	55.3	50
	Y	299-W18-32	(c)	1	158	50
Carbon tetrachloride, µg/L	N	299-W15-15	(c)	8	1,900	5
	N	299-W15-16	(c)	4	7,300	5
	N	299-W15-18	(c)	5	3,200	5
	N	299-W15-19	(c)	7	260	5
	N	299-W15-20	(c)	2	50	5
	N	299-W15-23	(c)	1	170	5
	N	299-W15-24	(c)	2	450	5
	N	299-W18-21	(c)	8	1,100	5
	N	299-W18-23	(c)	11	710	5
	N	299-W18-24	(c)	4	1,400	5
	N	299-W18-26	(c)	13	380	5
	N	299-W18-27	(c)	6	370	5
	N	299-W18-28	(c)	8	26	5
Gross alpha, pCi/L	N	299-W18-21	(c)	1	15	15
Iron, µg/L	Y	299-W18-32	(c)	1	601	300
Methylene chloride, µg/L	N	299-W15-15	(c)	2	92	5
	N	299-W15-16	(c)	1	180	5
	N	299-W18-23	(c)	2	180	5
	N	299-W18-26	(c)	1	88	5
	N	299-W18-27	(c)	1	14	5
Nitrogen in nitrate, µg/L	N	299-W15-15	(c)	2	15,800	10,000
	N	299-W15-16	(c)	2	19,800	10,000
	N	299-W15-18	(c)	2	28,400	10,000
	N	299-W15-19	(c)	1	12,000	10,000
	N	299-W18-24	(c)	2	19,300	10,000
pH	N	299-W15-19	(c)	1	8.52	8.5
	N	299-W15-20	(c)	5	8.53	8.5
	N	299-W15-23	(c)	1	8.57	8.5
	N	299-W15-24	(c)	1	8.7	8.5
	N	299-W18-26	(c)	1	6.17	8.5
Trichloroethylene, µg/L	N	299-W15-16	(c)	3	7	5
	N	299-W18-24	(c)	1	58	5
Waste Management Area A-AX						
Chromium, µg/L	Y	299-E24-19	Down	2	1,660	100
Gross beta, pCi/L	N	299-E25-46	Down	2	158	50
Iodine-129, pCi/L	N	299-E24-19	Down	2	5.52	1
	N	299-E24-20	Down	2	4.33	1
	N	299-E25-40	Up	3	5.46	1
	N	299-E25-41	Up	2	3.39	1
	N	299-E25-46	Down	2	5.71	1

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Manganese, µg/L	Y	299-E24-19	Down	1	52.2	50
Nickel, µg/L	Y	299-E24-19	Down	2	359	100
		Waste Management Area B-BX-BY				
Aluminum, µg/L	Y	299-E33-18	Down	1	333	50
	Y	299-E33-42	Down	1	112	50
Antimony, µg/L	Y	299-E33-39	Down	1	21.7	6
Gross alpha, pCi/L	N	299-E33-13	Down	1	98.2	15
	N	299-E33-18	Down	2	58.4	15
	N	299-E33-38	Down	2	29.6	15
	N	299-E33-5	Down	1	114	15
Gross beta, pCi/L	N	299-E33-13	Down	1	1,770	50
	N	299-E33-16	Down	1	250	50
	N	299-E33-18	Down	2	336	50
	N	299-E33-31	Down	5	265	50
	N	299-E33-32	Down	4	104	50
	N	299-E33-38	Down	4	613	50
	N	299-E33-41	Down	6	3,400	50
	N	299-E33-42	Down	5	220	50
	N	299-E33-5	Down	1	1,040	50
Iodine-129, pCi/L	N	299-E33-13	Down	1	5.57	1
	N	299-E33-16	Down	1	4.09	1
	N	299-E33-18	Down	2	5.22	1
	N	299-E33-21	Down	2	3.57	1
	N	299-E33-31	Down	6	5.77	1
	N	299-E33-32	Down	5	5.9	1
	N	299-E33-33	Up	5	5.43	1
	N	299-E33-36	Up	5	5.26	1
	N	299-E33-38	Down	5	6.21	1
	N	299-E33-39	Down	2	1.95	1
	N	299-E33-41	Down	5	6.73	1
	N	299-E33-42	Down	3	7.65	1
	N	299-E33-43	Down	5	4.37	1
	N	299-E33-5	Down	1	5.41	1
Nitrogen in nitrate, µg/L	N	299-E33-13	Down	1	20,100	10,000
	N	299-E33-16	Down	1	66,900	10,000
	N	299-E33-18	Down	2	19,800	10,000
	N	299-E33-31	Down	1	11,200	10,000
	N	299-E33-38	Down	2	20,600	10,000
	N	299-E33-41	Down	1	10,800	10,000
	N	299-E33-5	Down	1	12,300	10,000
pH	N	299-E33-36	Up	4	8.58	8.5
Technetium-99, pCi/L	N	299-E33-13	Down	1	2,760	900
	N	299-E33-38	Down	3	2,360	900
	N	299-E33-41	Down	3	12,000	900
	N	299-E33-5	Down	1	1,950	900
Total dissolved solids, µg/L	N	299-E33-16	Down	1	620,000	500,000

Table A.27. (contd)

Constituent	Filter(a)	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Waste Management Area C						
Iodine-129, pCi/L	N	299-E27-12	Down	2	5.09	1
	N	299-E27-13	Down	3	4.5	1
	N	299-E27-14	Up	3	5.09	1
	N	299-E27-15	Down	2	4.04	1
	N	299-E27-7	Up	1	4.07	1
pH	N	299-E27-12	Down	4	8.67	8.5
	N	299-E27-13	Down	4	8.86	8.5
	N	299-E27-15	Down	2	8.53	8.5
Waste Management Area S-SX						
Aluminum, µg/L	Y	299-W22-44	Down	1	18,300	50
	Y	299-W22-45	Down	1	59.7	50
	Y	299-W22-46	Down	2	97.1	50
	Y	299-W23-13	Up	1	584	50
	Y	299-W23-14	Up	2	65.3	50
	Y	299-W23-15	Down	1	67.9	50
Cadmium, µg/L	Y	299-W22-44	Down	1	50	5
	Y	299-W22-45	Down	1	7.9	5
Carbon tetrachloride, µg/L	N	299-W23-15	Down	1	40	5
Gross alpha, pCi/L	N	299-W22-45	Down	1	202	15
	N	299-W23-13	Up	1	75.8	15
Gross beta, pCi/L	N	299-W22-39	Down	3	120	50
	N	299-W22-45	Down	2	79.2	50
	N	299-W22-46	Down	5	2,270	50
Iron, µg/L	Y	299-W22-44	Down	1	1,120	300
	Y	299-W23-13	Up	1	536	300
Nickel, µg/L	Y	299-W22-44	Down	1	212	100
Nitrogen in nitrate, µg/L	N	299-W22-46	Down	3	11,800	10,000
Technetium-99, pCi/L	N	299-W22-46	Down	5	5,020	900
Tritium, pCi/L	N	299-W22-46	Down	5	65,200	20,000
	N	299-W23-14	Up	4	276,000	20,000
	N	299-W23-15	Down	4	28,000	20,000
Waste Management Area T						
Aluminum, µg/L	Y	299-W10-19	Down	1	81.4	50
	Y	299-W11-28	Down	2	60.2	50
Cadmium, µg/L	Y	299-W11-28	Down	1	6.5	5
Carbon tetrachloride, µg/L	N	299-W10-19	Down	2	1,600	5
	N	299-W11-27	Down	3	360	5
Chromium, µg/L	Y	299-W10-15	Down	1	106	100
	Y	299-W11-28	Down	1	115	100
Fluoride, µg/L	N	299-W10-15	Down	1	4,460	4,000

Table A.27. (contd)

Constituent	Filter[(a)]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Gross beta, pCi/L	N	299-W10-15	Down	3	181	50
	N	299-W10-16	Up	1	57.8	50
	N	299-W11-27	Down	5	13,700	50
	N	299-W11-28	Down	5	220	50
Iron, µg/L	Y	299-W10-15	Down	1	309	300
	Y	299-W11-27	Down	1	876	300
	Y	299-W11-28	Down	3	609	300
Manganese, µg/L	Y	299-W10-15	Down	1	117	50
	Y	299-W11-28	Down	4	166	50
Methylene chloride, µg/L	N	299-W10-19	Down	1	10	5
Nitrogen in nitrate, µg/L	N	299-W10-15	Down	3	69,800	10,000
	N	299-W10-16	Up	4	52,800	10,000
	N	299-W10-19	Down	4	30,400	10,000
	N	299-W11-27	Down	6	52,100	10,000
	N	299-W11-28	Down	5	35,400	10,000
Ruthenium-106, pCi/L	N	299-W10-15	Down	1	31.9	30
Sulfate, µg/L	N	299-W11-27	Down	6	326,000	250,000
Technetium-99, pCi/L	N	299-W11-27	Down	6	21,700	900
Total dissolved solids, µg/L	N	299-W10-15	Down	3	831,000	500,000
	N	299-W10-16	Up	4	663,000	500,000
	N	299-W10-19	Down	1	510,000	500,000
	N	299-W11-27	Down	5	1,040,000	500,000
	N	299-W11-28	Down	5	640,000	500,000
Trichloroethylene, µg/L	N	299-W10-19	Down	1	12	5
	N	299-W11-28	Down	1	11	5
Tritium, pCi/L	N	299-W10-15	Down	3	32,100	20,000
	N	299-W10-16	Up	4	40,400	20,000
	N	299-W11-28	Down	5	62,900	20,000
		Waste Management Area TX-TY				
Aluminum, µg/L	Y	299-W10-17	Down	2	79.5	50
	Y	299-W10-18	Down	1	65.5	50
	Y	299-W14-12	Down	2	71.2	50
	Y	299-W15-22	Up	1	53.4	50
Chromium, µg/L	Y	299-W15-22	Up	1	306	100
Gross beta, pCi/L	N	299-W10-17	Down	5	201	50
	N	299-W10-18	Down	4	125	50
	N	299-W14-12	Down	4	457	50
	N	299-W15-22	Up	4	595	50
Iodine-129, pCi/L	N	299-W14-12	Down	4	3.42	1
Nickel, µg/L	Y	299-W15-22	Up	1	108	100
Nitrogen in nitrate, µg/L	N	299-W10-17	Down	5	35,000	10,000
	N	299-W10-18	Down	4	21,400	10,000
	N	299-W14-12	Down	3	46,700	10,000
	N	299-W15-22	Up	4	29,100	10,000

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Technetium-99, pCi/L	N	299-W14-12	Down	3	1,180	900
	N	299-W15-22	Up	1	1,340	900
Total dissolved solids, µg/L	N	299-W10-17	Down	2	543,000	500,000
	N	299-W14-12	Down	2	646,000	500,000
Tritium, pCi/L	N	299-W10-17	Down	5	36,800	20,000
	N	299-W14-12	Down	4	65,200	20,000
	N	299-W15-22	Up	2	41,100	20,000
Waste Management Area TX-TY Assessment Wells						
Aluminum, µg/L	Y	299-W10-21	Down	1	51.1	50
	Y	299-W11-31	Down	1	76.7	50
	Y	299-W6-4	Down	1	62.6	50
	Y	299-W6-9	Down	1	53.6	50
Antimony, µg/L	Y	299-W6-4	Down	1	20.8	6
Carbon tetrachloride, µg/L	N	299-W10-20	Down	2	1,700	5
	N	299-W10-21	Down	2	630	5
	N	299-W6-10	Up	1	640	5
	N	299-W6-2	Down	2	170	5
Chloroform, µg/L	N	299-W10-21	Down	1	200	100
Gross beta, pCi/L	N	299-W11-31	Down	4	253	50
	N	299-W6-10	Up	3	62.7	50
	N	299-W6-4	Down	1	52.4	50
Methylene chloride, µg/L	N	299-W10-20	Down	1	220	5
	N	299-W10-21	Down	1	22	5
Nitrogen in nitrate, µg/L	N	299-W10-20	Down	5	34,900	10,000
	N	299-W10-21	Down	5	34,700	10,000
	N	299-W11-31	Down	4	28,200	10,000
	N	299-W6-10	Up	5	28,100	10,000
	N	299-W6-2	Down	4	11,800	10,000
	N	299-W6-4	Down	4	21,500	10,000
	N	299-W6-9	Down	4	14,800	10,000
pH	N	299-W6-4	Down	1	9.19	8.5
Total dissolved solids, µg/L	N	299-W11-31	Down	1	540,000	500,000
Trichloroethylene, µg/L	N	299-W6-10	Up	2	10	5
Tritium, pCi/L	N	299-W11-31	Down	4	61,100	20,000
	N	299-W6-10	Up	5	64,200	20,000
	N	299-W6-4	Down	4	25,400	20,000
Waste Management Area U						
1,4-Dichlorobenzene, µg/L	N	299-W18-30	Down	1	240	75
Carbon tetrachloride, µg/L	N	299-W18-25	Up	1	150	5
	N	299-W18-30	Down	5	1,000	5
Gross beta, pCi/L	N	299-W19-12	Down	2	146	50
	N	299-W19-31	Down	3	251	50
	N	299-W19-32	Down	1	69.9	50

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Manganese, µg/L	Y	299-W19-32	Down	3	183	50
Nickel, µg/L	Y	299-W19-32	Down	3	413	100
pH	N	299-W19-12	Down	2	8.63	8.5
Nonradioactive Dangerous Waste Landfill						
1,1-Dichloroethane, µg/L	N	699-25-34D	Down	1	2	1
Aluminum, µg/L	Y	699-25-33A	Down	1	77.8	50
	Y	699-25-34B	Down	1	137	50
	Y	699-26-33	Down	1	218	50
	Y	699-26-34A	Up	1	72.8	50
	Y	699-26-35A	Up	1	53.3	50
	Y	699-26-35C	Up	1	50.2	50
Iodine-129, pCi/L	N	699-26-35A	Up	1	1.75	1
Tritium, pCi/L	N	699-25-34A	Down	2	112,000	20,000
	N	699-25-34B	Down	2	102,000	20,000
	N	699-25-34D	Down	2	100,000	20,000
	N	699-26-33	Down	2	106,000	20,000
	N	699-26-34A	Up	2	96,300	20,000
	N	699-26-34B	Down	2	96,100	20,000
	N	699-26-35A	Up	3	102,000	20,000
	N	699-26-35C	Up	2	38,300	20,000
300 Area Process Trenches						
1,2 cis-Dichloroethylene, µg/L	N	399-1-16B	Down	10	190	70
Aluminum, µg/L	Y	399-1-10A	Down	1	55.3	50
Bis(2-ethylhexyl)phthalate, µg/L	N	399-1-10A	Down	1	9	6
	N	399-1-10B	Down	1	9	6
	N	399-1-16A	Down	1	9	6
	N	399-1-17A	Down	1	9	6
	N	399-1-17B	Down	1	9	6
	N	399-1-18A	Up	1	9	6
	N	399-1-18B	Up	1	9	6
Gross alpha, pCi/L	N	399-1-17A	Down	3	182	15
Gross beta, pCi/L	N	399-1-17A	Down	4	65	50
Iron, µg/L	Y	399-1-10B	Down	2	460	300
	Y	399-1-17B	Down	3	504	300
	Y	399-1-18B	Up	2	482	300
Manganese, µg/L	Y	399-1-10B	Down	2	145	50
	Y	399-1-16B	Down	4	65	50
	Y	399-1-17B	Down	3	85.9	50
Methylene chloride, µg/L	N	399-1-10B	Down	1	6	5
	N	399-1-16A	Down	1	7	5
	N	399-1-16B	Down	4	97	5
	N	399-1-17A	Down	1	7	5
	N	399-1-17B	Down	1	5	5
	N	399-1-18A	Up	1	5	5
	N	399-1-18B	Up	1	650	5

Table A.27. (contd)

Constituent	Filter[a]	Well Name	Upgradient/ Downgradient	Number of Exceedences	Maximum Result	Drinking Water Standard
Thallium, µg/L	Y	399-1-16B	Down	1	2.4	2
Trichloroethylene, µg/L	N	399-1-16B	Down	4	10	5

NOTE: To convert nitrogen in nitrate to nitrate as NO_3^-, multiply by 4.5.

(a) Y indicates sample filtered in field before analysis; N indicates unfiltered sample.

(b) Sampled during drilling. Not representative of groundwater in area.

(c) Gradient in Low-Level Waste Management Area 4 changing because of pump-and-treat effects.

Appendix B

Statistics

Appendix B

Statistics

C. J. Chou

Data gathered in support of groundwater monitoring at the Hanford Site are used to evaluate the changes noted in groundwater quality from baseline conditions of the various operations facilities. The methods used for the statistical evaluations are described in this appendix. The facilities included in this evaluation are the 1) *Resource Conservation and Recovery Act of 1976* (RCRA) liquid and solid waste treatment, storage, and/or disposal units; 2) Solid Waste Landfill; and 3) liquid effluent-receiving facilities.

The RCRA units with a potential to contaminate groundwater require monitoring as prescribed in 40 CFR 265 and WAC 173-303-400 (interim status) and 40 CFR 264 and WAC 173-303-645 (final status). During fiscal year 1997, groundwater-monitoring activities at most of the RCRA units were governed under interim-status regulations, except for the 183-H solar evaporation basins and the 316-5 process trenches that were subject to a compliance-level program under the final-status regulations.

Because the Solid Waste Landfill is not a RCRA hazardous waste site, its operations fall under the regulations of WAC 173-304. A permit application for the Solid Waste Landfill was prepared (DOE/RL-90-38).

Operations at the 200 Areas Treated Effluent-Disposal Facility and the State-Approved Land-Disposal Site began during 1995. These facilities are regulated under WAC 173-200 and WAC 173-216. Because these are discharge permit disposal facilities, both require effluent and groundwater monitoring.

During fiscal year 1997, the integrated Hanford Site groundwater-monitoring project developed a data quality objectives-based process that integrates various groundwater-monitoring projects for the Hanford Site. This process will be used to justify why data are being collected, how the data will be used to make decisions, and the amount of data needed to meet criteria specified by the stakeholders. Efforts are under way to work with the stakeholders in developing a groundwater-monitoring strategy that will allow the use of technically improved statistical evaluation procedures (e.g., methods allowed under final status) rather than strict adherence to interim-status requirements.

B.1 Statistical Methods

B.1.1 RCRA Interim-Status Facilities

The primary objectives of RCRA groundwater monitoring are to comply with the intent of applicable interim- and final-status state and federal regulations; to assess potential impacts on groundwater quality; and to identify near-term corrective measures, if feasible, to mitigate the impacts. In accordance with WAC 173-303-400, RCRA projects are monitored under one of three levels of efforts: 1) background monitoring, 2) indicator parameter evaluation, or 3) groundwater quality assessment. All of the RCRA facilities at the Hanford Site have completed their initial background monitoring programs.

Statistical evaluations for interim status RCRA facilities during fiscal year 1997 consisted of reestablishing background levels to reflect changing conditions and evaluating the facility's impact on groundwater quality. A general description of the applicable statistical methods that are appropriate for these interim-status facilities is provided in this section.

The statistical method used to summarize background data is the averaged replicate t-test method as described in Appendix B of OSWER-9950.1 and Chou (1991). The averaged replicate t-test method for each contamination indicator parameter is calculated as:

$$t=\left(\bar{x}_i - \bar{x}_b\right)/S_b * \sqrt{1+1/n_b} \qquad \text{(B.1)}$$

where t = test statistic
$\bar{x}_i$ = average of replicates from the ith monitoring well
$\bar{x}_b$ = background average
S_b = background standard deviation
n_b = number of background replicate averages.

The guiding documentation (OSWER-9950.1) states that a test statistic larger than the Bonferroni critical value, t_c, (i.e., $t > t_c$) indicates a statistically significant probability of contamination. These Bonferroni critical values depend on the overall false-positive rate required for each sampling period (i.e., 1% for interim status), the total number of wells in the monitoring network, and the number of degrees of freedom (n_b - 1) associated with the background standard deviation. Because of the nature of the test statistic in Equation (B.1), results to be compared to background do not contribute to the estimate of the variance. The test can be reformulated, without prior knowledge of the results of the sample to be compared to background (i.e., $\bar{x}_i$), in such a way that a critical mean, CM, can be obtained:

$$CM=\bar{x}_b + t_c * S_b * \sqrt{(1+1/n_b)} \quad \text{(one tailed)} \qquad \text{(B.2)}$$

$$CM=\bar{x}_b \pm t_c * S_b * \sqrt{(1+1/n_b)} \quad \text{(two tailed)} \qquad \text{(B.3)}$$

For pH, a two-tailed CM (or critical range) is calculated and a one-tailed CM is calculated for specific conductance, total organic carbon, and total organic halides. The CM (or range for pH) is the value above which (or above/below in the case of pH) a compared value is determined to be statistically different from background.

The measured values for total organic carbon from upgradient (background) wells during the initial background periods for most of the RCRA facilities were less than the contractually required quantitation limit of 1,000 µg/L for DataChem Laboratories, Inc., Salt Lake City, Utah (DataChem). These values were reported with the contractually required quantitation limit value followed by a U qualifier. Estimates of the background standard deviations cannot be obtained. In addition, laboratory-reporting practices changed since April 1993. Results below the contractually required quantitation limit but above the method detection limit are reported with the measured value followed by an L qualifier. Results below the method detection limit are reported with the measured value followed by a U qualifier. The lack of estimates of background variability precludes the determination of total organic carbon critical means for various RCRA facilities. In this case, a limit of quantitation is to be used as the threshold value for upgradient/downgradient comparisons. For fiscal year 1997, a limit of quantitation of 1,113 µg/L, calculated using field blanks data, was used for total organic carbon. Note: this value is different than the 1996 calculated value of 525 µg/L (see Appendix D in DOE/RL-96-01) because the change of analytical laboratories (from DataChem to Quanterra Environmental Services, St. Louis, Missouri [Quanterra] during fiscal year 1997) necessitated the reevaluation of the limit of quantitation. For comparisons to be conducted in fiscal year 1998, the updated limits of quantitation for total organic carbon and total organic halides were calculated to be 1,179 and 21.3 µg/L, respectively, using fiscal year 1997 field blanks data (given in Appendix D).

Because of concerns over the laboratory's procedure for total organic halides, samples were analyzed by another laboratory from November 1993 to May 1995. The lack of four consecutive quarters of consistent data did not provide the needed background values from which critical means could be derived. However, the data were evaluated using the following steps: 1) screening total organic halide values from upgradient wells; 2) if results from upgradient wells indicated a history of nondetections, a limit of quantitation was used as the upgradient/downgradient comparison value; and 3) if total organic halides were historically detected, a limit of quantitation could not be used as a surrogate background value. In this case, the background value must be derived based on four quarters of monitoring data and used in the statistical evaluation (e.g., 216-S-10 pond and ditch).

Finally, if the calculated critical ranges for pH were too large to be meaningful because of the requirement to use four quarters of data to establish background (e.g., 120-D-1 ponds, Liquid Effluent-Retention Facility), the upgradient/downgradient comparison value would be revised to the critical range by using all available data. The expansion of the background data set to include more than 1 year's data provides a better estimate of background mean and background standard deviation. More important, it increases the number of degrees of freedom associated with the background standard deviation. Other things being equal, a smaller t_c value and a narrower critical range for pH would result. This approach is preferred because it complies with both the requirements and the spirit of the regulations.

B.1.2 RCRA Final-Status Facilities

Three levels of groundwater-monitoring programs are required under final-status regulations (40 CFR 264 Subpart F and WAC 173-303-645): detection monitoring, compliance monitoring, and corrective action. During fiscal year 1997, the 183-H solar evaporation basins and the 316-5 process trenches were monitored under the RCRA final-status compliance-level monitoring requirements.

Statistical methods appropriate for a final-status groundwater-monitoring program include analysis of variance, tolerance intervals, prediction intervals, control charts, test of proportions, or other statistical methods approved by the State of Washington Department of Ecology (Ecology). The important factors to consider when selecting appropriate statistical methods are the distribution(s) of monitoring parameters; the nature of the data; and the proportions of nondetections, seasonal, temporal, and spatial variations. The statistical evaluation procedures chosen for final-status facilities will be based on guidance given in PB89-151047, EPA/530-R-93-003, and American Society for Testing and Materials (1996). Specific statistical methods are to be addressed in the unit-specific permit applications and/or in the groundwater-monitoring plans.

B.1.2.1 Detection-Level Monitoring

In a detection-level groundwater-monitoring program, the objective is to detect a potential impact from a regulated unit by testing for statistically significant changes in geochemistry in a downgradient monitoring well relative to baseline levels. These baseline levels could be obtained from upgradient (or background) wells and the comparisons are referred to as interwell (or between-well) comparisons. Alternatively, if baseline values are obtained from historical measurements from that same well, the comparisons are referred to as intrawell (or within-well) comparisons. Groundwater parameter data (pH, specific conductance, total organic carbon, total organic halides, heavy metals, waste constituents, or reaction products) from downgradient compliance-point wells will be compared semiannually with baseline data to determine whether there is a statistically significant increase (or decrease for pH) over baseline concentrations.

A two-phase testing strategy (EPA/530-R-93-003, pp. 67-75) has been proposed for the Liquid Effluent-Retention Facility and low-level burial grounds and will be implemented on incorporation into the permit in accordance with the permit modification schedule. In the first phase, an upper tolerance limit (for each constituent of concern) with prescribed coverage is calculated based on background (upgradient well) data and will be compared to individual compliance-point (downgradient well) samples. The second phase is applicable to instance(s) where an initial exceedance(s) occurred. In this phase, an upper prediction limit (using background data) will be calculated and compared to results of verification samples (i.e., confirmation sampling). Specifically, two verification samples are to be obtained sequentially (from the well that exceeds the tolerance limit) and analyzed for the constituent in question. A statistically significant evidence of contamination from the regulated unit is declared if both verification samples exceed the prediction limit. Detailed descriptions of the rationale and procedures are provided in PNNL-11620.

B.1.2.2 Compliance-Level Monitoring

A compliance-level groundwater-monitoring program will be established for a unit if groundwater sampling during detection-level monitoring reveals a statistically significant evidence of contamination for constituents of concern at any monitoring well at the compliance point. In compliance-level monitoring, the objective is to determine whether specified concentration limits (e.g., groundwater-protection standards) have been exceeded. This is accomplished by comparing the concentration of a constituent of concern to a concentration limit, such as a risk-based maximum concentration limit; alternative concentration limit; area or natural background; or applicable, relevant, and appropriate requirements. These concentration limits would be applied during compliance monitoring to determine whether corrective action might be necessary.

Maximum concentration limits will be identified for each groundwater-monitoring constituent of interest. Alternative concentration limits will be proposed after considering the observed concentrations of chemical constituents in the groundwater that might have originated from the regulated unit in question. The area background, natural background, and other standards that are applicable, relevant, and appropriate requirements will be evaluated when proposing an alternative concentration limit. The parameters monitored, the concentration limits, and the statistical methods are specified in the unit-specific groundwater-monitoring plan (e.g., WHC-SD-EN-AP-180).

B.1.2.3 Corrective Action

A corrective action program is initiated if a concentration limit at the point of compliance is exceeded. Exceedance is defined as statistically significant evidence of increased contamination. Details for the corrective-action program will be specified in the unit-specific permit application. In addition, a groundwater-monitoring plan, which will be used to assess the effectiveness of the corrective-action measures, will be submitted to Ecology for approval. That monitoring plan will be similar in scope to the compliance-level groundwater-monitoring program and will include all relevant information pertaining to the location and description of monitoring wells, monitoring network, well construction and development, sampling and analysis plans, statistical methods, and quality assurance and quality control procedures.

In May 1997, the first phase of a corrective-action groundwater-monitoring plan for the 183-H solar evaporation basins was released (PNNL-11573) because of exceedances of concentration limits in some of the downgradient wells (Section B.2.2.1). Proposed in that plan are the monitoring network, list of constituents to be analyzed for, and protocols for sampling and analysis that will be employed during the operation of the pump-and-treat system for chromium-contaminated groundwater. The plan will be implemented when incorporated into the RCRA permit.

In November 1997, efforts were under way with Ecology, Bechtel Hanford, Inc., and the U.S. Department of Energy to obtain a class 1 permit modification (with Ecology approval) to change the sampling schedule and statistical method specified in the compliance monitoring plan for the 316-5 process trenches because of exceedances of concentration limits in some of the downgradient compliance wells (Section B.2.2.2). The goal is to implement on a timely basis a corrective-action groundwater-monitoring program that meets the intent for final-status compliance monitoring for these process trenches. The proposed statistical method is recommended by American Society for Testing and Materials (1996), EPA/530-R-93-003, Gibbons (1994), and PB89-151047. The method combines the advantages of a

Shewhart control chart (sensitive to large and abrupt shifts in concentrations) with the CUSUM (cumulative sum) control chart (sensitive to small and gradual changes). In general, for each constituent of interest and for each well within the 316-5 process trenches network, the following steps are proposed:

- Step 1 – Identify a representative baseline period.

- Step 2 – Establish appropriate control limits (see American Society for Testing and Materials 1996, EPA/530-R-93-003, and Gibbons 1994).

- Step 3 – Monitor quarterly those wells where maximum contaminant levels have been and/or will be exceeded. In essence, these exceedance wells are monitored for trend(s) under a corrective-action mode.
    - If future observations are within the established upper and lower control limits, the process behaves as expected. Continue the quarterly monitoring frequency until reduced monitoring is warranted (e.g., trend analysis demonstrates concentrations are below the maximum contaminant levels).
    - If future observations exceed the established upper control limits, the process is out of control. Results will be communicated to the U.S. Department of Energy, Bechtel Hanford, Inc., and Ecology for appropriate future action(s).

- Step 4 – Monitor semiannually those wells where maximum contaminant levels have not been exceeded. In essence, these nonexceedance wells are monitored on a timely basis to provide confidence that concentrations of constituents of concern do not increase with potentially new release(s) from the regulated unit.
    - The calculated upper control limits are *much lower* than the maximum contaminant levels specified in the permit.
    - The use of upper control limits as comparison values is more sensitive to detect additional release(s) of constituents of concern, if any, than the use of maximum contaminant levels. Hence, it is judged to be more protective of human health and environment.
    - If future observations are within the established upper control limits, the process is in control. Continue the semiannual monitoring frequency until exceedance(s) of the control limit is observed and confirmed.
    - If confirmed, conduct a miniassessment on that well to identify possible causes and to assess the likelihood of exceeding the maximum contaminant level. Adjust the sampling frequency accordingly (e.g., Step 3).

B.1.3 Solid Waste Landfill

Groundwater-monitoring activities for the Solid Waste Landfill are regulated under WAC 173-304-490, requiring no replicate analyses. Thus, the tolerance interval approach, suitable for individual sample comparisons, was used for performing the required comparisons between upgradient and downgradient wells for determining whether a significant change over background occurred for constituents specified in WAC 173-304-490. The statistical evaluations are described as follows.

B.1.3.1 Calculating Background Summary Statistics

Summary statistics were calculated using background samples for the site (Table B-11 in DOE/RL-91-03). The results were presented in Table B.1 of PNNL-11470. Some of the background data are below the contractual detection limits required of the contracting laboratory or below the contractually required quantitation limit. In cases where measured values are available (e.g., most of the total organic carbon values), they were used in calculating the summary statistics. In cases where the proportion of nondetections is between 15% and 50%, less-than values were replaced by half of their contractual detection limits and/or contractually required quantitation limits, and the usual calculations were performed (e.g., filtered iron). In cases where the proportion of nondetections is greater than 50%, summary statistics are not calculated (e.g., nitrite, ammonium, filtered zinc, filtered manganese, coliform, and chemical oxygen demand).

B.1.3.2 Testing Assumption of Normality of Data

The tolerance interval defines a concentration range (from background or upgradient well data) that contains at least a specified proportion (coverage) of the population with a specified probability (confidence level). There are two types of tolerance intervals: parametric and nonparametric. Parametric tolerance interval techniques are sensitive to the assumption that the data are drawn from a normal population. The statistical tests used for evaluating whether the data follow a specified distribution are called goodness-of-fit tests. The Lilliefors test is used to evaluate the fit of a hypothesized normal or lognormal distribution. STATGRAPHICS™, Version 6.0 (Statistical Graphics Corporation, Rockville, Maryland) was used to calculate the Lilliefors test statistics. Test procedures are described by Conover (1980). If the data are not normal, the Lilliefors test was applied to the natural logarithm of the data to see if the transformed data are approximately normal. This is equivalent to testing the hypothesis that the concentration measurements follow a lognormal distribution. If the proportion of nondetections is more than 15%, a goodness-of-fit test is not performed and a nonparametric tolerance interval will be calculated to the extent possible.

Results of the Lilliefors test are presented in Table B.1. Temperature, field pH, and chloride concentration measurements from background wells are approximately normally distributed. Specific conductance, total organic carbon, nitrate, and sulfate concentrations are neither normal nor lognormal.

B.1.3.3 Establishing Background Levels

Tolerance intervals are constructed from the data on upgradient wells. Both the upper and lower bounds of the interval (two sided) were calculated for field pH. For other constituents of concern, only the upper bounds of the intervals (one sided) were calculated.

If a normal (or a lognormal) distribution is a reasonable approximation of the background concentrations, a parametric tolerance interval, TI, of the following form is calculated:

$$\mathrm{TI} = \bar{x}_b \pm k^*S_b \text{ (two sided) or } \mathrm{TI} = \bar{x}_b + k^*S_b \text{ (one sided)} \tag{B.4}$$

where: k = a normal tolerance factor, which depends on the number of background samples (n), coverage (P%), and confidence level (Y). A coverage of 95% and confidence level of 95% are recommended (PB89-151047). With n = 16, P = 95%, and Y = 95%, k is 2.523 (k is 2.566 if n = 15) for a one-sided normal tolerance interval (Natrella 1966).

If background concentrations do not follow a normal or a lognormal distribution, a nonparametric tolerance interval can be constructed (Conover 1980). A two-sided nonparametric tolerance interval is just the range of the observed data. An upper one-sided nonparametric tolerance limit is the largest observation. The number of background samples determines the coverage (P%) and the confidence level (Y) associated with that proportion. For a one-sided 95% (P = 95%) nonparametric tolerance interval with 95% (Y = 95%) probability, the number of background samples required is 59 (Conover 1980). With only 15 background samples (nitrate, filtered iron, and filtered zinc), the coverage is 85% and the confidence level is 90% (i.e., the upper one-sided tolerance limit defined by the largest background concentration contains at least 85% of the background population with 90% confidence). More background samples are needed if a larger coverage and/or a larger confidence level are desired.

In cases where all of the background values are below the contractually established detection limits or where the proportion of nondetections is more than 15%, a limit of quantitation was used (e.g., total organic carbon). In cases where a limit of quantitation is not available (e.g., coliform and chemical oxygen demand), the contractually required quantitation limits were used as the background threshold values. The resulting tolerance limits, limits of quantitation, and background threshold values are also presented in Table B.1.

B.1.3.4 Comparisons with Background Levels

Once the background threshold values are established, data from compliance-point wells were compared individually with these background concentration levels. If the background levels are exceeded, it is interpreted as providing evidence of statistically significant contamination.

B.1.4 Liquid Effluent-Receiving Facilities

Operation of the 200 Areas Treated Effluent-Disposal Facility and State-Approved Land-Disposal Site began during 1995. These facilities are regulated under WAC 173-200 and WAC 173-216, both requiring effluent and groundwater monitoring. Another facility, the 4608 B/C ponds (also called the 400 Area process ponds), is also designated as a WAC 173-216 discharge permit site, and the permit was issued on August 1, 1996. The principal groundwater quality regulations (WAC 173-200) emphasize the nondegradation of current groundwater quality. These regulations require "Establishment of an enforcement limit as near the natural ground water quality as practical," and establishment of the point of compliance in the groundwater "...as near the source as technically, hydrogeologically, and geographically feasible."

B.1.4.1 Preoperational Monitoring

Groundwater quality data from the preoperational phase were used to establish the background (baseline) values for the potential constituents of concern. In essence, background values were calculated using the parametric tolerance interval approach discussed above because background water quality is statistically defined as the 95% upper tolerance interval with a 95% confidence (Ecology 1996, p. 65). The baseline values were provided to Ecology to allow the determination of enforcement limits for specific constituents in groundwater.

B.1.4.2 Operational Monitoring

The objectives of collecting and evaluating the groundwater quality data from operational monitoring are 1) to determine if groundwater quality has changed from the baseline, preoperational conditions; 2) to evaluate the impacts, if any, that operation of the facility have on the quality of groundwater in the uppermost aquifer; and 3) to demonstrate compliance with the groundwater enforcement limits set forth in the permit.

Statistical approaches used for preoperational and operational monitoring were described in detail in the groundwater-monitoring plans for the 200 Areas Treated Effluent-Disposal Facility (WHC-SD-EN-WP-012, Rev. 1) and State-Approved Land-Disposal Site (WHC-SD-C018H-PLN-004, Rev. 1). Statistical evaluations for the 400 Area process ponds will be initiated when the monitoring network (i.e., compliance well 699-2-6A) and groundwater-monitoring plan are in place (see Section 5.11.1.1 of the main text).

B.2 Results of Evaluation

B.2.1 RCRA Interim-Status Facilities

During fiscal year 1997, exceedances of critical means for the contamination indicator parameters were confirmed for one RCRA interim-status facility (Waste Management Area [WMA] U), triggering an assessment of groundwater contamination required by 40 CFR 265.93. Exceedances for this WMA and other facilities are provided below.

B.2.1.1 WMA U

Analysis of groundwater from downgradient well 299-W18-30, sampled in August 1996, indicated that total organic halide concentrations in the samples (408 μg/L) exceeded the upgradient/downgradient comparison value (critical mean) for the site (241 μg/L). Verification sampling in February 1997 and analysis by two independent laboratories yielded average total organic halide values of 533 and 673 μg/L, confirming the August 1996 exceedance. A letter of notification was sent to the U.S. Department of Energy on March 21, 1997, indicating the reported exceedance is clearly the result of an encroachment of a carbon tetrachloride plume from the northwest and is not related to the tank farm. Therefore, because there is clearly an upgradient source for the detected contamination, an assessment plan is not necessary.

The letter of notification fulfilled both the requirements of a 7-day clock for notification and a 15-day clock for submitting a groundwater quality assessment plan (40 CFR 265.93[d][1] and [d][2]).

B.2.1.2 216-S-10 Pond and Ditch

Analysis of groundwater from downgradient well 299-W26-12, sampled in June 1996, indicated that specific conductance concentrations in the samples (308 µS/cm) exceeded the upgradient/downgradient comparison value (critical mean) for the site (301.1 µS/cm). Two sets of verification sampling in October 1996 yielded average specific conductance values of 255.5 and 262.2 µS/cm, confirming the initial suspicion of an error in field measurements.

The background concentrations for total organic halides at upgradient wells 299-W26-7 and 299-W26-8 historically have been below the analytical detection limits. The limit of quantitation for total organic halides has been used as the surrogate background value for statistical evaluations; however, an upward trend was noted in one of the upgradient wells (299-W26-8). During the June 1996 sampling event, observed values from this well exceeded the limit of quantitation for this parameter. These changing conditions upgradient of the facility render the surrogate background value irrelevant for statistical evaluations. The upgradient wells were sampled on a quarterly basis, and a critical mean for total organic halides was reestablished in September 1997. The new values will be applied when data from the October through December 1997 sampling are received.

B.2.1.3 120-D-1 Ponds

Field pH measured in March 1997 from downgradient well 199-D8-6 averaged 9.32, exceeding the upper range of 9.31. This well also showed elevated pH in February 1996, and an assessment report was prepared and submitted to Ecology (WHC-SD-EN-EV-033). The elevated pH was caused by the presence of alkaline ash sediment beneath the ponds (WHC-EP-0666), which are not part of this RCRA unit. No further action is necessary. The ponds will remain in indicator evaluation status.

B.2.1.4 1324-N/NA Liquid Waste Disposal Facilities

Concentrations of specific conductance measured in March 1997 from downgradient wells 199-N-59 (average = 1,068.75 µS/cm), 199-N-72 (average = 1,052.25 µS/cm) and 199-N-73 (average = 1,112 µS/cm) exceeded the upgradient/downgradient comparison value (critical mean) of 618.7 µS/cm, as they did again in September 1997. The exceedances were expected and the data are in line with historical measurements. A previous groundwater quality assessment conducted at the facilities indicated that the elevated specific conductance is caused by the nonhazardous constituents sulfate and sodium (WHC-SD-EN-EV-003). Because an assessment has already been completed and the elevation in specific conductance is caused by nonhazardous constituents, no further action is necessary.

B.2.1.5 Total Organic Carbon Exceedances in Various RCRA Sites

Results from five RCRA sites indicated that total organic carbon concentrations in several downgradient wells exceeded the upgradient/downgradient comparison values in the first and second quarters of calendar year 1997. The affected sites were WMA U (wells 299-W19-31 and 299-W19-32), WMA A-AX (upgradient well 299-E25-41), low-level (LL) WMA 4 (well 299-W15-23), 1324-N/NA liquid waste-disposal facilities (well 199-N-59), and 216-S-10 pond and ditch (well 299-W26-10). All of the observed exceedances occurred in the first quarter of calendar year 1997, except for the 216-S-10 pond and ditch that occurred in the second quarter of calendar year 1997.

Concerns have been raised over the apparent high bias and poor precision of total organic carbon data observed earlier in 1997. The required verification sampling was postponed, and the laboratory was instructed to make improvements in their analytical procedures. These changes became effective on July 22, 1997 and seem to have reduced the bias. Results from the third quarter of calendar year 1997 indicated the following.

- The critical mean (1,373.2 µg/L) was exceeded again in the same downgradient well (199-N-59) (average = 2,595 µg/L) at 1324-N/NA in August 1997. The new data suggest that total organic carbon may be increasing in this well, and verification sampling has been performed.
- The critical mean (1,179 µg/L) was exceeded in a downgradient well (199-N-81) at 1325-N in August 1997. This result was much higher than previous trends. Verification sampling has been performed.
- The exceeding well (299-W15-23) noted during the first quarter of calendar year 1997 at LLWMA 4 was dry and could not be sampled in September 1997. No further action is proposed for this site (see Section 5.9.2.7 of the main text).
- Third quarter data from upgradient well 299-E25-41 at WMA A-AX confirmed the exceedance noted in the first quarter as a laboratory error. No further action is necessary.
- Third quarter data from downgradient wells 299-W19-31 and 299-W19-32 at WMA U confirmed the exceedance noted in the first quarter as a laboratory error. No further action is necessary.
- The 216-S-10 monitoring network was sampled during the fourth quarter of calendar year 1997 and results have not yet been received.

B.2.2 RCRA Final-Status Facilities

B.2.2.1 183-H Solar Evaporation Basins

This facility has been monitored under final-status regulations (WAC 173-303-645); four independent samples have been collected semiannually (September through December and March through June) since September 1995. Results of these groundwater-sampling events indicated that concentration limits of chromium, nitrate, technetium-99, and uranium have been, and still are being, exceeded in some of the downgradient wells. Because of these exceedances, a revised postclosure plan and a corrective-action groundwater-monitoring plan were completed and will be incorporated into the Hanford Site RCRA Permit. A summary of the semiannual groundwater-sampling results is presented in Table B.2.

B.2.2.2 316-5 Process Trenches

The 316-5 process trenches began final-status monitoring (WAC 173-303-645) in December 1996. Four independent samples were collected from December 1996 through March 1997 and again from June through September 1997. Exceedances were noted for trichloroethylene, 1,2-cis-dichloroethylene, and uranium in some of the downgradient compliance wells. Confirmation sampling was not conducted because these exceedances were expected. A summary of groundwater-sampling results is presented in Table B.3.

Efforts are under way with Ecology, Bechtel Hanford, Inc., and the U.S. Department of Energy to obtain a Class 1 permit modification (with Ecology approval) to change the sampling schedule and statistical method specified in the compliance monitoring plan to implement the corrective-action groundwater-monitoring program before the next permit modification (December 1998).

B.2.3 Solid Waste Landfill

The sampling results from fiscal year 1997 were compared to the background levels (see Table B.1). The sampling and comparison results are given in Table B.4. Values for specific conductance exceeded the background level in downgradient wells 699-22-35, 699-23-34A, 699-23-34B, 699-24-34A, 699-24-34B, 699-24-34C, and 699-25-34C for all sampling events during this reporting period. This pattern of exceedances is similar to that observed from 1990 through 1996. Detailed discussions are presented in Section 5.12.3.1 of the main text.

B.2.4 200 Areas Treated Effluent-Disposal Facility and State-Approved Land-Disposal Site

Groundwater samples are collected quarterly and analyzed for the permit constituents. Groundwater monitoring at the 200 Areas Treated Effluent-Disposal Facility has not detected any changes in groundwater quality caused by operation and no permit criteria for constituents in groundwater were exceeded during fiscal year 1997. Results of groundwater data analyzed for the State-Approved Land-Disposal Site have indicated that tritium-rich effluent began affecting groundwater in July 1996. Analyses also indicate that sulfate, calcium, and specific conductance have been elevated by the leaching of natural soil constituents by the effluent.

B.3 Background Tables

This section provides critical means tables (Tables B.5 through B.24) for RCRA facilities that are/have been in indicator parameter evaluation monitoring status during fiscal year 1997. Some revisions were made in fiscal year 1997 to reflect 1) the change in monitoring network (e.g., LLWMA 2 and 216-A-36B), 2) a change in upgradient groundwater chemistry (216-S-10 pond and ditch), or 3) a change in monitoring status (216-B-3 pond system reverts to detection level). Note that the number of digits presented in these tables do not reflect the precision of the analytical methods. These digits are for formatting purposes only.

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Table B.1. Results of Lilliefors Test for Normality and Background Threshold Values for Solid Waste Landfill

Constituent	Test Statistic, Raw Data	Test Statistic, Log Value	Upper Tolerance Limit	Background Threshold Value[(a)]
Temperature, °C	0.115 ns	NA	21.0[(b)]	21.0
Specific conductance, µS/cm	0.162 s	0.207 s	550[(c)]	550
Field pH Field pH[(d)]	0.140 ns 0.089 ns	NA NA	[5.7, 8.75][(b)] [6.2, 8.46][(b)]	[6.2, 8.46]
Total organic carbon, µg/L	0.191 s	0.181 s	750[(c)] 1,179[(e)]	1,179
Chloride, µg/L	0.104 ns	NA	9,045[(b)]	9,045
Nitrate, µg/L	0.168 s	0.195 s	33,800[(c)]	33,800
Nitrite, µg/L	NC	NC	30[(e)]	30
Ammonium, µg/L	NC	NC	100[(c)] 124[(e)]	124
Sulfate, µg/L	0.179 s	0.190 s	51,500[(c)]	51,500
Iron, filtered, µg/L	NC	NC	78[(c)] 102[(e)]	102
Zinc, filtered, µg/L	NC	NC	34[(c)] 38[(e)]	38
Manganese, filtered, µg/L	NC	NC	11[(c)] 3.2[(e)]	11
Coliform, most probable number	NC	NC	16[(c)] 1[(f)]	16
Chemical oxygen demand, mg/L	NC	NC	3[(f)]	3

(a) Background threshold value for each constituent is the larger of the upper tolerance limit or the applicable limit of quantitation.
(b) Based on normal distribution.
(c) Maximum value reported; for pH range reported.
(d) Outliers removed.
(e) Based on limit of quantitation (Appendix D).
(f) Based on contractually required detection limit.
NA = Not applicable.
NC = Not calculated; insufficient measured values.
ns = Not significant at 0.05 level of significance.
s = Significant at 0.05 level of significance.

Table B.2. Summary of Semiannual Groundwater-Sampling Results for the 183-H Solar Evaporation Basins

Sampling Time	Constituent of Concern	Concentration Limit	Well Exceeding Concentration Limit
September, October, November, December 1996	Chromium	122 µg/L	199-H4-12C and 199-H4-3
	Nitrate	45,000 µg/L	199-H4-12A, 199-H4-18, 199-H4-3. 199-H4-4, and 199-H4-9
	Technetium-99	900 pCi/L	199-H4-18, 199-H4-3, and 199-H4-4
	Uranium	20 µg/L	199-H4-18, 199-H4-3, and 199-H4-4
March, April, May, and June 1997	Chromium	122 µg/L	199-H4-12C
	Nitrate	45,000 µg/L	199-H4-12A, 199-H4-18, 199-H4-3, 199-H4-4, and 199-H4-9
	Technetium-99	900 pCi/L	199-H4-3 and 199-H4-4
	Uranium	20 µg/L	199-H4-3 and 199-H4-4

Table B.3. Summary of Groundwater-Sampling Results for the 316-5-Process Trenches

Sampling Time	Constituent of Concern	Concentration Level	Well Exceeding Concentration Limit
December 1996, January, February, and March 1997	Trichloroethylene	5 µg/L	399-1-16B
	cis-1,2-Dichloroethylene	70 pCi/L	399-1-16B
June, July, August, and September 1997	Uranium	20 µg/L	399-1-10A, 399-1-16A, and 399-1-17A

Table B.4. Sampling Results for Required Constituents[a] at the Solid Waste Landfill

Constituent	Tolerance Interval[b]	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-34A
Temperature, °C	21.0	Nov 1996	17.3	18.1	17.5	18.0
		Feb 1997	17.6	17.7	17.4	18.2
		May 1997	18.3	18.5	18.2	18.7
		August 1997	18.7	18.8	18.7	19.6
Specific conductance, µS/cm	550	Nov 1996	776[c]	618[c]	779[c]	595[c]
		Feb 1997	796[c]	632[c]	753[c]	608[c]
		May 1997	822[c]	663[c]	761[c]	636[c]
		August 1997	794[c]	643[c]	769[c]	634[c]
Field pH	[6.2, 8.46]	Nov 1996	6.8	6.6	6.8	6.7
		Feb 1997	6.9	6.7	6.8	6.8
		May 1997	6.9	6.6	6.9	6.8
		August 1997	6.9	6.6	6.7	6.8
Total organic carbon, µg/L	1,179	Nov 1996	<530	<530	<530	<530
		Feb 1997	<530	<530	560	<530
		May 1997	<530	<530	<530	<530
		August 1997	<370	<370	<370	<370
Chloride, µg/L	9.045	Nov 1996	6,040	6,010	5,700	6,300
		Feb 1997	<5,730	5,560	5,890	6,190
		May 1997	5,690	5,340	5,470	5,490
		August 1997	5,600	5,380	5,800	5,760
Nitrate, µg/L	33,800	Nov 1996	14,000	11,500	12,100	13,800
		Feb 1997	<14,200	11,800	12,700	13,100
		May 1997	14,300	11,600	13,100	12,400
		August 1997	14,100	11,200	13,000	12,900
Nitrite, µg/L	30	Nov 1996	<2	<2	<2	<2
		Feb 1997	<2	<2	<2	<2
		May 1997	<2	<2	<2	<2
		August 1997	<2	<2	<2	<2
Ammonium, µg/L	124	Nov 1996	<28	<28	<28	<28
		Feb 1997	<28	<28	<28	<28
		May 1997	<34	<34	<34	<34
		August 1997	<34	<34	<34	<34
Sulfate, µg/L	51,500	Nov 1996	53,200[c]	41,800	49,700	41,800
		Feb 1997	527,000[c,d]	43,300	50,300	41,700
		May 1997	53,700[c]	42,600	52,000[c]	41,700
		August 1997	53,900[c]	42,800	51,500	42,100
Iron, filtered, µg/L	102	Nov 1996	34.1	54.0	57.9	34.4
		Feb 1997	48.1	44.1	71.0	39.5
		May 1997	51.5	65.3	57.9	50.9
		August 1997	63.4	57.9	241.0[c]	41.9
Zinc, filtered, µg/L	38	Nov 1996	14.6	5.7	310	9.0
		Feb 1997	16.0	19.3	28.0	22.0
		May 1997	18.8	14.8	14.4	234[c]
		August 1997	48.6[c]	32.2	85.4[c]	27.4
Manganese, filtered, µg/L	11	Nov 1996	3.0	5.3	4.6	2.6
		Feb 1997	5.2	3.6	4.6	3.1
		May 1997	4.4	4.2	4.6	3.5
		August 1997	5.2	4.6	4.2	3.3
Chemical oxygen demand, µg/L	3	Nov 1996	<3,000	<3,000	<3,000	<3,000
		Feb 1997	<3,000	<3,000	<3,000	<3,000
		May 1997	<3,000	<3,000	<3,000	<3,000
		August 1997	<3,070	<3,070	<3,070	<3,070
Coliform bacteria, most probable number	16	Nov 1996	0.0	0.1	0.0	2.2
		Feb 1997	0.0	0.0	0.0	0.0
		May 1997	0.0	0.0	0.0	0.0
		August 1997	0.0	0.0	0.0	0.0

Table B.4. (contd)

Constituent	Tolerance Interval[b]	Date	Well 699-24-34B	Well 699-24-34C	Well 699-24-35	Well 699-25-34C	Well 699-26-35A
Temperature, °C	21.0	Nov 1996	18.3	18.1	17.8	18.7	19.8
		Feb 1997	18.7	18.0	17.6	18.3	19.5
		May 1997	18.9	18.8	18.3	19.5	20.2
		August 1997	19.2	19.5	18.9	19.6	19.8
Specific conductance, µS/cm	550	Nov 1996	616[c]	671[c]	497	558[c]	444
		Feb 1997	614[c]	681[c]	526	562[c]	469
		May 1997	641[c]	700[c]	536	578[c]	477
		August 1997	619[c]	713[c]	504	572[c]	461
Field pH	[6.2, 8.46]	Nov 1996	6.7	6.9	7.0	7.1	7.4
		Feb 1997	6.7	7.0	7.0	7.2	7.4
		May 1997	6.7	6.9	7.1	7.3	7.4
		August 1997	6.7	6.8	7.2	7.0	7.7
Total organic carbon, µg/L	1,179	Nov 1996	<530	<530	<530	<530	<530
		Feb 1997	<530	<530	<530	<530	<530
		May 1997	<530	<530	<530	<530	<530
		August 1997	<370	<370	<370	<370	<370
Chloride, µg/L	9.045	Nov 1996	6,470	6,980	6,100	6,990	6,900
		Feb 1997	6,610	6,950	7,080	7,690	7,100
		May 1997	5,890	7,000	6,970	6,930	7,100
		August 1997	6,140	6,860	7,060	7,210	6,900
Nitrate, µg/L	33,800	Nov 1996	17,400	19,500	10,800	22,500	19,700
		Feb 1997	15,100	20,400	10,500	22,100	22,000
		May 1997	14,700	20,300	11,300	21,600	22,300
		August 1997	12,900	18,600	10,900	21,500	21,400
Nitrite, µg/L	30	Nov 1996	<2	<2	<2	<2	<2
		Feb 1997	<2	<2	<2	<2	<2
		May 1997	<2	<2	<2	<2	<2
		August 1997	<2	<2	<2	<2	<2
Ammonium, µg/L	124	Nov 1996	<28	<28	<28	<28	<28
		Feb 1997	<28	<28	<28	68	<28
		May 1997	<34	<34	<34	<34	<34
		August 1997	<34	<34	<34	<34	<34
Sulfate, µg/L	51,500	Nov 1996	41,200	39,800	42,000	39,300	33,800
		Feb 1997	42,300	41,900	41,000	38,400	38,000
		May 1997	44,400	41,400	43,000	41,700	38,300
		August 1997	42,100	40,400	40,000	42,300	37,700
Iron, filtered, µg/L	102	Nov 1996	31.4	58.1	58.7	35.4	50.9
		Feb 1997	33.7	82.5	46.3	56.1	99.3
		May 1997	60.5	56.2	46.1	40.2	31.2
		August 1997	42.9	37.8	62.5	41.9	22.8
Zinc, filtered, µg/L	38	Nov 1996	235[c]	15.1	8.5	15.3	10.3
		Feb 1997	16.1	24.1	16.4	22.6	15.8
		May 1997	315[c]	188[c]	14.8	13.2	19.3
		August 1997	31.5	30.3	30.5	41.5[c]	34.9
Manganese, filtered, µg/L	11	Nov 1996	2.2	6.5	5.1	2.0	4.7
		Feb 1997	2.7	4.9	3.4	3.4	2.4
		May 1997	3.2	6.1	3.5	3.0	2.6
		August 1997	3.5	3.5	3.5	4.0	1.6
Chemical oxygen demand, µg/L	3	Nov 1996	<3,000	<3,000	<3,000	<3,000	<3,000
		Feb 1997	<3,000	7,000[c]	<3,000	<3,000	<3,000
		May 1997	<3,000	<3,000	5,000[c]	<3,000	<3,000
		August 1997	6,000[c]	<3,070	<3,070	<3,070	<3,070

Table B.4. (contd)

Constituent	Tolerance Interval[b]	Date	Well 699-24-34B	Well 699-24-34C	Well 699-24-35	Well 699-25-34C	Well 699-26-35A
Coliform bacteria, most probable number	16	Nov 1996	0.0	0.0	0.0	2.2	0.0
		Feb 1997	0.0	0.0	0.0	0.0	0.0
		May 1997	0.0	0.0	0.0	0.0	0.0
		August 1997	0.0	0.0	0.0	0.0	0.0

(a) WAC 173-304.
(b) Numbers obtained from Table B.1 (background threshold value column).
(c) Exceeding background threshold values.
(d) Suspected data, a request for analytical data evaluation has been filed.
< = Data values less than the contractually required quantitation limit; number given is the respective limit.

Table B.5. Critical Means for 16 Comparisons--Background Contamination Indicator Parameter Data for the 120-D-1 Ponds[a]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	5	4	8.122	519.40	15.265	655.2	655.2
Field pH	4[b]	3	15.145	8.223	0.151	[5.66, 10.78]	[7.06, 9.31][c]
Total organic carbon, µg/L	5	4	8.122	853.65	70.751	1,483.1	1,483.1
Total organic halides, µg/L	5	4	8.122	8.752	3.239	37.6	37.6

(a) Data collected from March 1995 to February 1996 for upgradient well 199-D5-13.
(b) Excluding invalid pH data collected on March 14, 1995.
(c) Values calculated using data collected from May 1995 to August 1996 because the critical range calculated using only four quarters of data is too large to be meaningful.
df = Degrees of freedom (n-1)..
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.6. Critical Means for 20 Comparisons--Background Contamination Indicator Parameter Data for 1301-N Liquid Waste-Disposal Facility[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	10	9	4.7815	592.70	272.527	1,959.4	1,959.4
Field pH[(b)]	9	8	5.6180	7.855	0.248	[6.38, 9.33]	[6.38, 9.33]
Total organic carbon, µg/L	10	9	4.7815	377	205.037	1,405.2	1,405.2
Total organic halides, µg/L	10	9	4.7815	10.742	5.087	36.2	36.2

(a) Data collected from February 1994 to February 1995 for upgradient wells 199-N-57 and 199-N-34.
(b) Excluding suspect pH data collected on September 6, 1994 from well 199-N-57.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table B.7. Critical Means for 16 Comparisons--Background Contamination Indicator Parameter Data for 1324-N/NA Liquid Waste-Disposal Facilities[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4[(b)]	3	11.984	260.812	26.709	618.7	618.7
Field pH	4[(b)]	3	15.145	8.198	0.115	[6.26, 10.14]	[7.59, 8.87][(c)]
Total organic carbon, µg/L	4[(d)]	3	11.984	291.875	80.710	1,373.2	1,373.2
Total organic halides, µg/L	5	4	8.122	6.470	2.385	27.7	27.7

(a) Data collected from May 1994 to May 1995 for upgradient well 199-N-71.
(b) Excluding outliers specific conductance and pH collected on March 1, 1995 and August 26, 1994, respectively.
(c) Values calculated using data collected from May 1994 to September 1996 because the critical range calculated using only four quarters of data is too large to be meaningful.
(d) Excluding invalid data collected on November 4, 1994; blank contamination.
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.8. Critical Means for 16 Comparisons--Background Contamination Indicator Parameter Data for 1325-N Liquid Waste-Disposal Facility[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	11.984	501.75	14.046	689.9	689.9
Field pH	4	3	15.145	7.991	0.129	[5.81, 10.18]	[6.57, 9.05][(b)]
Total organic carbon,[(c)] µg/L	4	3	11.984	500	NC	NC	1,179
Total organic halides, µg/L	4	3	11.984	11.185	2.952	50.7	50.7

(a) Data collected from May 1992 to March 1993 for upgradient well 199-N-74, except for total organic halide that was collected from June 1994 to March 1995.
(b) Values calculated using data collected from May 1992 to November 1994 because the critical range calculated using only four quarters of data is too large to be meaningful.
(c) Critical means not calculated because of lack of background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.9. Critical Means for 36 Comparisons--Background Contamination Indicator Parameter Data for 216-A-29-Ditch[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.976	217.75	28.382	397.6	397.6
Field pH	8	7	6.699	7.792	0.308	[5.60, 9.98]	[6.16, 9.71][(b)]
Total organic carbon,[(c)] µg/L	8	7	5.976	499.375	98.758	1,125.3	1,179
Total organic halides, µg/L	8	7	5.976	5.964	2.509	21.9	21.9

(a) Data collected from April 1994 to January 1995 for upgradient wells 699-43-43 and 699-43-45.
(b) Values calculated using data collected from April 1994 to July 1995 (wells 699-43-43 and 699-43-45) because the critical range calculated using only four quarters of data is too large to be meaningful.
(c) Upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 36 comparisons.

Table B.10. Critical Means for 24 Comparisons--Background Contamination Indicator Parameter Data for 216-A-36B Crib[a]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.5799	273.312	77.643	732.8	732.8
Field pH	8	7	6.2684	8.024	0.319	[5.91, 10.14]	[6.76, 9.26]
Total organic carbon,[b,c] µg/L	8	7	5.5799	618.75	117.830	1,316.1	1,316.1
Total organic halides,[b,c,d] µg/L	8	7	5.5799	4.469	1.544	13.6	21.3

(a) Data collected from September 1988 to June 1989 for upgradient wells 299-E24-18 and 299-E25-36. The upgradient/downgradient comparison values will be used until June 1997. After that, the 216-A-36B crib will be combined with the 216-A-10 and 216-A-37-1 cribs (i.e., PUREX cribs) in an assessment program.
(b) Critical means were calculated from values reported below the contractually required detection limit (DOE/RL-91-03).
(c) Critical means were calculated using data analyzed by United States Testing Company, Inc., Richland, Washington.
(d) Upgradient/downgradient comparison value is limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 24 comparisons.

Table B.11. Critical Means for 24 Comparisons--Background Contamination Indicator Parameter Data for 216-A-10 Crib[a]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.5799	273.31	77.643	732.8	732.8
Field pH	8	7	6.2684	8.024	0.319	[5.90, 10.14]	[6.76, 9.26][b]
Total organic carbon,[c,d] µg/L	8	7	5.5799	618.75	117.83	1,316.1	1,316.1
Total organic halides,[c,d,e] µg/L	8	7	5.5799	4.47	1.544	13.6	21.3

(a) Data collected from November 1988 to August 1989 for upgradient wells 299-E24-18 and 299-E25-36. The upgradient/downgradient comparison values will be used until June 1997. After that, the 216-A-36B crib will be combined with the 216-A-10 and 216-A-37-1 cribs (i.e., PUREX cribs) in an assessment program.
(b) Values calculated using data collected from November 1988 to August 1992 (wells 299-E24-18 and 299-E25-36) because the critical range calculated using only four quarters of data is too large to be meaningful.
(c) Critical means calculated from values reported below the contractually required detection limit (DOE/RL-91-03).
(d) Critical means calculated using data analyzed by United States Testing Company, Inc., Richland, Washington.
(e) Upgradient/downgradient comparison value is limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 24 comparisons.

Table B.12. Critical Means for 48 Comparisons--Background Contamination Indicator Parameter Data for 216-B-63 Trench[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	21	20	4.224	369.393	60.192	629.6	629.6
Field pH	20	19	4.572	7.975	0.190	[7.08, 8.87]	[7.08, 8.87]
Total organic carbon,[(b)] µg/L	20	19	4.267	500	NC	NC	1,179
Total organic halides,[(c)] µg/L	NC	NC	NC	NC	NC	NC	21.3

(a) Data collected from July 1992 to April 1993 for upgradient wells 299-E27-8, 299-E27-9, 299-E34-10, and 299-E27-17. Data collected from July 1992 to July 1993 for upgradient well 299-E27-11.

(b) Critical means not calculated because of lack background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

(c) Critical means not calculated because of problems associated with data quality for samples analyzed by DataChem Laboratories, Inc., Salt Lake City, Utah. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table B.13. Critical Means for 20 Comparisons--Background Contamination Indicator Parameter Data for 216-S-10 Pond and Ditch[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	248.375	9.186	301.1	301.1
Field pH	8	7	6.0818	7.888	0.178	[6.74, 9.04]	[6.74, 9.04]
Total organic carbon,[(b)] µg/L	7[(c)]	6	5.9588	500	NC	NC	1,179
Total organic halides, µg/L	8	7	5.4079	7.284	5.49	38.8	38.8

(a) Data collected from August 1991 to June 1992 for upgradient wells 299-W26-7 and 299-W26-8, except for total organic halides (background period is December 1996 to September 1997).

(b) Critical means not calculated because of lack of background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

(c) Excluding values collected on February 11, 1992 from well 299-W26-7 because of nonconformance report.

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table B.14. Critical Means for 16 Comparisons--Background Contamination Indicator Parameter Data for Liquid Effluent-Retention Facility(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	11.984	332.125	11.736	489.4	489.4
Field pH	4	3	15.145	7.742	0.311	[2.48, 13.01]	[6.25, 9.42](b)
Total organic carbon,(c) µg/L	4	3	11.984	718.75	295.364	4,676	4,676
Total organic halides,(d) µg/L	NC	NC	NC	NC	NC	NC	21.3

(a) Data collected from June 1991 to April 1992 for upgradient well 299-E26-11.

(b) Values calculated using data from June 1991 to October 1993 (well 299-E26-11) because the critical range calculated using four quarters of data is too large to be meaningful.

(c) Critical means calculated from values reported below the contractually required quantitation limit.

(d) Critical means not calculated because of problems associated with data quality for samples analyzed by DataChem Laboratories, Inc., Salt Lake City, Utah. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.15. Critical Means for 68 Comparisons--Background Contamination Indicator Parameter Data for LLWMA 1(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	26(b)	25	4.2027	373.721	74.637	693.4	693.4
Field pH	27	26	4.4409	7.896	0.330	[6.40, 9.39]	[6.40, 9.39]
Total organic carbon,(c) µg/L	26	25	4.2027	500	NC	NC	1,179
Total organic halides,(d) µg/L	NC	NC	NC	NC	NC	NC	21.3

(a) Data collected from July 1992 to April 1993 for upgradient wells 299-E28-26, 299-E28-27, 299-E28-28, 299-E33-28, 299-E33-29; from July 1992 to January 1993 for 299-E33-35; and from September 1991 to July 1992 for 299-E32-4.

(b) Excluding outlier collected on July 2, 1992 from well 299-E33-28.

(c) Critical means not calculated because of lack of background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

(d) Critical means not calculated because of problems associated with data quality for samples analyzed by DataChem Laboratories, Inc., Salt Lake City, Utah. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 68 comparisons.

Table B.16. Critical Means for 52 Comparisons--Background Contamination Indicator Parameter Data for LLWMA 2[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	12	11	4.9786	404.104	41.359	618.4	618.4
Field pH	12	11	5.4261	8.206	0.225	[6.94, 9.48]	[6.94, 9.48]
Total organic carbon,[(b)] µg/L	12	11	4.9786	272.667	71.404	642.7	1,179
Total organic halides,[(b)] µg/L	12	11	4.9786	2.992	1.289	9.7	21.3

(a) Data collected from May 1995 to November 1996 for upgradient wells 299-E27-10, 299-E34-3, and 299-E34-7.

(b) Upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 52 comparisons.

Table B.17. Critical Means for 32 Comparisons--Background Contamination Indicator Parameter Data for LLWMA 3[(a)]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	12	11	4.7248	439.812	26.865	571.9	571.9
Field pH	12	11	5.1621	8.120	0.294	[6.54, 9.70]	[6.54, 9.70]
Total organic carbon,[(b)] µg/L	10	9	5.1241	195.75	42.296	423.1	1,179
Total organic halides, µg/L	9	8	5.4284	8.731	7.183	49.8	49.8

(a) Data collected from February 1994 to March 1995 for upgradient wells 299-W10-13 and 299-W9-1. Critical means calculated for area not impacted by upgradient source of contamination.

(b) Critical means calculated from values reported below contractually required detection limit. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 32 comparisons.

Table B.18. Critical Means for 40 Comparisons--Background Contamination Indicator Parameter Data for LLWMA 3[a]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	17	16	4.3467	580.941	32.230	725.1	725.1
Field pH	17	16	4.6820	7.838	0.3867	[5.97, 9.70]	[5.97, 9.70]
Total organic carbon,[b,c] µg/L	15	14	4.4995	367.833	107.483	867.3	1,179
Total organic halides, µg/L	14	13	4.5978	797.923	319.605	2,319.0	2.319.0

(a) Data collected from February 1994 to March 1995 for upgradient wells 299-W10-19, 299-W10-20, and 299-W10-21. Critical means calculated for area impacted by upgradient source of contamination.
(b) Critical means calculated from values reported below contractually required detection limit.
(c) The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 40 comparisons.

Table B.19. Critical Means for 56 Comparisons--Background Contamination Indicator Parameter Data for LLWMA 4[a]

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	16	15	4.586	328.594	133.345	958.9	958.9
Field pH	16	15	4.938	7.779	0.261	[6.45, 9.11]	[6.45, 9.11]
Total organic carbon,[b,c] µg/L	15	14	4.676	470.0	142.428	1,157.8	1,179
Total organic halides,[b] µg/L	11	10	5.2814	2,029.796	2,002.864	13,078	13,078

(a) Data collected from October 1988 to July 1989 for upgradient wells 299-W15-16, 299-W15-18, and 299-W18-24 and from October 1992 to August 1993 for the newly installed upgradient well 299-W18-32.
(b) Critical means calculated using data analyzed by United States Testing Company, Inc., Richland, Washington.
(c) The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 56 comparisons.

Table B.20. Critical Means for 20 Comparisons--Background Contamination Indicator Parameter Data for WMA A-AX(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	396.563	59.671	738.8	738.8
Field pH	8	7	6.0818	7.798	0.194	[6.55, 9.05]	[6.55, 9.05]
Total organic carbon,(b) µg/L	6(c)	5	5.4079	500	NC	NC	1,179
Total organic halides,(d) µg/L	NC	NC	NC	NC	NC	NC	21.3

(a) Data collected from July 1991 to May 1992 for upgradient wells 299-E25-40 and 299-E25-41.
(b) Critical means not calculated because of lack of background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
(c) Excluding values collected on February 28, 1992 from wells 299-E25-40 and 299-E25-41 because of nonconformance report.
(d) Critical means not calculated because of problems associated with data quality for samples analyzed by DataChem Laboratories, Inc., Salt Lake City, Utah. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table B.21. Critical Means for 16 Comparisons--Background Contamination Indicator Parameter Data for WMA C(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	4	3	11.9838	353.063	14.244	543.9	543.9
Field pH	4	3	15.1451	8.038	0.109	[6.19, 9.88]	[6.19, 9.88]
Total organic carbon,(b) µg/L	4	3	11.9838	500	NC	NC	1,179
Total organic halides,(c) µg/L	NC	NC	NC	NC	NC	NC	21.3

(a) Data collected from July 1991 to August 1992 for upgradient well 299-E27-14.
(b) Critical means not calculated because of lack of background standard deviation estimate. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
(c) Critical means not calculated because of problems associated with data quality for samples analyzed by DataChem Laboratories, Inc., Salt Lake City, Utah. The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
NC = Not calculated.
t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table B.22. Critical Means for 20 Comparisons--Background Contamination Indicator Parameter Data for WMA U(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.4079	308.875	39.032	532.8	532.8
Field pH	8	7	6.0818	8.008	0.091	[7.42, 8.59]	[7.42, 8.59]
Total organic carbon,(b) µg/L	8	7	5.4079	275.031	82.580	748.7	1,179
Total organic halides, µg/L	8	7	5.4079	102.994	24.120	241.3	241.3

(a) Data collected based on semiannual sampling events from February 1995 to August 1996 for upgradient wells 299-W18-25 and 299-W18-31.

(b) The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table B.23. Critical Means for 28 Comparisons--Background Contamination Indicator Parameter Data for Nonradioactive Dangerous Waste Landfill(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	8	7	5.7282	335.31	80.088	821.9	821.9
Field pH	7	6	7.2227	7.546	0.685	[2.26, 12.84]	[5.16, 9.87](b)
Total organic carbon,(c,d,e) µg/L	8	7	5.7282	424.65	89.98	971.3	1,179
Total organic halides,(d,e) µg/L	8	7	5.7282	5.15	1.83	16.3	21.3

(a) Data collected from November 1987 to July 1988 for upgradient wells 699-26-34A and 699-26-35A.

(b) Values calculated using data collected from November 1987 to June 1992 (wells 699-26-34A and 699-25-35A) because the critical range calculated using four quarters of data is too large to be meaningful.

(c) Critical means calculated from values reported below the contractually required detection limit.

(d) Critical means calculated using data analyzed by United States Testing Company, Inc., Richland, Washington.

(e) The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table B.24. Critical Means for 52 Comparisons--Background Contamination Indicator Parameter Data for 216-B-3 Pond(a)

Constituent	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, μS/cm	15	14	4.6371	417.667	7.215	452.2	452.2
Field pH	15	14	5.0064	7.704	0.262	[6.35, 9.06]	[6.35, 906]
Total organic carbon,(b,c) μg/L	15	14	4.6371	174.150	123.011	763.3	1,179
Total organic halides,(b,c) μg/L	14	13	4.7428	3.980	2.242	15.0	21.3

(a) Data collected from January 1994 to January 1997 for upgradient well 299-E32-4.
(b) Critical means calculated from values reported below the contractually required detection limit.
(c) The upgradient/downgradient comparison value is the limit of quantitation (Appendix D).
df = Degrees of freedom (n-1).
n = Number of background replicate averages.
t_c = Bonferroni critical t-value for appropriate df and 52 comparisons.

Appendix C

Analytical Methods

Appendix C

Analytical Methods

B. M. Gillespie

The methodology for analysis of chemical constituents in groundwater at the Hanford Site for fiscal year 1997 conforms to the U.S. Environmental Protection Agency's (EPA's) *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (SW-846); *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-82-055) or other EPA methods; and the *Annual Book of ASTM Standards* (American Society for Testing and Materials 1986). The methodologies used for analysis of radiochemical constituents were developed by the analyzing laboratory and are recognized as acceptable within the technical radiochemical industry. The methodologies used to obtain routine data results are presented in Table C.1. During fiscal year 1997, samples were analyzed for chemical constituents by four primary laboratories and for radiochemical analytes by three primary laboratories. Brief descriptions of each methodology for each test ordered follow. Some tests were performed by slightly different methodologies, dependent on the laboratory. A section on field measurement methodology is also included.

C.1 Chemical Analyses

C.1.1 Volatile Organic Compounds

Volatile organic compounds were analyzed by gas chromatography per Methods 8010/8020, 8240, or 8260 (SW-846). Volatile organic compounds are extracted from the water sample using a purge-and-trap system (e.g., Method 5030 [SW-846]). Purged sample components are trapped in a tube containing suitable sorbent materials. When purging is complete, the sorbent tube is heated and backflushed with helium to desorb trapped sample components onto a gas chromatography column. The column separates the analytes, which are then detected with either a photoionization detector or a halogen-specific detector placed in series for Methods 8010/8020. For Methods 8240 and 8260, the compounds are identified and quantified using a mass spectrometer.

C.1.2 Semivolatile Organic Compounds

Semivolatile organic compounds were analyzed by Method 8270 (SW-846) after extraction into methylene chloride, using a fused-silica capillary column. Polynuclear aromatic hydrocarbons, chlorinated hydrocarbons and pesticides, phthalate esters, organophosphate esters, nitrosamines, haloethers, aldehydes, ethers, ketones, anilines, pyridines, quinolines, aromatic nitro compounds, and phenols (including nitrophenols) could be analyzed using this methodology.

C.1.3 Polychlorinated Biphenyls and Pesticides

Organochloride pesticide and polychlorinated biphenyl compounds were determined by Method 8080 (SW-846). This method specifies gas chromatographic conditions for detection. Prior to analysis, appropriate sample-extraction techniques must be used. Both neat and diluted organic liquids may be analyzed by direct injection. A 2- to 5-mL sample is injected into a gas chromatograph, using the solvent-flush technique, and separated compounds are detected by an electron-capture detector or an electrolytic conductivity detector.

Organophosphorus pesticides were determined by Method 8140 (SW-846), which specifies gas chromatographic conditions for the detection of microgram-per-liter levels. Prior to analysis, appropriate sample-extraction techniques must be used. Both neat and diluted organic liquids may be analyzed by direct injection. A 2- to 5-mL aliquot of the extract is injected into a gas chromatograph, and compounds in the gas chromatograph effluent are detected with a flame photometric or thermionic detector.

C.1.4 Dioxins and Dibenzofurans

Dioxins and dibenzofurans were determined by Method 8280 (SW-846). Dioxins and dibenzofurans are determined by matrix-specific extraction, analyte-specific cleanup, and high-resolution capillary column gas chromatography/low-resolution mass spectrometry techniques.

C.1.5 Chlorinated Herbicides

Herbicides were determined by Method 8150 (SW-846), which specifies extraction, esterification, and gas chromatographic conditions. Spiked samples are used to verify the applicability of the chosen extraction technique to each new sample type. The esters are hydrolyzed with potassium hydroxide, and extraneous organic material is removed by a solvent wash. After acidification, the acids are extracted with solvent and converted to their methyl esters using diazomethane as the derivation agent. After the excess reagent is removed, the esters are determined by gas chromatography, employing electron-capture, microcoulometric, or electrolytic conductivity detectors. The results are reported as the acid equivalents.

C.1.6 Phenols

Phenolic compounds were determined by Method 8040 (SW-846), which specifies gas chromatographic conditions for the detection of phenolic compounds. A sample is extracted using methylene chloride and is then injected into the gas chromatograph using the solvent-flush technique. The compounds in the gas chromatograph effluent are detected by a flame ionization detector. This method also provides for the preparation of pentafluorobenzyl-bromide derivatives, with additional cleanup procedures for electron-capture gas chromatography.

C.1.7 Cyanide

Cyanide was determined by Methods 9010 or 9012 (SW-846). The sample is acidified, converting any cyanide to hydrocyanic acid. The sample is then distilled, and the hydrocyanic acid trapped in an absorber scrubber of sodium hydroxide solution. The cyanide ion is converted to cyanogen chloride with

Chloramine-T, and color formation is achieved through the addition of pyridine barbituric acid. The cyanide concentration is then determined by volumetric titration, colorimetry, or automated ultraviolet colorimetry.

C.1.8 Inductively Coupled Plasma Metals Analysis

Samples were acid digested before analysis by Methods 3010 or 3015 (SW-846) and then injected into a plasma per Method 6010 (SW-846). Metal concentrations are determined by inductively coupled atomic emission spectrometry.

C.1.9 Alkalinity

Method 310.1 (EPA-600/4-82-055) was used to determine alkalinity, depending on the laboratory. The sample is titrated electrometrically with hydrochloric or sulfuric acids to an end point of pH 4.5.

C.1.10 Anions

Nitrate, nitrite, bromide, chloride, fluoride, phosphate, and sulfate were determined using Method 9056 (SW-846) or Method 300.0 (EPA-600/4-84-017). The sample is introduced into an ion chromatograph, where the anions of interest are separated and measured with a conductivity detector. Specific methods for the detection of individual anions used in some instances are given below.

- Total nitrate plus nitrite were determined by Method 353.1 (EPA-600/4-79-020), which is a colorimetric method that first reduces the nitrate to nitrite with either hydrazine or cadmium. Total nitrite is determined colorimetrically by using sulfanilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye. The results are expressed as nitrogen in nitrate plus nitrite.

- Total Kjeldahl nitrogen was determined by Method 351.2 (EPA-600/4-79-020). The sample is heated in the presence of sulfuric acid, potassium sulfate, and mercuric sulfate. An AutoAnalyzer is used for ammonia determination.

C.1.11 Atomic Absorption Analysis of Metals

Lead, arsenic, cadmium, chromium, iron, thallium, and selenium were analyzed by graphite furnace atomic absorption analysis. SW-846 methods used were 7060 (arsenic), 7131 (cadmium), 7191 (chromium), 7421 (lead), 7740 (selenium), and 7841 (thallium) after acid digestion. Method 236.2 (EPA-600/4-82-055) was used for iron analysis. Samples are introduced into the pyrolitic graphite chamber and atomized. Background subtraction techniques are used to correct for absorbance or scatter of light.

Chromium was also analyzed by flame atomic absorption analysis (Method 218.2, EPA-600/4-82-055) after digestion. The sample is atomized by direct aspiration into the flame.

Method 7470 (SW-846), a cold-vapor atomic absorption technique, is based on the absorption of radiation at 253.7-nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration.

Method 7195 (SW-846) was used to separate hexavalent chromium [Cr(VI)] by coprecipitation of lead chromate with lead sulfate. The Cr(VI) is then reduced and quantified as trivalent chromium [Cr(III)] by flame or furnace atomic absorption (Methods 7190 or 7191).

C.1.12 Sulfides

Method 9030 (SW-846) was used to measure the concentration of total and dissolved sulfides. The sample is treated with zinc acetate to produce zinc sulfide. Excess iodine is added to oxidize the sulfide to sulfur under acid conditions. The excess iodine is back titrated with sodium thiosulfate or phenylarsine oxide.

C.1.13 Total Dissolved Solids

Total dissolved solids were determined by Method 160.1 (EPA-600/4-82-055) or Standard Method 209B (American Public Health Association 1985). These methods dry the sample to 180°C and determine the total dissolved solids content by the gravimetric technique.

C.1.14 Total Suspended Solids

Total suspended solids were determined by Method 160.2 (EPA-600/4-82-055). The sample is filtered through a glass fiber filter and the residue is dried to constant weight at 103° to 105°C.

C.1.15 Total Organic Halides

Method 9020 (SW-846) was used to determine total organic halides. The sample is passed through an activated carbon column. The column is washed to remove any trapped inorganic halides. The sample is then combusted to convert the adsorbed organohalides to hydrogen halide, which is trapped and titrated electrolytically using a microcoulometric detector.

C.1.16 Total Organic Carbon

Method 9060 (SW-846) or Method 415.1 (EPA-600/4-79-020) was used to determine total organic carbon. This method uses a carbonaceous analyzer to convert the organic carbon in the sample to carbon dioxide by either catalytic combustion or wet chemical oxidation. The carbon dioxide is then directly measured by an infrared detector or converted to methane and measured by a flame ionization detector. The amount of carbon dioxide or methane measured is directly proportional to the concentration of carbonaceous material in the sample.

C.1.17 Total Carbon

Total carbon was determined based on instrument manufacturer parameters and Method 415.1 (EPA-600/4-82-055). Carbon in a sample is converted to carbon dioxide by catalytic combustion or wet chemical oxidation. The carbon dioxide formed is measured directly by an infrared detector or converted to methane and measured by a flame ionization detector. The amount of carbon dioxide or methane is directly proportional to the concentration of carbonaceous material in the sample.

C.1.18 Conductivity

Method 120.1 (EPA-600/4-82-055) or Method 9050 (SW-846) was used to determine the electrical conductivity of a sample. The conductivity of a sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type, or equivalent.

C.1.19 Ammonia

A colorimeter was used to determine ammonia by Method 350.1 (EPA-600/4-79-020, SW-846). The method uses alkaline phenol and hypochlorite to react with ammonia to form indenophenol blue in an amount that is proportional to the ammonia concentration. The blue color formed is intensified with sodium nitroprusside. The concentration is measured by use of a calibrated colorimeter.

C.1.20 pH

Method 9040 (SW-846) was used to determine pH. The pH of a sample is determined potentiometrically, using either a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH.

C.1.21 Turbidity

Standard Method #214A (American Public Health Association 1985) or Method 180.1 (EPA-600/4-79-020), the nephelometric method, was used to determine turbidity of samples. Under defined conditions, the methods are based on a comparison of the intensity of light scattered by the sample with the intensity of light scattered by a standard reference suspension. The higher the intensity of scattered light, the higher the turbidity. Readings are given in nephelometric turbidity units.

C.1.22 Coliform

Method 9131 (SW-846) was used to determine coliform by the tube fermentation technique. This method consists of a three-stage procedure in which the results are statistically expressed in terms of the most probable number. The three stages are used to determine the probability of coliform growth based on gas production and culture growth.

C.1.23 Chemical Oxygen Demand

Method 410.1 (EPA-600/4-79-020, EPA-600/4-82-055) was used to determine chemical oxygen demand. Organic and oxidizable inorganic substances in the sample are oxidized by potassium dichromate in 50% sulfuric acid solution at reflux temperature. Silver sulfate is used as a catalyst and mercuric sulfate is added to remove chloride interference. The excess dichromate is titrated with standard ferrous ammonium sulfate, using orthophenanthroline ferrous complex as an indicator.

C.1.24 Nonhalogenated Volatile Organics

Nonhalogenated volatile organic compounds were determined by Method 8015 (SW-846). Samples are introduced into the gas chromatograph using the purge-and-trap system (Method 5030 [SW-846]). Detection is achieved by a flame ionization detector.

C.1.25 Total Petroleum Hydrocarbons

Three methods were used to determine total petroleum hydrocarbons, the first of which was Method 418.1 (EPA-600/4-79-020). This method determines the mineral oils by acidifying the sample to pH <2 and serially extracting with fluorocarbon-113 in a separatory funnel. Interferences are removed with silica gel absorbent. Infrared analysis of the extract is performed by direct comparison with standards.

Total petroleum hydrocarbon, gasoline range, was determined using the method in State of Washington Department of Ecology (1992), which adapts Methods 5030 and/or 8020 (SW-846) to perform the analysis. The method involves purging an aliquot of sample via a purge and trap concentrator and analyzing the purged components using a gas chromatograph equipped with a flame ionization detector.

Total petroleum hydrocarbon, diesel range, was determined using the method in State of Washington Department of Ecology (1992), which adapted Methods 3510 and 8000 (SW-846). The method involves extracting the samples with methylene chloride and injecting a portion of the extract into a gas chromatograph equipped with a flame ionization detector. Quantitation is accomplished by integrating to baseline, as a group, the area of components after dodecane through tetracosane.

C.1.26 Oil and Grease

Method 413.1 (EPA-600/4-79-020) was used to determine oil and grease in groundwater samples. In this method, the sample is acidified to a low pH (<2) and serially extracted with fluorocarbon-113 in a separatory funnel. The solvent is evaporated from the extract and the residue weighed. The definition of oil and grease is based on the procedure used. The nature of the oil and/or grease and the presence of extractable nonoily matter will influence the material measured and interpretation of results. Oil and grease are measures of biodegradable animal greases and vegetable oils along with the relative nonbiodegradable mineral oils.

C.2 Radiological Analyses

The methodologies described below are typical for most analyses but each laboratory may use a slightly different, or modified, process.

C.2.1 Gross Alpha and Gross Beta

Gross alpha and gross beta were determined by Methods 9310 (SW-846) or 900.0 (EPA-600/4-80-032). An aliquot of water is evaporated onto a stainless steel counting planchet. The residue is dried to constant weight and counted for alpha and beta radioactivity. Activity is determined using a standardized counting efficiency versus sample solids curve for the detector system. Efficiencies are determined by using strontium/yttrium-90 and americium-241 certified standards.

C.2.2 Gamma Spectrometry

Gamma scans provided a quantitative assay for a large number of gamma-emitting isotopes with a range of half-lives. Because these assays are performed by high-resolution counting techniques, it is possible to identify isotopes of interest with a high degree of confidence. In addition, a software library search can be used to identify unknowns. Isotopes routinely reported include cobalt-60, ruthenium-106, antimony-125, and cesium-137; numerous other isotopes are reported when detected. Laboratory-specific methods are used.

Samples were counted directly, using an intrinsic (hyperpure) germanium or lithium-drifted germanium detector. Isotopes with gamma-ray energies from 60 to 2,000 KeV are detected. Activity concentrations are determined using a laboratory computer system-supplied isotope library.

C.2.3 Total Uranium

Total uranium analyses were generally performed by laser kinetic phosphorimetry but may also be performed by alpha-counting determinations of individual isotopes for activity.

The laser kinetic phosphorimetry method pretreats the water samples for organic and halide-quenching interferents (if necessary) and particulates are filtered out. The uranium is complexed with a substance such as phosphoric acid for it to phosphoresce. The concentration is calculated based on the phosphorescence of the sample in a laser phosphorimeter.

C.2.4 Uranium Isotopes

Uranium was separated from lead, radium, and thorium on a hydrochloric acid anion-exchange resin column; iron was removed by passing the sample through a nitric acid anion-exchange resin column. The uranium fraction is eluted and electrodeposited on a disk for alpha spectrometry counting.

C.2.5 Carbon-14

The carbon in a sample was converted to carbon dioxide through oxidizing and distillation. The carbon dioxide is converted to salts of carbonic acid. The carbonates are then precipitated as barium carbonate and counted by liquid scintillation.

C.2.6 Tritium

Sodium hydroxide was added to the tritium sample. The alkaline sample is then distilled, and a fraction (5 mL) is mixed with scintillation cocktail, allowed to sit while the chemiluminescence decayed, and then counted by liquid-scintillation instrumentation. Laboratory-specific methods or Method 906.0 (EPA-600/4-80-032) were used.

C.2.7 Low-Level Tritium

The sample was distilled in the presence of potassium permanganate to eliminate solids and organic material that may cause quenching. The sample is then enriched in a basic medium by electrolysis to a small volume. The enriched volume is transferred to a liquid-scintillation vial with scintillation cocktail and allowed to sit for 24 hours while the chemiluminescence decays and temperature equilibrium is reached. It is then counted by liquid-scintillation instrumentation.

C.2.8 Nickel-63

A nickel carrier was added to the sample. Separation of iron from the sample is performed using extraction chromatography or ion exchange. The sample is finally purified through extraction chromatography and counted by liquid scintillation.

C.2.9 Technetium-99

The technetium-99 samples were wet ashed with nitric acid and hydrogen peroxide to destroy organic material in the sample. Actinides, lanthinides, alkaline earths, transition metals, and lead are removed through precipitation as hydroxides and carbonates. Technetium, as the pertechnetate ion, is adsorbed from a weak nitric acid solution on a strongly basic anion-exchange resin column. The technetium is then eluted with a stronger nitric acid solution and determined by liquid-scintillation beta counting.

C.2.10 Americium-241

Americium and curium were concentrated in the sample by coprecipitation on ferric hydroxide. Thorium and plutonium are separated from the americium and curium as the sample passes through an anion-exchange resin column conditioned with dilute nitric acid. The iron is then separated from the americium and curium by coprecipitation on calcium oxalate. The americium and curium are then extracted into a bidentate organophosphorus solvent (DDCP) from a nitric acid solution and then back-extracted with weak nitric acid. Traces of iron, thorium, and any organic residue are removed by passing the solution through a cation-exchange resin column. The americium and curium are eluted from the cation-exchange resin column with dilute hydrochloric acid, electrodeposited or precipitated on a counting disk, and counted by alpha spectrometry.

C.2.11 Plutonium Isotopes

The sample was acidified with nitric acid, the plutonium oxidation state was adjusted to +4 with sodium nitrite, and the solution was loaded onto an anion-exchange resin column. The plutonium is eluted with hydrochloric acid and ammonium iodide. The sample is electrodeposited or coprecipitated on a counting disk, and the activity counted by alpha spectrometry.

C.2.12 Neptunium-237

Neptunium is first coprecipitated on lanthanum fluoride. The neptunium is then extracted in 2-thenoyltrifluoroacetone in xylene (TTA), electrodeposited, and counted through alpha energy analysis.

C.2.13 Radiostrontium

Samples of strontium-90 were precipitated first as a nitrate and then as a carbonate. Calcium, barium, lead, and radium are removed by coprecipitation on barium chromate. Iron and other fission products are removed through hydroxide scavenging. The gravimetric yield of carrier (or strontium-85 tracer yield) is determined along with the total radiostronium activity by beta counting, following final carbonate precipitation. For strontium-90 and/or strontium-89 determination, yttrium-90 is separated from the strontium by hydroxide and oxalate precipitations. The yttrium oxalate is converted to yttrium oxide, weighed for chemical recovery, and counted by beta-proportional counting for activity.

C.2.14 Iodine-129

Iodine-129 analyses presented a particular challenge because of the need for specially sensitive measurement. The iodine-129 interim drinking water standard is 1 pCi/L -- the lowest for any radionuclide (40 CFR 141). The contractual detection limit (referred to as the minimum detectable concentration) is 1 pCi/L for the most sensitive method used by the primary radiological laboratory.

Iodine isotopes were first separated from interfering radioactive isotopes by oxidation to iodine (I_2) with sodium nitrite and then extracted into carbon tetrachloride from dilute acid media. The iodine is next reduced to iodide with sodium bisulfite. It is then backextracted into water, precipitated as silver iodide, and counted on a low-energy photon detector. Chemical yield is determined gravimetrically.

C.2.15 Radium-226

The radium was concentrated and separated by coprecipitation on barium sulfate using Method 903.1 (EPA-600/4-80-032). The precipitate is dissolved in ethylenediaminetetraacetic acid (EDTA) reagent and stored for ingrowth of radon-222. After ingrowth and radon-222 progeny are in equilibrium with the parent, the sample is alpha counted in a scintillation cell.

C.2.16 Total Alpha - Radium

The total radium alpha activity was determined by Method 9315 (SW-846). Radium is coprecipitated in water samples with mixed barium and lead sulfates. The carriers are added to an alkaline solution containing citrate, which prevents precipitation during carrier exchange with radium isotopes in the sample. Ammonium sulfate is then used to precipitate the sulfates, which are purified by nitric acid washes. The precipitate is dissolved in an alkaline solution containing EDTA, and the barium and radium sulfates are precipitated by addition of acetic acid, thus separating radium from lead and other radionuclides. The precipitate is dried on a plate, weighed to determine chemical yield, and alpha counted to determine the activity concentration of the radium isotopes.

C.3 Field Measurements

Several tests were performed in the field by the sampling staff or by trained personnel in a mobile laboratory. The tests used are listed below and are also presented in Table C.1.

C.3.1 Volatile Organic Compounds

Field-screening methods for volatile organic compounds are based on Method 8010 (SW-846) by gas chromatography.

C.3.2 Alkalinity

The field-screening method used to determine alkalinity is based on Standard Method 2320 (American Public Health Association 1989). This method is an electrochemical titration method.

C.3.3 Conductivity

Conductivity is measured in the field using company-specific procedures based on Method 9050 (SW-846), electrical conductivity.

C.3.4 pH

The pH of groundwater samples is determined by potentiometric measurement using company-specific procedures based on EPA methodology and instrument manuals.

C.3.5 Turbidity

Turbidity measurements performed in the field are nephelometric measurements based on Method 180.1 (EPA-600/4-79-020) or Standard Method 214A (American Public Health Association 1985).

C.3.6 Dissolved Oxygen

Field measurements for dissolved oxygen are based on the membrane electrode Method 360.1 (EPA-600/4-79-020).

C.3.7 Temperature

The temperature of field samples is based on company-specific and instrument manual methodology using electronic digital thermometers.

C.3.8 Total Uranium

Laser kinetic phosphorimetry is used to determine total uranium in field samples using instrument manufacturer's and company-specific methods.

C.3.9 Hexavalent Chromium

Method 7196 (SW-846) was used to determine hexavalent chromium [Cr(VI)] by colorimetry by reaction with diphenylcarbazide in acid solution. The red-violet color of unknown composition is produced. Addition of an excess of diphenylcarbazide yields the red-violet product, and its absorbance is measured photometrically at 540 nm.

C.4 References

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Table C.1. Methodologies Used to Obtain Routine Data Results for Project Samples

Analytical Test	User[(a)]	Reference	Analytical Methodology
		Chemical Analyses	
Volatile organic compounds	G, E, F	Method 8010/8020 (SW-846)	Gas chromatography
	E	Method 8240 (SW-846)	Gas chromatography/mass spectrometry
	G, E	Method 8260 (SW-846)	Gas chromatography/mass spectrometry
Semivolatile organic compounds	G, E	Method 8270 (SW-846)	Gas chromatography/mass spectroscopy
Polychlorinated biphenyls and pesticides	G, E	Method 8080 (SW-846)	Gas chromatography
Organophosphorus pesticides	G	Method 8140 (SW-846)	Gas chromatography
Dioxins and dibenzofurans	G	Method 8280 (SW-846)	High-resolution gas chromatography/low-resolution mass spectrometry
Chlorinated herbicides	G	Method 8150 (SW-846)	Gas chromatography
Phenols	G	Method 8040 (SW-846)	Gas chromatography
Cyanide	G	Method 9012 (SW-846)	Colorimetry
	E	Method 9010 (SW-846)	Titration or spectrophotometry, automated ultraviolet colorimetry
Inductively coupled plasma metals	G, E	Method 6010 (SW-846)	Inductively coupled plasma, atomic emission spectrometry
Alkalinity	G, E	Method 310.1 (EPA-600/4-82-055)	Electrochemical titration
		Method 310.2 (EPA-600/4-82-055)	Colorimetric titration
	F	Standard 2320 (APHA 1989)	Electrochemical titration
Nitrogen, nitrate-nitrite[(b)]	E	Method 353.1 (EPA-600/4-79-020)	Colorimetric, hydrazine reduction
	E	Method 351.2 (EPA-600/4-79-020)	Total Kjeldahl nitrogen
Anions	E	Method 9056 (SW-846) or	Ion chromatography
	G, E	Method 300.0 (EPA-600/4-84-017)	

Table C.1. (contd)

Analytical Test	User[a]	Reference	Analytical Methodology
Lead	G, E	Method 7421 (SW-846)	Graphite furnace atomic absorption
Arsenic	G, E	Method 7060 (SW-846)	Graphite furnace atomic absorption
Thallium	G	Method 7841 (SW-846)	Graphite furnace atomic absorption
Selenium	G, E	Method 7740 (SW-846)	Graphite furnace atomic absorption
Cadmium	G	Method 7131 (SW-846)	Graphite furnace atomic absorption
Chromium	E	Method 218.2 (EPA-600/4-82-055) Method 7191 (SW-846)	Flame atomic absorption Graphite furnace atomic absorption
Iron	E	Method 236.2 (EPA-600/4-82-055)	Graphite furnace atomic absorption
Hexavalent chromium	E	Method 7196 (SW-846)	Coprecipitation and atomic absorption
Mercury	G, E	Method 7470 (SW-846)	Cold vapor furnace atomic absorption
Sulfides	G, E	Method 9030 (SW-846)	Titration
Total dissolved solids	G	Method 160.1 (EPA-600/4-82-055)	Dried to 180°C and gravimetric technique
Total suspended solids	E	Method 160.2 (EPA-600/4-82-055)	Filtered and dried to 105°C, gravimetric
Total organic halides	G, E	Method 9020 (SW-846)	Electrolytic titration
Total organic carbon	G G, E	Method 9060 (SW-846) Method 415.1 (EPA-600/4-79-020)	Carbon analyzer
Total carbon	G	Method 415.1 (EPA-600/4-82-055)	Carbon analyzer
Conductivity	G, E F	Method 120.1 (EPA-600/4-82-055) Method 9050 (SW-846)	Electrical conductivity
Ammonium ion	G, E	Method 350.1 (EPA-600/4-82-055)	Colorimetric
PH	G, E F	Method 9040 (SW-846) Company specific	Potentiometric measurement
Turbidity	G, E, F E F	Method 214A (APHA 1985) Method 180.1 (EPA-600/4-79-020) Method 180.1 (EPA-600/4-79-020)	Nephelometric
Coliform	G	Method 9131 (SW-846)	Tube fermentation technique
Chemical oxygen demand	G, E	Method 410.1 (EPA-600/4-82-055)	Titration

Table C.1. (contd)

Analytical Test	User[(a)]	Reference	Analytical Methodology
Dissolved oxygen	F	Method 360.1 (EPA-600/4-79-020)	Membrane electrode
Temperature	F	Company specific	Electronic digital thermometer
Nonhalogenated volatile organics	E	Method 8015 (SW-846)	Purge and trap/gas chromatography/flame ionization detector
Total petroleum hydrocarbons	G, E	WTPH-Gasoline and diesel (Ecology 1992)	Gas chromatography/flame ionization detector
	E	Method 418.1 (EPA-600/4-79-020) or WTPH-Gasoline (Ecology 1992)	Spectrophotometric, infrared or gas chromatography/flame ionization detector
Oil/grease	G, E	Method 413.1 (EPA-600/4-79-020)	Gravimetric/separatory funnel extraction
		Radiological Analyses	
Gross alpha and gross beta	G E	Method 9310 (SW-846) Method 900.0 (EPA-600/4-80-032)	Gas-flow proportional counting
Gamma spectrometry	G	Laboratory specific	Intrinsic germanium counting
Total uranium	G, E	Laboratory specific	Laser kinetic phosphorimetry or fluorophotometry
	F	Company specific	Laser kinetic phosphorimetry
Isotopic uranium	G	Laboratory specific	Anion-exchange resin separation with alpha energy analysis
Carbon-14	G, E	Laboratory specific	Separation and liquid scintillation counting
Tritium	G E	Laboratory specific Method 906.0 (EPA-600/4-80-032)	Distillation and liquid scintillation counting
Low-level tritium	G, R	Laboratory specific	Electrolysis to enriched volume and liquid scintillation counting
Nickel-63	E	Laboratory specific	Separation and liquid scintillation counting
Technetium-99	G, E	Laboratory specific	Anion-exchange resin column separation with liquid scintillation counting
Americium-241	E	Laboratory specific	Anion- and cation-exchange resin separation with alpha energy analysis
Isotopic plutonium	G, E	Laboratory specific	Anion-exchange resin separation with alpha energy analysis
Neptunium-237	E	Laboratory specific	Liquid-liquid separation and alpha energy analysis

Table C.1. (contd)

Analytical Test	User[a]	Reference	Analytical Methodology
Strontium-90	G, E	Laboratory specific	Nitrate and carbonate coprecipitation, gravimetric yield, and beta gas-flow-proportional counting
Iodine-129	G	Laboratory specific	Chemical separation, coprecipitated, and counted on low-energy photon detector
Radium-226	E	Method 903.1 (EPA-600/4-80-032)	Coprecipitation and alpha counting
Total alpha radium	G, E	Laboratory specific 9315 (SW-846)	Coprecipitation and alpha counting

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(a) E = Environmental Restoration Contractor, Bechtel Hanford, Inc.
F = Field (all contractors).
G = Groundwater Monitoring Project, Pacific Northwest National Laboratory.
(b) Also analyzed by anion methods.

Appendix D

Quality Assurance and Quality Control

Appendix D

Quality Assurance and Quality Control

D.1 Introduction

H. Hampt

The groundwater chemistry quality assurance/quality control (QA/QC) information for fiscal year (FY) 1997 for the Groundwater Monitoring Project and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) projects is presented in this appendix. The Groundwater Monitoring Project includes the *Resource Conservation and Recovery Act of 1976* (RCRA), Operational Monitoring, and Groundwater Surveillance projects. The RCRA, Operational, and Groundwater Surveillance projects are managed by Pacific Northwest National Laboratory. CERCLA projects are managed by Bechtel Hanford, Inc.

The QA/QC practices used by the Groundwater Monitoring Project ensure the reliability and validity of field and laboratory measurements conducted to support these programs. The primary components used to assess data quality are accuracy, precision, and detection (Mitchell et al. 1985). Representativeness, completeness, and comparability may also be used. These parameters are evaluated through laboratory QC checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind samples and blanks, and interlaboratory comparisons. Acceptance criteria have been established for each of these parameters. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence.

The QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (OSWER-9950.1, SW-846). U.S. Department of Energy (DOE) Orders and internal requirements provide the guidance for the collection and analysis of samples for the Operational Monitoring and Groundwater Surveillance projects. QC practices for the Groundwater Monitoring Project samples are described in the project-specific QA project plan. Guidance for the QC practices for CERCLA samples is provided in project-specific documents (e.g., DOE/RL-88-36; DOE/RL-90-08; DOE/RL-90-21; DOE/RL-91-46; DOE/RL-91-53; Section 1.5 in DOE/RL-92-03; DOE/RL-96-07; DOE/RL-96-90, Draft A).

A glossary of QA/QC terms is given below.

- accuracy – The closeness of agreement between an observed value and a true value. Accuracy is assessed by means of reference samples and percent recoveries. Laboratory matrix spikes; laboratory control samples; EPA water pollution, water supply, and interlaboratory comparison programs; and blind samples might all be used to assess accuracy.

- blind sample – A sample that contains a concentration of analyte that is known to the supplier but unknown to the analyzing laboratory. The analyzing laboratory is informed that the sample is a QC sample and not a field sample. The blind, the double blind, and the matrix-matched double blind samples are used to assess accuracy and monitor the performance of the analytical laboratory(ies).

- comparability – The confidence with which one set of data can be compared to another. Ideally, comparability should be evaluated using replicates to ensure that samples analyzed by different laboratories or by the same laboratory over different time periods are comparable.

- completeness – The RCRA project determines completeness by calculating the number of unflagged data resulting from the validation process, divided by the total number of data evaluated, and multiplying by 100. The calculated percentages used in reporting completeness are conservative because all data flagged with B, H, Q, R, and Y (see flags) are used in calculating the percentage complete; however, flagged data may still be valid.

- contractually required quantitation limit – A value intended to be the lowest analyte concentration in a given matrix that the laboratory can be expected to achieve consistently; agreed on under the contract statement of work.

- double blind sample – A sample that contains a concentration of analyte that is known to the supplier but is unknown to the analyzing laboratory. The analyzing laboratory is not informed that the sample is a QC sample. All attempts are made to make this sample appear like a field sample. For example, the double blind sample should be submitted to the laboratory within the same time period and with a sample identification number similar to that of the field samples. The double blind sample may or may not include matrix matching. The blind, the double blind, and the matrix-matched double blind samples are used to assess accuracy and monitor the performance of the analytical laboratory(ies).

- equipment blank – A sample that contains Type II reagent water and preservative. An equipment blank is filled by pumping or washing Type II reagent water through a nondedicated pump or manifold. The equipment blank is analyzed for all constituents scheduled for the sampling event.

- field duplicate sample – A sample used to determine the repeatability of an analytical measurement by comparing the results with those of an identical sample that was collected at the same time and location. These samples are stored in separate containers and are analyzed independently by the same laboratory.

- field trip blank – A sample that contains only Type II reagent water. At the time of sample collection, the field trip blank is filled at the sampling site by pouring Type II reagent water from a cleaned container into vials. After collection, the field trip blank is treated in the same manner as the other samples collected during the sampling event. Field trip blanks are collected only on days when other samples are collected for volatile organics analysis and are analyzed for volatile organic constituents only.

- flags – Flags alert data users to limitations on reported data values. In general, data flags are assigned by onsite working personnel. An exception is the B flag that is assigned by the analytical laboratory. The flags that are used include the following:

    - B - data associated with contamination in the laboratory method blank
    - F - suspect data currently under review
    - H - laboratory holding time exceeded
    - G - reviewed data considered valid

  - P - potential problem (with the sample or well that may have affected the data)
  - Q - result associated with suspect field QC data
  - R - reviewed data are unusable
  - Y - reviewed data continue to be suspect.

- full trip blank – A sample that contains only Type II reagent water and preservative, as required. A full trip blank is used to check for contamination in sample bottles and sample preparation. The full trip blank is analyzed for all constituents of interest on all types of sample bottles used during that sampling period. The frequency of collection for a full trip blank is 1 per 20 samples, or 1 per sampling batch. A full trip blank is filled in the field sampling laboratory using the same sample-preparation procedures as for real samples. The full trip blank is not opened in the field.

- limit of detection – The lowest concentration level that is statistically different from a blank. This is calculated by the average blank signal plus three standard deviations for the blank analyses.

- limit of quantitation – The level above which quantitative results may be obtained with a specified degree of confidence. This is calculated as the blank mean plus 10 standard deviations of the blank.

- matrix-matched double blind sample – A matrix-matched double blind sample contains a concentration of analyte that is known to the supplier but unknown to the analyzing laboratory. The sample matrix has been altered to closely match that of the field samples. The laboratory is unaware that the sample has been spiked.

- method detection limit – The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero. The method detection limit is determined from replicate analyses of a sample containing the analyte in a given matrix type.

- minimum detectable activity – The level of activity that is practically achievable by a radiochemistry counting measurement system.

- precision – The agreement among a set of individual measurements of the same property, usually under prescribed similar conditions. Precision is calculated by using relative percent difference of the duplicate/replicate analyses. These samples should contain concentrations of analyte above the method detection limit and may involve the use of matrix spikes. For Groundwater Monitoring Project samples, results from laboratory duplicates, matrix spike duplicates, blind samples, and field duplicates are used to evaluate precision.

- relative percent difference – The relative percent difference is calculated as follows:

$$RPD = \frac{|D_1 - D_2|}{(D_1 + D_2) \div 2} \times 100$$

where D_1 = original sample value
D_2 = duplicate sample value.

- reliable detection level – A detection limit set at two times the concentration of the method detection limit so the risk of both false-positives and false-negatives falls below 1%.

- representativeness – An expression of the degree to which samples represent the actual composition of the groundwater in the aquifer. Representativeness is addressed qualitatively by the specification of well construction, sampling locations, sampling intervals, and sampling and analysis techniques addressed in monitoring plans.

- Type II reagent water – Distilled or deionized water that is free of contaminants that may interfere with the analytical test.

D.2 Sample Collection and Field Quality Control

H. Hampt, J. V. Borghese

D.2.1 Groundwater Monitoring Project

Groundwater sampling for FY 1997 was conducted by Waste Management Federal Services, Northwest Operations. Their tasks included bottle preparation, sample set coordination, field measurements, sample collection, sample shipping, well pumping, and coordination of purgewater containment and disposal. Quality requirements for sampling activities are defined in their statement of work and approved sampling procedures are followed.

The precision and accuracy of field measurements are gauged through the use of field duplicates and several types of field blanks. Field QC samples can reveal problems with the entire measurement process, from sample collection to laboratory analysis.

The analytical results of field QC samples are considered acceptable if the following evaluation criteria are met:

- field duplicates – Results of field duplicates must have precision within 20%, as measured by the relative percent difference. Only results that are quantifiable are evaluated.

- blanks – Three kinds of blanks are used to check for contamination resulting from field activities and/or bottle preparation: full trip, field trip, and equipment blanks. For chemical analyses, results above two times the method detection limit are identified as suspected contamination. For common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is set at five times the method detection limit. For radiochemistry data, blank results are flagged if they are greater than two times the total propagated analytical uncertainty.

- blind samples – Blind samples are periodically forwarded to the laboratories to evaluate their performance. The number and the criteria for the types of blind samples used in FY 1997 are listed in Table D.1.

If a field QC sample does not meet the established criteria, it is assumed that there are potential problems with the data for other samples that are associated with that field QC sample. Those data are flagged with a Q, as being associated with a field QC sample that was out of limits.

Table D.2 provides a summary of the field duplicate and field blank QC results evaluated during FY 1997. The percentages of acceptable field blank and duplicate results in FY 1997 were very high (e.g., 88% to 99%), indicating good precision and little problem with contamination overall.

Tables D.3 and D.4 summarize the total number of field blanks and field duplicates exceeding QC limits per method. Methods not listed in Tables D.3 or D.4 were 100% acceptable for field blanks or field duplicates.

Blank results were flagged as potentially contaminated for volatile organics, inductively coupled plasma (ICP), metals, total organic halides, gross beta, tritium, technetium-99, strontium-90, potassium-40, semivolatile organics, cyanide, anions, and total dissolved solids.

The number of flagged ICP metal field blank results continued to increase in FY 1997. It was determined that the high ICP metal blanks are not arising from the water system used by the sampling teams. Waste Management Federal Services of Hanford, Inc. was notified in early 1997 that many metals blank results were above QC limits. A thorough examination of the water-system equipment was conducted, and samples collected from the water system were analyzed by an alternative laboratory. All of those results, except sodium, were below detection limits. The sodium in the samples was thought to occur as a result of leaching from glass sample bottles; therefore, Waste Management Federal Services of Hanford, Inc. immediately began to collect samples for metals analyses in polyethylene bottles. After the investigation was completed, the laboratory was asked to examine the large number of metals blank results that had been qualified. One possible explanation for the large number of qualified positive blank results is that the laboratory detection limits for some metals were too low. The Groundwater Monitoring Project is currently reviewing requirements for metals reporting limits.

A Groundwater Monitoring Project data quality objective is that the method detection limit must be less than one-third the maximum contaminant level. In most cases, the method detection limit was considerably below the maximum contaminant level, so results from trip or equipment blanks that were not within control limits do not have a significant impact on the quality of the data.

Duplicate results were flagged for volatile organics, ICP metals, total dissolved solids, gross beta, and technetium-99 samples. A few duplicate results (e.g., gross beta, technetium-99, and some ICP metals) were outside QC limits by a large margin, and the laboratory has been asked to reanalyze the gross beta and technetium-99 samples. In the future, the laboratory may be asked also to analyze other results that are outside of limits.

D.2.2 CERCLA Program

Groundwater-monitoring samples are collected by trained staff according to approved procedures. Field QC samples are collected and evaluated according to project-specific requirements (DOE/RL-90-08; DOE/RL-91-53; DOE/RL-96-90, Draft A; DOE/RL-91-46; DOE/RL-97-36, Rev. 2; BHI-00038, Rev. 2; DOE/RL-96-07; and DOE/RL-92-76). In general, field QC samples consist of field duplicates, splits, equipment blanks, and volatile organic trip blanks. Field QC data are evaluated as necessary to make decisions that may modify or terminate a remedial action. In FY 1997, no such decisions were made. An evaluation of field QC for CERCLA projects is not included in this appendix.

D.3 Holding Times

H. Hampt

Chemical constituent concentrations in groundwater samples are required to be determined within a specified time frame, or holding time, from the time of collection to the time of analysis or preparation. Samples must be analyzed within this time frame or the concentration of the constituents of concern may, in some instances, be compromised by volatilization, decomposition, or other chemical changes. Samples are also refrigerated to slow potential chemical reactions within the sample matrix. Holding times for constituents frequently analyzed for by the Groundwater Monitoring Project are listed in Table D.5. There is no designated holding time for radiochemical constituents because they do not change chemically or decompose under ambient temperatures. Results of radionuclide analysis are corrected for decay between sampling and analysis dates.

Of the 36,005 nonradiochemical constituents analyzed for the Groundwater Monitoring Project, 1,249 holding times were exceeded in FY 1997. This number represents 3.5% of holding-time exceedances, which is higher than the exceeded holding times experienced by RCRA, Operational, and Groundwater Surveillance projects in the past. Throughout FY 1997, ~10% of holding times were missed for anions each quarter; however the laboratory appears to have steadily shortened the holding times for all anion constituents since August 1997. During the third quarter of FY 1997, high percentages of phenol, semivolatile organic, volatile organic, and pesticide/polychlorinated biphenyl holding times were also exceeded. Data for which holding times were exceeded were flagged with an H. The impact on data is unclear at this point. These data may still be used for general trending purposes.

D.4 Analytical Results

H. Hampt, D. L. Stewart

Routine analyses of hazardous and nonhazardous chemicals for the Groundwater Monitoring Project were performed by Quanterra Environmental Services (Quanterra), St. Louis, Missouri. Routine analyses of hazardous and nonhazardous chemicals for CERCLA projects were performed by Quanterra, St. Louis, Missouri; ThermoNutech, Richmond, California; and/or Lockheed Analytical Services, Las Vegas, Nevada.

These laboratories participate in the EPA's Water Pollution and Water Supply Performance Evaluation Studies. Quanterra maintains internal QC programs that meet the requirements of OSWER-9950.1. QC blind spiked samples are also submitted for analysis to Quanterra by the Groundwater Monitoring Project. QC blind spiked samples were submitted by the Groundwater Monitoring Project to ThermoNutech once during FY 1997 to evaluate them as an alternative laboratory.

Routine radiochemical analyses for Groundwater Monitoring Project samples were performed by Quanterra, Richland, Washington. Quanterra participates in DOE's Quality Assessment Program and EPA's Environmental Monitoring and Support Laboratory Intercomparison Studies and maintains an internal QC program. QC blind spiked samples are also submitted.

Radiochemical analyses of samples for CERCLA were performed at Quanterra in Richland, Washington, ThermoNutech, and/or Lockheed Analytical Services. ThermoNutech and Lockheed also participate in DOE's Quality Assessment Program, EPA's Environmental Monitoring and Support Laboratory Intercomparison Studies, and the EPA's Water Pollution and Water Supply Performance Evaluation Studies. These data, however, are not included in this appendix.

D.4.1 EPA and DOE Studies

D.4.1.1 EPA Water Pollution and Water Supply Studies for Quanterra

Every quarter the contracted laboratories report their results from these studies. The EPA distributes standard water samples as blind samples to participating laboratories. These samples contain specific organic and inorganic analytes at concentrations unknown to the participating laboratories. After analysis, results are submitted to the EPA. Regression equations are used to determine acceptance and warning limits. The results of these studies independently verify the level of laboratory performance and are expressed as a percentage of EPA-acceptable results. Results from these studies for Quanterra are summarized in Table D.6. The percentage of EPA-acceptable results was high, indicating excellent performance overall for the samples analyzed; however, several results do raise some concerns. The laboratory had unacceptable results for orthophosphate for both water pollution studies and one water supply study in FY 1997. The corrective actions proposed by the laboratory consist only of monitoring future studies because the laboratory was unable to find the cause of the poor results. The laboratory also had a failure for sulfate. On the most recent water supply study, the laboratory did have acceptable results for both phosphate and sulfate. The Groundwater Monitoring Project will consider contracting anion analyses to another laboratory if the problems evident in the studies from earlier in FY 1997 persist. Misses occurred for several other analytes throughout the year, but either the misses were for constituents that were not of particular concern to the Groundwater Monitoring Project or the unacceptable result occurred only once during the year and was followed by an acceptable rating on subsequent performance evaluation studies.

D.4.1.2 EPA Characterization and DOE Environmental Results for Quanterra

Routine Groundwater Monitoring Project radiochemical analyses were performed by Quanterra in Richland, Washington. Quanterra participates in DOE's Quality Assessment Program at the Environmental Measurements Laboratory, New York, and in EPA's Laboratory Intercomparison Studies at the National Exposure Research Laboratory, Characterization Research Division, Las Vegas, Nevada.

These programs provide blind samples containing specific amounts of one or more radionuclides. After sample analysis, the results are forwarded to DOE or EPA for comparison with known values and with results from other laboratories. Both DOE and EPA evaluate the accuracy of results by determining if results fall within ±3 standard deviations of the mean of all results reported in the intercomparison study (EPA-600/4-81-004, EML-587, EML-591). Summaries of FY 1997 results for water samples for the various programs are provided in Table D.7.

All of the results from the analyses conducted during FY 1997 were within the ±3 standard deviations of the mean, except one result each for cobalt-60, cesium-134, and cesium-137 that were deemed to be outliers by the EPA and one result each for manganese-54 and cobalt-60 that were outside of the DOE acceptable limits. Quanterra determined that their results for the EPA study were off because of a calculation error. The recalculated results were within the EPA control limits. Quanterra recounted the gamma scan samples from the DOE study and obtained similar results to their initial results. Quanterra then requested another water sample and obtained results that were within the DOE control limits. Overall, Quanterra's performance on the samples that were analyzed for DOE and EPA was acceptable.

D.4.2 Double Blind Standard Evaluation

The Groundwater Monitoring Project forwarded blind spiked QC samples and replicate samples to Quanterra during FY 1997. Blind spiked samples and blanks were generally prepared in triplicate and submitted to check the accuracy and precision of analyses. Overall, 75% of the blind spike determinations were within control limits (see Table D.1). Laboratory results were most often outside of limits for gross beta, fluoride, cyanide, total organic carbon, and total organic halides. Procedural changes were implemented at Quanterra in July 1997 that appear to have improved the accuracy and precision of the total organic carbon analysis.

The most recent gross beta results also show an improvement. An earlier set of gross beta results that were out of limits appears to be anomalous. Those samples are now being reanalyzed by Quanterra. Both of the earlier sets of gross beta samples were spiked with strontium-90. In November 1997, a set of gross beta samples spiked with technetium-99 was forwarded to Quanterra because unexpected ratios of technetium-99 to gross beta were noted at a few sites in 1997. The results from the November blind samples will help to evaluate the unexpected ratios that were observed.

The total organic halide results outside of the QC limits were generally from standards spiked at very low concentrations. It is expected that the laboratory's accuracy will suffer at levels closer to the detection limit. Further investigation into the fluoride and cyanide results will be conducted by the project.

Blind spiked samples were also forwarded to ThermoNutech during the third quarter of 1997. The results from both laboratories are presented in Table D.8. The ThermoNutech results were out of limits for total organic halides, cyanide, and gross alpha. The total organic halide results were generally out of limits at lower concentrations, which is similar to the results obtained by Quanterra. All three cyanide and gross alpha results were also out of limits. Because ThermoNutech does not usually analyze groundwater samples, additional investigation will be conducted if the Groundwater Monitoring Project submits samples to ThermoNutech in the future.

D.4.3 Laboratory Internal QA Programs

Quanterra maintains an internal QA/QC program. Every month, Quanterra supplies a QC report to the Groundwater Monitoring Project that includes results on laboratory control samples, matrix spikes, matrix duplicates, matrix spike duplicates, and blanks. Precision and accuracy information is obtained from these reports. The results from these reports indicate that the QC programs at both Quanterra laboratories are functioning adequately.

The internal QA program at the Quanterra Richland Laboratory involves routine calibrations of counting instruments, yield determinations of radiochemical procedures, frequent radiation check source and background counts, replicate and spiked sample analyses, use of matrix and reagent blanks, and maintenance of control charts to indicate analytical deficiencies. Available calibration standards traceable to the National Institute of Standards and Technology were used for radiochemical calibrations.

D.4.3.1 Issue Resolution

Issue resolution forms are methods of documentation of problems encountered with the analysis, data, and/or data deliverable. The forms are generated by the laboratory and forwarded to the Groundwater Monitoring Project as soon as possible after a potential problem is identified. The forms indicate if direction on the part of the Groundwater Monitoring Project is required. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse effect on the data integrity. These issues may include, but are not limited to, the following:

- lost sample
- broken bottles
- instrument malfunctions
- calibration standards out of acceptable range
- laboratory control standards out of acceptable range
- matrix spike recovery out of acceptable range
- blank contamination
- procedural noncompliance
- chain-of-custody discrepancies
- shipping temperatures out of acceptable range
- misreported data.

D.4.3.2 Laboratory Audits/Assessments

Laboratory activities are regularly assessed by surveillance and auditing processes to ensure that quality problems are prevented and/or detected. Regular assessment supports continuous process improvement.

An assessment of the Quanterra St. Louis Laboratory was conducted from August 11 through 13, 1997 by the Hanford Site's Integrated Contractor Assessment Team, consisting of representatives from Bechtel Hanford, Inc., Pacific Northwest National Laboratory, and Waste Management Federal Services of Hanford, Inc. The purpose of the assessment was to evaluate the continued capability of the Quanterra St. Louis Laboratory to analyze and process samples for the Hanford Site as specified in the Statement of Work between Waste Management Federal Services of Hanford, Inc. and Quanterra.

The assessment scope was based on the analytical and QA requirements for groundwater samples. The primary area of focus was the implementation of the Quanterra St. Louis Laboratory's QA program and compliance to their technical operating procedures. The specific assessment areas for the Groundwater Monitoring Project were the implementation of the total organic halides, total organic carbon, and anion procedures.

Twelve findings and four observations were identified during the assessment. These findings and observations related to deficiencies in four specific programmatic areas: document control, quality improvement, work process, and calibration. No significant deficiencies were noted in the performance of total organic carbon, total organic halides, and anion analyses. Corrective action responses to the assessment findings and observations have been evaluated. Nine findings and all observations have been closed. Closure of the remaining three audit findings are still pending.

D.4.4 Completeness and Comparability of RCRA Project Data

For FY 1997, 91% of the data were considered complete. Flags were assigned for QC problems, violated holding times, rejected data, suspect data, and laboratory blank contamination.

Samples are split in the field and forwarded to two or more laboratories for analysis when problems arise that require confirmation of the routine laboratory's results. In FY 1997, several samples for gross beta, technetium-99, and total organic halides were split and forwarded to Quanterra and the Waste Characterization and Sampling Facility for analysis. The results from the technetium-99 and gross beta samples are listed in Table D.9. The poor agreement between the gross beta results may indicate a problem; however, it is difficult to draw conclusions because the data set is limited.

Total organic halide splits were forwarded to the laboratory once as part of a verification-sampling effort and as a follow-up to intercomparison splits forwarded to Quanterra, Waste Characterization and Sampling Facility, and Datachem in FY 1996. Results from the total organic halide splits in FY 1996 were inconclusive for two sample sets. The results from FY 1997 show good comparability between samples from one well, but results from the other well show poor agreement.

D.5 Limit of Detection, Limit of Quantitation, and Method Detection Limit

C. J. Chou, H. Hampt

Detection and quantitation limits are essential in evaluating data quality and usefulness because they provide the limits of a method's measurement. The detection limit is the lower limit at which a measurement can be differentiated from background. The quantitation limit is the lower limit where a measurement becomes quantifiably meaningful. The limit of detection (LOD), limit of quantitation (LOQ), and method detection limit (MDL) are useful for evaluating groundwater data.

The LOD is defined as the lowest concentration level that is statistically different from a blank (Currie 1988). The concentration at which an analyte can be detected depends on the variability of the blank response. For the purpose of this discussion, the blank is taken to be a method blank.

In general, the LOD is calculated as the mean concentration in the blank plus three standard deviations of that concentration (EPA/540/P-87-001). The blank-corrected LOD is simply three times the blank standard deviation. At three standard deviations from the blank mean, the false-positive and the false-negative error rates are each ~7% (Miller and Miller 1988). A false-positive error is an instance when an analyte is declared to be present but is, in fact, absent. A false-negative error is an instance when an analyte is declared to be absent but is, in fact, present.

The LOD for a radionuclide is typically computed from the counting error associated with each reported result (e.g., EPA 520/1-80-012) and represents instrumental or background conditions at the time of analysis. In contrast, the LOD and LOQ for the radionuclides shown in Table D.10 are based on variability resulting from both counting error and uncertainties introduced by sample handling. In the latter case, a sample of distilled water (submitted as a sample) is processed as if it were an actual sample. Thus, any random cross contamination of the blank during sample processing will be included in the overall error, and the values shown in Table D.10 are most useful for assessing long-term variability in the overall process.

The LOQ is defined as the level above which quantitative results may be obtained with a specified degree of confidence (Keith 1991). The LOQ is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87-001). The blank-corrected LOQ is simply 10 times the blank standard deviation. The LOQ is most useful for defining the lower limit of the useful range of concentration measurement technology. When the analyte signal is 10 times larger than the standard deviation of the blank measurements, there is a 95% probability that the true concentration of the analyte is ±25% of the measured concentration. The LOD and LOQ are shown graphically in Figure D.1. For purposes of illustration, the numbers appearing in this figure are the respective blank mean, LOD, and LOQ for total organic carbon and total organic halides (see Table D.10).

The MDL is defined as the minimum concentration of a substance that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero. The MDL is determined from analysis of a sample in a given matrix containing the analyte (Currie 1988). The MDL is 3.14 times the standard deviation of the results of 7 replicates of a low-level standard. Note that the MDL, as defined above, is based on the variability of the response of low-level standards rather than on the variability of the blank response.

For this report, total organic carbon, total organic halides, and radionuclide field blank data are available for LOD and LOQ determinations. The field blanks are QC samples that are introduced into a process to monitor the performance of the system. The use of field blanks to calculate LOD and LOQ is preferred over the use of laboratory blanks because field blanks provide a measure of the errors in the entire sampling and analysis system. Methods to calculate LOD and LOQ are described in detail in DOE (Appendix A of DOE/RL-91-03). The results of the LOD and LOQ determinations are listed in Table D.10.

Because of the lack of blank data for other constituents of concern, it was deemed necessary to calculate approximate LOD and LOQ values using variability information obtained from low-level standards. The data from the low-level standards are obtained from laboratory MDL studies. As shown in Figure D.1, the values along the horizontal axis are measured in units of standard deviation of the measurement process (i.e., based on a well-known blank). If low-level standards are used, the variability of the difference between the sample and blank response is increased by a factor of $\sqrt{2}$ (Currie 1988, p. 84). The formulas are summarized below:

$$\mathrm{MCL} = 3.14 \times s$$

$$\mathrm{LOD} = 3 \times (\sqrt{2} \times s)$$
$$= 4.24 \times s$$

$$\mathrm{LOQ} = 10 \times (\sqrt{2} \times s)$$
$$= 14.14 \times s$$

where s = standard deviation from the seven replicates of the low-level standard.

The results of MDL, LOD, and LOQ calculations for other constituents of concern are listed in Table D.11.

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Table D.1. Summary of Quanterra Quarterly Double Blind Spike Determinations for Fiscal Year 1997

Constituent	Number of Results Reported[(a,b)]	Number of Results Within Project Control Limits[(c)]	Control Limits, %
Carbon tetrachloride	12	12	Determined each quarter
Chloroform	12	12	Determined each quarter
Trichloroethene (TCE)	12	12	Determined each quarter
Total organic halides spiked with 2,4,6-trichlorophenol	7	2	±25
Total organic halides spiked with CCl_4, $CHCl_3$, and TCE	7	2	±25
Total organic carbon spiked with potassium phthalate	6	3	±25
Fluoride	12	5	±25
Nitrate	12	12	±25
Cyanide	12	5	±25
Chromium	12	12	±20
Gross alpha spiked with ^{239}Pu	6	4	±10
Gross beta spiked with ^{90}Sr	6	0	±10
Tritium	12	12	60 to 140
^{60}Co	12	12	60 to 140
^{137}Cs	12	12	60 to 140
^{90}Sr	12	12	60 to 140
^{99}Tc	12	11	60 to 140
^{129}I	6[(d)]	5	60 to 140
Uranium	12	12	60 to 140
^{239,240}Pu	12	10	60 to 140

(a) Blind samples were submitted in triplicate each quarter and compared to actual spike values.

(b) Total organic halides, total organic carbon, gross alpha, and gross beta samples were submitted in triplicate during the second and third quarters of FY 1997 only.

(c) Project control limits are given in the project-specific quality assurance project plan.

(d) Twelve samples were forwarded to the laboratory during the year: 3 were not analyzed because of a laboratory error, 3 were not analyzed because sample volume did not meet required detection limits.

Table D.2. Summary of Fiscal Year 1997 Quality Control Sample Results

Quarter	Field Duplicates, % acceptable	Field Blanks, % acceptable
October – December 1996	99	91
January – March 1997	95	88
April - June 1997	99	90
July - September 1997	99	90

Table D.3. Field Blanks Exceeding Quality Control Limits in Fiscal Year 1997

Method Names	Constituents	Total Analyses	Q Flags	% Out of Limits	Range of Out-of-Limit Results
SW-846, 8010/8020, µg/L	1,4-Dichlorobenzene	27	1	4	0.11
	Chloroform	16	4	31	0.14 to 0.43
	Methylene chloride	16	5	31	3.0 to 4.3
	Toluene	16	2	13	0.05
SW-846, 8260, µg/L	2-Butanone	21	2	10	27
	Acetone	21	1	5	50
	Carbon tetrachloride	21	1	5	10
	Methylene chloride	21	1	5	35
SW-846, 6010, µg/L	Aluminum	62	3	5	60.7 to 337
	Antimony	62	1	2	44.4
	Barium	62	34	55	1.4 to 14.4
	Beryllium	62	2	3	1
	Calcium	62	46	74	61.4 to 818
	Copper	62	3	5	9.7 to 29.3
	Iron	62	15	24	17.1 to 216
	Magnesium	62	12	19	68.7 to 672
	Manganese	62	8	13	1.9 to 5.2
	Potassium	62	1	2	2,230
	Silver	62	1	2	3.9
	Sodium	62	41	66	129 to 917
	Strontium	62	11	18	2.3 to 8.7
	Vanadium	62	2	3	18.8 to 20.7
	Zinc	62	31	50	10.8 to 155
SW-846, 9020, µg/L	Total organic halides	83	8	10	9.7 to 17.3
SW-846, 9012, µg/L	Cyanide	2	1	50	7.55
SW-846, 8270, µg/L	Bis(2-ethylhexyl)phthalate	2	1	50	9
EPA-600/4-81-004, 160.1, µg/L	Total dissolved solids	14	5	36	9 to 55
EPA-600/4-81-004, 300.0, µg/L	Chloride	70	13	19	20 to 1,760
	Fluoride	70	1	1	190
	Nitrate	70	11	16	20 to 250
	Phosphate	70	1	1	540
	Sulfate	70	3	4	300 to 6,860
ITAS Gamma, pCi/L	Potassium-40	12	5	42	96 to 236
ITAS GB, pCi/L	Gross beta	47	2	4	11.3 to 18.4
ITAS H-3, pCi/L	Tritium	57	3	5	91.5 to 814
ITAS SR89,90, pCi/L	Strontium-90	15	1	7	23,700
ITAS Tc-99, pCi/L	Technetium-99	40	1	3	229

Table D.4. Field Duplicates Exceeding Quality Control Limits in Fiscal Year 1997

Method Names	Constituent	Total Analyses	Q Flags	% Out of Limits	Out-of-Limit Results, relative percent difference
SW-846, 8010/8020	1,4-Dichlorobenzene	9	1	11	40
	1,1,1-Trichloroethene	9	1	11	26
	Carbon tetrachloride	9	1	11	195
SW-846, 8260	Methylene chloride	5	1	20	31
SW-846, 6010	Barium	27	2	7	32, 72
	Calcium	27	2	7	198, 197
	Chromium	27	1	4	125
	Iron	27	1	4	127
	Magnesium	27	1	4	26
	Manganese	27	1	4	171
	Sodium	27	2	7	195, 26
	Strontium	27	1	4	34
	Vanadium	27	1	4	24
	Zinc	27	1	4	97
EPA-600/4-81-004, 160.1	Total dissolved solids	16	1	6	28
ITAS GB	Gross beta	24	1	4	158
ITAS Tc-99	Technetium-99	21	2	10	47

Table D.5. Groundwater Monitoring Project Holding Times

Methods	Constituents	Holding Times
SW-846, 8010/8020/8260	Volatile organics	14 days
SW-846, 8270	Semivolatile organics	7 days before extraction; 40 days after extraction
SW-846, 8080	Pesticides	7 days before extraction; 40 days after extraction
SW-846, 8080	Polychlorinated biphenyls	7 days before extraction; 40 days after extraction
SW-846, 8150	Chlorinated herbicides	7 days before extraction; 40 days after extraction
SW-846, 8040	Phenols	7 days before extraction; 40 days after extraction
SW-846, 6010	ICP metals	6 months
SW-846, 7060	Arsenic	6 months
SW-846, 7421	Lead	6 months
SW-846, 7470/7471	Mercury	28 days
SW-846, 7740	Selenium	6 months
SW-846, 7841	Thallium	6 months
SW-846 9010/9012	Cyanide	14 days
SW-846, 9020	Total organic halides	28 days
SW-846, 9060	Total organic carbon	28 days
EPA-600/4-81-004, 300.0	Bromide	28 days
EPA-600/4-81-004, 300.0	Chloride	28 days
EPA-600/4-81-004, 300.0	Fluoride	28 days
EPA-600/4-81-004, 300.0	Nitrate	72 hours
EPA-600/4-81-004, 300.0	Nitrite	72 hours
EPA-600/4-81-004, 300.0	Phosphate	72 hours
EPA-600/4-81-004, 300.0	Sulfate	28 days
EPA-600/4-81-004, 310.1	Alkalinity	14 days
EPA-600/4-81-004, 410.4	Chemical oxygen demand	28 days

ICP = Inductively coupled-plasma (metals).

Table D.6. Results of EPA Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies

Laboratory	WP036 November 1996 %Acceptable	WS038 March 1997 %Acceptable	WP037 May 1997 %Acceptable	WS039 September 1997 %Acceptable
Quanterra Environmental Services, St. Louis, Missouri	96[a]	89[b]	96[c]	95[d]

(a) Unacceptable results were for beryllium, chlordane, and orthophosphate.
(b) Unacceptable results were for 2,2-dichloropropane, molybdenum, orthophosphate, residual free chlorine, sulfate, 1,2,3-trichlorobenzene, and 1,2,3-trichloropropane.
(c) Unacceptable results were for arsenic, oil and grease, and orthophosphate.
(d) Unacceptable results were for 1,1-dichloroethylene, trans-1,2-dichloroethylene, and turbidity.

Table D.7. Summary of Quanterra Interlaboratory Performance, Fiscal Year 1997

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
	DOE Quality Assessment Program Environmental Measurements Laboratory	
Gross alpha, gross beta, ^{3}H, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, uranium	2	2[a,b]
^{60}Co, ^{54}Mn	2	1[a,b]
^{55}Fe, ^{234}U, ^{235}U	1	1[a,b]
	EPA Laboratory Intercomparison Studies National Exposure Research Laboratory	
Gross alpha, gross beta, ^{89}Sr, ^{90}Sr, ^{226}Ra, ^{228}Ra, uranium	3	3[c]
Tritium	2	2[c]
^{60}Co, ^{134}Cs, ^{137}Cs	2	1[c,d]
^{65}Zn, ^{129}I, ^{133}Ba	1	1[c]

(a) Control limits from EML-587 and EML-591.
(b) One result for gross alpha and one result for tritium were acceptable but outside warning limits.
(c) Control limits from EPA-600/4-81-004.
(d) One result of each was determined to be an outlier.

Table D.8. Comparison of Quanterra and ThermoNutech Double Blind Spike Determinations for 3rd Quarter Fiscal Year 1997

Constituent	Spike Amount	Number of Samples Analyzed by Each Laboratory	Number of Quanterra Results Within Project Control Limits	Number of ThermoNutech Results Within Project Control Limits
Carbon tetrachloride	7 µg/L	3	3	3
Chloroform	50 µg/L	3	3	3
Trichloroethene (TCE)	7 µg/L	3	3	3
Total organic halides (spiked with 2,4,6-trichlorophenol)	10 µg/L (50 µg/L)	2 2	0 1	0 1
Total organic halides (spiked with CCl_4, $CHCl_3$, and TCE)	10 µg/L (50 µg/L)	2 2	0 2	0 2
Total organic carbon spiked with potassium phthalate	1,500 µg/L	3	3	3
Fluoride	1 mg/L	3	2	3
Nitrate as N	10.2 mg/L	3	3	3
Cyanide	100 µg/L	3	0	0
Chromium	300 µg/L	3	3	3
Gross alpha spiked with ^{239}Pu	11.6 pCi/L	3	1	0
Gross Beta spiked with ^{90}Sr	51.2 pCi/L	3	0	3
Tritium	208,600 pCi/L	3	3	3
^{60}Co	51 pCi/L	3	3	3
^{137}Cs	200.9 pCi/L	3	3	3
^{90}Sr	61.6 pCi/L	3	3	3
^{99}Tc	205.9 pCi/L	3	2	3
Uranium	932.7 µg/L	3	3	3
^{239,240}Pu	7.07 pCi/L	3	3	3

Table D.9. Comparability of Data

Quanterra Sample Number	Quanterra Result, pCi/L	Waste Characterization and Sampling Facility Sample Number	Waste Characterization and Sampling Facility Result, pCi/L
		Gross Beta	
B0LVW9	541	B0LVW7	780
B0LVX0	189	B0LVW8	490
		Technetium-99	
B0LVW9	1,490	B0LVW7	1,100
B0LVX0	741	B0LVW8	760

Table D.10. Summary of Quanterra Environmental Services Groundwater Field Blanks Data

Period	Number of Samples	Mean, µg/L	Standard Deviation, µg/L	LOD, µg/L	LOQ, µg/L
		Constituent: Total Organic Carbon			
10/15/96 - 12/11/96	18	244.24	87.52	507[a]	1,120[a]
01/30/97 - 03/17/97	9[b]	272.42	100.92	575	1,282
04/07/97 - 06/11/97	19	321.89	86.40	581	1,186
Summary	46	281.83	89.71	551	1,179
		Constituent: Total Organic Halides			
02/04/97 - 03/17/97	7[b]	1.46	1.25	3.8[c]	12.5[c]
04/07/97 - 06/11/97	19	0.59	2.35	7.0	23.5
Summary	26	0.82	2.13	6.4	21.3
		Constituent: Antimony-125			
10/24/96 - 12/16/96	2	-0.339	0.882	2.65[c]	8.82[c]
02/11/97 - 03/24/97	3[b]	-0.066	0.528	1.59	5.28
04/28/97 - 06/16/97	4	0.112	2.670	8.01	26.70
08/05/97 - 09/19/97	4	0.235	2.836	8.51	28.36
Summary	13	0.040	2.282	6.84	22.82
		Constituent: Cesium-134			
10/24/96 - 12/16/96	5[b]	1.290	1.316	3.95[c]	13.16[c]
02/04/97 - 03/24/97	4	0.767	0.757	2.27	7.57
04/28/97 - 06/16/97	4	0.319	1.810	5.43	18.10
08/05/97 - 09/19/97	4	-1.003	0.798	2.39	7.98
Summary	17	0.399	1.252	3.76	12.52
		Constituent: Cesium-137			
10/24/96 - 12/16/96	5	0.561	2.186	6.56[c]	21.86[c]
02/04/97 - 03/24/97	5	-0.074	2.018	6.05	20.18
04/28/97 - 06/16/97	4	1.336	2.779	8.34	27.79
08/05/97 - 09/19/97	4	0.556	1.266	3.80	12.66
Summary	18	0.556	2.127	6.38	21.27
		Constituent: Cobalt-60			
10/24/96 - 12/16/96	5	-0.068	1.373	4.12[c]	13.73[c]
02/04/97 - 03/24/97	5	0.405	2.328	6.98	23.28
04/28/97 - 06/16/97	4	3.028	2.935	8.81	29.35
08/05/97 - 09/19/97	4	0.887	1.108	3.32	11.08
Summary	18	0.963	2.049	6.15	20.49

Table D.10. (contd)

Period	Number of Samples	Mean, µg/L	Standard Deviation, µg/L	LOD, µg/L	LOQ, µg/L
		Constituent: Europium-154			
10/24/96 - 12/16/96	5	-6.230	7.251	21.75(c)	72.51(c)
02/04/97 - 03/24/97	5	3.212	7.970	23.91	79.70
04/28/97 - 06/16/97	4	-2.038	2.238	6.71	22.38
08/05/97 - 09/19/97	4	0.160	5.758	17.27	57.58
Summary	18	-1.256	6.430	19.29	64.30
		Constituent: Gross Alpha			
10/15/96 - 12/11/96	8	0.093	0.100	0.30(c)	1.00(c)
01/09/97 - 03/24/97	9	0.020	0.117	0.35	1.17
04/07/97 - 06/11/97	9	0.034	0.113	0.34	1.13
07/08/97 - 09/19/97	8	0.185	0.290	0.87	2.90
Summary	34	0.080	0.170	0.51	1.70
		Constituent: Gross Beta			
10/15/96 - 12/11/96	7(b)	1.264	1.299	3.90(c)	12.99(c)
01/09/97 - 03/24/97	9	1.479	1.477	4.43	14.77
04/07/97 - 06/11/97	10	0.704	0.807	2.42	8.07
07/08/97 - 09/19/97	8	1.024	0.766	2.30	7.66
Summary	34	1.100	1.119	3.36	11.19
		Constituent: Iodine-129			
10/15/96 - 12/16/96	4	-0.276	0.519	1.56(c)	5.19(c)
02/11/97 - 03/24/97	4	0.221	0.536	1.61	5.36
04/07/97 - 06/16/97	9	-0.034	0.258	0.77	2.58
07/31/97 - 09/19/97	3	-0.078	0.167	0.50	1.67
Summary	20	-0.038	0.376	1.13	3.76
		Constituent: Strontium-90			
02/04/97 - 03/24/97	3	0.148	0.067	0.20(c)	0.67(c)
04/09/97 - 06/16/97	4	0.161	0.106	0.32	1.06
08/05/97 - 09/02/97	4	0.212	0.046	0.14	0.46
Summary	11	0.176	0.078	0.24	0.78
		Constituent: Technetium-99			
11/04/96 - 12/16/96	7	2.090	1.443	4.33(c)	14.43(c)
01/20/97 - 03/24/97	7	2.892	2.529	7.59	25.29
04/01/97 - 06/11/97	6	1.925	2.337	7.01	23.37
07/24/97 - 09/02/97	3(b)	3.867	2.556	7.67	25.56
Summary	23	2.523	2.191	6.57	21.91

Table D.10. (contd)

Period	Number of Samples	Mean, µg/L	Standard Deviation, µg/L	LOD, µg/L	LOQ, µg/L
		Constituent: Tritium			
10/15/96 - 12/16/96	11[(b)]	88.0	89.8	269.3[(c)]	897.6[(c)]
01/13/97 - 03/24/97	9	49.3	96.8	290.5	968.3
04/07/97 - 06/11/97	10	38.6	101.7	305.2	1,017.4
07/08/97 - 09/19/97	11	82.3	135.5	406.4	1,354.7
Summary	41	65.9	108.1	324.3	1,080.9
		Constituent: Uranium, µg/L			
11/04/96 - 12/16/96	4	0.0056	0.0048	0.014	0.0482[(c)]
01/20/97 - 03/24/97	5	0.0106	0.0117	0.035	0.1171
04/01/97 - 06/19/97	6	0.0098	0.0046	0.013	0.0464
07/17/97 - 09/02/97	4	0.0128	0.0056	0.016	0.0555
Summary	19	0.0098	0.0074	0.022	0.0739

(a) LOD equals the mean blank concentration plus 3 standard deviations; LOQ equals the mean blank concentration plus 10 standard deviations.

(b) Excluded outlier.

(c) LOD (blank corrected) equals 3 times the blank standard deviation and LOQ (blank corrected) equals 10 times the blank standard deviation.

LOD = Limit of detection.
LOQ = Limit of quantitation.

Table D.11. Calculations for Selected Constituents

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
Ammonium	Ammonium ion	27.6	37.3	124.3
Chemical oxygen demand	Chemical oxygen demand	3,067	4,141	13,811
EPA-600/4-81-004, Alkalinity	Alkalinity	299	404	1,346
SW-846, Arsenic	Arsenic	2	3	9
SW-846, Cyanide	Cyanide	3.05	4.12	13.73
SW-846, Herbicides	2,4,5-T	0.257	0.347	1.157
	2,4,5-TP	0.064	0.086	0.29
	2,4-Dichlorophenoxyacetic acid	3.98	5.37	17.92
	2-secButyl-4,6-dinitrophenol (DNBP)	0.096	0.130	0.43
SW-846, ICP metals	Aluminum	26.52	35.81	119.42
	Antimony	15.7	21.2	70.7
	Barium	0.6	0.8	2.7
	Beryllium	0.5	0.7	2.3
	Cadmium	2.2	3.0	9.9
	Calcium	70.47	95.16	317.34
	Chromium	2.4	3.2	10.8
	Cobalt	2	3	9
	Copper	4	5	18
	Iron	22.7	30.7	102.2
	Magnesium	16.5	22.3	74.3
	Manganese	0.7	0.9	3.2
	Nickel	10.2	13.8	45.9
	Potassium	1,165.4	1,573.7	5,248.0
	Silver	2.6	3.5	11.7
	Sodium	30.5	41.2	137.3
	Strontium (elemental)	0.4	0.5	1.8
	Tin	26.9	36.3	121.1
	Vanadium	2	3	9
	Zinc	8.4	11.3	37.8
SW-846, Lead	Lead	0.8	1.1	3.6
SW-846, Mercury	Mercury	0.011	0.015	0.050
SW-846, Pesticides	Disulfoton	0.124	0.167	0.558
	Methyl parathion	0.166	0.224	0.748
	Phorate	0.097	0.13	0.44
SW-846, Pesticides/ polychlorinated biphenyls	4,4'-DDD	0.007	0.009	0.031
	4,4'-DDE	0.005	0.007	0.02
	4,4'-DDT	0.01	0.01	0.05
	Aldrin	0.011	0.015	0.050
	Alpha-BHC	0.006	0.008	0.027

Table D.11. (contd)

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
	Aroclor-1016	0.198	0.267	0.892
	Aroclor-1221	0.13	0.18	0.59
	Aroclor-1232	0.14	0.19	0.63
	Aroclor-1242	0.18	0.24	0.81
	Aroclor-1248	0.21	0.28	0.95
	Aroclor-1254	0.1	0.1	0.5
	Aroclor-1260	0.189	0.255	0.851
	Beta-BHC	0.019	0.026	0.086
	Chlordane	0.098	0.13	0.44
	Delta-BHC	0.004	0.005	0.02
	Dieldrin	0.008	0.01	0.04
	Endosulfan II	0.009	0.01	0.04
	Endosulfan sulfate	0.039	0.053	0.18
	Endrin	0.005	0.007	0.02
	Endrin aldehyde	0.01	0.01	0.05
	Gamma-BHC (Lindane)	0.009	0.01	0.04
	Heptachlor	0.011	0.015	0.050
	Heptachlor epoxide	0.005	0.007	0.02
	Methoxychlor	0.017	0.023	0.077
	Toxaphene	0.136	0.184	0.612
SW-846, Phenol	2,4,6-Trichlorophenol	2.417	3.264	10.884
	2,4-Dichlorophenol	1.925	2.599	8.669
	2,4-Dimethylphenol	1.817	2.454	8.182
	2,4-Dinitrophenol	0.53	0.72	2.4
	2,6-Dichlorophenol	1.902	2.568	8.565
	2-Chlorophenol	1.942	2.622	8.745
	2-Nitrophenol	1.509	2.038	6.795
	2-secButyl-4,6-dinitrophenol (DNBP)	0.522	0.705	2.35
	3,4-Methylphenol	3.544	15.026	50.112
	4,6-Dinitro-2-methyl phenol	0.464	0.626	2.09
	4-Chloro-3-methylphenol	2.032	2.744	9.150
	4-Nitrophenol	1.509	2.038	6.795
	Pentachlorophenol	2.158	2.914	9.718
	Phenol	0.944	1.27	4.25
	2,3,4,6-Tetrachlorophenol	1.429	1.930	6.435
	2,4,5-Trichlorophenol	1.807	2.440	8.137
SW-846, Selenium	Selenium	0.9	1.2	4.0
SW-846, Semi-VOAs	Acenapthene	1.6	2.2	7.2
	Acenapthylene	1.5	2.0	6.8
	Acetophenone	3.4	4.6	15.3

Table D.11. (contd)

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
	4-Aminobiphenyl	3.7	5.0	16.7
	Aniline	2.7	3.6	12.2
	Anthracene	1.6	2.2	7.2
	Aramite	7.6	10.3	34.2
	Benzo(a)anthracene	1.9	2.6	8.6
	Benzo(b)fluoranthene	2	3	9
	Benzo(k)fluoranthene	1.1	1.5	5.0
	Benzo(ghi)perylene	2.3	3.1	10.4
	Benzo(a)pyrene	2.2	3.0	9.9
	Bezyl alcohol	0.93	1.26	4.19
	bis(2-chloroethoxy)Methane	1.6	2.2	7.2
	bis(2-chloroethyl)Ether	1.5	2.0	6.8
	bis(2-chloroispropyl)Ether	3.1	4.2	14.0
	4-Bromophenyl phenyl ether	1.9	2.6	8.6
	Butyl benzyl phthalate	2.2	3.0	9.9
	p-Chloroaniline	3.5	4.7	15.8
	Chlorobenzilate	4.1	5.5	18.5
	4-Chloro-3-methylphenol	1.1	1.5	5.0
	2-Chloronapthalene	1.4	1.9	6.3
	2-Chlorophenol	1.2	1.6	5.4
	4-Chlorophenylphenyl ether	1.6	2.2	7.2
	Chrysene	2.1	2.8	9.4
	Diallate (peak 1)	6.4	8.6	28.8
	Diallate (peak 2)	7.3	9.8	32.9
	Dibenzo(a,h)anthracene	2.3	3.1	10.4
	Dibenzofuran	1.4	1.9	6.3
	Di-n-butyl phthalate	1.6	2.2	7.2
	1,2-Dichlorobenzene	1.2	1.6	5.4
	1,3-Dichlorobenzene	1.3	1.8	5.8
	1,4-Dichlorobenzene	1.41	1.90	6.35
	3,3-Dichlorobenzidine	3.1	4.2	14.0
	2,6-Dichlorophenol	5	7	22
	Diethyl phthalate	1.6	2.2	7.2
	0,0-diethyl 0-2-pyrazinyl phophorothiolate	3.5	4.7	15.8
	Dimethoate	3.7	5.0	16.7
	p-(dimethyl-amino)Azobenzene	4.8	6.5	21.6
	7,12-Dimethyl-benz(a)anthracene	4.4	5.9	19.8
	Di-n-octyl phthalate	1.8	2.4	8.1
	Ethyl methanesufonate	3.3	4.4	14.9
	Famphur	49	66	221

Table D.11. (contd)

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
	Fluoranthene	1.6	2.2	7.2
	Fluorene	1.5	2.0	6.8
	Hexachlorobenzene	1.8	2.4	8.1
	Hexachlorobutadiene	0.89	1.20	4.01
	Hexachlorocyclopentadiene	1	1	4
	Hexachloroethane	0.98	1.32	4.41
	Hexachloropropene	5.2	7.0	23.4
	Ideno(1,2,3-cd)pyrene	2.5	3.4	11.2
	Isodrin	4.1	5.5	18.5
	Isophorone	1.4	1.9	6.3
	Isosafrole	4.1	5.5	18.5
	Kepone	30	40	135
	Methapyrilene	26	35	117
	3-Methylcholanthrene	17	23	76
	Methyl methanesulfonate	1.5	2.0	6.8
	2-Methylnapthalene	1.5	2.0	6.8
	1,4-Napthoquinone	1.9	2.6	8.6
	1-Naphthylamine	4.4	5.9	19.8
	2-Napthylamine	4.4	5.9	19.8
	2-Nitroaniline	2.1	2.8	9.4
	3-Nitroaniline	1	1	4
	4-Nitroaniline	1.5	2.0	6.8
	Nitrobenzene	1.2	1.6	5.4
	2-Nitrophenol	1.4	1.9	6.3
	4-Nitrophenol	2.1	2.8	9.4
	N-nitrosodi-n-butylamine	5.3	7.2	23.9
	N-nitrosodiethylamine	2.9	3.9	13.0
	N-nitrosodimethylamine	1.3	1.8	5.8
	N-nitrosodiphenylamine	1.5	2.0	6.8
	N-nitrosodipropylamine	1.1	1.5	5.0
	N-nitrosomethylethylamine	5.2	7.0	23.4
	Pyrene	1.6	2.2	7.2
	Pyridine	0.96	1.30	4.32
	Safrole	4.4	5.9	19.8
	1,2,4,5-Tetrachlorobenzene	4.9	6.6	22.1
	2,3,4,6-Tetrachlorophenol	3.7	5.0	16.7
	Tetraethyl dithiopyrophosphate	4.6	6.2	20.7
	o-Toluidine	3.2	4.3	14.4
	1,2,4-Trichlorobenzene	1.1	1.5	5.0
	2,4,5-Trichlorophenol	0.76	1.03	3.42

Table D.11. (contd)

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
	2,4,6-Trichlorophenol	1.2	1.6	5.4
	0,0,0-Triethyl phosphorothiolate	5	7	23
	sym-Trinitrobenzene	22	30	99
	2-Methylphenol	0.97	1.31	4.37
	2-Nitrophenol	1.4	1.9	6.3
	Bis(2-ethylhexyl)phthalate	2.9	3.9	13.0
	Naphthalene	1.4	1.9	6.3
	Pentachlorophenol	1.6	2.2	7.2
	Phenol	0.42	0.57	1.89
SW-846, Thallium	Thallium	0.6	0.8	2.7
SW-846, VOAs	Acetonitrile	23.5	31.7	105.8
	Acrolein	21.4	28.9	96.4
	Acrylnitrile	8.5	11.5	38.3
	Allyl chloride	1.2	1.6	5.4
	Bromodichloromethane	0.54	0.73	2.43
	Bromoform	0.36	0.49	1.62
	Chlorobenzene	0.75	1.013	3.38
	Chloroethane	1	1	4
	Dibromochloromethane	0.33	0.44	1.49
	1,2-Dibromo-3-chloropropane	1.2	1.6	5.4
	1,2-Dibromoethane	0.34	0.46	1.53
	Dichlorodifluoromethane	2.313	3.123	10.416
	1,1-Dichloroethylene	0.97	1.31	4.37
	1,2-Dichloropropane	1	1	4
	cis-1,3-Dichloropropane	0.51	0.69	2.30
	trans-1,3-Dichloropropene	0.29	0.39	1.30
	1,4-Dioxane	460	621	2071
	Ethylbenzene	1.3	1.8	5.8
	Ethyl methacrylate	0.55	0.74	2.48
	2-Hexanone	1.8	2.4	8.1
	Isobutyl alcohol	380	513	1,711
	Methacrylonitrile	2.2	3.0	9.9
	Bromomethane	1.4	1.9	6.3
	Chloromethane	3.3	4.4	14.9
	Styrene	0.64	0.86	2.88
	1,1,1,2-Tetrachloroethane	0.567	0.766	2.553
	1,1,2,2-Tetrachloroethane	1.5	2.0	6.8
	Trichlorofluoromethane	2.3	3.1	10.4
	1,2,3-Trichloropropane	0.773	1.044	3.481
	Vinyl acetate	3.6	4.9	16.2

Table D.11. (contd)

Method Name	Constituent Name	MDL, µg/L	LOD, µg/L	LOQ, µg/L
	1,1,1-Trichloroethane	0.89	1.20	4.01
	1,1,2-Trichloroethane	0.5	0.7	2.2
	1,1-Dichloroethane	1	1	4
	1,2-Dichloroethane	0.72	0.97	3.24
	1,4-Dichlorobenzene	0.92	1.24	4.14
	1-Butanol	12.6	17.0	56.7
	2-Butanone	2.1	2.8	9.4
	Acetone	9.7	13.1	43.7
	Benzene	0.84	1.13	3.78
	Carbon disulfide	0.74	1.00	3.33
	Carbon tetrachloride	0.71	0.96	3.20
	Chloroform	0.86	1.16	3.87
	Ethyl cyanide	4.8	6.5	21.6
	Hexone	1	1	4
	Methylene chloride	3.8	5.1	17.1
	Tetrachloroethene	0.92	1.24	4.14
	Tetrahydrofuran	9.8	13.2	44.1
	Toluene	0.79	1.07	3.56
	Trichloroethylene	2	3	9
	Vinyl chloride	3.4	4.6	15.3
	Xylenes (total)	0.71	0.96	3.20
	1,2-Dichloroethylene (total)	0.63	0.85	2.84
EPA-600/4-81-004, Ion chromatography	Bromide	11	15	50
	Chloride	22	30	99
	Fluoride	13	18	58
	Nitrate as N	2	3	9
	Nitrite as N	1	1	4
	Phosphate	22	30	99
	Sulfate	23	31	104

ICP = Inductively coupled-plasma (metals).
LOD = Limit of detection.
LOQ = Lime of quantitation.
MDL = Method detection limit.
VOA = Volatile organic analytes.

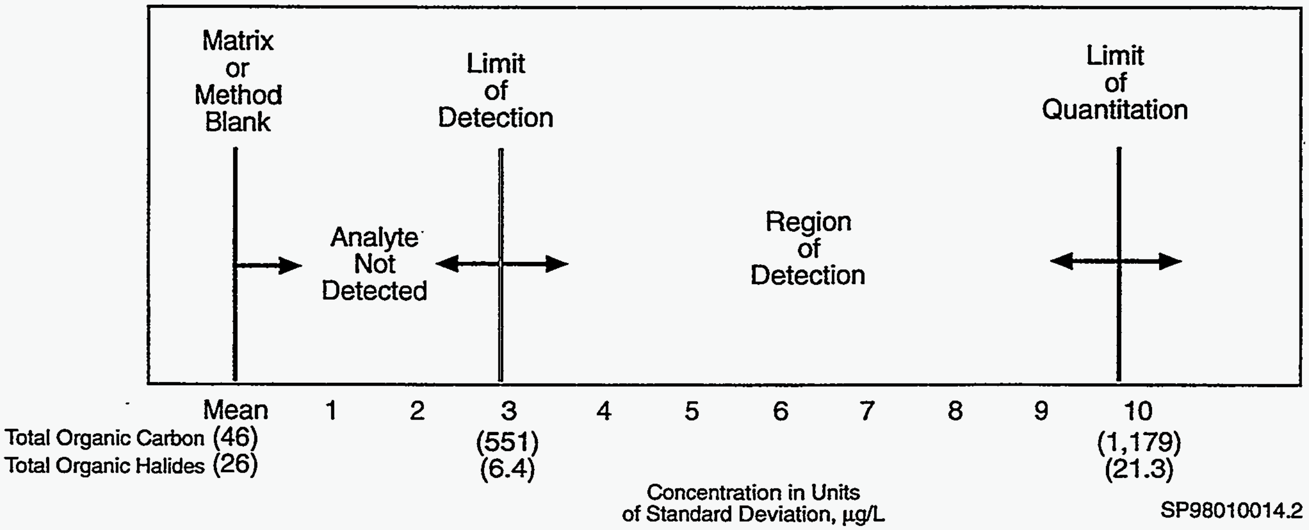

Figure D.1. Levels of Detection and Quantitation

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