

AR TARGET SHEET

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3.0 Vadose Zone

D. G. Horton

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 and future vadose zone and groundwater contamination. Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in fiscal year 1999 to better understand and alleviate the spread of subsurface contamination. This chapter summarizes major findings from these efforts, focused primarily on vadose zone soil contamination associated with reactor operations, past single-shell tank leaks, and liquid disposal to ground as a result of spent fuel processing.

An overview of the major soil column sources of groundwater contamination is provided in PNNL-13080. This section discusses vadose zone contamination that could impact groundwater in the future. Much of the evidence for continuing impact on groundwater from vadose zone contamination is discussed in Section 2.0. An overall evaluation depends, to a large degree, on a synthesis of vadose zone and groundwater monitoring and characterization data to present a comprehensive picture of contaminant fate and transport. Significant fiscal year 1999 vadose zone results are summarized here but the bulk of the data synthesis on impact to groundwater is presented and discussed in Section 2.0.

3.1 100 Areas

The Hanford Site 100 Areas are located in the northern part of the site along the Columbia River. Eight nuclear reactors were located in the 100 Areas. They operated from the mid 1940s until 1987 and were used for production of defense related nuclear material. Considerable vadose zone contamination is associated with those past-practice activities. Current decontamination and remediation activities focus on sites in the 100 Area because they are located near the Columbia River.

This section describes the significant vadose zone related activities that occurred in the 100 Areas in fiscal year 1999. These activities include soil sampling and analysis to support remediation of the 116-C-1 process effluent trench and the 1301-N and 1325-N cribs and trenches, sampling and analysis to select a waste site for initial deployment of technology for in situ reduction of hexavalent chromium, and laboratory studies to measure the distribution coefficient and leachability of chromium in sediment to support future remedial action goals and plans. This section does not discuss excavation done to remediate contaminated sites. Those efforts are described in the appropriate parts of Section 2.0.

3.1.1 Soil Remediation at 116-C-1 Trench

D. G. Horton

The 116-C-1 process effluent trench was remediated in 1997, and a test pit was dug to groundwater in early 1998 by Bechtel Hanford, Inc. Analysis of data from the pit became available in 1999 (CVP-98-00006, Rev. 0). This section summarizes the results of those analyses. For a full description of the work, see CVP-98-00006, Rev. 0.

The 116-C-1 trench is located within the 100-BC-1 Operable Unit in the 100 B/C Area of the Hanford Site (see Plate 1). The trench is 167 meters long, 32 meters wide, and 5 meters deep. The 116-C-1

site is an unlined trench that was used to dispose of 700 million liters of contaminated cooling water from the 100 B/C Area retention basins after ruptured fuel elements were detected in the reactors. The 116-C-1 trench continued to receive contaminated cooling water until reactor operations ceased in 1968. An additional 40 billion liters of high-temperature reactor cooling water was discharged to the trench during a 150-day infiltration test in 1967. That water contained 700 ppb chromium as the major contaminant. The infiltration likely influenced the distribution of contaminants beneath the site.

The most mobile contaminants at the 116-C-1 trench have been flushed through the vadose zone to groundwater as a result of infiltration testing in 1967.

The contaminants of concern at the 116-C-1 trench include americium-241; cobalt-60; cesium-137; europium-152, -154, and -155; nickel-63; plutonium-238, -239/240; strontium-90; uranium-238; total chromium; hexavalent chromium; mercury; and lead.

The remedial actions taken at the 116-C-1 trench included (1) excavating the site to the extent required to meet specified soil cleanup levels, (2) disposing of contaminated excavation materials at the Environmental Restoration Disposal Facility at the 200 Areas, and (3) backfilling the site with clean soil to adjacent grade elevations and support subsequent revegetation. As part of the remediation activities, a characterization test pit was excavated to groundwater.

The vadose zone beneath the 116-C-1 site consists of the Hanford formation and is predominantly sand and gravel with various amounts of silt and cobble-size material. The groundwater is ~12.8 meters below the surface.

The test pit was 38 by 38 meters square and was located in the southwestern third of the trench. The test pit was centered at an area of elevated activity near the trench inlet pipe. The material was removed in 1.5-meter lifts using a backhoe. Soil samples were taken from each quadrant of the test pit and composited for each of the eight lifts. Figure 3.1-1 shows a cross section of the 116-C-1 trench with the locations of the test pit and samples.

Figure 3.1-2 shows the distribution of the constituents of concern with respect to depth beneath the trench. The results were obtained using U.S. Environmental Protection Agency approved methods on the bulk sample. The figure shows that most remaining contamination in the vadose zone is within ~5 meters of the base of the remedial action excavation. More mobile contaminants, such as strontium-90, however, are slightly deeper in the soil column. The most mobile contaminants, such as hexavalent chromium, that was present at ~700 µg/L in the cooling water, have been flushed through the vadose zone to groundwater as a result of the infiltration test done on the trench after disposal of contaminated cooling water. See Section 2.2 for discussions of groundwater under the 100 C Area.

The maximum concentration of total chromium is ~10 times higher than background values. It is possible that some of the hexavalent chromium was reduced in the vadose zone to form the distribution of total chromium seen in Figure 3.1-2. Alternatively, some trivalent chromium may have been disposed to the trench.

As part of the remedial action, the RESRAD computer code (ANL 1997) was used to model the impact of residual contaminants of concern on the vadose zone, groundwater, and Columbia River. A rural residential exposure scenario was used, though future land use of the 100 Area is not yet defined (CVP-98-00006, Rev. 0). The model predicted a maximum dose rate of 8.2 mrem/yr at the present, decreasing to 0.066 mrem/yr in 1,000 years from direct exposure to the soil. The

total excess cancer risk from direct exposure to radionuclides was calculated to be the largest, 7.7×10^{-5} , at the present and decreasing to 1.8×10^{-7} in 1,000 years.

All concentrations of the non-radionuclide contaminants of concern (total chromium, hexavalent chromium, lead, and mercury) were below remedial action goals, or cleanup levels, for direct exposure to the soil. The excess cancer risk from hexavalent chromium in the overburden and the excavated zone was well below the individual and cumulative risk limits.

The estimated radionuclide dose via the groundwater and/or the Columbia River was well below the 4-mrem/yr dose rate limit. Also, the remaining concentrations of total chromium, hexavalent chromium, lead, and mercury in the soil were either less than 100 times the maximum contamination level, less than background concentration, or modeled with RESRAD to be less than remedial action goals.

Remediation of the 116-C-1 trench meets cleanup standards and the site is reclassified as closed in accordance with the Tri-Party Agreement (Ecology et al. 1989). A more complete description of the project and the results can be found in CVP-98-00006, Rev. 0.

3.1.2 Soil Sampling and Analysis at 1301-N and 1325-N Trenches

D. G. Horton

Bechtel Hanford, Inc. collected and analyzed four subsurface soil samples from test pits excavated in each of the 1301-N and 1325-N trenches in 1998. They also collected and analyzed four samples of surface soil from each of the 1301-N trench and the 1325-N crib. Plate 1 shows the locations of the facilities. Figures 3.1-3 and 3.1-4 show the sample locations. The purpose of the activity was to facilitate the remedial action design and disposal process of contaminated soil that will be excavated from the site. This section summarizes the sampling activities and the analytical results. A much more complete description can be found in BHI-01271, Rev. 0.

The 1301-N and 1325-N cribs and trenches received radioactive liquid waste containing activation and fission products as well as small quantities of corrosive liquids and laboratory chemicals generated by various N Reactor operations. Overflow from the cribs was discharged to the trenches. As the liquid waste percolated through the vadose zone soil beneath the trenches, radioactive and hazardous materials were sorbed onto the soil. Different contaminants would have migrated to different depths based on adsorption characteristics of individual constituents.

Previous investigations had shown that soil contamination was highest near the surface of the facilities and decreased dramatically with depth. The contaminants of concern were cesium-137, chromium, cobalt-60, europium-154 and -155, mercury, nitrate, plutonium-239/240, strontium-90, and tritium at both 1301-N and 1325-N.

Samples from test pits in the 1301-N and 1325-N trenches show that radionuclide concentrations drop sharply in the upper 0.6 meter of the surface or the base of the backfill.

Four samples of soil were obtained from the surface of the 1301-N trench and four from the surface of the 1325-N crib. The samples were collected in sample bottles that were attached to a telescoping painter pole. The sample bottles were lowered through hatchways in the covers of the crib and trench. The upper 50 to 75 millimeters of soil were scraped into the sample bottle and removed from the facility through the access port.

The samples from 1301-N trench were sandy silt with between 5% and 50% organic debris. The samples from the 1325-N crib ranged from semi-dry to slightly moist silt to coarse sand and silt. One sample contained ~50% pebbles; a second sample contained some animal hair and pieces of wood; and a third sample contained a piece of clay.

Figure 3.1-5 shows the results of the analyses of radionuclide concentrations in the surface samples from the 1301-N trench. Radionuclide concentrations are plotted according to their distance down the trench from the crib. Also shown on the figure are the average values of process sample data collected between 1980 and 1985 for comparison. All older data were decay corrected to January 1999. One value for plutonium-239/240, collected in 1982 at 147 meters from the crib, is not included in the calculated average because it was considered unrepresentative.

The 1999 data show that, within a factor of 10, concentrations of radionuclides are fairly constant along the length of the trench. There is a slight increase in the concentrations of all constituents in the 1999 samples obtained ~150 meters from the crib and this is mirrored for some radionuclides at 112 meters distance in the older data set. The exact locations of the older data are not known with certainty because each set of data included only nine locations, yet there are 10 access ports in the trench. BHI-01271, Rev. 0 assumed that ports 1 through 9 (the closest to the crib) were historically sampled. However, if it were assumed that ports 2 through 10 were sampled, the older data would be shifted one location farther from the crib. This would improve the match between the 1999 and the historical 150-meter sample for several isotopes.

Figure 3.1-6 shows the results of the analyses of radionuclide concentrations in the surface samples from the 1325-N crib. Radionuclide concentrations are plotted according to their position within the crib. Also shown on the figure are the average values of process sample data collected between 1985 and 1987 for comparison. The older data were decay corrected to January 1999. The 1999 data show that, within a factor of 10, concentration levels are fairly constant across the crib. Also, the 1999 values are within a factor of 10 of the average 1985 to 1987 process data.

A hydraulic excavator was used to dig one test pit in each trench. The excavator bucket was used to collect three discrete grab samples of soil at selected

depths. Also, one composite soil sample was taken at each trench by combining and homogenizing a portion of each grab sample.

The samples from the 1301-N trench were collected from depths of 0 to 0.3 meters, 0.3 to 0.6 meters, and 0.6 to 1.5 meters. The samples were from the Hanford formation and were moist, sandy gravel to gravel. The gravel content increased with depth. Samples from the 1325-N trench were obtained from depths of 0.61 to 1 meters, 1 to 1.4 meters, and 1.4 to 1.8 meters. A 0.61-meter layer of backfill was removed before collecting the shallowest sample. The Hanford formation sediment was poorly sorted sandy gravel to gravel, and the gravel content increased with depth in the 1325-N trench pit.

Field instruments were used to map the soil in each excavation bucket to locate the highest alpha and beta-gamma concentration. Samples were collected from the areas of highest concentration, placed in a clean stainless steel bowl, homogenized, and then transferred to sample bottles for transport to the laboratory.

Figure 3.1-7 shows the results of analysis of the radionuclides in samples from the pits in both trenches. The average depth of each excavation bucket is used as the sample depth. The data from 0 meter for the 1301-N trench in Figure 3.1-7 are the average values of the surface samples taken from that trench. Also, the top of the first sample from the 1325-N trench is placed at a depth of 0.6 meter because 0 meter was the top of the gravel backfill, which was removed. The data on Figure 3.1-7 show that the concentration of most radionuclides drops off rapidly with depth by a factor of 10 to 100 within the first 0.6 meter of the surface at the 1301-N trench or the base of gravel backfill at the 1325-N trench. However, the concentration of most isotopes below 0.6 meter remains substantial. See Section 2.4 for discussion of groundwater beneath the 1301-N and 1325-N facilities.

3.1.3 In Situ Gaseous Reduction Approach

*E. C. Thornton, K. J. Cantrell, J. M. Faurote,
T. J. Gilmore, K. B. Olsen, R. Schalla*

This section summarizes the fiscal year 1999 activities to identify a waste site for initial deployment of the in situ gaseous reduction approach to remediation of hexavalent chromium. A full account of the activities can be found in PNNL-13107.

In situ gaseous reduction is a technology currently being developed by the U.S. Department of Energy (DOE) for the remediation of soil waste sites contaminated with hexavalent chromium. The chemical reaction of primary interest is the reduction of hexavalent chromium to trivalent chromium, with subsequent precipitation as a non-toxic solid product. The technique involves injection of a dilute hydrogen sulfide gas mixture into the vadose zone at a hexavalent

In fiscal year 1999, investigators searched for suitable locations to test an innovative method of removing chromium from the vadose zone. The best site for initial use of the method was found to be the 183-DR facility in the 100 D Area.

chromium waste site through a central borehole (Figure 3.1-8). The gas mixture is then drawn through the waste site by vacuum applied at extraction boreholes located at the site boundary. Monitoring the breakthrough of hydrogen sulfide at the extraction wells provides a basis to assess treatment progress.

Field testing of the in situ gaseous reduction approach was demonstrated at White Sands Missile Range in 1998 by injecting 200 mg/L hydrogen sulfide into chromate-contaminated soil. Final findings indicate that 70% of the hexavalent chromium present at the site was reduced to trivalent chromium during the test.

The primary objective of the Hanford Site 1999 study was to select one or two waste sites for an initial deployment of the in situ gaseous reduction technology. Six sites were selected for screening. The selected sites were suspected to contain small but highly contaminated vadose zone plumes. As such, the chance of detecting a vadose plume was less than that for a larger plume such as those associated with retention basins or cribs.

The selected sites were the 100 C plutonium crib, the 183-DR head house and filter plant, an area near the 108-D Building, the 190-D complex, the 183-H solar evaporation basins, and the 183-KE and 183-KW chromate transfer stations. The soil samples collected at the 100 C plutonium crib were obtained from an excavation pit. Subsurface samples collected at the other sites were obtained by Geoprobe™ and cone penetrometer. In addition, surface samples were collected for analysis at several of the above sites.

One hundred eighty-three soil samples were collected and analyzed in the laboratory for hexavalent chromium by colorimetry. Also, 70 samples were collected from 7 new boreholes drilled in the 100 D Area to support in situ reduction/oxidation (redox). These samples were also analyzed for hexavalent chromium. This section summarizes the results of those analyses. A detailed description of the work will be finalized and published in fiscal year 2000 (PNNL-13107).

3.1.3.1 Summary of Characterization Activities

Characterization data collected during this study is summarized below.

100 D Well Cuttings

Bechtel Hanford, Inc. drilled 12 new groundwater monitoring wells at 100 D Area in fiscal year 1999. Pacific Northwest National Laboratory (PNNL) participated in this effort by analyzing vadose zone samples (cuttings) from seven of these wells for hexavalent chromium. The objective of this effort was to obtain information regarding sources of hexavalent chromium

contamination associated with the plume west of the DR Reactor. The wells chosen for sediment analyses were 199-D4-20 and 199-D5-38 through 199-D5-43 (Figure 3.1-9). The samples ranged from depths of 1.5 to 24 meters (top of the unconfined aquifer).

All sample analytical results were non-detections (less than 0.4 mg/kg hexavalent chromium). These negative results may be related, in part, to the locations of the wells. The wells were not drilled near the vadose zone source, which appears to be in the vicinity of the 183-DR facility (see Figure 3.1-9). However, it also appears that hexavalent chromium may be reduced during the drilling process. Reduction may be brought about by iron released during abrasion of the drill bit or by exposure of fresh ferrous iron-bearing surfaces of basalt cobbles fractured during drilling. It is concluded that future efforts to characterize the distribution of hexavalent chromium in the vadose zone by drilling should be undertaken by collecting unaltered core (e.g., split spoon) samples.

100 C Plutonium Crib

The 100 C plutonium crib (116-C-2A on Plate 1) in the 100 C Area is being remediated, primarily by excavation. Following recent excavation of surface material at this site, sediment samples were collected from the pit for analysis of hexavalent chromium. All samples were below the limits of detection for hexavalent chromium for the analytical method used. Thus, this site is eliminated from the list of candidate test sites for deployment of the in situ gaseous reduction technology.

183-DR Head House and Filter Plant

The location of the 183-DR facility is shown in Figure 3.1-9. This facility appears to be the source of hexavalent chromium present in the plume west of the site. This facility was originally used to remove suspended solid material from the cooling water and to add hexavalent chromium as a corrosion inhibitor before passing the water into the DR Reactor.

A series of Geoprobe™ holes were driven in the vicinity of the former head house and filter plant by CH2M Hanford, Inc. and PNNL staff to obtain sediment samples for analysis of hexavalent chromium. The locations of these holes are shown in Figure 3.1-10. The Geoprobe™ had difficulty obtaining samples at depths greater than ~4.6 meters, which appears to be the top of an open-framework gravel. However, some samples were collected down to 7.2 meters. Essentially no hexavalent chromium was detected in any of these samples.

A cone penetrometer, operated by Applied Research Associates, Inc., was used to obtain sediment samples at a depth of 3.9 meters near the center of the site (see Figure 3.1-10). Possible hexavalent chromium contamination was found at less than or at 0.5 mg/kg in these samples.

Groundwater monitoring data strongly suggest that the 183-DR facility was responsible for the hexavalent chromium groundwater plume present in this area. However, it appears that hexavalent chromium has migrated too deeply in the vadose zone at this site to be reached by Geoprobe™ or cone penetrometer. Vadose zone boreholes should be drilled and sediment samples analyzed to determine the vertical distribution of hexavalent chromium contamination at the 183-DR site.

108-D Site

This facility is located north of D Reactor (see Figure 3.1-9). It appears that the 108-D facility may have been the source of the hexavalent chromium groundwater plume located north of the reactor and may originally have been a chromate transfer station. Access to this site is difficult because of the presence of underground radionuclide contamination. However, a Geoprobe™ sampling location was set up a short distance to the west of a fence surrounding the area of subsurface radioactivity. Hexavalent chromium was detected at low concentrations (less than or at 1 mg/kg) in samples collected by Geoprobe™ at the site.

It is concluded that the 108-D site is not suitable for a demonstration of the in situ gaseous reduction technology because of underground radionuclide contamination, which would increase the costs and complexity of conducting a demonstration, and because of the low levels of hexavalent chromium contamination observed.

190-D Complex

This facility is located west of D Reactor. Hexavalent chromium was added to cooling water at this facility before entering the reactor, and fairly widespread contamination is present in the area. Hexavalent chromium staining of soil and concrete debris is visible in surface materials, commonly reaching levels of several hundred to greater than 1,000 mg/kg.

The locations of ten Geoprobe™ and two cone penetrometer holes at this site are shown in Figure 3.1-11. The highest value of hexavalent chromium obtained was 6.3 mg/kg from a sample collected from depths of 3 to 3.6 meters at location GPD26. This is the same location where a value of 6.96 mg/kg was reported by Bechtel Hanford, Inc. (BHI-01185, Rev. 0) from a sample collected at a depth of 4 meters. Samples from two cone penetrometer holes, which were drilled to a depth of 9.7 meters, suggest that the depth of contamination does not exceed 6.1 meters.

It is concluded that significant levels of hexavalent chromium contamination exist in the soil at the 190-D site. However, the contamination appears to be localized and restricted to shallow depths. Thus, in situ remediation probably is not a viable option at this site.

183-H Solar Evaporation Basins

The 183-H solar evaporation basins were a former waste storage facility in the 100 H Area. The basins are associated with contaminated soil and groundwater in the area. A total of four Geoprobe™ and four cone penetrometer holes (Figure 3.1-12) were driven at this site and sediment samples were collected and analyzed

for hexavalent chromium. Levels of hexavalent chromium in all samples were at or below the limits of detection (less than or at 0.4 mg/kg).

183-KE and 183-KW Chromate Transfer Stations

The 183-KE and 183-KW chromate transfer stations are located in the 100 K Area. They are sites where hexavalent chromium stock solutions were unloaded from railcars near the head house of the water treatment basins. As at 183-DR and 190-D, hexavalent chromium was added to reactor cooling water as a corrosion inhibitor. Surface soil stained by hexavalent chromium is particularly noticeable at 183-KW, where an area containing ~400 mg/kg hexavalent chromium has been identified. Chromium contamination of groundwater at 183-KE also has been monitored in the past several years.

Geoprobe™ sampling was undertaken at both 183-KE and 183-KW. Samples collected to a depth of ~2.3 meters at 183-KE did not contain detectable hexavalent chromium. Deeper sampling could not be achieved because of gravel or cobble beds. It is probable that hexavalent chromium contamination exists at depth in light of existing groundwater contamination but is apparently deeper than 3 meters. A field demonstration would be difficult to undertake at this site because the facility is still being used and access is limited because of utilities.

Hexavalent chromium was detected in sediment samples obtained from several Geoprobe™ holes at 183-KW. Geoprobe™ hole GPKW2 (Figure 3.1-13) had especially high concentrations, up to 420 mg/kg at depth of 2.6 meters. Significant hexavalent chromium concentrations were also detected in samples collected from hole GPKW3, which was driven in the area of surface soil contaminated with hexavalent chromium. A concentration of 11 mg/kg was measured in a sample collected at depths of 0.6 to 1.3 meters. Hexavalent chromium concentrations decreased to 3 mg/kg between 1.3 to 1.8 meters. Two cone penetrometer holes were also driven at 183-KW, but analysis

of samples indicated that hexavalent chromium concentrations are relatively low (less than or at 2 mg/kg).

The 183-KW site was originally considered to be a potential test site for in situ gaseous remediation because of the presence of elevated levels of hexavalent chromium in the soil and because the site has been identified for remediation. However, Geoprobe™ and cone penetrometer refusal was commonly encountered at ~3 meters, due to a gravel or cobble layer, so that no samples could be collected below that depth. In addition, contamination appears to be sporadic and may be largely found on the surface. Finally, site utilities limit access to the site.

3.1.3.2 Conclusions and Recommendations

The 190-D site has significant concentrations of hexavalent chromium in the soil (as high as 7 mg/kg). However, contamination is limited to depths shallower than 6 meters and is in localized areas. Significant concentrations of hexavalent chromium also occur in sediment at the 183-KW site, but the distribution appears to be sporadic. At the 183-KW site, the use of the Geoprobe™ and cone penetrometer was limited to shallow sampling activities because of refusal at depths of 3 meters.

The 183-DR site is judged to be the best site available for undertaking an initial deployment of the in situ gaseous reduction technology at the Hanford Site. Geoprobe™ and cone penetrometer sampling at this site were severely hampered by the presence of concrete and construction debris and fill. Nevertheless, recent groundwater monitoring data strongly indicate that a deep vadose zone source of hexavalent chromium exists at 183-DR, and several sediment samples were obtained that appear to have low concentrations of hexavalent chromium. It is recommended that several vadose zone boreholes be drilled to groundwater at 183-DR. Sediment and groundwater samples should be collected and analyzed to verify that this site is the source for the groundwater plume.

3.1.4 Bench Scale Distribution Coefficient and Leach Studies on Hexavalent Chromium in Contaminated Vadose Zone Sediment from 100 D Area

R. J. Serne and D. G. Horton

Important decisions affecting the cost and extent of remedial actions in the 100 Areas are currently based on the predictions of the very conservative computer model RESRAD. To date, the RESRAD code has used only the distribution coefficient (K_d), and not leachability, to evaluate impact to groundwater. K_d is a measure of the relative concentration of contaminant sorbed on the sediment to that dissolved in solution; the smaller the K_d , the more contaminant is in solution (groundwater). The modeling results indicate a potential impact to groundwater from contaminated vadose sediment at the 100 D Area, assuming a hexavalent chromium K_d value of zero.

Scientists performed laboratory tests in 1999 to study factors that affect the way chromium moves through the vadose zone. Preliminary results suggest that relatively insoluble forms of chromium may be present.

Use of the distribution coefficient assumes that hexavalent chromium is adsorbed on exchange sites of minerals in the sediment. Alternatively, hexavalent chromium, in 100 D Area contaminated sediment, may be present as an insoluble precipitate. Batch and flow-through leach tests are appropriate to evaluate this alternative. The results of leach tests combine the effects of desorption and dissolution. Currently, results of leach tests for hexavalent chromium in sediment are not as readily available in the literature as are K_d results, and chromium leach tests have not been performed on Hanford Site sediment.

The rate of hexavalent chromium movement through the vadose zone to groundwater will depend on which mechanism, desorption or dissolution, releases

hexavalent chromium to pore water. Therefore, experiments were done in 1999 to measure both the leach rate and K_d of hexavalent chromium using sediment samples from the 100 D Area. The RESRAD computer model can evaluate hexavalent chromium impact on groundwater using leachability parameters, which represent combined dissolution and desorption effects. Implementing the results of the 1999 experiments will provide a more accurate picture of actual potential impact to groundwater and support future remedial action cleanup goals and planning.

3.1.4.1 Samples and Methods

The 116-D-7 retention basin site, located north of the 100-DR-1 Operable Unit, was selected as the field area to obtain samples for K_d and leachability tests. Both contaminated and uncontaminated samples were obtained for use in the bench-scale testing. The primary objectives of the bench-scale tests were to estimate K_d and leach rates for hexavalent chromium specific to the Hanford formation sediment in the 100 Areas.

Batch adsorption tests were run using 50 grams of oven dry Hanford formation sediment and 200 milliliters of Hanford Site groundwater spiked with hexavalent chromium. Three different spike levels, 0.1, 1.0, and 10 mg/L of hexavalent chromium (as sodium dichromate) were used. Triplicate container blanks, consisting of spiked groundwater without sediment, were analyzed to account for hexavalent chromium stability in groundwater and container adsorption of hexavalent chromium. Triplicate sediment blanks, consisting of uncontaminated Hanford formation sediment and deionized water, were analyzed to determine whether native chromium was leached from the sediment. Tests were run in triplicate for contact times of 4 and 14 days.

In addition, one leach test was performed using contaminated Hanford formation sediment from the 100 D Area. The test was done by packing a vertical column with a measured amount (weight and volume) of sediment and allowing a source of water to flow through the column at a constant rate for 43 days.

Hexavalent chromium was measured by colorimetry in solutions from the batch tests and by both colorimetry and inductive coupled plasma/mass spectrometry in column leach tests.

3.1.4.2 Results

The results of the K_d batch experiments are shown in Tables 3.1-1 and 3.1-2. The conclusion from the tests is that there is no significant hexavalent chromium adsorption onto the Hanford formation sediment. The average K_d for hexavalent chromium from the most dilute concentration tests after both 4 and 14 days of contact is 0.2 ± 0.1 mL/g. The K_d was found to be 0 at higher hexavalent chromium concentrations. The very low K_d measured from the smallest hexavalent chromium concentrations may well be an artifact of (1) the use of batch tests for very low sorbing constituents combined with (2) testing very near the detection limit for the analytical method used.

The results of the column leach test are shown in Figure 3.1-14. The results show that typical Hanford Site groundwater does not readily leach chromium bound to the Hanford formation sediment. After 43 days, less than 1% of the chromium present in the sediment was removed by ~12 pore volumes of solution. The 12 pore volumes represent the total amount of water that would flush through the vadose zone for a scenario with 15 centimeters of rainfall and 0.76 meter of irrigation per year.

A direct mass balance measurement of the hexavalent chromium in the sediment before leaching and after 43 days of leaching showed no measurable loss of hexavalent chromium from the sediment; within the analytical error both the pre- and post-leached sediment samples gave the same result. This corroborates the leachate solution analyses that found less than 1% of the hexavalent chromium was removed from the sediment.

Additional batch water leach tests, using contaminated sediment, showed that less than 1% of the

hexavalent chromium was leached after 16 hours of vigorous shaking. The exact amount removed varied from 0.04% to 0.71% depending on which analytical technique was used to measure chromium.

3.1.4.3 Conclusion

The findings of this study suggest that there is very little soluble chromium in the vadose zone sediments of the 100 D Area. This is contrary to the existence of high chromium concentrations in groundwater from some 100 D locations. The apparent incongruity may be an artifact of sampling (i.e., samples were collected outside areas of chromium contamination) or may represent some, as yet, unidentified geochemical process.

All solutions generated by mixing the contaminated sediment with uncontaminated Hanford Site groundwater resulted in hexavalent chromium concentrations between 0.002 to 0.05 mg/L. Also, the column effluents reached a steady state chromium concentration of either 0.003 or <0.01 mg/L depending on the analytical technique. These data suggest that a hexavalent chromium-bearing precipitate that is very insoluble in Hanford Site groundwater may be present in the sediment. Alternatively, the chromium in the sediment may be trivalent chromium that slowly oxidizes when leached with water. Therefore, the resulting leachate would contain very small concentrations of oxidized chromium as hexavalent chromium.

If hexavalent chromium in solution is controlled by slow oxidation of sediment containing trivalent chromium, then more kinetic testing is needed. More kinetic testing would allow extrapolation of the short-term laboratory leach data to the longer time spans to reflect natural dissolution of chromium from Hanford formation sediment in the 100 Areas. More column leach tests need to be performed using contaminated sediment with higher hexavalent chromium levels and at several flow rates slower than those used for the irrigation scenario in this work.

Table 3.1-1. Average 4-Day Contact Time K_d and Standard Deviation for Hexavalent Chromium (Cr[VI]) and Total Chromium Adsorption

Cr(VI) Concentration (mg/L)	K_d for Cr(VI) (mL/g)	Standard Deviation (mL/g)	K_d for Total Cr (mL/g)	Standard Deviation (mL/g)
0.1	0.3	0.1	0.0	0.3
1.0	0.0	0.0	0.2	0.3
10.0	0.0	0.05	0.3	0.3

Table 3.1-2. Average 14-Day Contact Time K_d and Standard Deviation for Hexavalent Chromium (Cr[VI]) and Total Chromium Adsorption

Cr(VI) Concentration (mg/L)	K_d for Cr(VI) (mL/g)	Standard Deviation (mL/g)	K_d for Total Cr (mL/g)	Standard Deviation (mL/g)
0.1	0.2	0.1	0.0	0.1
1.0	0.0	0.0	0.1	0.1
10.0	0.0	0.0	-0.2	0.1

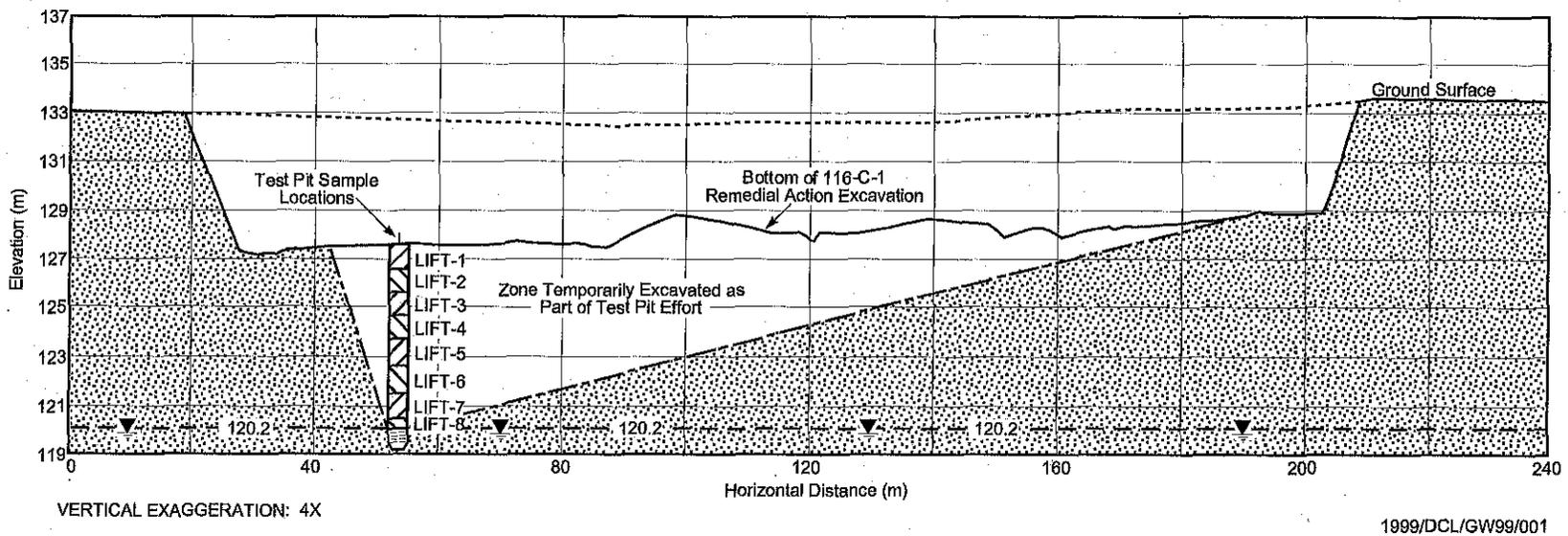


Figure 3.1-1. Cross Section of the 116-C-1 Trench Showing Location of the Test Pit and Distribution of Samples (adapted from CVP-98-00006, Rev. 0)

圖 3.14

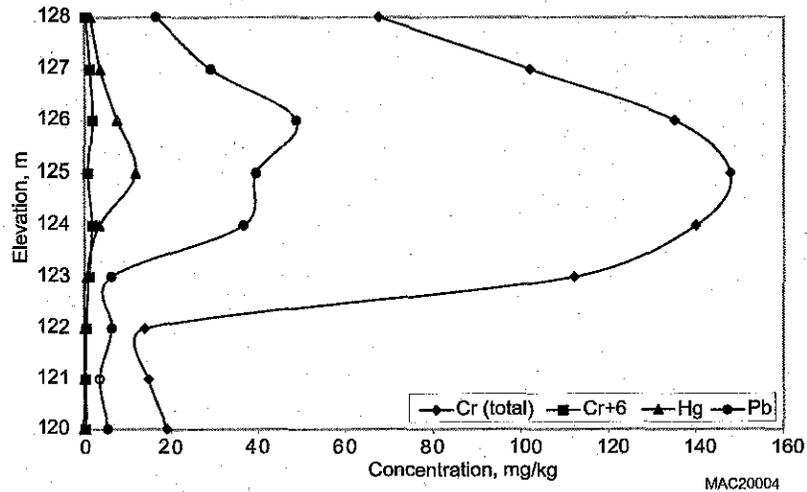
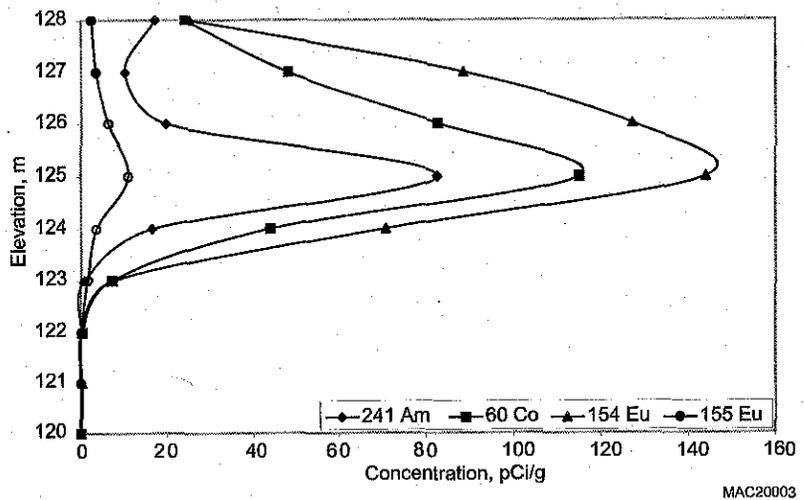
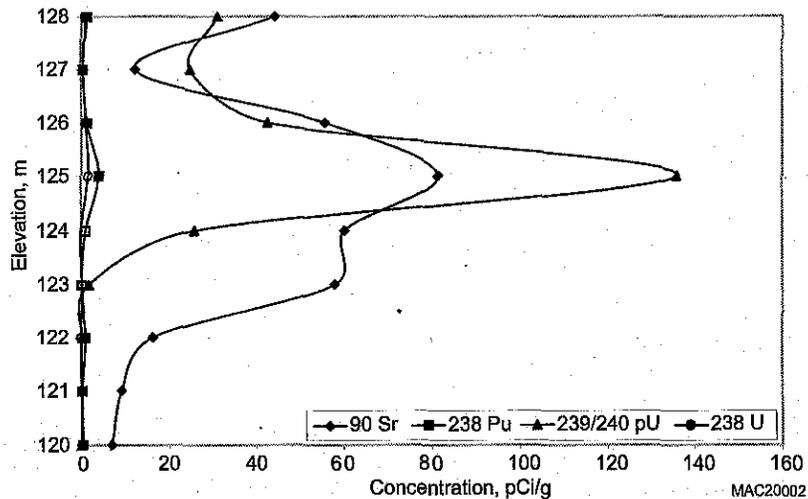
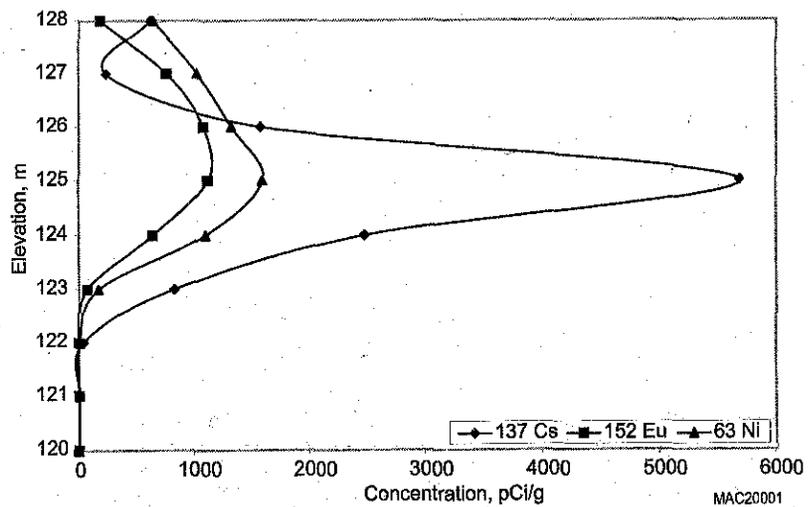


Figure 3.1-2. Analytical Results versus Depth for Selected Constituents in the 116-C-1 Trench Test Pit (adapted from CVP-98-00006, Rev. 0).
Open circles indicate values less than laboratory detection limit.

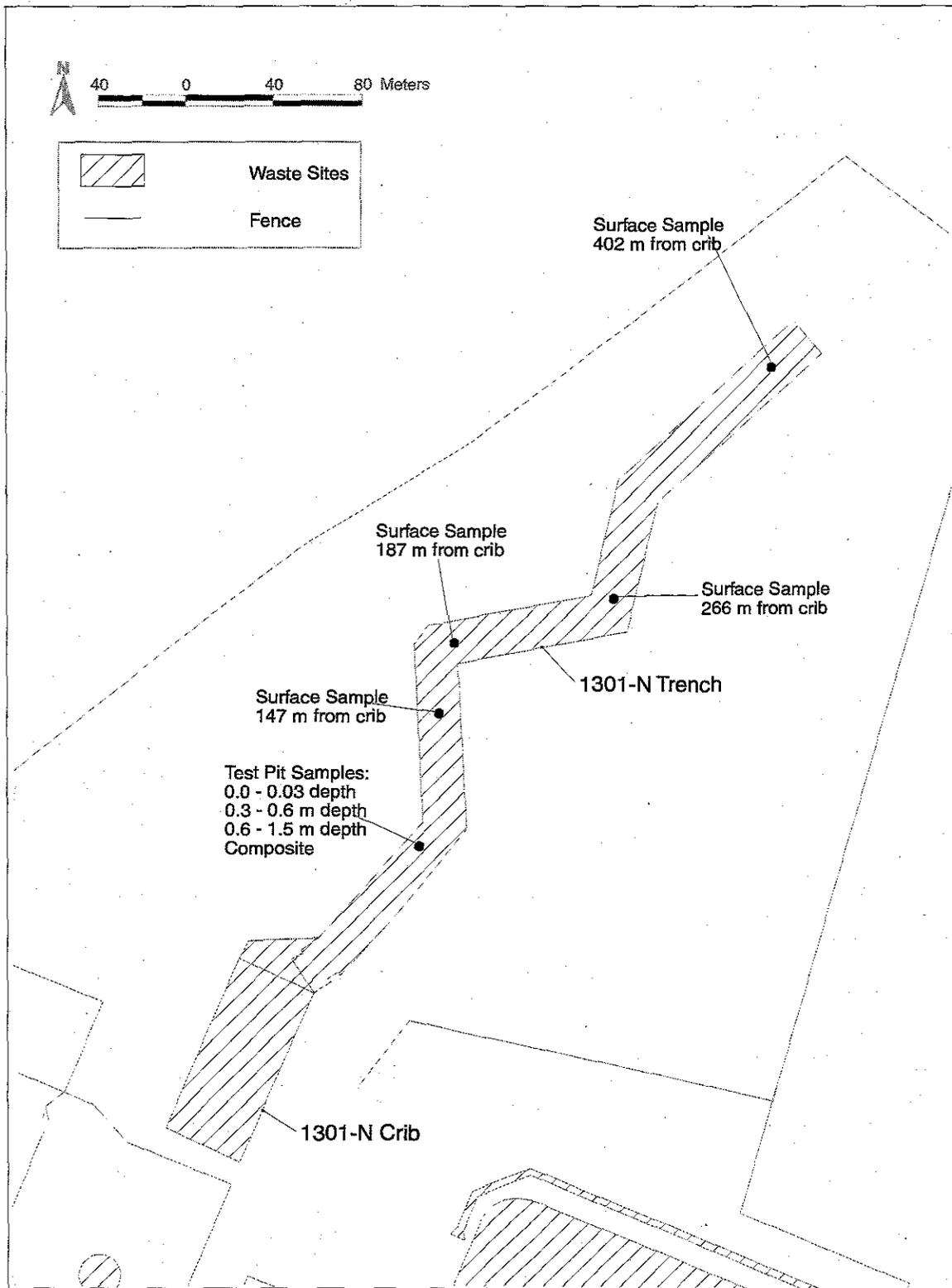


Figure 3.1-3. Map of the 1301-N Crib and Trench Showing the Locations of Samples Collected (adapted from BHI-01271, Rev. 0)

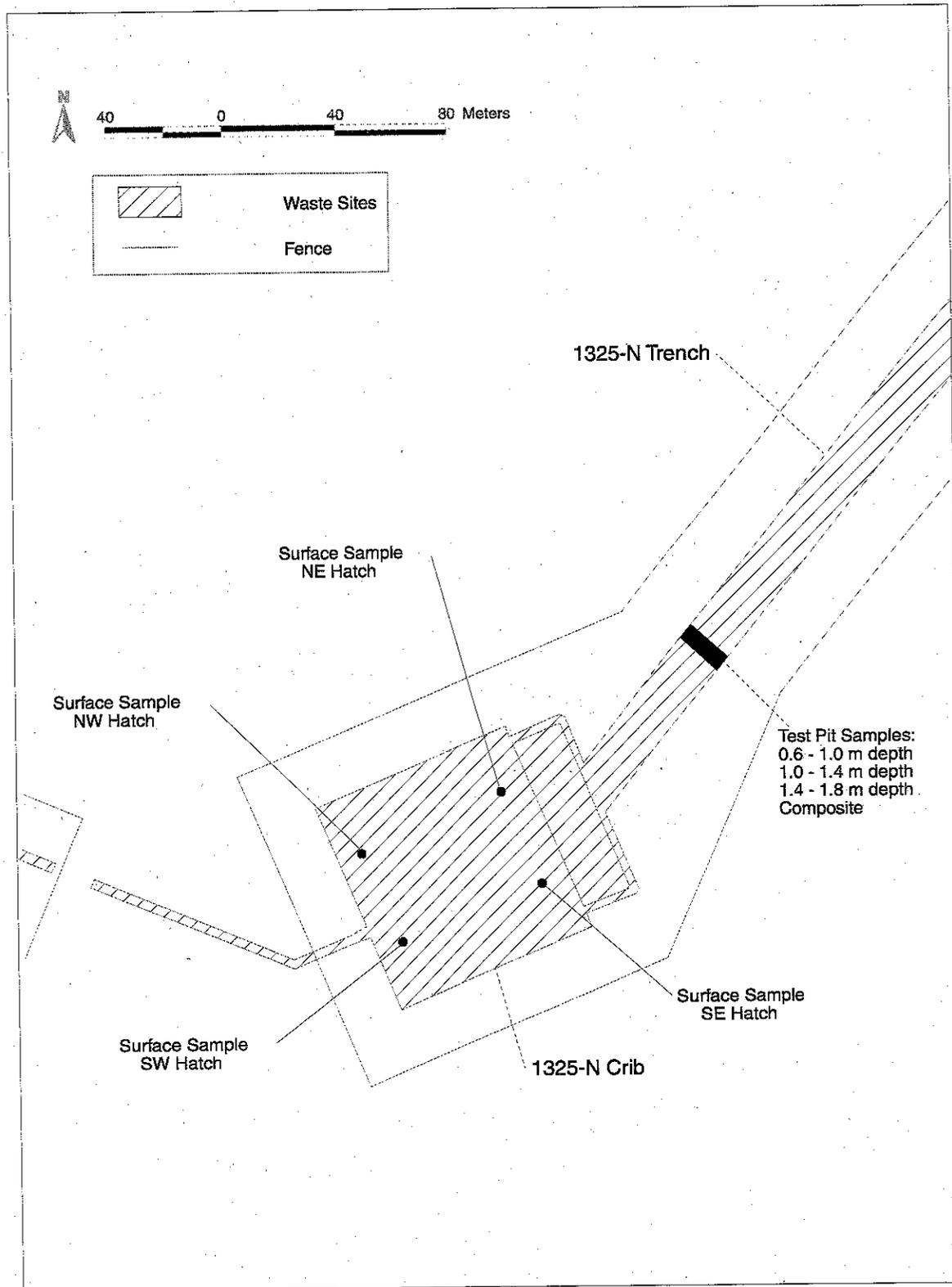


Figure 3.1-4. Map of the 1325-N Crib and Trench Showing the Locations of Samples Collected (adapted from BHL-01271, Rev. 0)

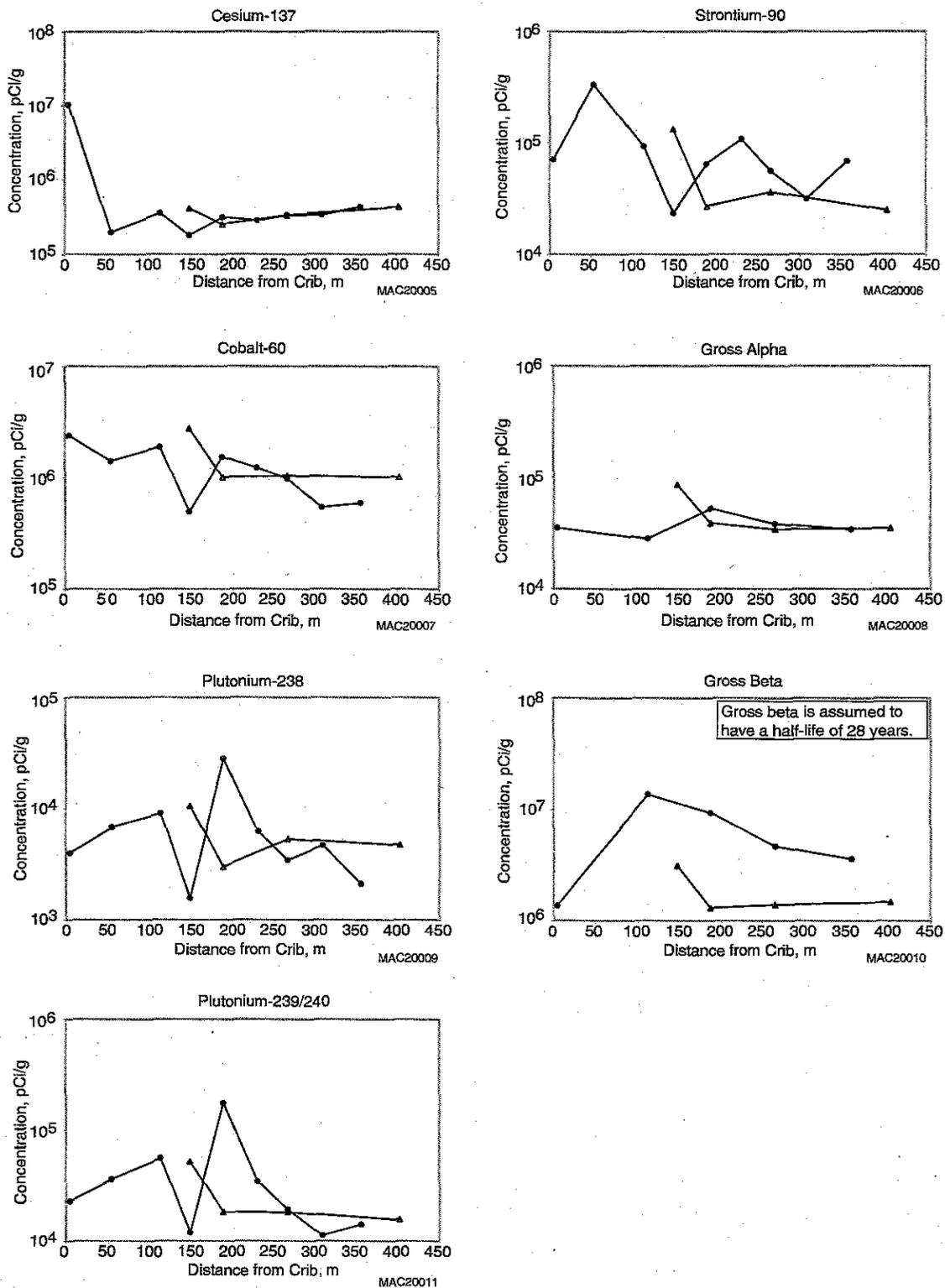


Figure 3.1-5. Concentration versus Distance from the 1301-N Crib for Selected Analytes in Samples from the 1301-N Trench. Triangles are 1999 data; circles are averaged 1980 to 1985 process data. Process data are decay corrected to January 1999 (adapted from BHL-01271, Rev. 0).

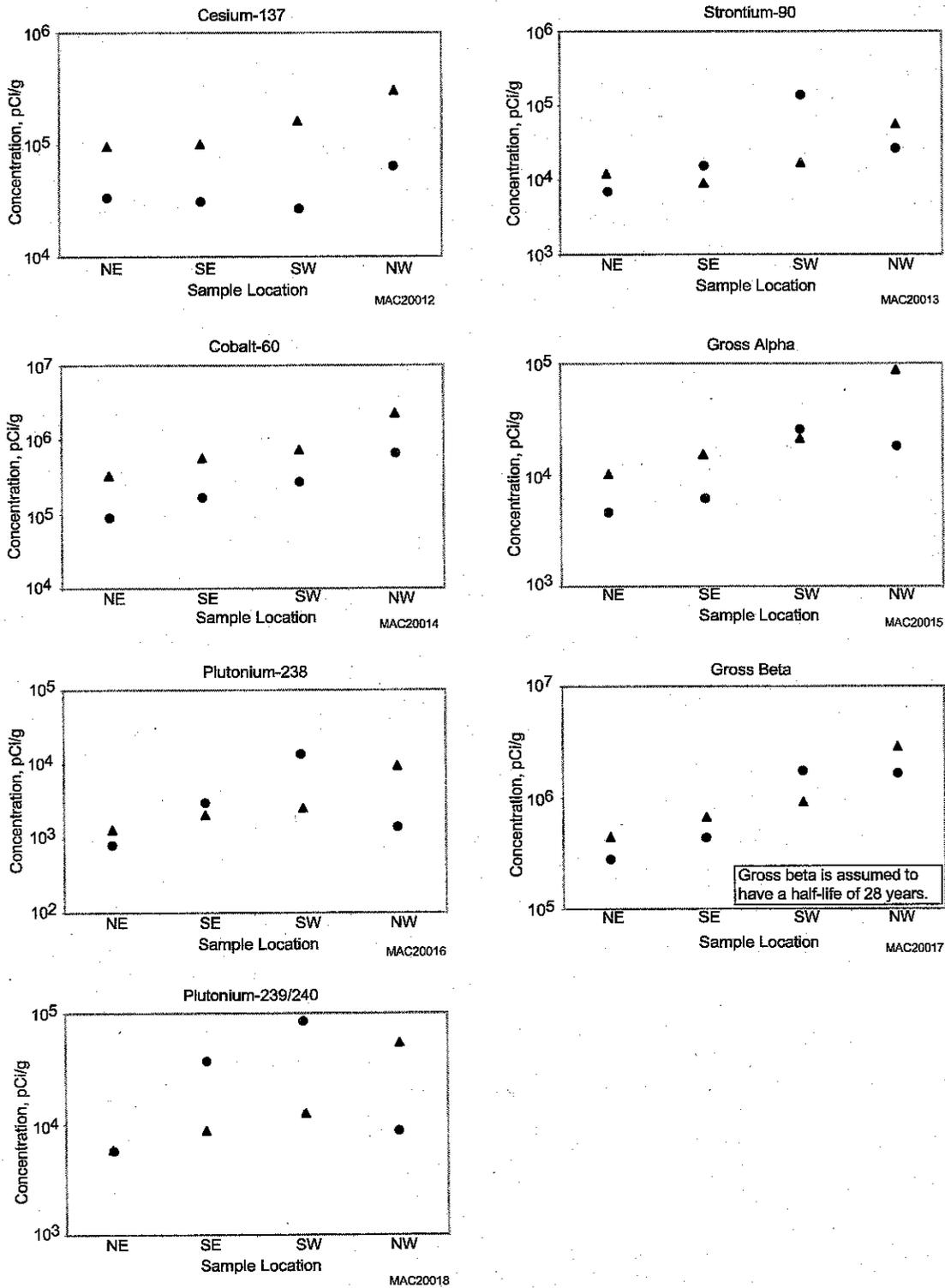


Figure 3.1-6. Concentration of Selected Analytes in Surface Samples from the 1325-N Crib (NE, SE, SW, and NW refer to the northeastern, southeastern, southwestern, and northwestern access hatches; see Figure 3.1-4). Triangles are 1999 data; circles are averaged 1985 to 1987 process data. Process data are decay corrected to January 1999 (adapted from BHI-01271, Rev. 0).

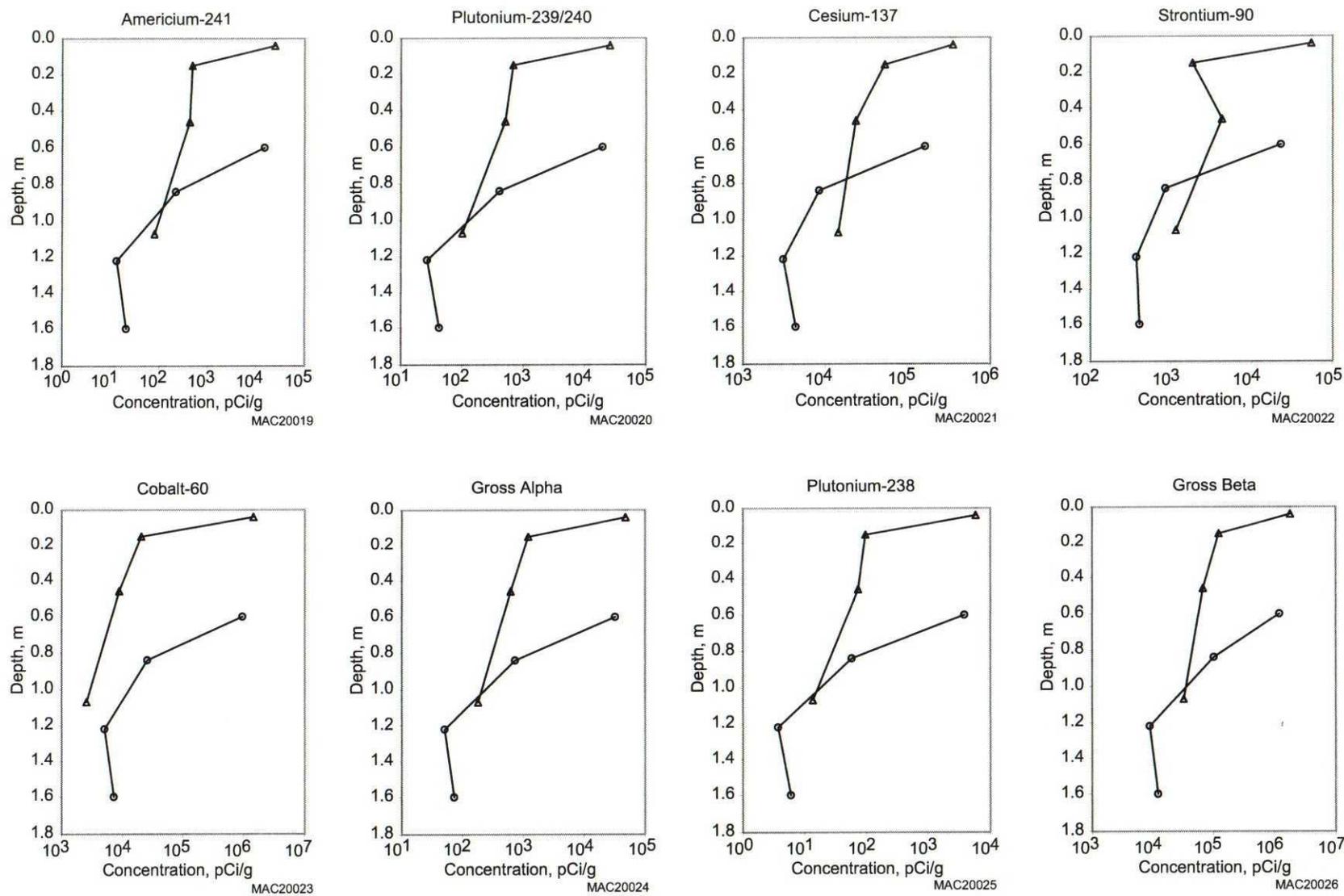


Figure 3.1-7. Activity versus Depth for Selected Analytes in Test Pit Samples from the 1301-N and 1325-N Trenches. Triangles are data from the 1301-N test pit; circles are data from the 1325-N test pit (adapted from BHI-01271, Rev. 0).

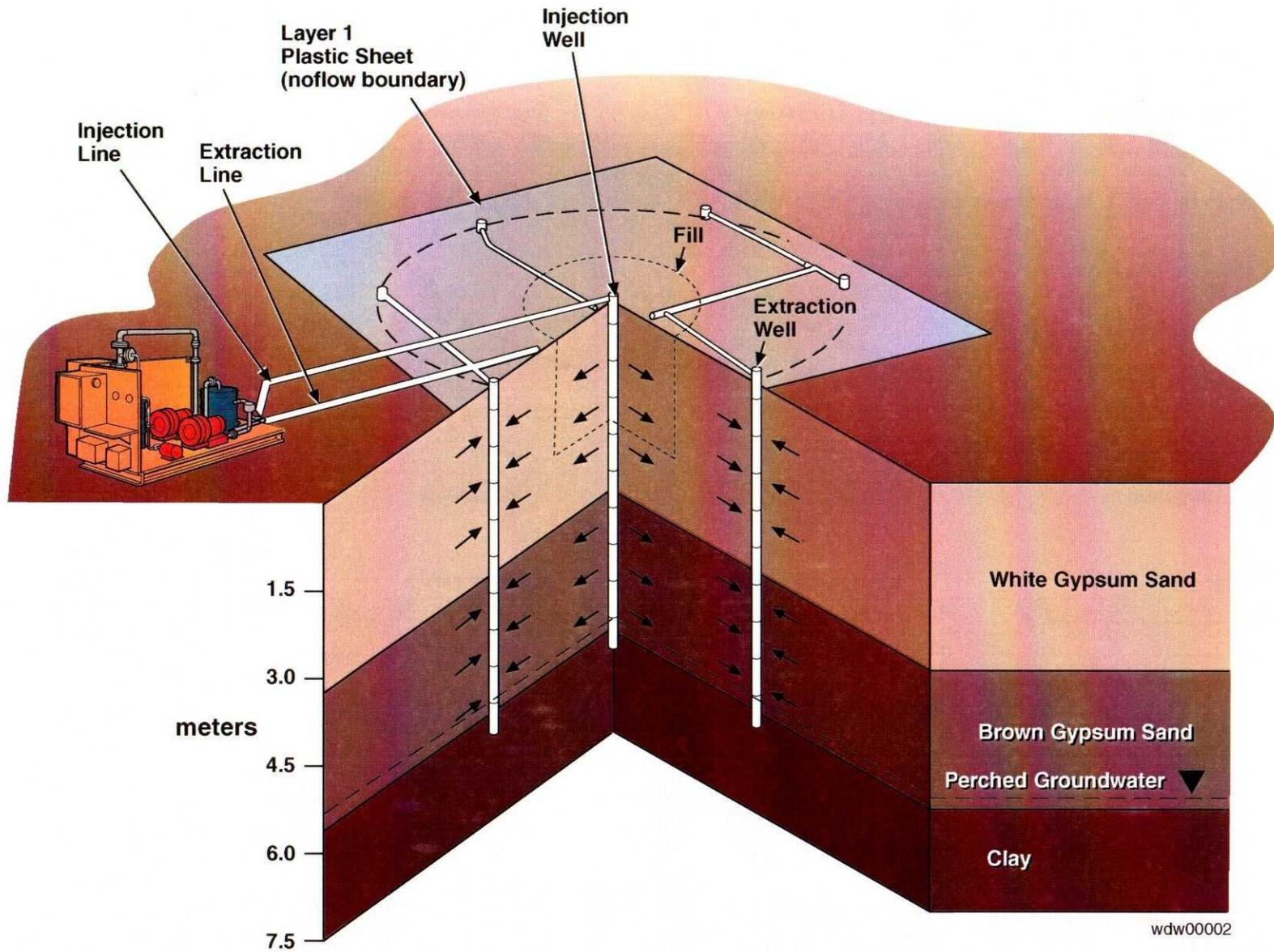
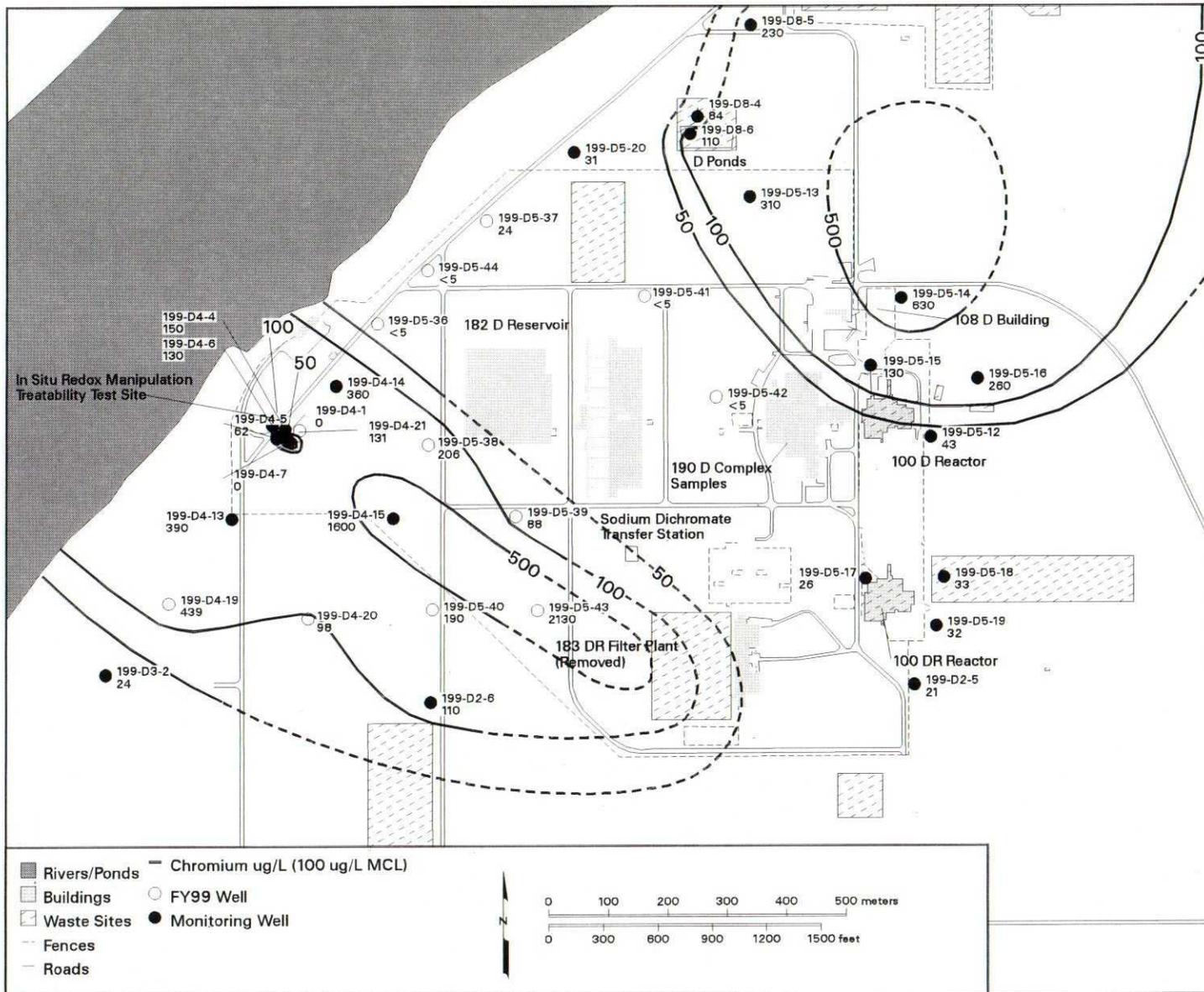


Figure 3.1-8. In Situ Gaseous Reduction System and Well Field Network



can_thor_99006 December 28, 1999 4:41 PM

Figure 3.1-9. Facilities, Wells, and Hexavalent Chromium Groundwater Plumes in 100 D Area

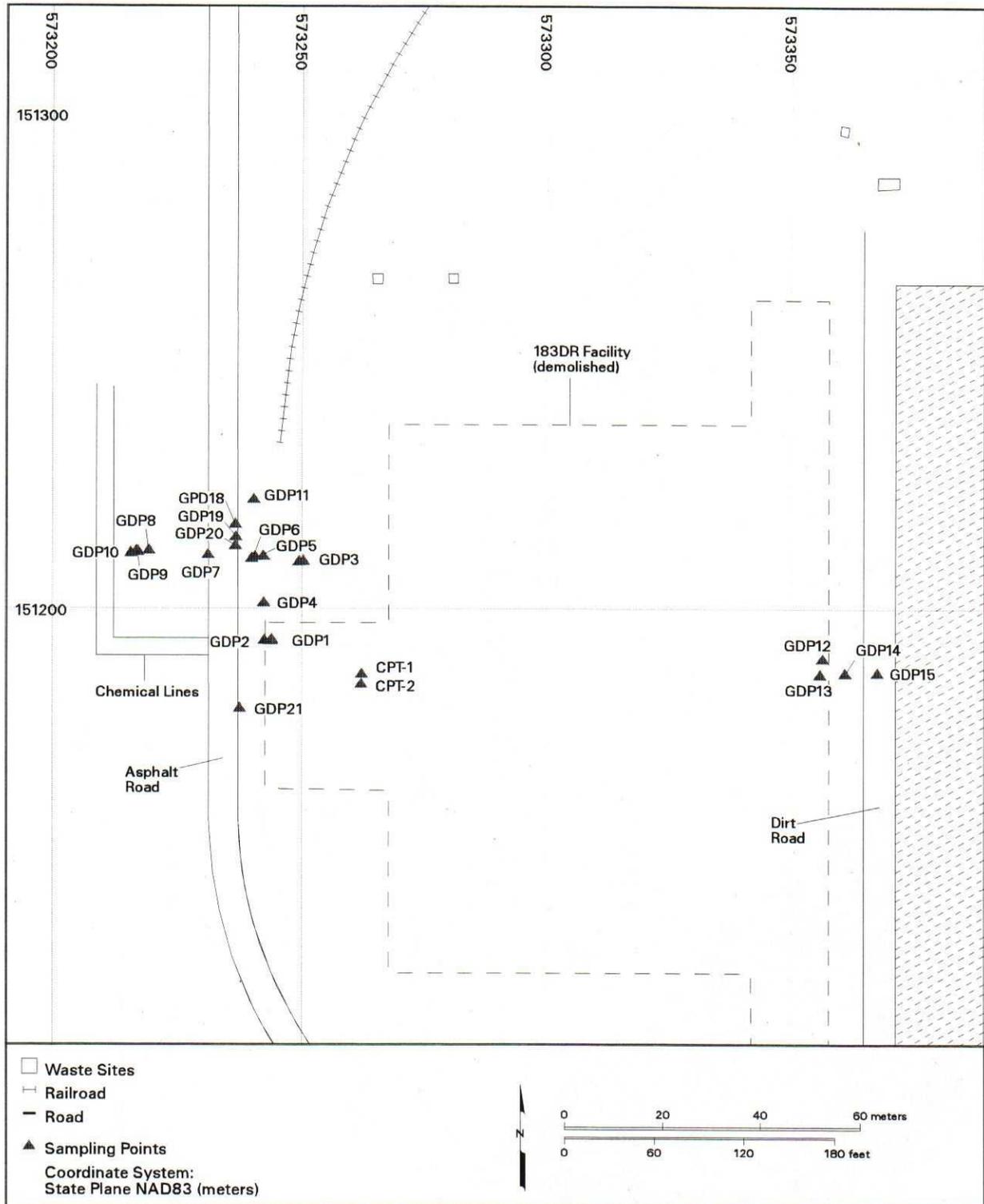
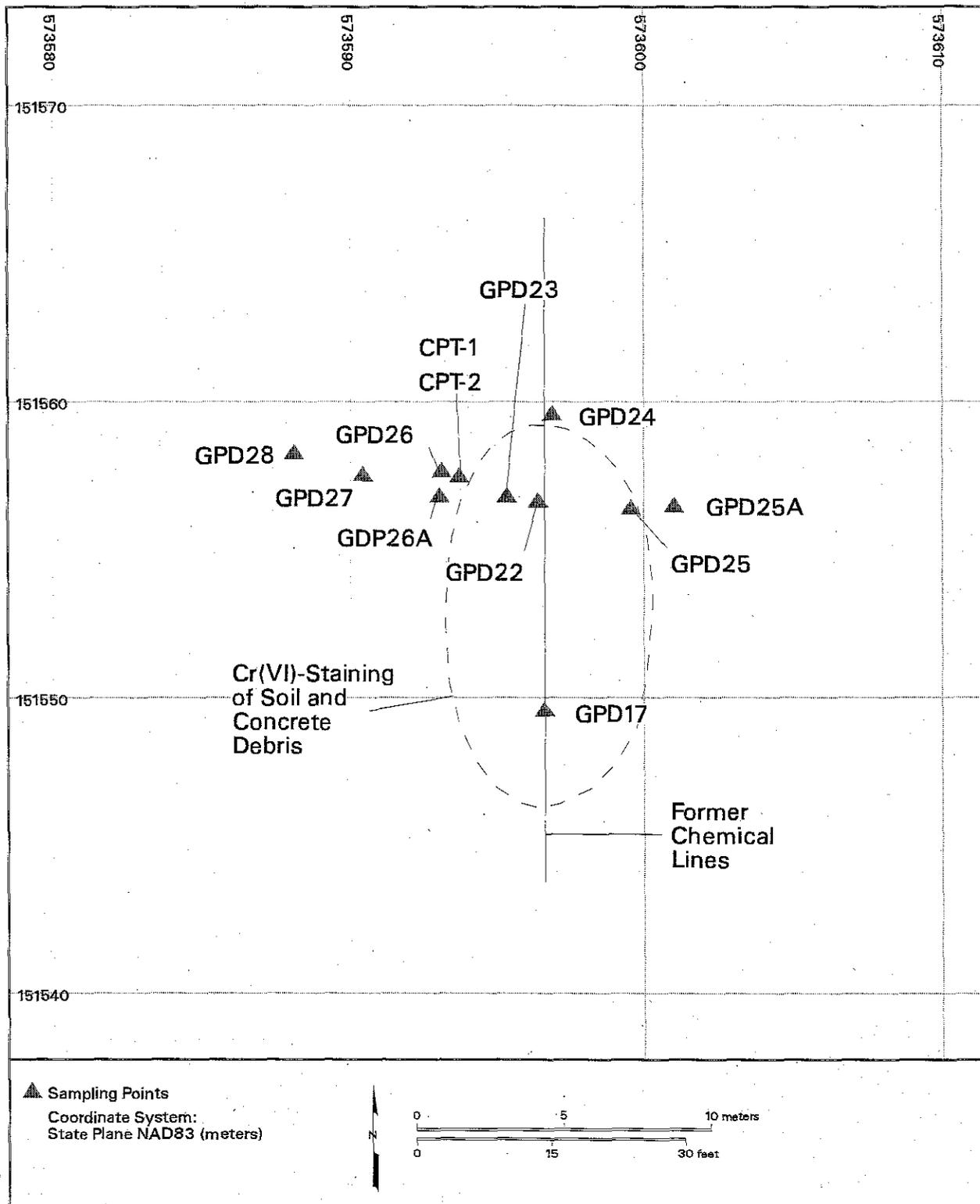
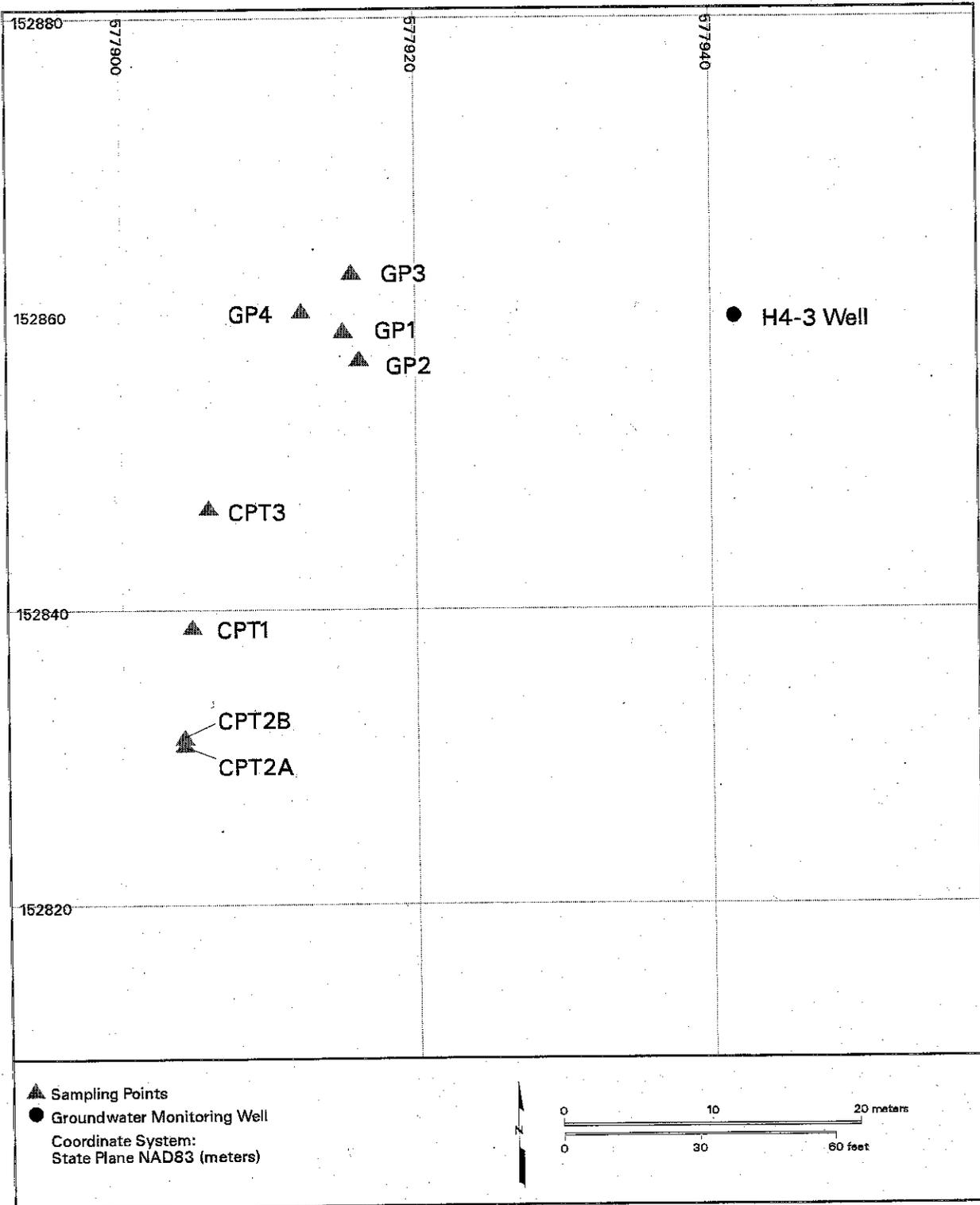


Figure 3.1-10. Map of Sample Locations at the 183-DR Head House and Filter Plant Site. Sample locations beginning with GP are Geoprobe™ sites; locations beginning with CPT are cone penetrometer sites.



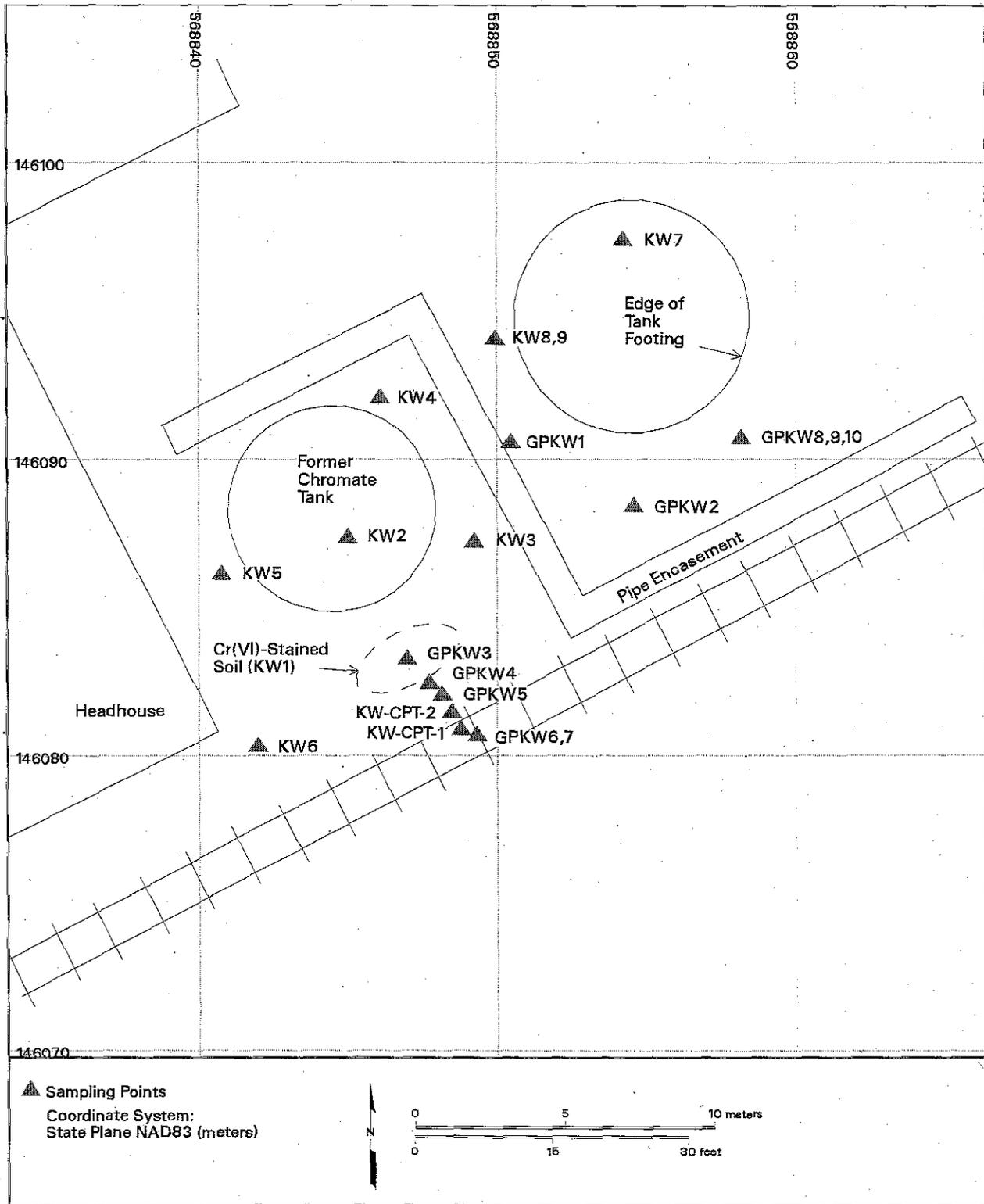
can_thor_99001 December 09, 1999 6:22 PM

Figure 3.1-11. Map of Sample Locations at the 190-D Complex. Sample locations beginning with GP are Geoprobe™ sites; locations beginning with CPT are cone penetrometer sites.



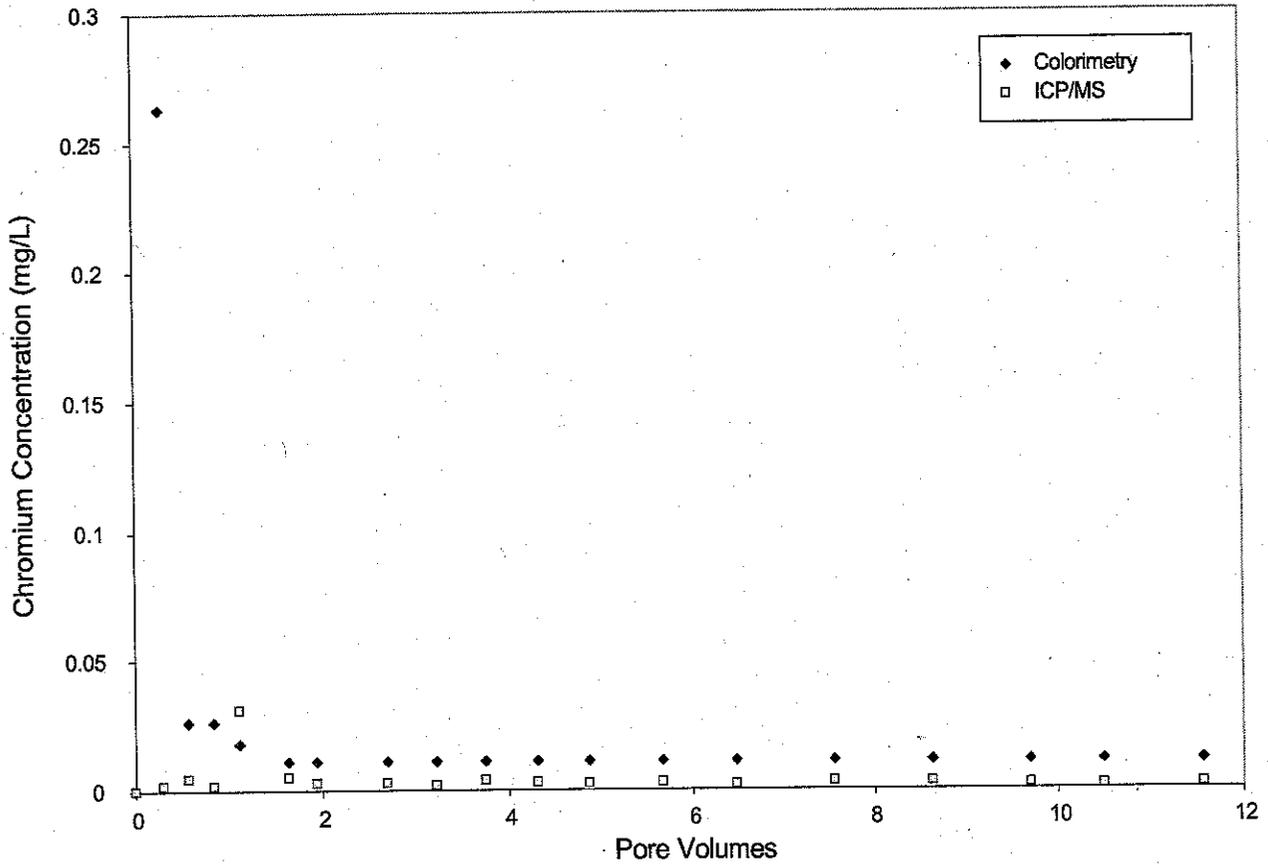
can_thor_99003 December 09, 1999 5:43 PM

Figure 3.1-12. Map of Sample Locations at the 183-H Solar Evaporation Basins (see Plate 1 for location of well H4-3). Sample locations beginning with GP are Geoprobe™ sites; locations beginning with CPT are cone penetrometer sites.



can_thor_99004 December 09, 1998 6:10 PM

Figure 3.1-13. Map of Sample Locations at the 183-KW Chromate Transfer Station. GP indicates Geoprobe™ samples, CPT indicates cone penetrometer samples, and KW indicates surface soil samples.



wdw99005

Figure 3.1-14. Effluent Hexavalent Chromium Concentrations (mg/L) versus Pore Volumes for Leach Test Samples

3.2 200 Areas

The Hanford Site 200 Areas are located in the central part of the site. Weapons grade plutonium was extracted from irradiated fuel at these locations. These areas are the location of the most significant vadose zone contamination at the Hanford Site.

This section presents the results of the characterization, monitoring, and remediation activities accomplished in the 200 Areas in fiscal year 1999.

3.2.1 200 Areas Characterization Activities

Several vadose zone characterization activities were undertaken at the 200 Areas in fiscal year 1999. At the SX Tank Farm, samples were collected and characterized from the decommissioning of one borehole drilled to characterize deep vadose zone contamination and from a second, new borehole adjacent to tank SX-115. Also, in SX Tank Farm, preliminary temperature and neutron capture borehole logging was accomplished. During 1999, baseline spectral gamma-ray logging at two single-shell tank farms (T and B) was completed and logging of the highest count rate zones at the tank farm was initiated.

Additional characterization activities were begun in 1999 at Gable Mountain Pond, 216-B-3 pond, 216-S-10 pond, and 216-B2-2 ditch, where test pits were dug and sampled and/or boreholes drilled and sampled. The results of these activities will be presented in calendar year 2000.

3.2.1.1 Decommissioning of Borehole 41-09-39 at the SX Tank Farm

R. J. Serne, D. G. Horton, D. A. Myers

Borehole 41-09-39 is located adjacent to single-shell tank SX-109 in the SX Tank Farm in the Hanford Site's 200 West Area. This borehole was originally constructed in 1996 by driving a closed end casing to a depth of 40 meters. The primary purpose of the

borehole was to determine the presence of cesium-137 at depths of 24 to 40 meters below ground surface. The borehole was then deepened in 1997 by milling out the end of the initial 18-centimeter casing and extending the bore using the percussion drilling method, while collecting near continuous soil samples. The borehole was temporarily finished as a monitoring well to allow collection of groundwater samples and ultimately for injecting sodium-bromide as a tracer to assess groundwater movement beneath the tank farm.

In fiscal year 1999, sediment samples were collected from a borehole in the SX Tank Farm. Results from a depth of 18 to 25 meters showed the highest levels of cesium-137 found under leaking tanks in the past 35 years.

In fiscal year 1999, the borehole was decommissioned to eliminate it as a potential pathway for contaminants to readily reach the groundwater. As part of the decommissioning effort, samples of the previously unsampled portion of the hole were collected and submitted for chemical and radiological analysis. After complete removal of the inner 10-centimeter-diameter casing, the outer 18-centimeter casing was hydraulically jacked out of the ground in stages. Side-wall samples were collected below the casing at prescribed depths. After complete removal of both casings, the borehole was filled with bentonite and grout.

Based on drilling records and geophysical logs, 16 sampling horizons were selected. These horizons were sampled using side-wall sampling techniques, with three aliquots of soil collected from each horizon. Details on the sampling and analysis data qualitative objective process and the sampling and analysis plans are found in HNF-4380, Rev. 1. Discussions of groundwater beneath the SX Tank Farm are in Section 2.8.

Either two or three aliquots of fifteen of the sixteen selected horizons were successfully sampled. One of the aliquots obtained at 19.8 to 20.1 meters was ten times more radioactive than the other two aliquots from this depth, so the highly radioactive aliquot was kept separate. All aliquots from each depth interval, except those from 19.8 to 20.1 meters, were mixed together to form one composite sample for each depth.

Analytical results show that the sediment has very high concentrations of cesium-137 and represents the most radioactive materials obtained from under leaking tanks in the past 35 years. Table 3.2-1 lists the descriptive lithology and the results of measurements made directly on the sediment. There appears to be some correlation between the particle size of the sediment and the cesium-137 content between depths of 18.3 and 33.2 meters; the finer grained the sediment, the higher the cesium-137 concentration. The region between depths of 18.3 and 25.3 meters has the highest concentration of cesium-137. A smaller region with high cesium-137 concentration exists between depths of 31.1 and 33.2 meters.

Several of the samples obtained from borehole 41-09-39 contained insufficient pore water to obtain a sample large enough for chemical analyses. A water extract, using 1 part water to 1 part dry sediment, was done on those samples to obtain sufficient leachate for analysis. The water extract gives an indication of which contaminants are readily leached and, therefore, fairly mobile. Table 3.2-2 lists the analytical results of water extracts from the sediment.

The data in Table 3.2-2 show large amounts of water leachable chromium (presumably hexavalent chromium, chromate), nitrate, sodium and technetium-99 in the sediment. Some selenium and cesium-137 were also leached from some samples in concentrations greater than background concentrations. (See DOE/RL-92-24, Rev. 3 and DOE/RL-96-12, Rev. 0 for background values.) Data for other anions (chloride, nitrite, sulfate, and phosphate) and other cations (arsenic, barium, cadmium, lead, molybdenum, silver, and uranium) are available from Pacific Northwest National Laboratory. Analyses of other major

cations (aluminum, calcium, iron, magnesium, manganese, and potassium) will be available in fiscal year 2000. The pH of the water extract is elevated slightly above natural pH values of 8.0 to 8.5 for samples from 18.6 to 25.3 meters below ground surface. The original tank liquor had pH values above 14 and free hydroxide concentrations perhaps as large as 1 M or higher. The water extract pH values show that the sediment has substantially buffered the pH of leaked fluids.

Analytical results of a strong acid (8 M nitric acid) leach of the sediment samples are shown in Table 3.2-3. These results approximate the total amount of contaminant in the sediment that would be environmentally available per U.S. Environmental Protection Agency suggestions in SW-846. The data in Table 3.2-3 show that greater than background levels of chromium, molybdenum, selenium, and technetium-99 are leached from the sediment. Concentrations of americium-241, neptunium-237, plutonium-239, and strontium-90 do not appear to be present in the sediment at levels above 1 pCi/g. Analytical results for aluminum, arsenic, barium, cadmium, copper, iron, lead, manganese, silicon, silver, and strontium will be documented in fiscal year 2000. Except for aluminum and iron, preliminary results for these metals show no concentration versus depth trends to suggest there is a major source of contamination in the vadose zone. Concentrations of aluminum and iron may be slightly elevated in samples from shallower depths where cesium-137, chromium, nitrate, and sodium are definitely present.

Table 3.2-4 shows the percent of cesium-137 that was leached from the sediment by the water extract compared to the total cesium-137 present in the sediment. The table also shows the percentages of chromium and technetium-99 that were leached by water compared to the amounts leached by the strong acid extract. The latter is an approximation of the total technetium-99 and chromium in the sediment.

Very little cesium-137 was leached by the water extract, indicating that most cesium-137 in the sediment from borehole 41-09-39 is not soluble and is bound to the sediment. Conversely, significant percentages of the chromium and technetium-99 were

leached by the water extract. These data can be used to estimate in situ distribution coefficients (K_d) for each chemical in each sediment sample. The calculated K_d s are shown in Table 3.2-5.

The K_d s in Table 3.2-5 are based on analysis of one aliquot of sediment from each depth being used for the water leach test and a second aliquot used for the acid leach test. In Table 3.2-5, any inhomogeneities in contaminant distribution that may have existed in the sediment are magnified due to the way that K_d s are calculated. Note, however, that none of the acid leached samples contained less mass than the water extracted samples for the two mobile contaminants, technetium-99 and chromium. This suggests that gross inhomogeneities were absent in the samples. The reason for the large variation in cesium-137 K_d values is unknown and will require further work.

The apparent large in situ K_d values for technetium-99, and perhaps chromium, in selected samples merit additional testing or more detailed investigations on the molecular scale to determine whether the sediment contains adsorbed or co-precipitated technetium-99 and chromium. The chromium K_d values for some of the samples that did not contain elevated total chromium concentrations represent native trivalent chromium in the sediment. The K_d values for the samples from 7.6 meters, 13.4 meters, 17.1 meters, and the 38.8 meters, in Table 3.2-5 may represent immobile native trivalent chromium. Large in situ K_d values for chromium in samples from other depths are unexplained at this time. More detailed geochemistry studies on borehole 41-09-39 sediment will be done in fiscal year 2000, and a final report of all results will be issued.

3.2.1.2 New Vadose Zone Borehole at Single-Shell Tank SX-115

D. A. Myers

The River Protection Project's Vadose Zone Project completed a characterization borehole (299-W23-19) in the SX Tank Farm adjacent to tank SX-115. This tank was selected for investigation because it is the source of the largest measured leak in the SX Tank

Farm. This tank had a measured loss of 189,000 liters during a sodium nitrate retrieval effort in the mid-1960s; this volume contained a significant amount of technetium-99. Groundwater monitoring wells to the southeast of the tank were some of the first to show increased technetium-99 concentrations at this *Resource Conservation and Recovery Act of 1976 (RCRA)* site. The borehole was sited near the tank adjacent to a zone of high gamma flux reported in BNWL-CC-701. The borehole was advanced using the reverse air-rotary method in a drive and drill mode. Near-continuous samples were collected through the Hanford formation by driving a split-spoon sampler ahead of a casing string. After samples were retrieved, the borehole was reamed out using reverse air rotary methods and the casing

A new vadose monitoring borehole was installed in the SX Tank Farm in fiscal year 1999. Analytical results from sediment samples will be available in 2000. The borehole was turned into a groundwater monitoring well after high concentrations of technetium-99 were detected in a groundwater sample.

advanced to the next sample location. All air-lifted cuttings were treated as if contaminated and all effluent air was passed through high-efficiency particulate air (HEPA) filters before being discharged to the atmosphere. No contamination was detected by field instruments during drilling. Action levels were exceeded due to the presence of naturally occurring potassium, uranium, and thorium isotopes in the fine-grained sediment associated with the Palouse soil and Plio-Pleistocene Unit. The well was drilled into the groundwater to allow sampling for the RCRA monitoring program. Analysis of the groundwater samples revealed technetium-99 concentrations up to 48,000 pCi/L, the highest levels found to date on the Hanford Site. Because of this finding, the well is to be completed as a RCRA assessment well rather than decommissioned as originally planned. Analysis of the sediment will be done in fiscal year 2000.

3.2.1.3 Temperature and Other Geophysical Logging at Single-Shell Tank Farms

D. A. Myers

Geophysical logging beyond the baseline logging program conducted by MACTEC-ERS and reported in Section 3.2.1.4 was conducted in both the 41-09-39 borehole and in the 299-W23-19 borehole. This special logging consisted of moisture, temperature, and neutron capture gamma spectroscopy logs. Moisture distribution was logged using a neutron moisture probe to assess the distribution of water throughout the vadose zone in both boreholes. Water in the vadose zone provides the mobilizing force to transport contaminants to the groundwater. Temperature logs were obtained in single-cased portions of both boreholes, and borehole wall temperatures were logged in 41-09-39 as the borehole was decommissioned. Temperatures were taken using a side-looking infrared instrument so that the temperatures represent the casing or borehole wall conditions and not the air inside the casing. The results of the temperature log of 41-09-39 are presented in Figure 3.2-1. The temperature distribution corresponds to an increase in gamma activity as seen on the gross gamma-ray log and to the distribution of radionuclides as determined by laboratory measurements (see Section 3.2.1.1).

Other geophysical logs were run in both boreholes, including spectral gamma, using a high-purity germanium (HPGe) tool and a neutron capture spectroscopy log. This latter log is generated by exciting formation elements with neutrons from a californium source and measuring gamma-ray energies emitted following excitation. These spectra are then analyzed to provide a distribution of specific elements. The tool was developed for Idaho National Engineering and Environmental Laboratory and is calibrated for chlorine only; providing only a relative abundance of other elements.

Figure 3.2-2 shows the neutron-gamma capture spectroscopy log from borehole SX-115. An attempt was made to use the tool to assess sediment dragdown

during drilling operations by salting the borehole with gadolinium sand. The sand was added to the bore at ~49 meters and then the bore was deepened normally. Unfortunately, the sand was added too rapidly and it bridged in the casing, so that the results represent some dragdown as well as some smearing inside the casing. Figure 3.2-2 shows the gadolinium distribution in the borehole as indicated by the neutron-gamma log. The hydrogen log in Figure 3.2-2 shows very fine changes in what is interpreted to be water content in the Hanford formation, as well as a major change in water content as the borehole passed through the Plio-Pleistocene Unit into the Ringold Formation. The high calcium content at a depth of ~47 meters reflects the calcium-rich Plio-Pleistocene caliche layer. The response on the 1778 keV log in Figure 3.2-2 is due to both aluminum and silicon.

3.2.1.4 Baseline Spectral Gamma-Ray Logging at B and T Tank Farms

R. G. McCain

Baseline vadose zone characterization in single-shell tank farms has been conducted by the U.S. Department of Energy (DOE), Grand Junction Office and its subcontractor, MACTEC-ERS, since 1995. By the end of fiscal year 1999, tank summary data reports had been issued for all 133 single-shell tanks with capacities of 2 million liters or greater (100 series tanks), and tank farm summary reports had been issued for 11 of 12 single-shell tank farms. Results of the Tank Farms Vadose Zone Characterization Program are posted on the Internet at: <http://www.doegjpo.com/programs/hanf/HTFVZ.html>.

Baseline characterization measurements were completed at boreholes in the B and the T tank farms in fiscal year 1999. A down hole, spectral gamma-ray logging system was used for the characterization. Tank summary data reports were published for each 100 series tank in both farms and a comprehensive report was published for the T Tank Farm (GJO-HAN-27). A similar report is in preparation for B Tank Farm.

Also during fiscal year 1999, a high rate logging system was developed and deployed to quantify high levels of radionuclides in zones where the spectral gamma logging system detector saturated. High rate logging operations will be completed in fiscal year 2000. This will complete the baseline vadose zone characterization logging for single-shell tank farms.

Spectral Gamma-Logging Methods and Procedures

A description of the system used by the DOE, Grand Junction Office and MACTEC-ERS during spectral gamma-ray logging of the single-shell tank farms is presented in PNNL-13080. The spectral gamma logging system data were collected in accordance with procedures documented in MAC-VZCP 1.7.10-1, Rev 2 and analyzed in accordance with MAC-VZCP 1.7.9, Rev 1. Details on other aspects of the project are provided in MAC-VZCP-1.7.2, Rev. 1; MAC-VZCP-1.7.3, Rev. 1; MAC-VZCP-1.7.4, Rev. 1; and P-GJPO-1779, Rev. 1.

Spectral gamma-ray logging of all single-shell tanks with capacities greater than 2 million liters was completed in fiscal year 1999. Results of the 1995 to 1999 logging are a baseline for future logging in the tank farms.

The spectral gamma-ray logging system was initially calibrated at the DOE, Grand Junction Office Borehole Calibration Facility (GJPO-HAN-1). Continuing calibration measurements were made at the Hanford Site calibration facilities, and the most recent calibration (October 1998) is documented in GJO-HAN-26.

The tank farm vadose zone monitoring networks consist of steel-cased boreholes (also known as drywells) arranged around the perimeter of each tank. Most of the single-shell tank monitoring networks were installed in the late 1960s and early to mid-1970s. The borehole depths range from ~23 to 46 meters below ground surface. Most are ~30 meters deep.

Borehole diameters are typically 15.2 to 20.3 centimeters, although holes as small as 10.2 centimeters or as large as 30.5 centimeters exist.

Borehole designations within the tank farm are xx-yy-zz, where xx refers to the numerical tank farm designation, yy refers to the tank number (06 is tank 106), and zz refers to the clock position of the borehole relative to the tank, where 12 o'clock is north. A borehole with the designation 50-06-05 is at the 5 o'clock position of tank T-106. A borehole with the designation 50-00-06 is in the T Tank Farm, is not directly associated with any tank, and is at the approximate 6 o'clock position on the tank farm perimeter.

All depths in the discussion of results are relative to the top of the borehole casings.

Spectral Gamma-Ray Logging Results at B Tank Farm

By the end of fiscal year 1999, all tank summary data reports were completed for the twelve 100 series tanks in the B Tank Farm. These reports are published as GJ-HAN-112 through GJ-HAN-114 and GJ-HAN-125 through GJ-HAN-133. Tank summary data reports were not prepared for the four 200 series tanks because there are few boreholes in the vicinity of those tanks. The tank farm report for B Tank Farm is in preparation and will be published by March 2000. Figure 3.2-3 shows the layout of tanks and boreholes for B Tank Farm. Tanks that are assumed to have leaked are indicated by shading. Borehole depths range from 18.3 to 48.5 meters; most are ~30.5 meters deep.

Spectral gamma-ray baseline logging in the B Tank Farm identified cesium-137, cobalt-60, europium-152, and europium-154. In the following discussions both europium-152 and -154 generally will be considered as europium-154 because this isotope occurs at greater activity levels and is more widespread than europium-152. The two isotopes are chemically identical and would be expected to have the same migration characteristics. Copies of all logs can be found in the

individual tank summary data reports, and log data will be posted on the internet at the DOE, Grand Junction web site.

Cesium-137 was found at ground surface and at shallow depths over much of the B Tank Farm, apparently as the result of surface spills and pipeline leaks. Cesium-137 associated with previous leaks from tanks B-110, B-111, B-107, B-105, and B-101 was encountered at depths between 17.4 and 26.5 meters.

Cobalt-60 was identified in boreholes associated with tanks B-101, B-105 and B-110. Europium-154 was detected in the area between tanks B-107 and B-104 and appears to be associated with a leak from tank B-107. Minor amounts of europium-154 were also detected in boreholes at tanks B-101 and B-110.

Anomalously high gross gamma counts, which could not be attributed to a specific isotope, were detected at depths of 21 to 25 meters in 3 boreholes to the northeast of tank B-110 (boreholes 20-10-02, 20-07-11, and 20-08-07). Examination of spectra within this depth interval shows an anomalously large amount of incoherent gamma energy in the Compton continuum. This suggests the presence of one or more beta-emitting radionuclides, such as strontium-90, in the vicinity of the boreholes. This zone extends at least 25 meters northeast of tank B-110 because it is encountered in borehole 20-08-07. An extensive zone of detector saturation was encountered from 7.6 to 30.5 meters in borehole 20-10-12, located immediately north of tank B-110. The thick interval of very high activity suggests this borehole is very close to the source of the contamination. Review of drilling records and historical gross gamma data indicates that the borehole encountered contamination beginning at ~7.6 meters when it was drilled in July 1973, indicating that the leak pre-dates the borehole. The leak may have been from the cascade line between tanks B-110 and B-111 or from tank B-110. Strontium-90 (inferred from the gamma-ray spectra) from this leak extends to depths of at least 25 meters and laterally at least 25 meters to the northeast.

Borehole geophysical data suggest that a leak also may have occurred on the southern side of tank B-106 prior to 1972. A contaminant zone at 14.3 to 17.1 meters in borehole 20-60-06 was observed when the borehole was drilled. This zone may be as much as 5 meters thick, based on samples obtained during drilling. Originally, the leak was attributed to tank B-105; however, it appears more likely that the contamination originated from tank B-106 based on subsurface contaminant distribution). Although, the possibility of a cascade line leak cannot be completely ruled out, the presence of contamination beginning 2 to 3 meters below the base of the tank excavation is very suggestive of a leak from tank B-106.

Spectral Gamma-Ray Logging Results at T Tank Farm

During fiscal year 1999, tank summary data reports were completed for ten of the twelve 100 series tanks in the T Tank Farm. These are published as GJ-HAN-115 through GJ-HAN-124. Tank summary data reports for the remaining two tanks (T-107 and T-110) were completed in 1995 (GJPO-HAN-1 and GJ-HAN-2). Tank summary data reports were not prepared for the four 200 series tanks because there are few boreholes near those tanks. The tank farm report for T Tank Farm was completed in fiscal year 1999 and published as GJO-HAN-27. Figure 3.2-4 shows the layout of tanks and boreholes for the tank farm. Tanks that are assumed to have leaked are indicated by shading. Borehole depths range from 26.5 to 76.8 meters; most are ~30.5 meters deep.

Two factors affect evaluation of both historical gross gamma data and spectral gamma-ray data for the T Tank Farm. First, the existing 15.2-centimeter casing in most boreholes was perforated near the bottom and top, and a 10.2-centimeter casing was installed with grout between the two casings. This was done in the 1970s to minimize the movement of near-surface contamination along the outside of the borehole casings. The retrofitted annular seals resulted in significant attenuation of gamma rays reaching the detector

so that the spectral gamma logging system had to double the count time from 100 to 200 seconds per measurement during 1999 logging. Observed count rates could be corrected for the effects of two casing thicknesses, but the attenuation associated with an unknown thickness of grout cannot be accounted for in the analysis. For this reason, most reported concentrations from the T Tank Farm probably are less than actual concentrations and, therefore, are considered as apparent concentrations. Also, the attenuation associated with the double-cased intervals precludes the use of shape factor analysis to identify the location of contamination with respect to the borehole.

The second factor affecting the evaluation of the logs is the periodic flooding of the T Tank Farm. The farm is located in a natural depression that tends to pond surface runoff so that surface flooding occurs as a result of rapid snowmelt and/or excess precipitation. Infiltration of this water may have carried contamination down the outside of borehole casings or may have drained and deposited contamination on the inside of some boreholes.

Baseline spectral gamma logging in the T Tank Farm identified cesium-137, cobalt-60, europium-154, and europium-152. As for the B Tank Farm, europium will be discussed in terms of europium-154 because this isotope occurs at greater concentrations and is more widespread than europium-152. Limited and relatively isolated occurrences of antimony-125, niobium-94, tin-126, uranium-235, and uranium-238 were detected around several boreholes. Copies of all logs can be found in the individual tank summary data reports, and log data are posted on the internet at the DOE, Grand Junction Office web site.

Near-surface and shallow subsurface cesium-137 contamination was detected primarily in the central portion of the T Tank Farm. This contamination resulted most likely from surface spills or leaks from piping systems that were related to routine tank farm operations. The highest near-surface cesium-137 concentration was ~105 pCi/g and was detected in the backfill material between tanks T-104 and T-107.

The thickest, near-surface distribution of cesium-137 (~8 meters) was also detected in this region around boreholes 50-04-03 and 50-04-07 (Figure 3.2-5), suggesting a relatively large spill or that several spills or leaks may have occurred in this area. Small, near-surface cesium-137 concentrations detected at ~6 meters in boreholes 50-06-03, 50-06-04, 50-06-18, and 50-06-05 may be the result of a transfer-line leak near the southeastern side of tank T-106.

A vertically continuous cesium-137 zone, with concentrations between 1,000 and 10,000 pCi/g, was detected near the southeastern side of tank T-101 near borehole 50-01-04 (see Figure 3.2-5). The zone extends from 6 meters to the bottom of the logged interval at 37.3 meters. This zone is probably the result of a leak through a spare fill line that occurred in 1969 when the tank was overfilled. The horizontal extent of this zone is poorly defined, as it was only detected in one borehole. Available data suggest the lateral extent is less than ~8 meters because it is not encountered in adjacent boreholes, but the vertical extent is unknown because the zone extends below the bottom of the borehole (37.3 meters).

Cobalt-60, up to ~10 pCi/g, and europium-154, up to ~12 pCi/g, were identified near the southern side of tank T-101 in borehole 50-01-06 (see Figure 3.2-5). Previous investigations suggested that the contamination originated from the vicinity of borehole 50-01-04 and that the probable source was a leak from the spare fill lines on tank T-101. Evaluation of historical gross gamma data suggests that the cobalt-60 may have migrated laterally in a southwesterly direction from borehole 50-01-06 to boreholes 50-04-10 and 50-04-08 between 1973 and 1976. The baseline logging effort identified cobalt-60 at concentrations up to ~1 pCi/g in the latter two boreholes. However, this does not preclude that the contamination detected in boreholes 50-04-08 and 50-04-10 originated from the T-106 leak. It is also possible that the observed contamination originated from both sources.

Cesium-137, up to ~300 pCi/g, was detected near the western side of tank T-101. This contamination

was present in 1973 when the borehole was drilled and may have resulted from a leak in the cascade line connecting tanks T-101 and T-102.

Cesium-137 and cobalt-60 were detected near the southeastern side of tank T-102 around borehole 50-02-05 (see Figure 3.2-5). This contamination was present when the borehole was drilled in 1974 and probably resulted from a leak in the spare fill lines. Tank T-102 is not designated as an assumed leaker, but a leak from the spare fill lines is possible because leaks are known to have occurred at the other two tanks in the cascade series as a result of overfilling.

Cobalt-60 and europium-154 were detected along the southeastern and southern sides of tank T-103 around boreholes 50-03-04, 50-02-08, 50-03-05, and 50-03-06. This contamination is attributed to a leak from the spare fill line on the southeast side of the tank. Evaluation of spectral gamma logging system data and historical gross gamma data suggest that contamination has migrated downward and laterally to the south, and that it has intermingled with the contaminant plume from the T-106 tank leak.

A broad plume of contamination was detected below ~10 meters in all of the boreholes on the eastern, western, and southern sides of tank T-106. This contamination is the result of a major leak from tank T-106 that occurred in 1973. The primary constituents are cesium-137, cobalt-60, europium-154, and europium-152 with lesser amounts of antimony-125, tin-126, uranium-235, and uranium-238. Figure 3.2-6 shows representative logs from the area.

Zones of extremely high gamma radiation flux were encountered around most of the boreholes that intersected this plume. The intense gamma flux caused saturation of the spectral gamma logging system detector in the core of the plume, yielding little useful data. High-rate logging of these boreholes is scheduled for fiscal year 2000. The rate of decrease in gamma activity observed on historical gross gamma logs indicate that cesium-137 is the predominant remaining gamma-emitting radionuclide. This is consistent with total activity reported in RHO-ST-14 that indicated the leak

contained ~40,000 curies of cesium-137, 14,000 curies of strontium-90, and 270,000 curies of radionuclides with half-lives of less than 3 years (99% of which was attributed to ruthenium-106). The highest gross gamma count rates were measured on the southeastern side of tank T-106 in boreholes 50-06-05 and 50-06-17 between 10 and 12.8 meters. This suggests that the leak probably originated at or near the bottom of the tank in this area. (The bottom of tank T-106 is at 12.2 meters.) Substantial contamination was encountered to the total depth logged in all but one borehole (50-06-18) in the area. Therefore, the maximum depth of contamination is not known. Spectral gamma logging system data from nearby borehole 50-06-05 (see Figure 3.2-6) indicate that cesium-137 has migrated to a depth of at least 36.3 meters. Freeman-Pollard (BHI-00061) reported the leading edge of the plume (as indicated by cobalt-60) to be at 36.8 meters with small amounts of the most mobile radionuclides (technetium-99) reaching 44.2 meters in borehole 50-06-18, also called borehole 299-W10-196 (BHI-00061).

3.2.2 200 Areas Monitoring Activities

Vadose zone monitoring in fiscal year 1999 included spectral gamma-ray logging at specific retention facilities in the 200 East Area, which are some of the most significant remaining potential sources of groundwater contamination. Also, remediation and monitoring of carbon tetrachloride in the 200 West Area continued during 1999. An additional 832 kilograms of carbon tetrachloride were removed from the vadose zone in fiscal year 1999.

3.2.2.1 Carbon Tetrachloride Monitoring and Remediation

V. J. Rohay, D. G. Horton

Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area. The U.S. Environmental Protection Agency and the Washington State Department of Ecology authorized DOE to initiate this remediation in 1992 as a *Comprehensive Environmental Response, Compensation,*

and Liability Act of 1980 (CERCLA) expedited response action. The primary focus in the following discussion is on fiscal year 1999 activities associated with the carbon tetrachloride removal. For descriptions of past work, see BHI-00720, Rev. 3 and Section 4.5 in PNNL-12086.

The 14.2 m³/min soil-vapor extraction system operated from March 29 through June 28, 1999, at the 216-Z-9 well field and from June 30 through September 30, 1999, at the combined 216-Z-1A/-12/-18 well field. (See PNNL-13080 for location maps of the well fields.) The system was shut down for the winter (October 1, 1998, through March 28, 1999). The 28.3 and 42.5 m³/min soil-vapor extraction systems were maintained in standby mode during fiscal year 1999.

Remediation of carbon tetrachloride in the 200 West Area vadose zone continued in fiscal year 1999. Over 76,000 kilograms of carbon tetrachloride have been removed by soil-vapor extraction since the system began operating in 1992.

To track the effectiveness of the remediation effort, soil-vapor concentrations of carbon tetrachloride were monitored at the inlet to the soil-vapor extraction system and at individual on-line extraction wells during the 6-month operating period. To assess the impact of non-operation of the soil-vapor extraction system, soil-vapor concentrations of carbon tetrachloride were monitored at off-line wells and probes during the entire fiscal year.

Monitoring at the Soil-Vapor Extraction System

Soil-vapor extraction to remove carbon tetrachloride from the vadose zone resumed March 29, 1999, at the 216-Z-9 well field. Initial on-line wells were selected close to the 216-Z-9 trench. As extraction continued, wells farther away from the crib were brought on-line. Each selection of on-line wells included wells open near the groundwater and wells

open near the less-permeable Plio-Pleistocene zone, where the highest carbon tetrachloride concentrations have consistently been detected. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction inlet were ~90 ppmv (Figure 3.2-7). After 3 months of extraction, concentrations had decreased to ~30 ppmv. The daily mass-removal rate increased significantly twice during the 3 months of extraction as a result of adjustments in the mix of on-line wells and the flow rate (see Figure 3.2-7).

Soil-vapor extraction resumed June 30, 1999, at the 216-Z-1A/-12/-18 well field. Extraction wells open near the Plio-Pleistocene Unit were selected within the 216-Z-1A tile field to optimize mass removal of contaminant. Initial carbon tetrachloride concentrations measured at the soil-vapor extraction inlet were ~40 ppmv. After 3 months of extraction, concentrations had decreased to ~25 ppmv. The daily mass-removal rate increased significantly twice during the 3 months of extraction as a result of adjustments in the mix of on-line wells and the flow rate (see Figure 3.2-7).

During 185 days of soil-vapor extraction in fiscal year 1999, 832 kilograms of carbon tetrachloride were removed from the vadose zone. Of this total, 447 kilograms were removed from the 216-Z-9 well field during 93 days of operation and 385 kilograms were removed from the 216-Z-1A/-12/-18 well field during 92 days of operation.

As of September 1999, ~76,500 kilograms of carbon tetrachloride had been removed from the vadose zone since extraction operations started in 1992 (see Table 3.2-6). Since initiation, the extraction systems are estimated to have removed 7% of the residual mass at the 216-Z-1A/-12/-18 well field and 22% of the mass at the 216-Z-9 well field. This estimate assumes that all of the mass that has not been lost to the atmosphere (21% of the original inventory), dissolved in groundwater (2% of the original inventory), or biodegraded (1% of the original inventory) is still available in the vadose zone as residual mass (BHI-00720, Rev. 3; WHC-SD-EN-TI-101).

Monitoring at Off-Line Wells and Probes

During October 1998 through March 1999, soil-vapor concentrations of carbon tetrachloride were monitored near the groundwater and near the ground surface to assess whether non-operation of the soil-vapor extraction system was allowing carbon tetrachloride to migrate out of the vadose zone. The maximum concentration detected near the ground surface (between 2 and 10 meters below ground surface) was 8 ppmv. Near the groundwater, at depths ranging from 58 to 64 meters below ground surface, the maximum concentration was 29 ppmv.

Soil-vapor concentrations were also monitored near the Plio-Pleistocene Unit to provide an indication of concentrations that could be expected during restart of the soil-vapor extraction system. The maximum concentration detected near the Plio-Pleistocene Unit (between 25 and 41 meters below ground surface) was 561 ppmv in well 299-W15-217 (35 meters deep) at the 216-Z-9 site. During fiscal year 1997 and fiscal year 1998 monitoring, the highest carbon tetrachloride concentrations were also detected in this well. These results, after 6 to 9 months of non-operation of the soil-vapor extraction system, are similar to those obtained during the 8-month rebound study conducted in fiscal year 1997 (BHI-01105) and during the 6 months of non-operation during the winter of fiscal year 1998 (BHI-00720, Rev. 3).

During April through June 1999, soil-vapor monitoring was continued at the 216-Z-1A/-12/-18 well field, while the soil-vapor extraction system was operated at the 216-Z-9 site. Concentrations detected during these additional 3 months of rebound were similar to those observed during the previous 6 months. Near the Plio-Pleistocene Unit, maximum concentrations ranged from 0 to 492 ppmv. The highest concentration was detected in well 299-W18-158L (37 meters deep) in the 216-Z-1A tile field, the well at which the highest concentration was detected during the fiscal year 1998 monitoring. These results were obtained after 9 months of rebound and are similar to those obtained during the 8-month rebound study conducted in fiscal year 1997 (BHI-01105).

During July through September 1999, soil-vapor monitoring was resumed at the 216-Z-9 site while the soil-vapor extraction system was operated at the 216-Z-1A/-12/-18 site. The highest concentration detected near the ground surface was 4 ppmv and the highest concentration detected near the groundwater was 24 ppmv. The maximum concentration detected was 267 ppmv at the Plio-Pleistocene Unit in well 299-W15-217. These results were obtained after only 3 months of rebound.

Because carbon tetrachloride concentrations did not increase significantly at the near-surface probes monitored in fiscal year 1999, temporarily suspending operation of the soil-vapor extraction system for 6 to 9 months appears to have caused minimal detectable vertical transport of carbon tetrachloride through the soil surface to the atmosphere. Because carbon tetrachloride concentrations did not increase significantly near the water table during this time, temporarily suspending operation of the soil-vapor extraction system appears to have had no negative impact on groundwater quality.

Carbon Tetrachloride Migration

Three major pathways through the vadose zone to groundwater are possible:

- sinking and lateral spreading of a heavier-than-air vapor phase down to the top of the aquifer
- transport of an organic liquid phase, or dense, non-aqueous-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
- transport of carbon tetrachloride dissolved in the aqueous phase either through disposal of aqueous waste or by contact between infiltrating recharge and carbon tetrachloride soil vapor and/or residual, dense, non-aqueous-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 3.2-8.

A numerical model was developed (BHI-00459) to simulate the primary transport processes shown in Figure 3.2-8, 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 be retained in the soil column and that a dense, non-aqueous-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, non-aqueous-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 3.2-8. The vapor-phase results were less definitive but suggested that vapor-phase transport is secondary to dense, non-aqueous-phase liquid as a groundwater contamination pathway in the vicinity of the disposal site.

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 trench were still present in the soil column as a non-aqueous phase, a relatively high soil-vapor concentration would be expected. For example, a pure, non-aqueous, 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 soil saturated with an organic contaminant, standard soil-vapor extraction will produce a vapor stream containing one-tenth to one-half the expected concentration (EPA 510-R-93-001). Therefore, vapor-extraction concentrations >12,000 ppmv of carbon tetrachloride would indicate that the soil near the extraction well is saturated with non-aqueous-phase liquid.

During initial extraction operations at the 216-Z-9 well field, soil-vapor carbon tetrachloride concentrations extracted from wells open above the

Plio-Pleistocene Unit were >12,000 ppmv, suggesting the presence of a non-aqueous phase. Soil vapor extracted from wells open below the Plio-Pleistocene were an order of magnitude lower and would not suggest the presence of a non-aqueous-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 non-uniformly distributed contaminant, and the presence of a non-aqueous-phase liquid cannot be ruled out.

During the soil-vapor monitoring of rebound concentrations conducted in fiscal year 1997 through 1999, the carbon tetrachloride vapor concentrations monitored deep within the vadose zone at the 216-Z-9 trench did not exceed 60 ppmv. These low vapor concentrations do not indicate the presence of a non-aqueous-phase liquid remaining in the vadose zone below the Plio-Pleistocene Unit; however, these measurements were not taken directly under the 216-Z-9 trench or at depth-discrete, narrow zones above the water table. Although carbon tetrachloride volatilizing from a residual non-aqueous-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, non-aqueous-phase, liquid source in the area of the 216-Z-9 trench 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

- non-uniform discharge, migration, and distribution of the non-aqueous-phase carbon tetrachloride
- non-optimal locations for monitoring
- non-equilibrium partitioning of carbon tetrachloride within the vadose zone
- discharge of carbon tetrachloride organic liquid mixtures rather than pure phase liquids
- vadose zone geologic heterogeneities and geostuctural dips.

Vertical and areal distribution of dissolved carbon tetrachloride discussed in Section 2.8.1.2 is consistent with a dense, non-aqueous-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 was a primary pathway, the top of the aquifer should have the highest concentrations and should decline rapidly with depth over a 1- to 2-meter interval.

The carbon tetrachloride plume map and vertical profiles discussed in Section 2.8.1.2 suggest there is a continuing source of groundwater contamination that produces somewhat uniform carbon tetrachloride concentrations with depth in the aquifer. A dense, non-aqueous-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, non-aqueous-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, non-aqueous-phase liquid 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 fiscal year 1997 through 1999 suggest that soil-vapor extraction remediation may have removed much of the vadose zone source and that the continuing groundwater source resides 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, 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.

3.2.2.2 Rapid Scan Gross Gamma-Ray Logging at Single-Shell Tank C-106

D. G. Horton, S. E. Kos

Waste removal operations (sluicing) at single-shell tank C-106 were initiated in November 1998. Waste Management Federal Services, Inc., Northwest Operations collected sodium iodide gross gamma logging data at tank C-106 on a monthly basis from February to September 1999 in support of the operations. Six boreholes were logged. Figure 3.2-9 shows the locations of the boreholes logged. The logs did not show any contribution to vadose zone contamination resulting from the sluicing operations during the months that log data were collected. Figures 3.2-10 and 3.2-11 show typical data from boreholes 30-06-02 and 30-06-03. The small variation among the gross gamma logs is due to the presence of radon gas and to statistical precision of the logging system. Levels of radon, from the decay of naturally occurring uranium in the sediment,

Waste from a single-shell tank in the C Tank Farm was sluiced to remove radionuclides and reduce in-tank temperature during fiscal year 1999. Geophysical logging indicated no additional vadose zone contamination resulted from sluicing activities.

increase inside the borehole casings during periods of low barometric pressure. This increase of radon causes a larger gross gamma count rate during periods of low atmospheric pressure than during periods of high atmospheric pressure.

The only borehole to show any significant deviations during the period from February to September is borehole 30-06-03 (see Figure 3.2-11). A thin zone at a depth of ~1 to 2 meters shows large month-to-month variations in gross gamma count rate. There is no pattern, such as continual increase or decrease in count rate, to the variations, and a reason for the variations is not known. In February, water from an undetermined source was standing in the bottom of borehole 30-06-03 at ~26 meters. The monthly logging monitored the decrease in the water level until the water dropped below the bottom of the borehole in September 1999. The variation in gross gamma count rate near the bottom of the plot in Figure 3.2-11 is due to the decreasing water level. The variation in count rate at the 1- to 2-meter zone and the water in the bottom of the borehole are probably not related.

3.2.2.3 Spectral Gamma-Ray and Neutron Moisture Monitoring of 200 East Area Specific Retention Facilities

D. G. Horton

The Hanford Groundwater Monitoring Project monitored 25 inactive liquid waste disposal facilities in the 200 East Area of the Hanford Site in 1999. The monitored facilities consisted of 6 cribs and 19 specific retention facilities. Specific retention facilities were chosen for monitoring because they are among the highest priority sites as determined by an evaluation of past-practice, liquid waste disposal facilities (PNNL-11958, Rev. 2). Specific retention facilities were liquid waste disposal sites designed to use the moisture retention capability of the soil to retain contaminants. Ideally, liquid disposed to specific retention facilities was to be limited to 6% to 10% of the soil volume between the facility and the groundwater so that the liquid would be retained in the soil and not reach the groundwater (WHC-MR-0227). No such

limits were imposed at normal cribs and trenches. The relatively small volumes of liquid discharged to specific retention facilities was probably insufficient to flush contaminants through the vadose zone to groundwater such that the discharged contaminants remain in the soil column. Thus, these sites represent potential sources for future contamination of groundwater at the Hanford Site.

Geophysical monitoring of the vadose zone beneath 25 inactive waste sites in the 200 East Area showed movement of cesium-137 and cobalt-60 beneath two facilities. Given the rate of movement and the half-lives of these contaminants, they are expected to decay before reaching groundwater.

Monitoring consisted of spectral gamma-ray and neutron moisture logging of 28 wells and boreholes. The work was done by the Hanford Groundwater Monitoring Project within the Pacific Northwest National Laboratory in conjunction with Three Rivers Scientific and Waste Management Federal Services, Inc., Northwest Operations. The 1999 monitoring was designed to address the question "What is the configuration of subsurface contamination beneath the facilities and has the contaminant distribution changed since it was last measured?" The results of previous borehole logging, where available, provided the baseline data to help answer this question.

This section briefly discusses the monitoring activities. A more detailed discussion can be found in PNNL-13077.

Facility Descriptions and Previous Monitoring

The facilities monitored in fiscal year 1999 can be placed into three groups based on geographic location and the type of effluent received. The three groups are

- Plutonium-Uranium Extraction (PUREX) facilities
- BC controlled area facilities
- BX trenches.

Table 3.2-7 lists the facilities that were monitored in each group. Figure 3.2-12 shows a map of the general locations of the monitored facilities.

The PUREX facilities include the 216-A-2, -4, and -7 specific retention cribs and the 216-A-18 specific retention trench. The 216-A-2 and -4 cribs are located 80 meters south of the 202-A (PUREX) Building and are ~46 meters apart. The 216-A-2 crib was active between January 1956 and January 1963 when it received 230,000 liters of low salt, neutral/basic waste (RHO-CD-673).

The 216-A-4 crib was active from December 1955 to December 1958 when it received 6.2 million liters of low salt, neutral/basic waste. Based on the volume of effluent disposed to the crib and on estimates of the pore volume in the sediment beneath the crib (DOE/RL-92-04), the 216-A-4 crib does not appear to have been operated as a specific retention facility.

The 216-A-7 crib is located inside the 200 East Area perimeter fence extension, 100 meters east of the A Tank Farm. The 216-A-7 crib was active between November 1955 and November 1966, when it received 326,000 liters of low salt neutral/basic waste. Based on the volume of effluent disposed to the crib and on estimates of the pore volume in the sediment beneath the crib (DOE/RL-92-04), the 216-A-7 crib does not appear to have been operated as a specific retention facility.

The 216-A-18 trench is located 150 meters east of AZ Tank Farm outside of the 200 East perimeter fence. The specific retention trench was active from November 1955 to January 1956, when it received 488,000 liters of depleted uranium waste from a cold start-up run at 202-A Building (DOE/RL-92-04).

The BC controlled area is located south of the 200 East Area (see Figure 3.2-12) and includes the 216-B-14 through -19 cribs and the 216-B-23, -25 through -27, -30 through -33, -52, and -53A trenches. The 216-B-14 through -19 cribs operated between January 1956 and December 1957 and each received

between 3.4 to 8.7 million liters of effluent. A complete operating history for each crib is given in DOE/RL-92-05. The cribs received high salt, neutral/basic, scavenged tributyl phosphate waste. DOE/RL-92-05 and RHO-CD-673 state that the BC controlled area cribs were deactivated after specific retention capacity was reached. However, comparing the volume defined by the crib dimensions and the thickness of the vadose zone with the volume of disposed effluent indicates that the specific retention capability of the cribs was exceeded.

The BC controlled area 216-B-23, -25 through -27, -30 through -33, -52, and -53A trenches are located south of the 200 East Area. Each trench was active for 1 to 3 months between October 1956 and January 1958, except the 216-B-58 trench that was active from November 1965 to June 1967. A complete operating history for each trench is given in DOE/RL-92-05. The 216-B-23 through -33 and -52 trenches received high-salt, neutral/basic scavenged tributyl phosphate waste; the 216-B-53A trench received neutral/basic waste from the Plutonium Recycle Test Reactor in the 300 Area. Detailed inventories for the BC controlled area facilities can be found in DOE/RL-92-05.

The BX specific retention trenches (216-B-35, -37, -38, -41, and -42) are located ~60 meters west of the BX Tank Farm. The trenches operated for 1 to 2 months each between February 1954 and February 1955. A complete operating history for each trench is given in DOE/RL-92-05. The 216-B-37 trench received first cycle bottoms from the 242-B waste evaporator; the 216-B-42 trench received high-salt, neutral/basic scavenged tributyl phosphate supernatant waste from the 221-U Building; and all other BX trenches received high-salt, neutral/basic, first cycle supernatant waste from the 221-B Building.

Methods

High-resolution gamma spectroscopy instrumentation and a neutron moisture tool were used to log the boreholes. Details concerning the logging methods,

data analysis, and data interpretation can be found in PNNL-13080 and PNNL-13077. The data collection and log analysis procedures are described in WMNW-CM-004.

Four of the wells logged in 1999 were previously logged with the high-resolution spectral gamma logging instrument. Time-lapse comparison of spectral log data was done for those boreholes. Interpretations of contaminant redistribution were based on changes among the data sets.

Historical gross gamma logs were compared with the gross gamma logs collected by the spectral instrument in 1999. The older logs were obtained with instruments that were operated only in the gross gamma mode. The detectors were typically scintillator crystal detectors, which have poor energy resolution compared to the high-purity germanium detectors used in the 1999 logging.

Differences in the detector composition and size result in different efficiencies for the gross gamma response. As a result, the comparison of older gross gamma log results with the 1999 gross gamma response was done qualitatively by plotting each log on a different scale in the same plot. Also, because the scaling factors are not known, no decay corrections were attempted for any comparisons of older gross gamma logs with 1999 gross gamma logs. However, changes in the depth distribution of contaminants can sometimes be evaluated using the gross gamma time-lapse comparison performed.

All depths referred to in the following discussions are relative to ground surface.

Results

This section contains brief descriptions of the spectral gamma-ray and neutron moisture logging results. A more detailed discussion is found in PNNL-13077. The complete data set can also be found in PNNL-13077 or on file at Pacific Northwest National Laboratory.

PUREX Facilities. The isotopes cesium-137, cobalt-60, europium-154, uranium-235, and uranium-238 were identified on the spectral gamma logs from boreholes monitoring the PUREX specific retention facilities. No previous spectral gamma logs are available for comparison to the 1999 logs, but several older gross gamma logs exist. One gross gamma log obtained in 1976 was digitized for comparison with the 1999 log (borehole 299-E24-53 at the 216-A-2 crib). The presence of several manmade, gamma-emitting radionuclides made the comparison very difficult, but the two logs showed the same general character suggesting no vertical movement of radionuclides (Figure 3.2-13). Lateral movement cannot be ruled out by the comparison. Qualitative, visual (not digitized) comparisons of the other 1999 gross gamma logs with historical gross gamma logs, from the monitored PUREX facilities, suggest that no vertical movement of radionuclides has occurred since the previous logging events. Most differences between historical logs and the 1999 logs can be explained by decay of relatively short-lived radionuclides.

BC Controlled Area Cribs and Trenches. The isotopes antimony-125, cesium-137, cobalt-60, and europium-154 were identified on the spectral gamma logs from boreholes monitoring the BC controlled area cribs and trenches. Three of the wells in this area had been previously logged in 1992 with a spectral gamma tool. The 1992 logs were compared with the 1999 logs. In two of the three wells with both 1992 and 1999 logs, zones were identified where cesium-137 concentration has increased since 1992. Cesium concentration increased by ~20% between 20 and 27 meters in well 299-E13-1, at the 216-B-14 crib, and by ~32% at ~25 meters in well 299-E13-5 (Figure 3.2-14), at the 216-B-18 crib. The movement of cesium-137 in well 299-E13-5 is interpreted to be lateral because there is no change in cesium-137 concentration above and below the zone of increase. The increase in cesium-137 concentration in well 299-E13-1 could result from vertical movement but more information is needed to make a definite interpretation.

There is an apparent increase in cesium-137 concentration between 7.3 and 8.5 meters in well 299-E13-3 at the 216-B-16 crib, but the increase may be the result of differences in the depths at which the 1992 and 1999 measurements were taken. Well 299-E13-1 also showed a small increase in cobalt-60 concentration between depths of 58 and 61 meters. All three wells with 1992 data showed a decrease in antimony-125 concentration that can be explained by natural decay.

Historical gross gamma logs from two wells, 299-E13-2 and 299-E13-4 were digitized to allow comparison with 1999 gross gamma logs (Figures 3.2-15 and 3.2-16). Differences between the 1976 and 1999 logs can be explained by natural decay of relatively short-lived radionuclides; the comparison, however, is qualitative. Similarly, most of the differences between the 1999 logs and the other historical logs in ARH-ST-156 reflect the decay of relatively deeper, short-lived isotopes and the much slower decay of the shallower and longer-lived isotopes.

BX Specific Retention Trenches. The isotopes antimony-125, cesium-137, and cobalt-60 were identified on the spectral gamma logs from boreholes at the BX specific retention trenches. The antimony-125 and cobalt-60 were identified only at or near detection limits by the summing technique described in Appendix A of PNNL-13077.

A 1984 gross gamma log from borehole 299-E33-289 was digitized and compared to the 1999 gross gamma results. The different instrument efficiencies allow only qualitative comparison. The depth profile of the contaminants match very well (Figure 3.2-17), but possible depth control errors in the 1984 data make any conclusion regarding vertical changes in contaminant distribution inconclusive. However, it is believed that no vertical migration of contaminants has occurred in the borehole since 1984.

One borehole at the BX trenches, 299-E33-290 at the 216-B-38 trench, was previously logged with a spectral gamma tool in 1992. Cesium-137 was the only

manmade radioisotope noted in both the 1992 and 1999 logs (Figure 3.2-18). Comparison of the 1992 and 1999 gross gamma logs indicated that a change in the distribution of cesium-137 was highly unlikely. Most of the qualitative differences between the 1999 logs and the historical logs from the BX trenches in ARH-ST-156 reflect the decay of short-lived isotopes, primarily ruthenium-106.

Summary

Only four of the boreholes logged in 1999 had previous spectral gamma logs for comparison. Two of those logs showed that changes in the subsurface distribution of manmade radioisotopes had occurred since 1992. Although the changes are not great, they do point to continued movement of contaminants in the vadose zone. The logs obtained in 1999 create a larger baseline for comparison with future logs.

None of the facilities monitored in 1999 have been used for at least 30 years and some for 40 years. Thus, the driving force for the changes is not known for certain but must be either natural recharge, residual moisture from facility operations, or moisture from adjacent facilities. There are several facilities, including cribs and tank farms near the BX trenches, that may contribute moisture to the subsurface under the trenches. There are no nearby liquid waste disposal facilities near the cribs and trenches in the BC controlled area, so the driving force there must be residual moisture from past operations or natural recharge.

The radionuclides that were observed to have moved since 1992 are cesium-137 and cobalt-60. Given the amount of movement and the half-lives of the isotopes, it is expected that they will decay to insignificant amounts before reaching groundwater. Although not seen to have moved in 1999, the same is expected for all of the other detected isotopes except those of uranium.

Unfortunately, gamma-ray logging cannot detect many of the contaminants of interest such as technetium-99, nitrate, and iodine-129, all of which can

be highly mobile in the vadose zone and, for the radionuclides, have long half-lives. The time series of gross gamma logs given in ARH-ST-156 for many of the specific retention facilities show large decreases in gamma intensity between the late 1950s and 1976. The maximum intensity is generally between a depth of 10 and 20 meters. The rapid decay is probably due to ruthenium-106 (half-life 1.02 years), and the ruthenium-106 probably reached a maximum depth of 10 to 20 meters with the original slug of water disposed in the short time (generally ~1 month) the facilities

operated. Depending on the chemical characteristics of the waste stream, the mobility of iodine-129 and technetium-99, as gauged by experimentally determined K_d s, is either near that of or greater than that of ruthenium-106. Thus, the minimum depth that iodine-129, nitrate, and technetium-99 probably reached during facility operation is indicated by the depth of rapid ruthenium-106 decay. Subsequent movement of the long-lived and mobile constituents cannot be measured with the available geophysical logging tools.

Table 3.2-1. Composition of Sediment from Borehole 41-09-39 in SX Tank Farm

Depth (m bgs) ^(a)	Lithology	Direct Measures on Dry Sediment					
		Moisture Content (wt. %)	Total Carbon (wt. %)	Organic Carbon (wt. %)	Cesium-137 (pCi/g)	Europium-152 (pCi/g)	Cobalt-60 (pCi/g)
7.6-7.9	Very fine- to medium-grained sand	8.12	0.16	0.06	6.059E+02	<0.217	0.66 + 0.27
13.4-13.7	Medium-grained sand	8.57	0.13	0.03	1.113E+03	<0.103	<0.0262
17.1-17.4	Very fine-grained sandy, clayey silt	16.27	0.18	0.03	2.600E+04	<1.03	<0.229
18.6-18.9	Silty, very fine- to medium-grained sand	12.84	0.25	0.14	1.246E+05	<1.73	<1.79
19.8-20.1	Fine- to medium-grained sand	4.71	0.27	0.13	6.258E+05	<39.2	<10.1
19.8-20.1	Fine-grained sand	5.29	0.19	0.08	4.092E+06	<153	<41
21.0-21.3	Fine- to coarse-grained sand	4.36	0.23	0.07	9.493E+03	<0.148	<0.0349
22.6-22.9	Fine- to medium-grained sand	5.17	0.25	0.08	2.342E+06	<65.4	<17.1
24.0-24.4	Silty, clayey sand	10.71	0.30	0.06	2.557E+06	<145	<25.6
25.0-25.3	Fine- to medium-grained sand	8.41	0.31	0.03	1.759E+07	<2660	<1240
27.4	Fine-grained sand	10.25	0.27	0.04	4.378E+04	<0.15	<0.041
29.0-29.3	Fine-grained sandy silt	8.12	0.28	0.06	3.825E+04	<1.03	<0.263
31.1-31.4	Clayey silt	10.40	0.30	0.12	1.619E+06	<117	<28.2
32.9-33.2	Very fine- to fine-grained sand/silt	12.01	0.45	0.28	3.374E+05	<7.19	<2.2
34.1	Very fine- to medium-grained sand	8.17	0.27	0.04	1.492E+03	<0.0965	<0.0202
38.8	Very fine- to fine-grained silty sand	12.66	0.44	0.08	4.199E+03	<0.123	<0.0271

(a) bgs = Below ground surface.

Table 3.2-2. Water Leachable Chemicals in Sediment from Borehole 41-09-39 in SX Tank Farm

Depth (m bgs) ^(a)	1:1 Water Extracts							
	pH	Specific Conductance (μ S/cm)	Nitrate (μ g/g soil)	Sodium (μ g/g soil)	Technetium-99 (pCi/g soil)	Cesium-137 (pCi/g soil)	Chromium (μ g/g soil)	Selenium (μ g/g soil)
7.6-7.9	8.4	188	13	32	0	N.D. ^(b)	5.0E-04	<5.00E-03
13.4-13.7	8.5	226	13	44	1	N.D.	2.9E-03	<5.00E-03
17.1-17.4	8.3	287	13	44	1	6.9	3.4E-03	<5.05E-03
18.6-18.9	8.6	355	13	90	1	9.6	8.1E-03	<5.00E-03
19.8-20.1	9.2	899	29	131	4	245	3.4E-01	<5.00E-03
19.8-20.1	9.8	504	18	232	8	3,974	3.4E-01	<5.00E-03
21.0-21.3	9.2	752	33	201	6	75	5.1E+00	<5.00E-03
22.6-22.9	9.6	719	44	201	8	261	4.1E+00	<5.00E-03
24.0-24.4	9.6	1,722	371	432	18	267	7.2E-01	<5.00E-03
25.0-25.3	8.70	8,293	2,838	2,343	393	38,150	7.5E+02	8.6E-02
27.4	8.33	41,820	28,036	12,515	2,749	221	7.1E+02	1.4E-01
29.0-29.3	7.9	41,010	32,770	11,899	7,076	747	2.6E+02	2.2E-01
31.1-31.4	8.0	41,910	31,656	12,581	6,140	9,665	5.3E+02	2.3E-01
32.9-33.2	8.1	56,480	42,488	19,095	11,897	1,636	4.8E+02	3.9E-01
34.1	8.1	42,770	32,822	12,600	8,560	63	1.8E+02	2.9E-01
38.8	7.9	16,550	12,813	1,889	334	63	1.1E-02	3.1E-02

(a) bgs = Below ground surface.

(b) ND = Not detected.

Table 3.2-3. Acid Extractable Chemicals from Sediments from Borehole 41-09-39 in SX Tank Farm

Depth (m bgs) ^(a)	Acid Extract					
	Technetium-99 (pCi/g) ICP/MS ^(b)	Technetium-99 (pCi/g) Radiolog- ical Analysis ^(c)	Uranium-238 (pCi/g) ICP/MS ^(b)	Chromium (µg/g)	Molybdenum (µg/g)	Selenium (µg/g)
7.6-7.9	<19.95	-47	0.14	6.5	7.89E-02	9.73E-02
13.4-13.7	<5.94	-5	0.23	6.0	4.01E-01	1.23E-01
17.1-17.4	28	292	0.20	24.1	6.01E-01	9.39E-02
18.6-18.9	11	-18	0.21	130.3	2.00E-01	6.85E-02
19.8-20.1	26	-12	0.13	80.3	1.03E+00	1.21E-01
19.8-20.1	(13 ± 4)	0 ± 22	0.13	69.5	3.99E-01	7.91E-02
21.0-21.3	<25.3	96	0.15	42.3	9.72E-01	1.09E-01
22.6-22.9	<35.3	12	0.15	122.0	1.50E+00	7.83E-02
24.0-24.4	2,400	3,006	0.15	597.4	1.08E+01	8.29E-02
25.0-25.3	1,088 ± 336	1,160 ± 280	0.21	1,458.6	1.28E+01	1.66E-01
27.4	3,241	3,586	0.15	1,277.8	5.23E+00	1.14E-01
29.0-29.3	7,618	7,468	0.16	710.7	1.71E+00	1.61E-01
31.1-31.4	12,979	13,036	0.21	1,169.6	4.39E+00	1.56E-01
32.9-33.2	13,766	13,877	0.19	783.9	2.29E+00	2.59E-01
34.1	9,840	9,906	0.12	298.5	4.39E-01	2.16E-01
38.8	405	405	0.16	15.8	2.26E+00	5.10E-02

(a) bgs = Below ground surface.

(b) ICP = Inductively coupled plasma emission spectroscopy.

(c) Rad = Radiological analysis.

Table 3.2-4. Estimates of Mobility of Cesium, Technetium, and Chromium in Samples from Borehole 41-09-39, Based on the Percent of the Constituent Leached by Water

Depth (m bgs) ^(a)	% Cesium-137 Leached by Water Versus Total Cesium in the Sediment	% Technetium-99 Leached by Water Versus Total Acid Extractable Technetium	% Chromium Leached by Water Versus Total Acid Extractable Chromium
7.6-7.9	NA	>81	0.01
13.4-13.7	NA	>16	0.05
17.1-17.4	0.03	1.8	0.01
18.6-18.9	0.01	6.5	0.01
19.8-20.1	0.04	15.8	0.43
19.8-20.1	0.10	60.1	0.50
21.0-21.3	0.79	>22	11.97
22.6-22.9	0.01	>22	3.35
24.0-24.4	0.01	0.8	0.12
25.0-25.3	0.22	36.1	51.09
27.4	0.50	84.8	55.71
29.0-29.3	1.95	92.9	36.63
31.1-31.4	0.60	47.3	45.14
32.9-33.2	0.48	86.4	61.34
34.1	0.42	87.0	58.73
38.8	0.15	82.4	0.07

(a) bgs = Below ground surface.

Table 3.2-5. Calculated In Situ Distribution Coefficients (K_d) for Samples from Borehole 41-09-39 in SX Tank Farm

Depth (m bgs) ^(a)	Cesium In Situ K_d (mL/g)	Technetium In Situ K_d (mL/g)	Chromium In Situ K_d (mL/g)
7.6-7.9	ND ^(b)	<130	13,059
13.4-13.7	ND ^(b)	5.17	2,090
17.1-17.4	3,772	54.97	7,047
18.6-18.9	13,017	14.44	15,994
19.8-20.1	2,554	5.33	234
19.8-20.1	1,030	0.66	201
21.0-21.3	127	3.58	7.4
22.6-22.9	8,989	3.58	28.8
24.0-24.4	9,589	131.22	832
25.0-25.3	461	1.77	1.0
27.4	199	0.18	0.8
29.0-29.3	51	0.08	1.7
31.1-31.4	168	1.11	1.2
32.9-33.2	206	0.16	0.6
34.1	237	0.15	0.7
38.8	53,262	0.21	1,377

(a) bgs = Below ground surface.

(b) ND = Not detected.

Table 3.2-6. Carbon Tetrachloride Inventory in Primary Disposal Sites

Well Field	Estimated Mass Discharged 1955 to 1973 ^(a) (kg)	Estimated Mass Lost to Atmosphere 1955 to 1990 ^(b) (kg)	Mass Removed Using Soil-Vapor Extraction 1991 to 1999 ^(c) (kg)
216-Z-1A	270,000	56,700	23,508 ^(d)
216-Z-9	130,000 to 480,000	27,300 to 100,800	52,954
216-Z-18	170,000	35,700	
Total	570,000 to 920,000	119,700 to 196,800	76,462

(a) Based on DOE/RL-91-32, Draft B.

(b) Based on WHC-SD-EN-TI-101.

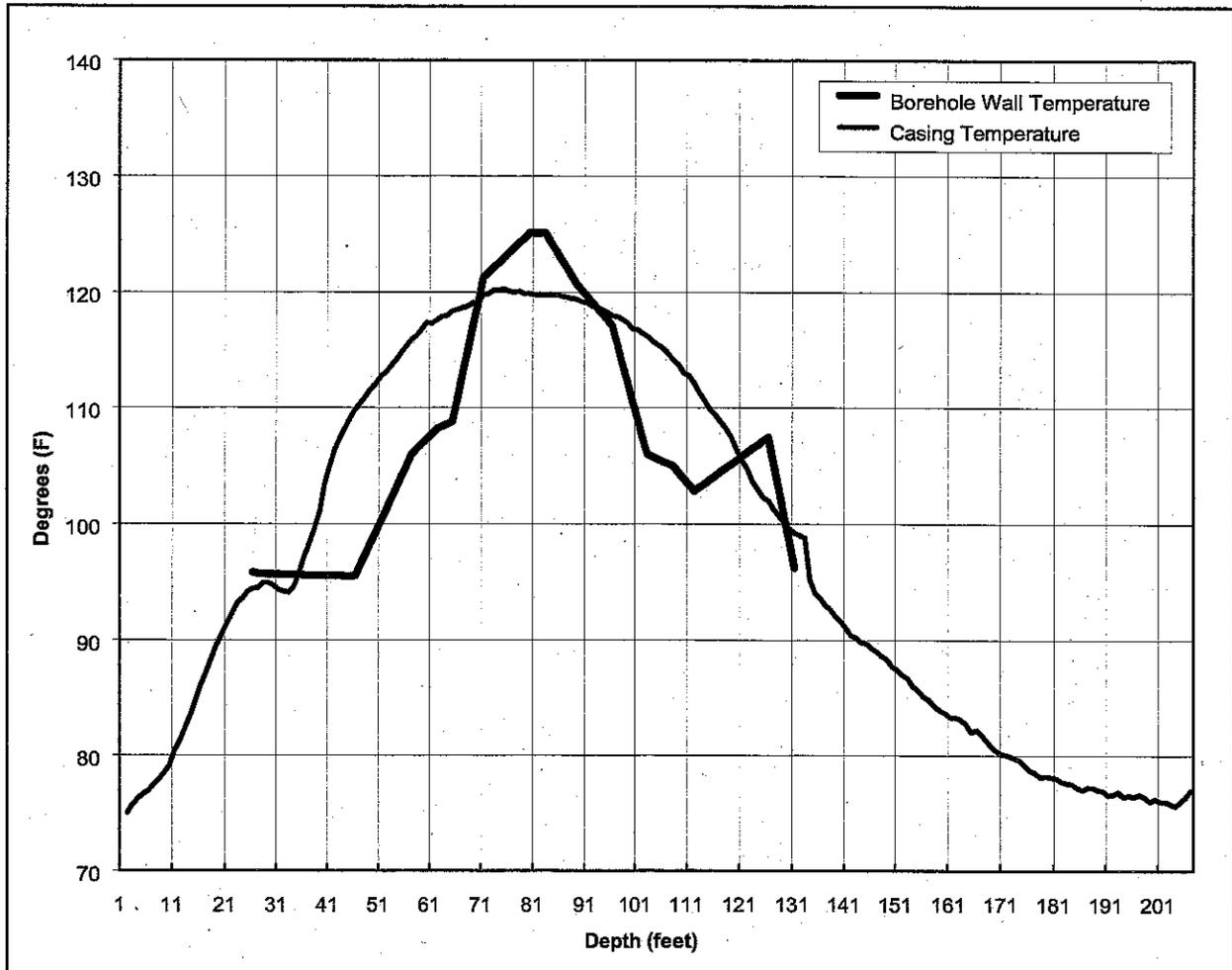
(c) Based on BHI-00720, Rev. 3.

(d) Includes mass removed from 216-Z-18 site; reported as a combined value because the well fields overlap.

Table 3.2-7. Liquid Disposal Facilities and Associated Boreholes and Wells Monitored with Spectral Gamma-Ray and Neutron Moisture Tools, Fiscal Year 1999

Facility	Well or Borehole	Facility	Well or Borehole
PUREX Facilities^(a)			
216-A-2 crib	299-E24-53	216-A-7 crib	299-E25-54
216-A-4 crib	299-E24-54	216-A-18 trench	299-E25-10
BC Controlled Area Facilities			
216-B-14 crib	299-E13-1	216-B-26 trench	299-E13-12
216-B-15 crib	299-E13-2	216-B-27 trench	299-E13-57
216-B-16 crib	299-E13-2	216-B-30 trench	299-E13-52
	299-E13-21		
216-B-17 crib	299-E13-4	216-B-31 trench	299-E13-58
216-B-18 crib	299-E13-5	216-B-32 trench	299-E13-59
216-B-19 crib	299-E13-6	216-B-33 trench	299-E13-60
216-B-23 trench	299-E13-55	216-B-52 trench	299-E13-54
216-B-25 trench	299-E13-56	216-B-53A trench	299-E13-61
BX Trenches			
216-B-35 trench	299-E33-286	216-B-41 trench	299-E33-8
216-B-37 trench	299-E33-287	216-B-42 trench	299-E33-10
	299-E33-288		
216-B-38 trench	299-E33-289		
	299-E33-290		

(a) PUREX = Plutonium-Uranium Extraction.



wdw99004

Figure 3.2-1. Temperature Distribution in Borehole 41-09-39

Well: 299-W23-19

Log Date: October 13, 1999

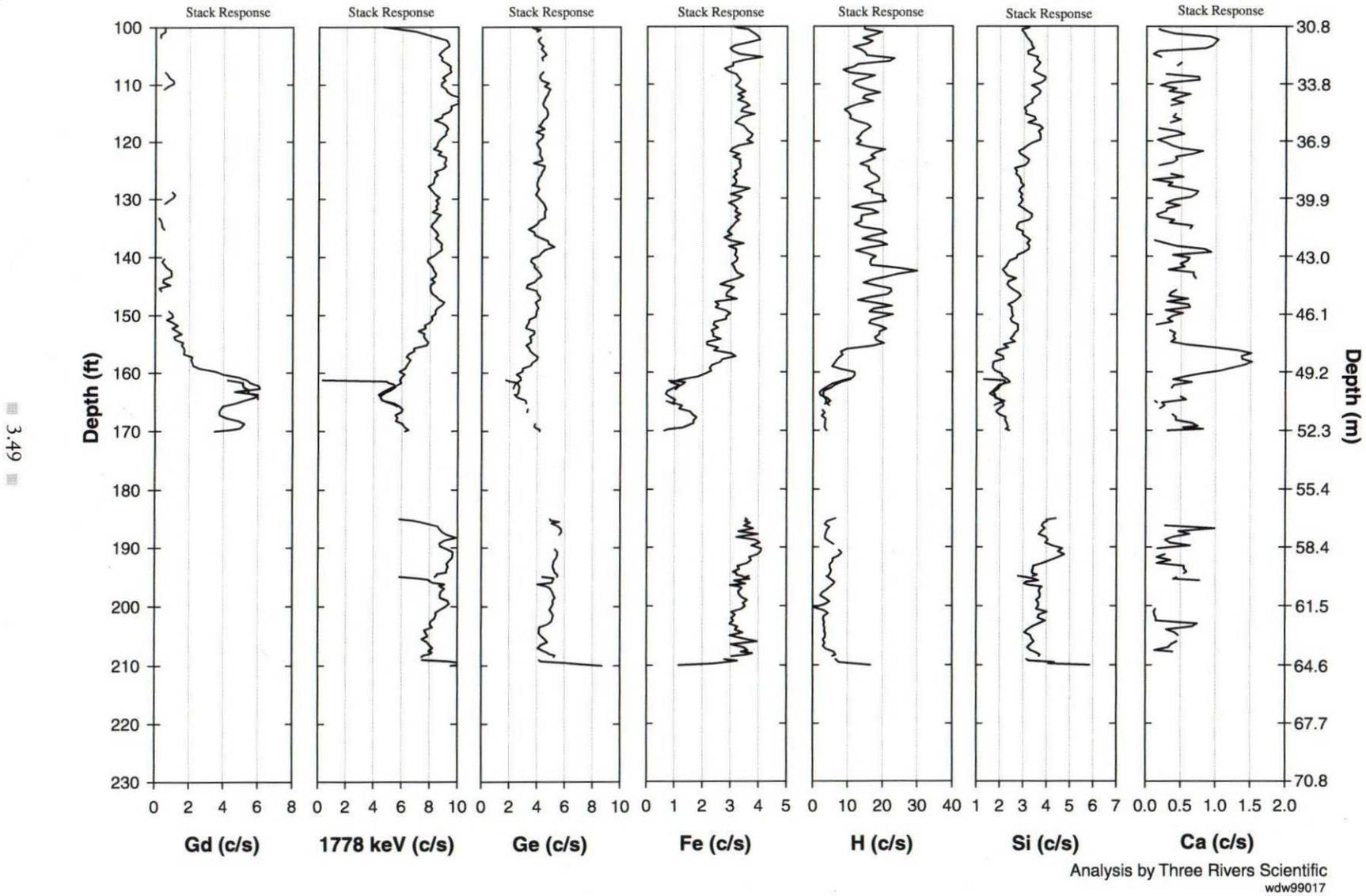


Figure 3.2-2. Neutron-Gamma Capture Spectroscopy Log from the New Borehole at Single-Shell Tank SX-115

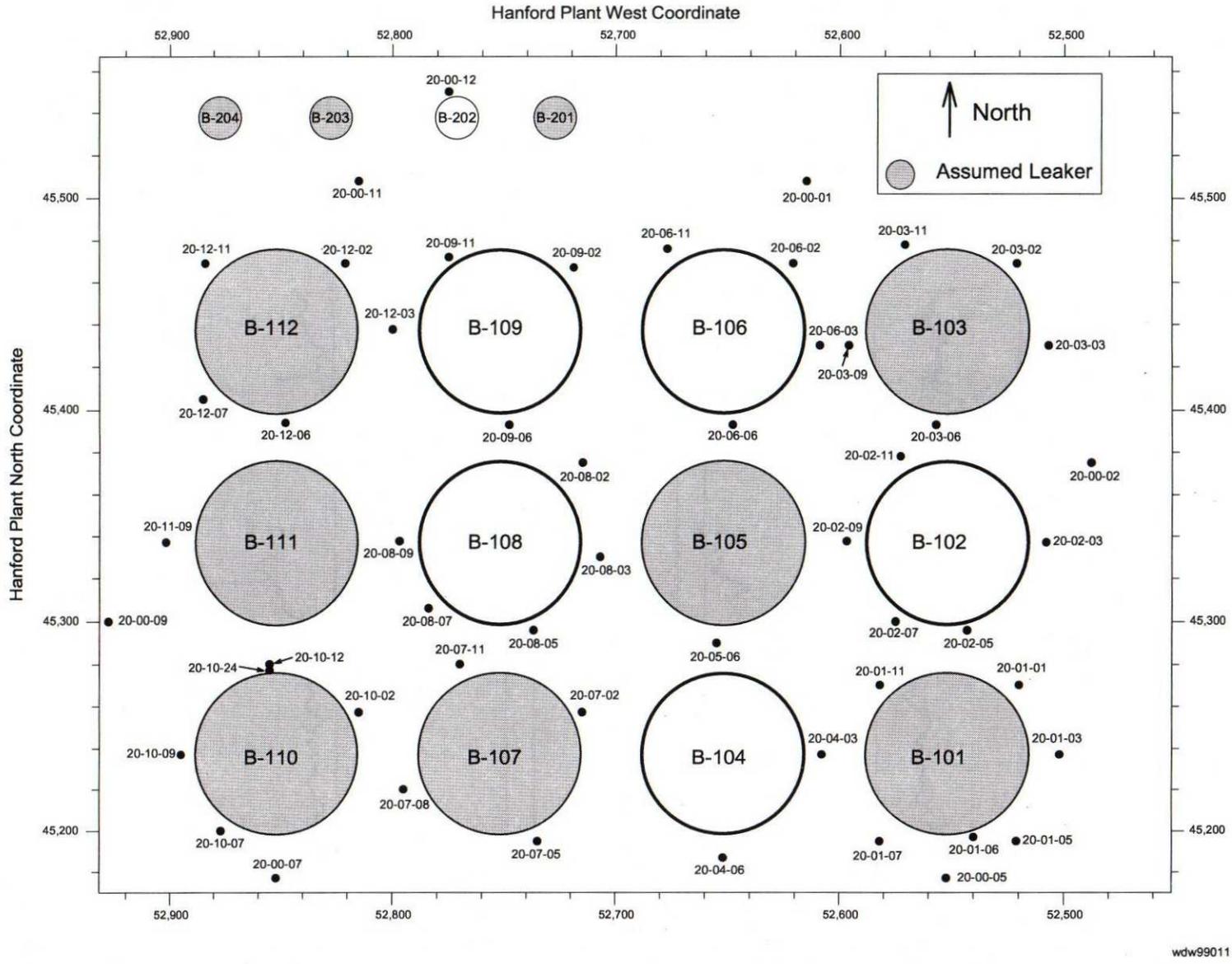


Figure 3.2-3. Map of B Tank Farm with Layout of Tanks and Locations of Monitoring Boreholes. Tanks indicated by shading are assumed to have leaked.

3.50

wdw99011

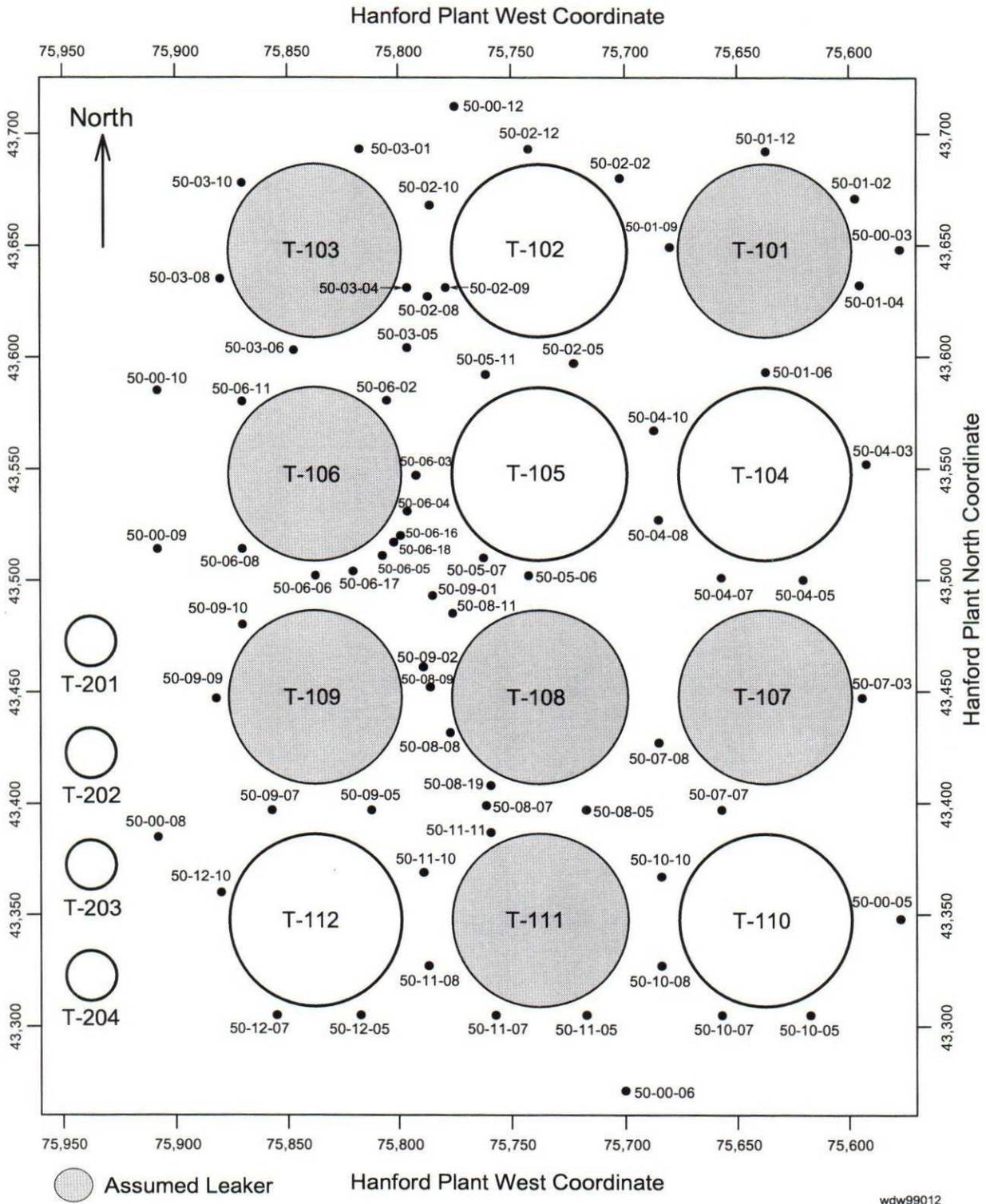


Figure 3.2-4. Map of T Tank Farm with Layout of Tanks and Locations of Monitoring Boreholes. Tanks indicated by shading are assumed to have leaked.

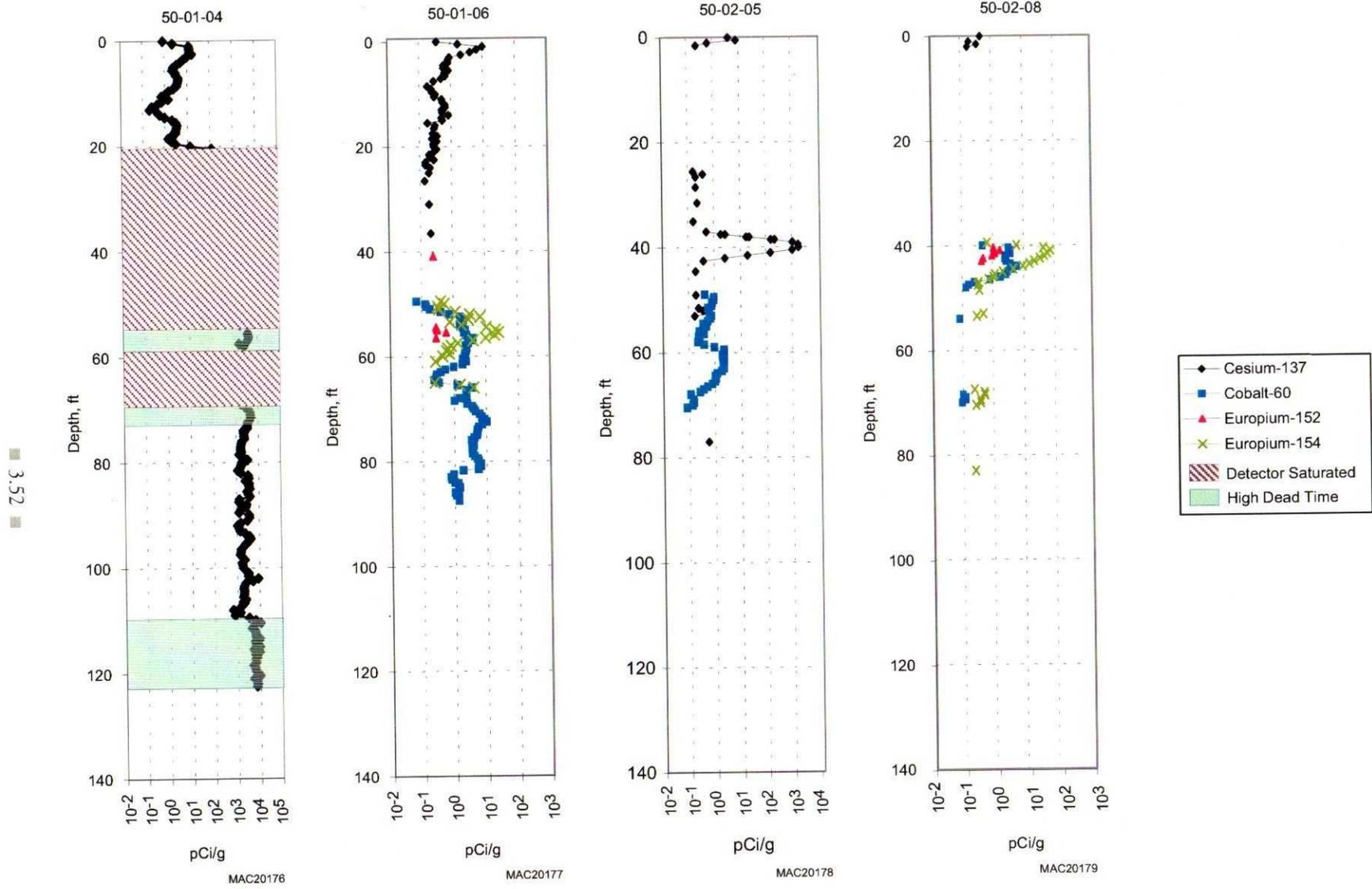


Figure 3.2-5. Selected Spectral Gamma-Ray Logs of Radionuclides Around Boreholes in T Tank Farm Showing Concentrations of Contaminants versus Depth (after GJO-99-101-TAR, GJO-HAN-27)

3.53

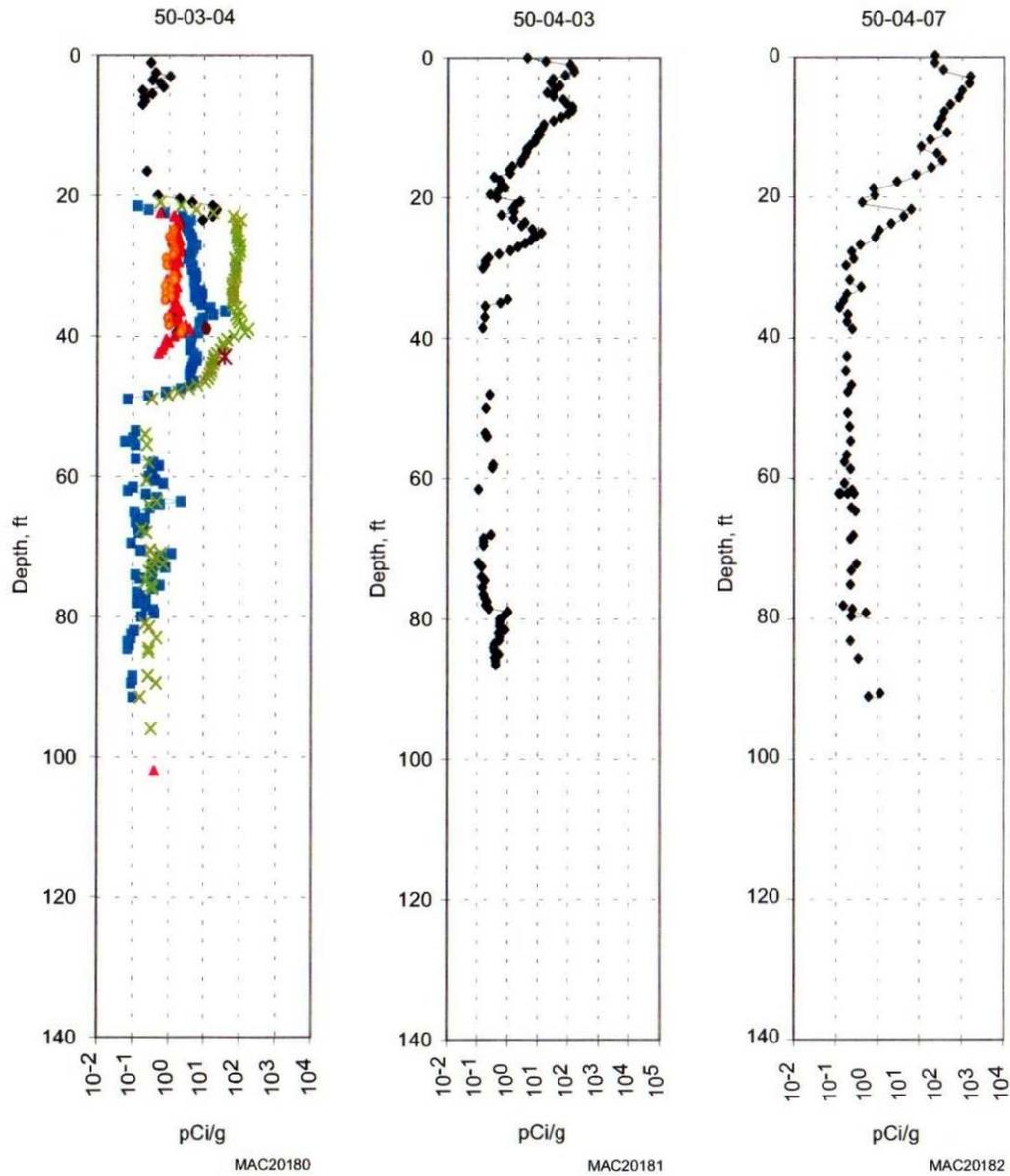


Figure 3.2-5. (contd)

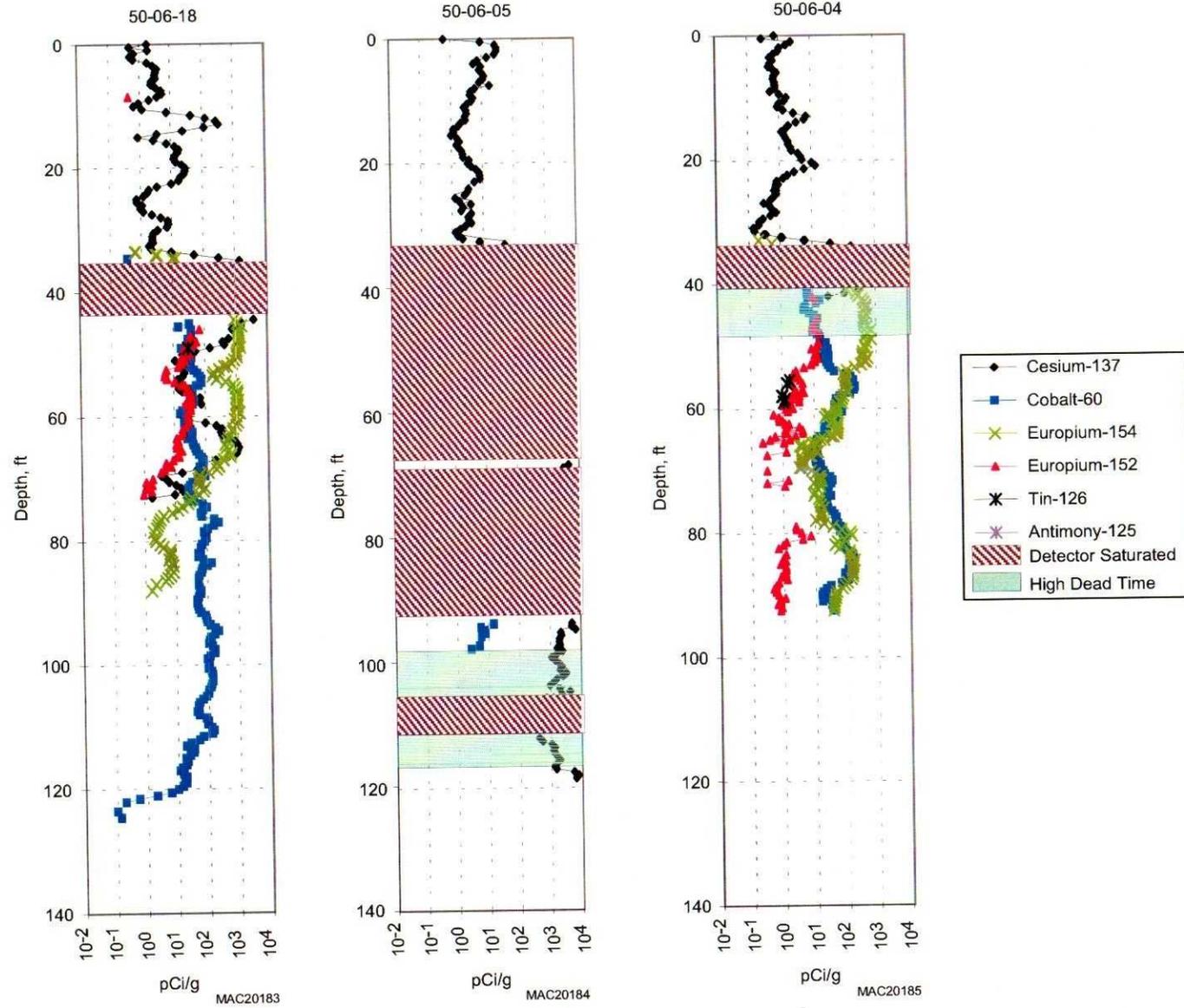


Figure 3.2-6. Selected Spectral Gamma-Ray Logs of Radionuclides Around Boreholes Near Tank T-106 in T Tank Farm Showing Concentrations of Contaminants versus Depth (after GJO-99-101-TAR, GJO-HAN-27)

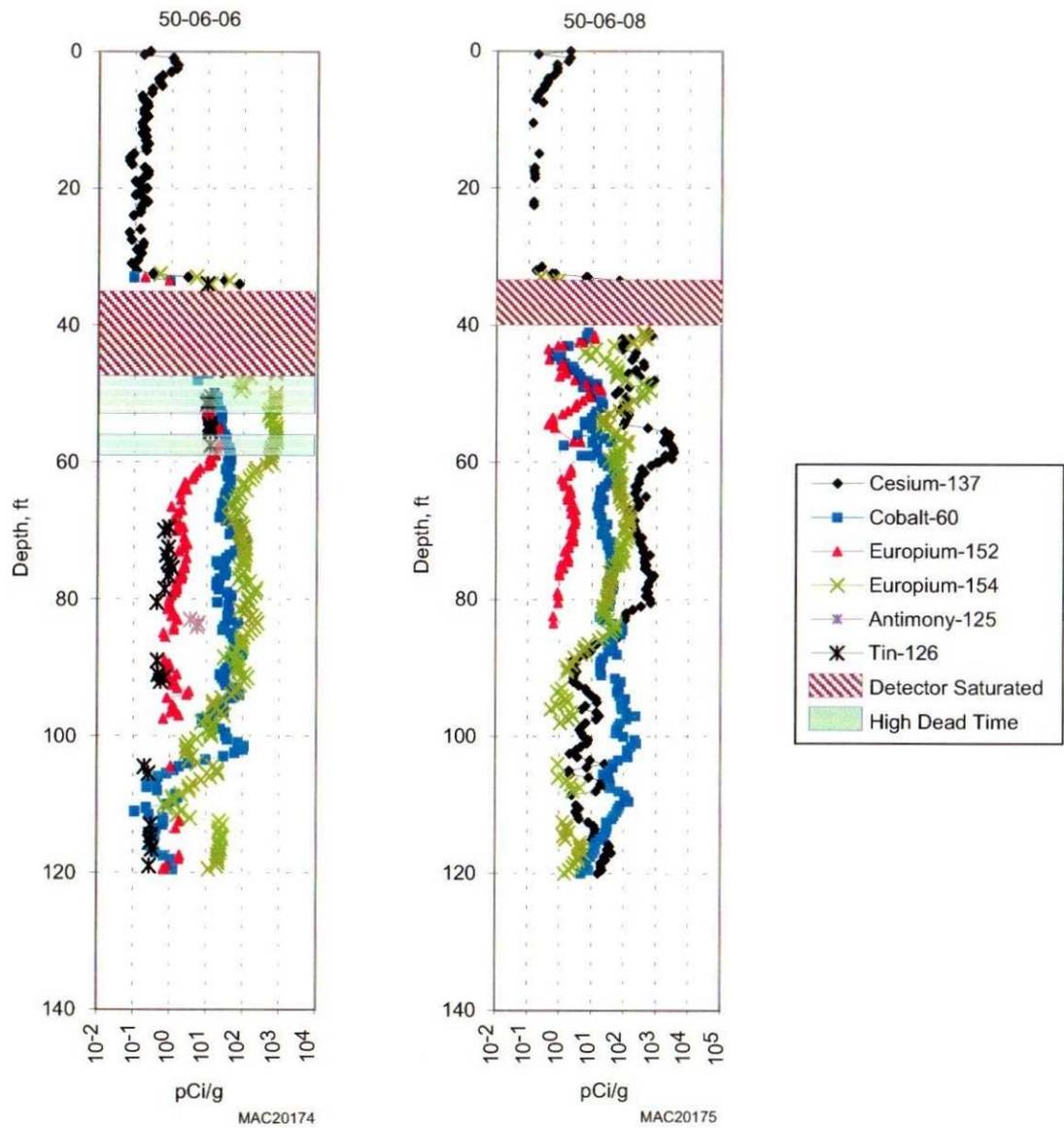


Figure 3.2-6. (contd)

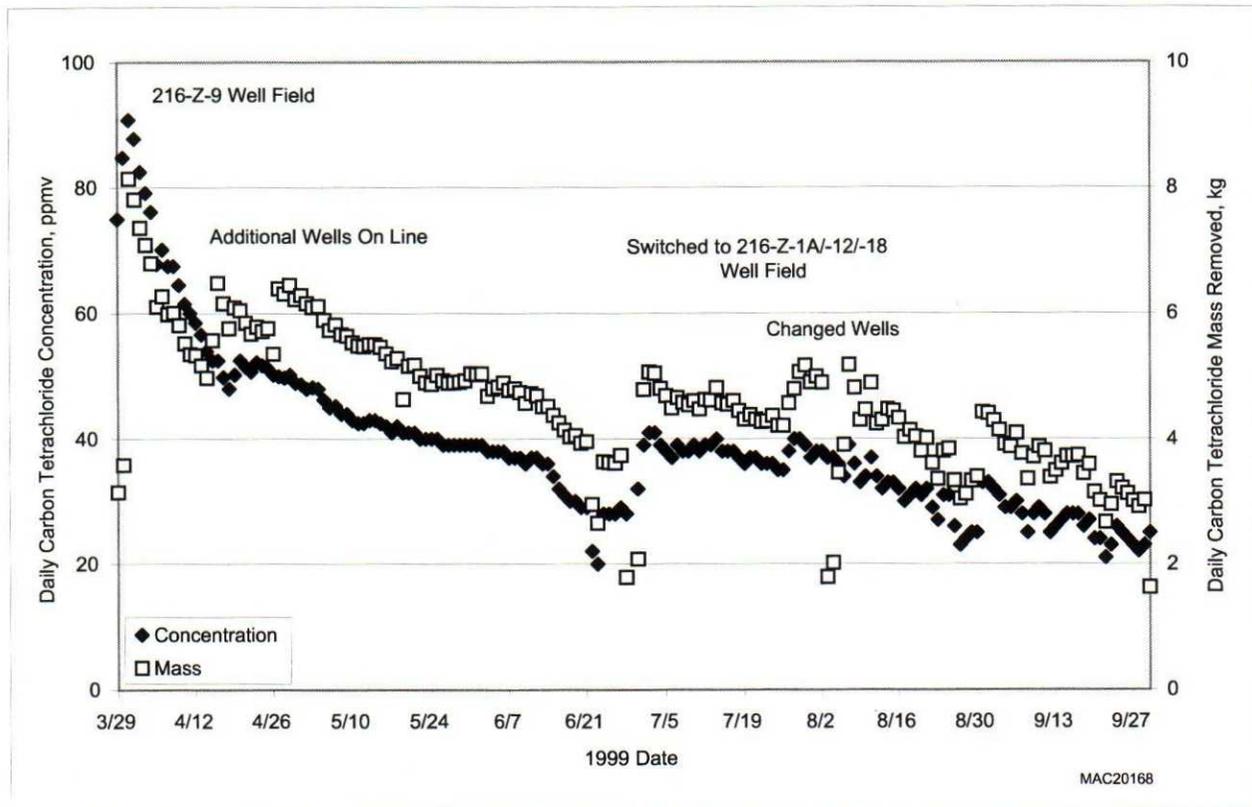
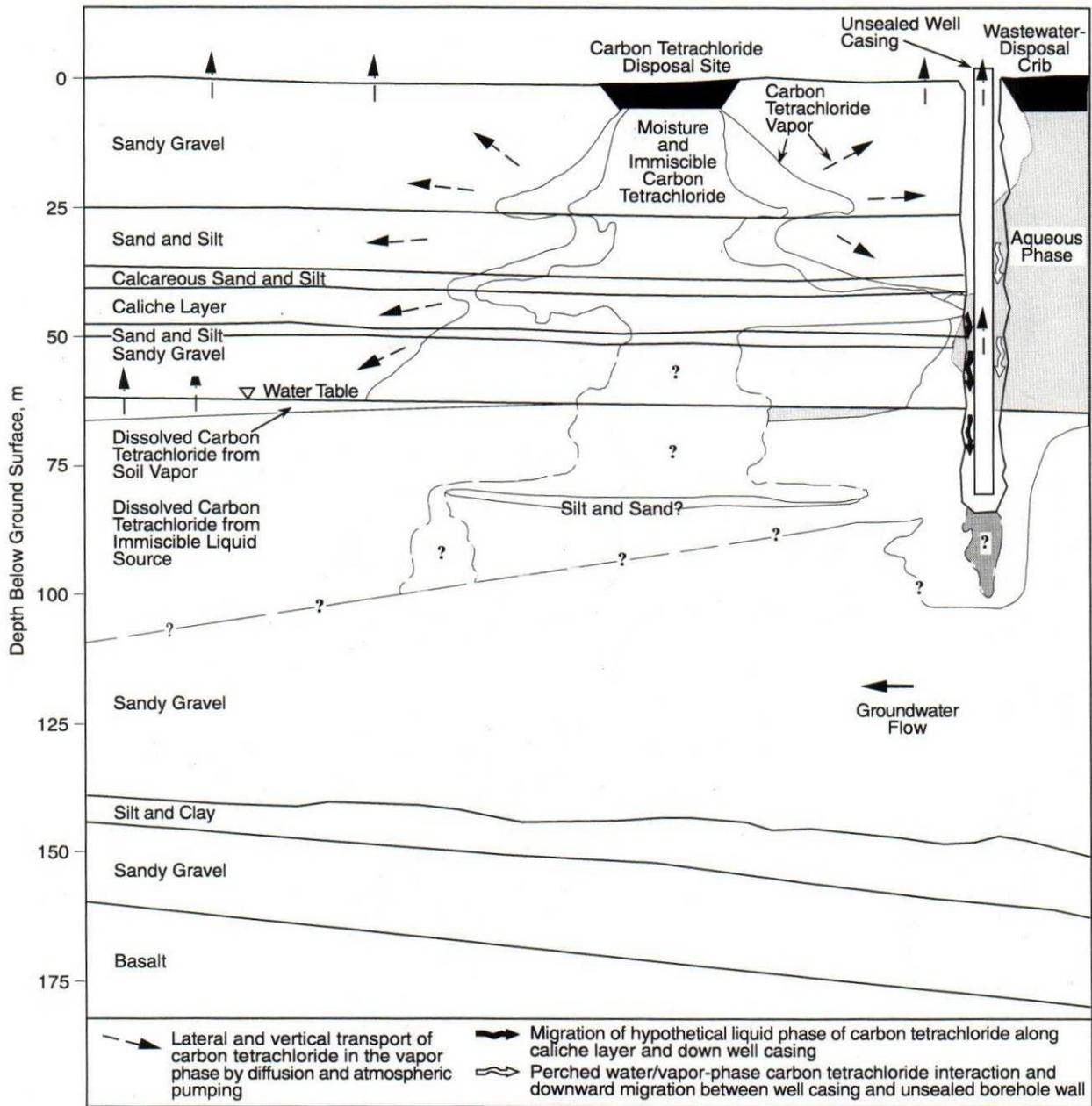
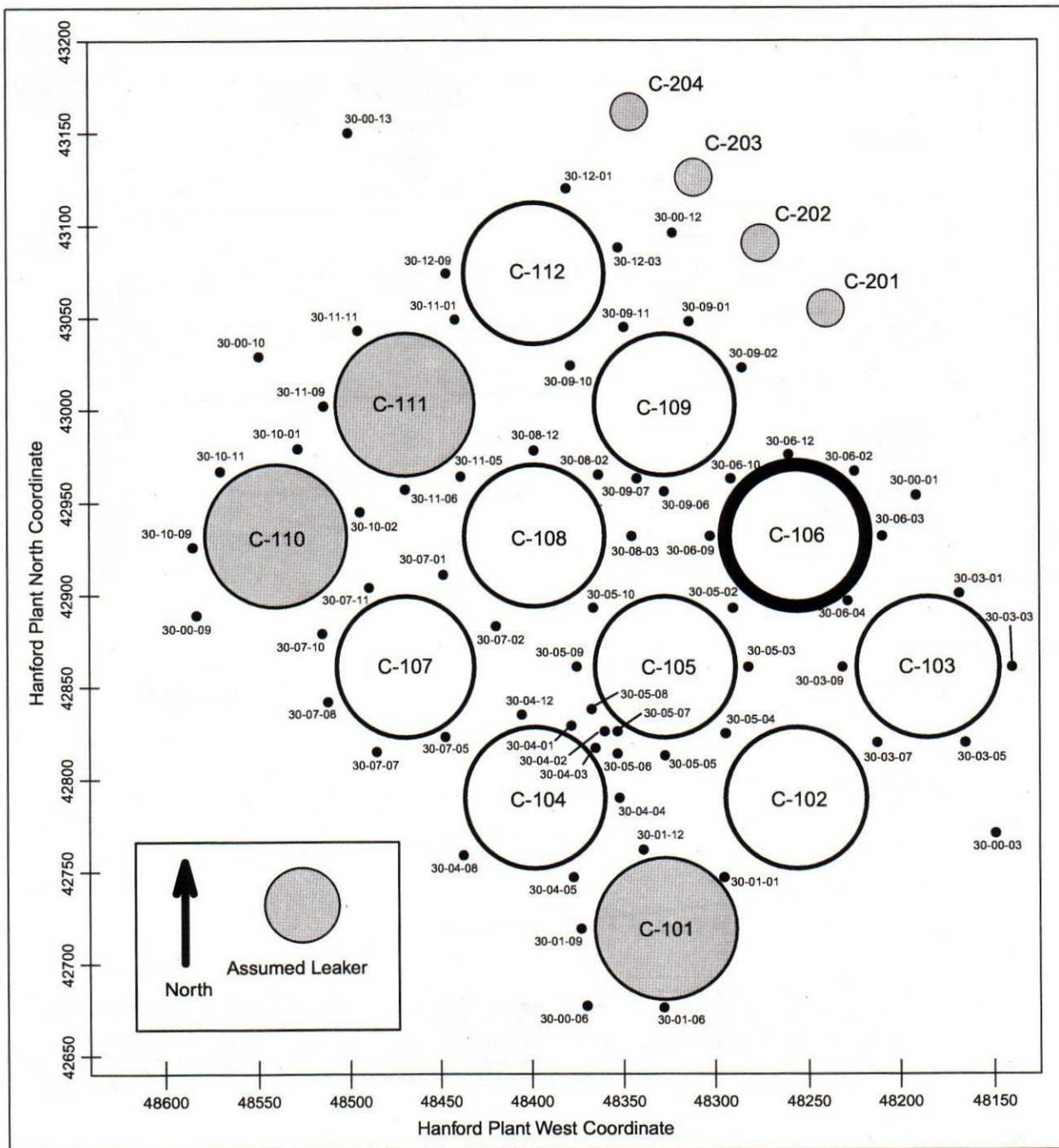


Figure 3.2-7. Time Series Concentrations of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-9 Well Field and the 216-Z-1A/-12/-18 Well Fields



RG98120214.1

Figure 3.2-8. Conceptual Model of Carbon Tetrachloride and Wastewater Migration Beneath 216-Z-9 Trench



wdw99019

Figure 3.2-9. Location Map for Boreholes Logged at Single-Shell Tank C-106 (adapted from GJ-HAN-84)

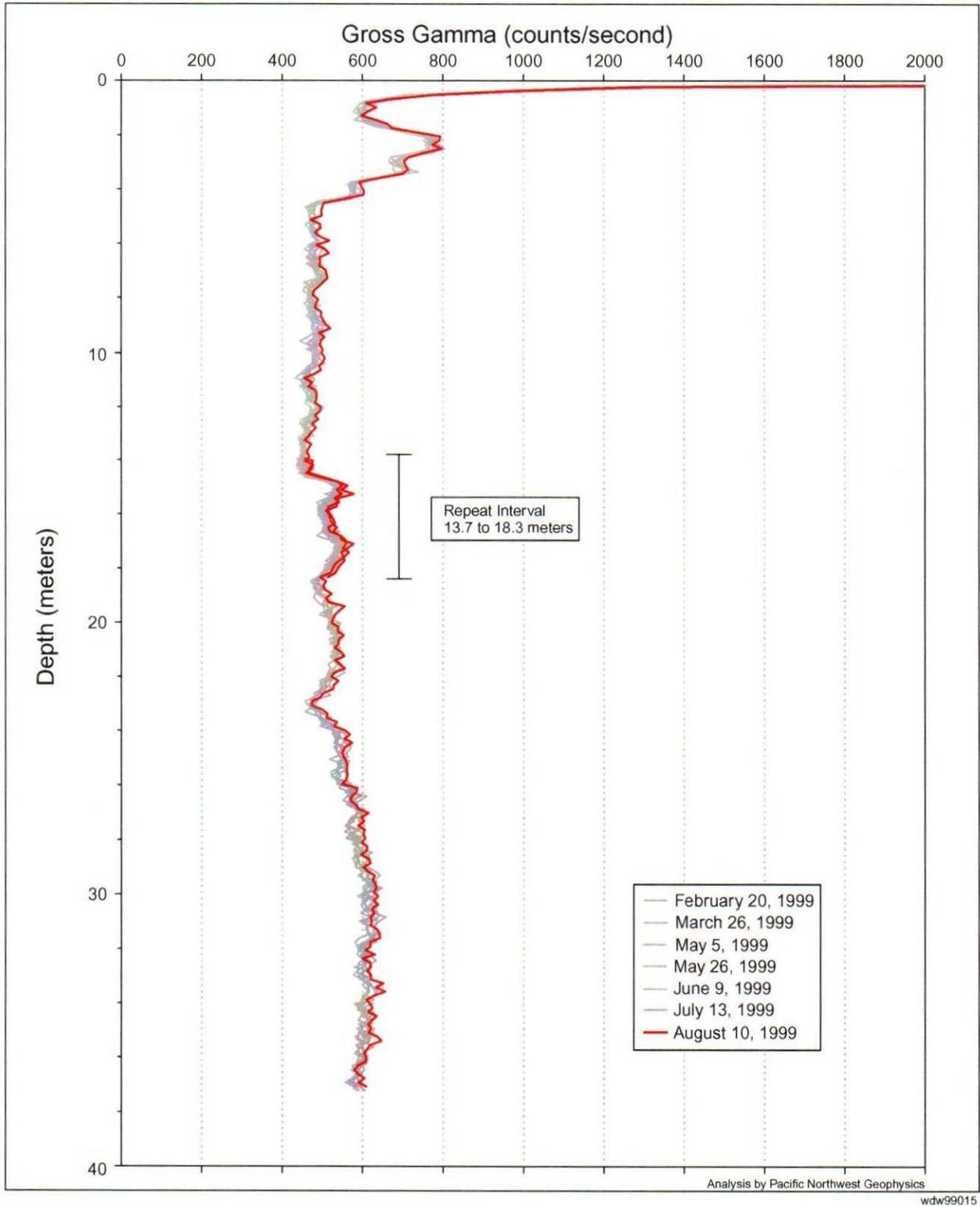


Figure 3.2-10. Time Series Gross Gamma-Ray Logs from Borehole 30-06-02

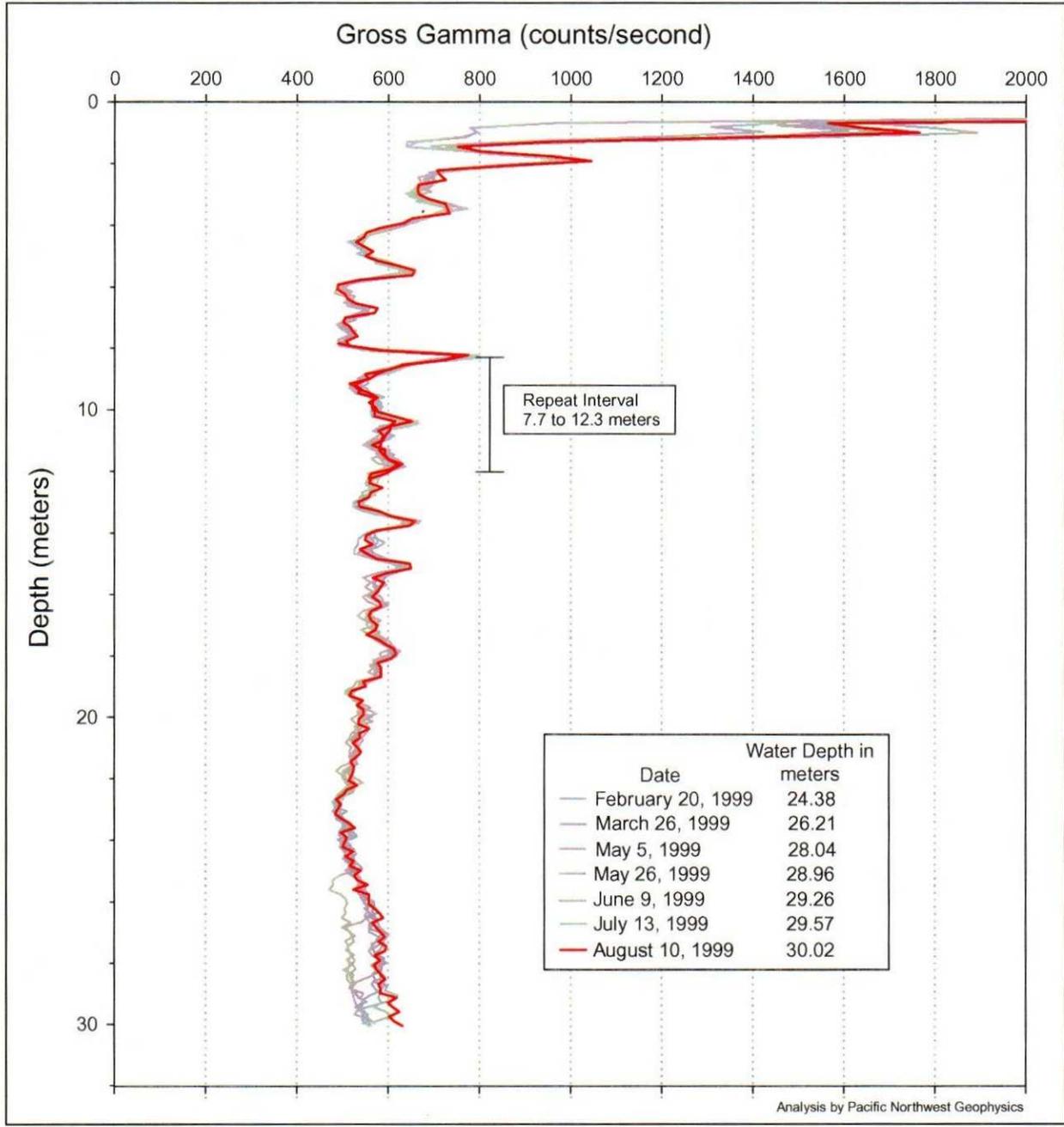
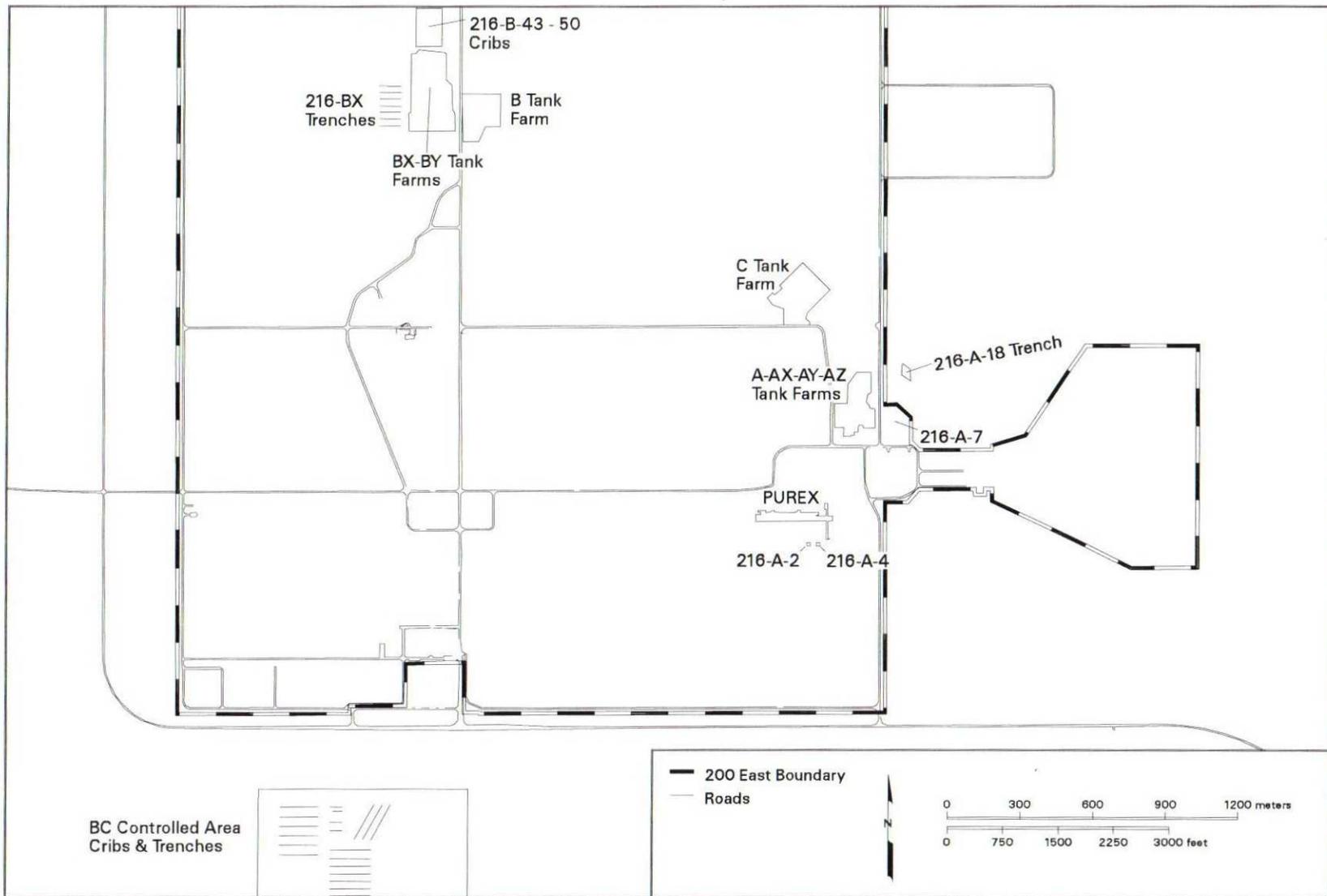


Figure 3.2-11. Time Series Gross Gamma-Ray Logs from Borehole 30-06-03



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Selected Features in the 200E Area

Figure 3.2-12. Map of the 200 East Area Showing Locations of Facilities Monitored, Fiscal Year 1999

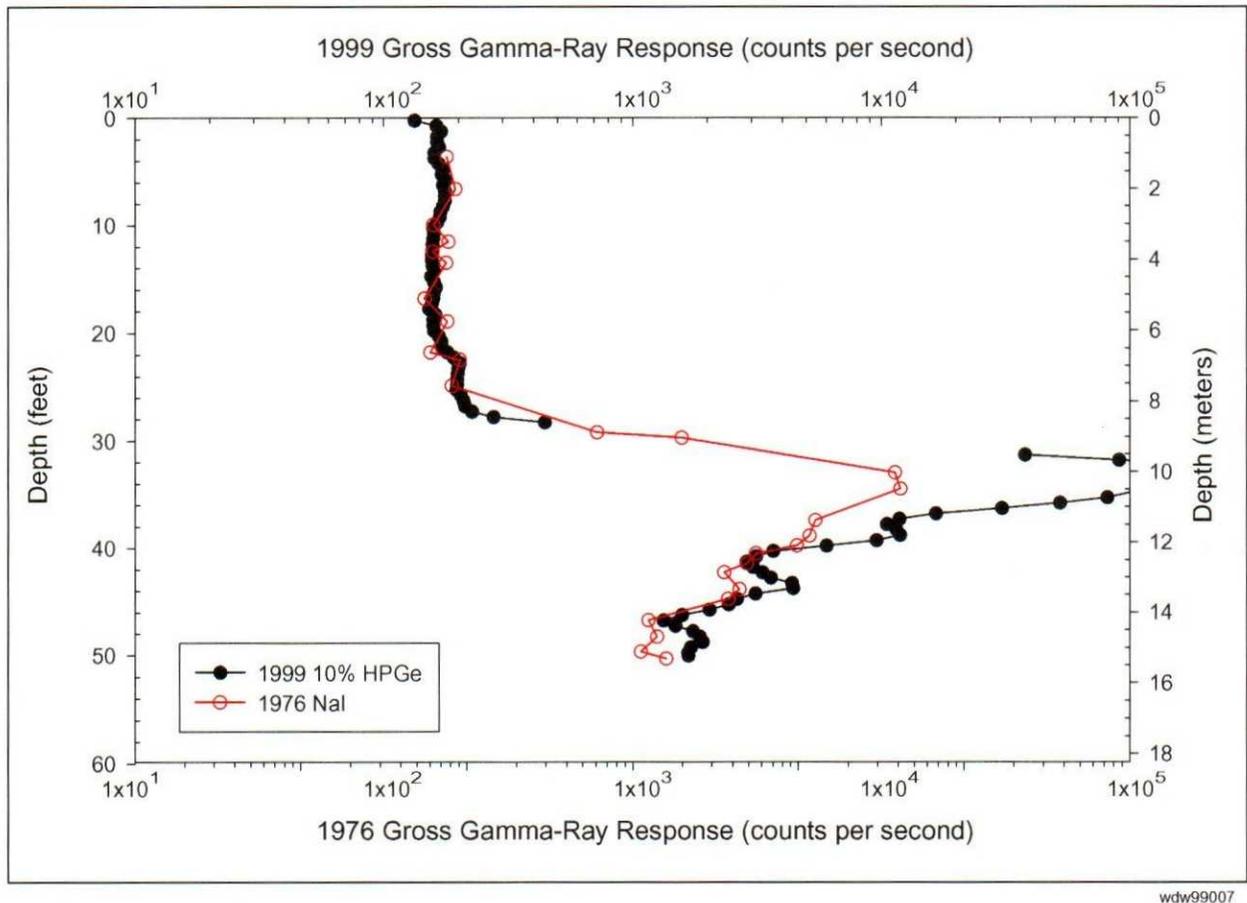
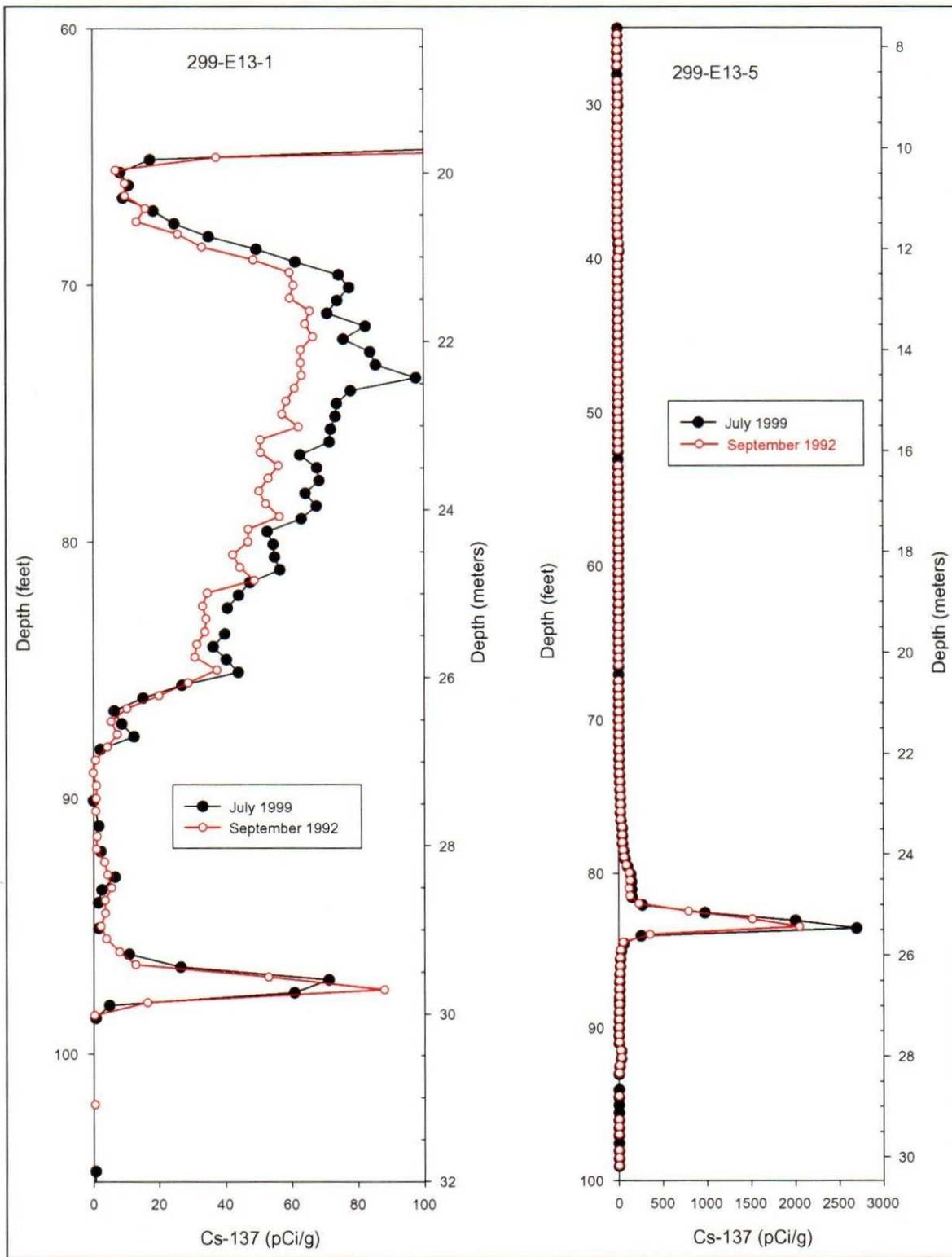


Figure 3.2-13. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E24-53 at the 216-A-2 Crib



wdw99008

Figure 3.2-14. Comparison of 1999 and 1992 Spectral Gamma-Ray Logs for Cesium-137 from Well 299-E13-1 at the 216-B-14 Crib and Well 299-E13-5 at the 216-B-18 Crib

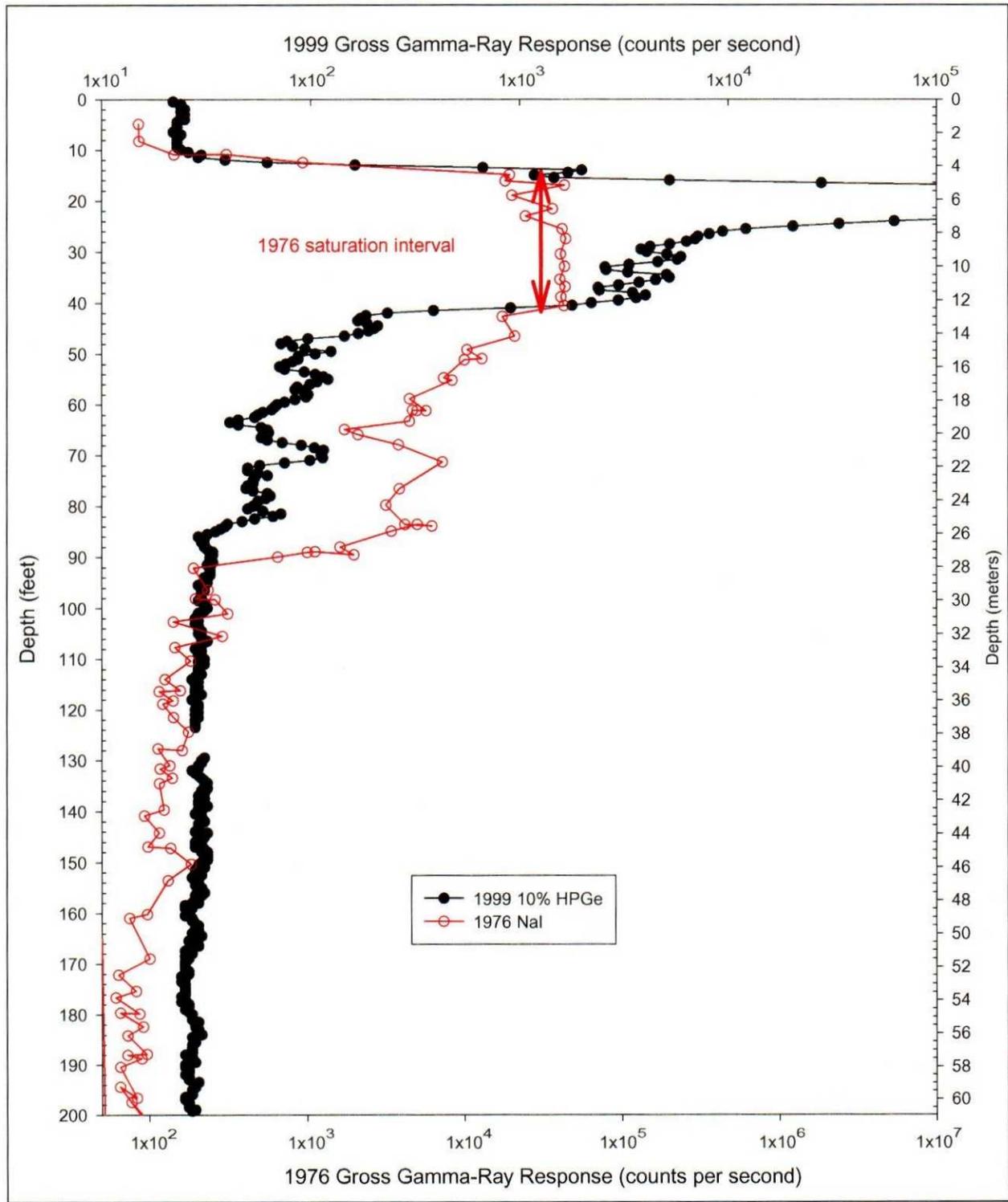


Figure 3.2-15. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E13-2 at the 216-B-15 Crib

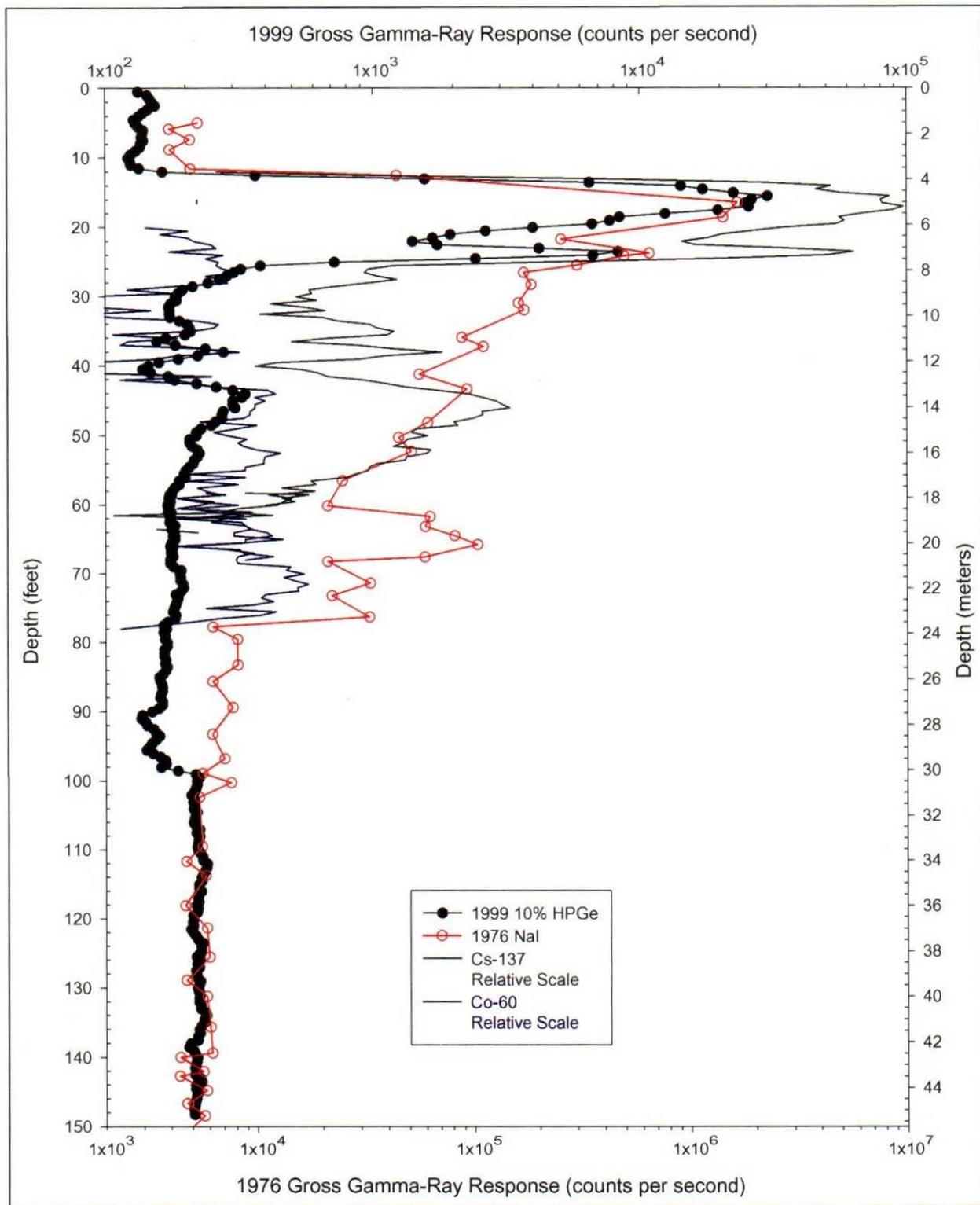


Figure 3.2-16. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E13-4 at the 216-B-17 Crib

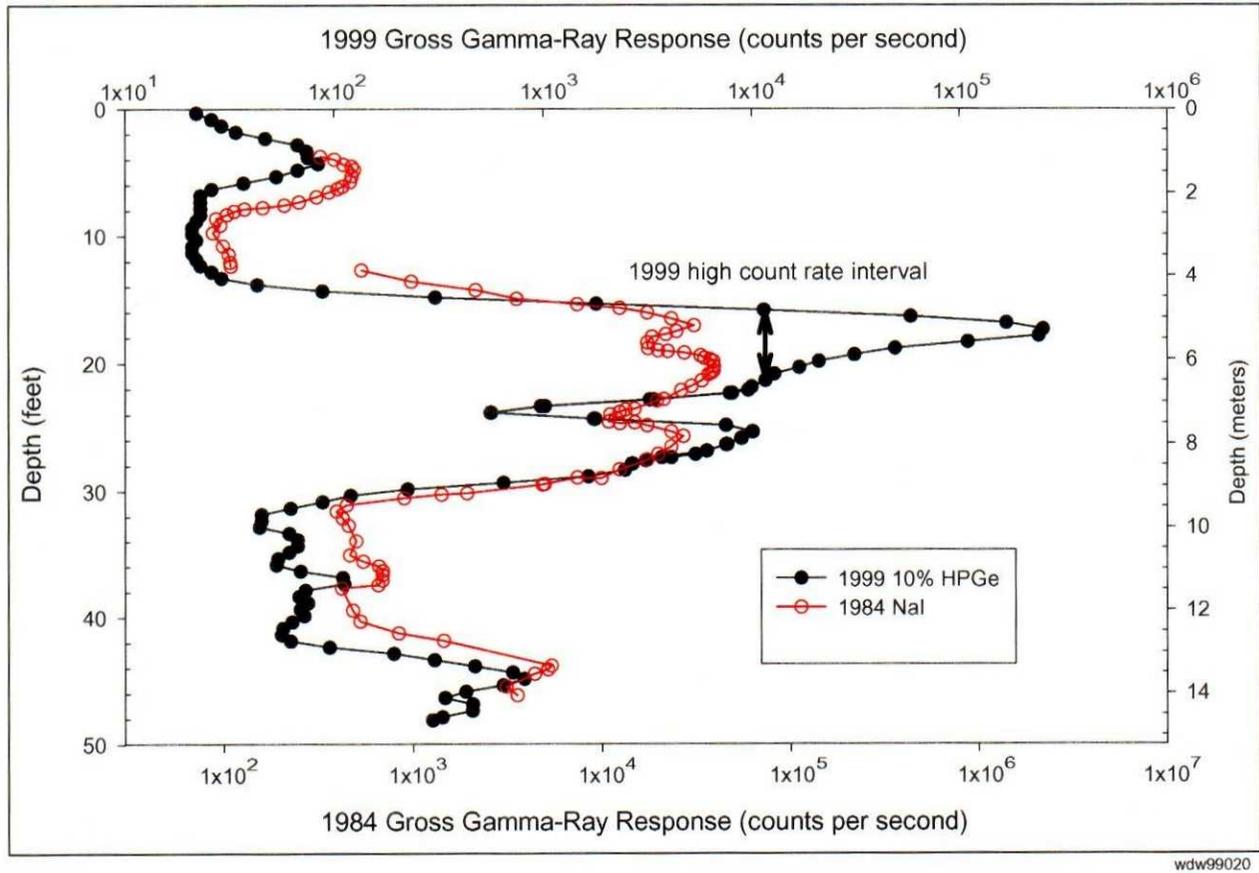
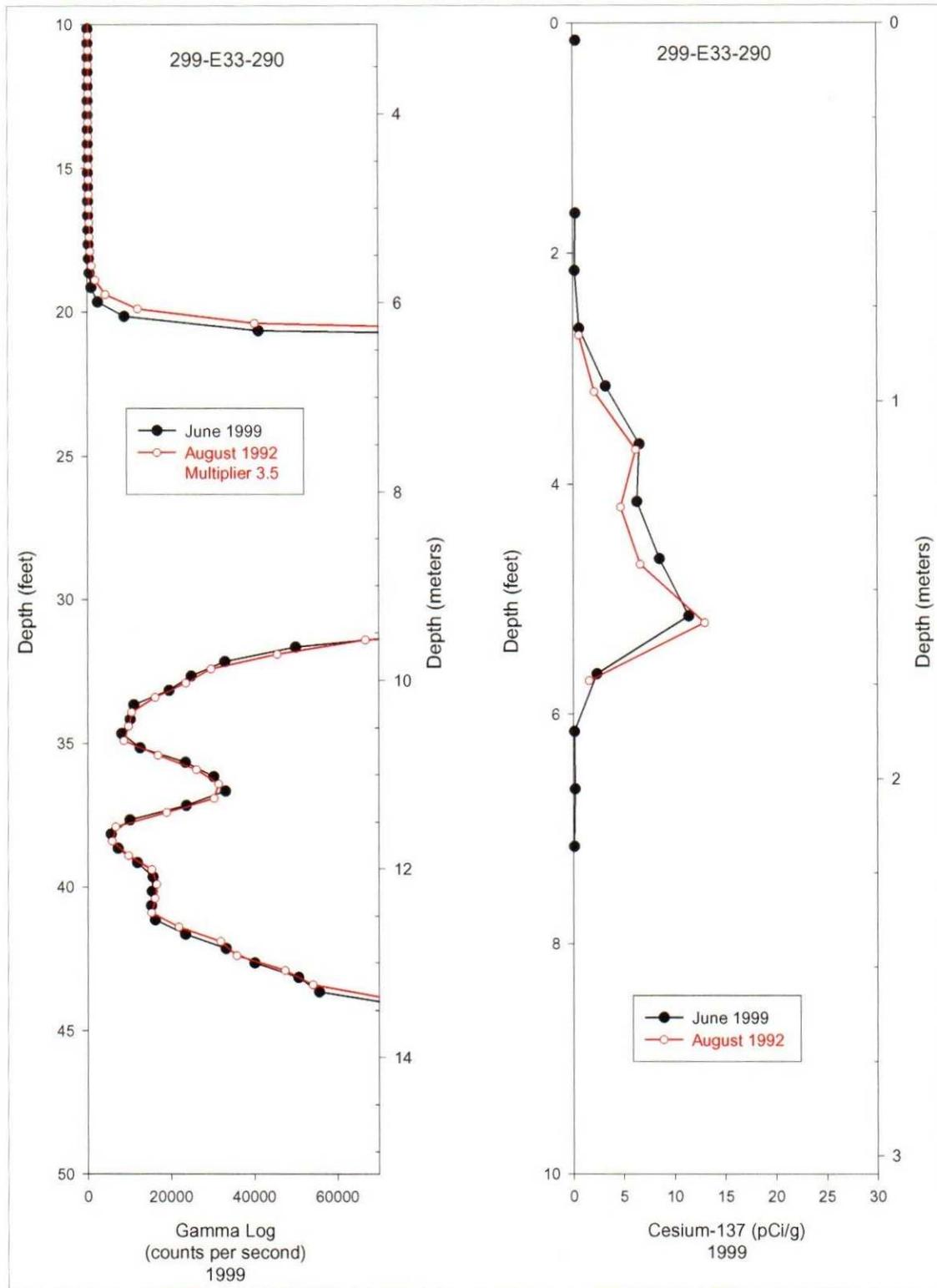


Figure 3.2-17. Comparison of 1999 and 1984 Gross Gamma-Ray Logs from Borehole 299-E13-289 at the 216-B-38 Crib



wdw99006

Figure 3.2-18. Comparison of 1999 and 1992 Gross Gamma-Ray Logs and Spectral Gamma-Ray Logs for Cesium-137 from Borehole 299-E33-290 at the 216-B-38 Trench

3.3 Additional Vadose Zone Related Investigations

In fiscal year 1999, several vadose zone related activities were accomplished that have potential applicability across the Hanford Site. The 175 lysimeters of the Hanford Site were inventoried and described in fiscal year 1999. Also, 4 years of field data from the Hanford Site prototype surface barrier were analyzed and interpreted. Those data have important applicability to contaminated sites that may be left in place and monitored during natural attenuation. Finally, tritium and helium-3/helium-4 were obtained from vadose zone sediment to extrapolate concentrations in the soil to concentrations in groundwater. This section discusses these activities.

3.3.1 Hanford Site Lysimeters

D. G. Horton, R. R. Kirkham

In fiscal year 1998, the participants of a data quality objective process for vadose zone monitoring identified moisture content and moisture movement as elements of concern for vadose zone monitoring of past-practice liquid waste disposal facilities. Consequently, the Hanford Groundwater Monitoring Project undertook an inventory of existing lysimeters and their conditions in fiscal year 1999. That inventory is summarized in Table 3.3-1.

Lysimeters measure the amount of water percolating through soil. Approximately 175 lysimeters exist at the Hanford Site. Most of these are inactive and need repair before they can be used. Active lysimeters are at the Field Lysimeter Test Facility and the Solid Waste Landfill. Some water storage data are collected from the lysimeters at the Fitzner/Eberhardt Arid Lands Ecology Reserve via data loggers and radio link to backup tapes, but currently, the data are not used.

Drainage from the lysimeter at the Solid Waste Landfill is sampled at least monthly and the leachate analyzed for several constituents of concern. The

Lysimeters measure moisture content and movement in the vadose zone. There are 175 lysimeters on the Hanford Site; most are inactive and need repair.

U.S. Department of Energy (DOE) reports results quarterly to the Washington State Department of Ecology. At the Field Lysimeter Test Facility, the weighing lysimeters are monitored hourly and the drainage lysimeters are monitored monthly for water storage.

Most of the lysimeters at the Hanford Site were designed for specific studies. As such, their application to vadose zone monitoring in the 200 Areas is limited. The limitation stems from the soil filling the lysimeters and the surface conditions of the lysimeters being different from the soil and surface conditions of most past-practice liquid disposal facilities. The lysimeters at the Field Lysimeter Test Facility and at the S-11 facility are the easiest to modify for potential vadose zone monitoring use.

3.3.2 Hanford Site Surface Barrier Technology

G. W. Gee, A. L. Ward

A field-scale prototype surface barrier was constructed in 1994 over an existing waste site as part of a *Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)* treatability test. The barrier was designed to be used at waste sites in arid climates and to have a 1,000-year performance. The barrier was monitored for 4 years to ascertain its stability and long-term performance. The 4 years of data were compiled and analyzed in 1999. This section summarizes that work; a more complete discussion is found in DOE/RL-99-11.

Natural construction materials (e.g., fine soil, sand, gravel, cobble, basalt riprap, asphalt) were selected because of the demand for the barrier to perform for at least 1,000 years without maintenance. Most of these natural construction materials are available in large quantities on the Hanford Site and some are known to have existed in place for thousands of years (e.g., basalt). The current barrier consists of a 2-meter-thick, fine-soil layer overlying other layers of coarser materials that include sands, gravels, and basalt rock (riprap) and a low permeability asphalt layer. The barrier is designed to limit recharge to <0.5 millimeter per year. Figure 3.3-1 shows the construction details of the barrier.

A prototype surface barrier was constructed in 1994 to isolate a waste site from infiltrating moisture. Data collected since then indicate the barrier successfully prevents surface water and precipitation from reaching the waste site.

Each layer serves a distinct purpose. The fine soil layer acts as a medium to store moisture until the processes of evaporation and transpiration recycle any excess water back to the atmosphere. The fine soil layer also provides the medium to establish plants that are necessary for transpiration to take place. The coarser materials placed directly below the fine soil layer create a capillary break that inhibits downward percolation of water through the barrier. The placement of fine soil directly over coarser materials also encourages plants and animals to limit their biological activities to the upper, fine soil portion of the barrier, thereby reducing biointrusion into the lower layers. The coarser materials also help to deter inadvertent human intruders from digging deeper into the barrier profile.

Low-permeability layers are placed below the capillary break to (1) divert any percolating water that crosses the capillary break away from the waste zone and (2) limit the upward movement of noxious gases from the waste zone. The coarse materials located

above the low-permeability layers also serve as a drainage medium to channel any percolating water to the edges of the barrier.

In addition to testing the performance of a capillary barrier, the prototype is being used to test two different side-slope designs:

- a relatively flat apron (10:1, horizontal:vertical) of clean fill gravel
- a relatively steep (2:1) embankment of fractured basalt riprap (PNL-8391; Ward and Gee 1997).

A shrub and grass cover was established on the soil surfaces of the prototype in November 1994. Shrubs were planted at a density of two plants per square meter with four sagebrush (*Artemisia tridentata*) plants to every one rabbitbrush (*Chrysothamnus nauseosus*) plant.

3.3.2.1 Results of Field Tests

Designing a maintenance-free barrier requires an understanding of how natural processes affect barrier performance. A series of tests was designed to provide a better understanding of these processes.

From November 1994 through October 1997, soil plots on the northern half of the prototype barrier were irrigated such that the total water applied, including natural precipitation, was 480 millimeters per year or 3 times the long-term annual average for the water year (November 1 through October 31). This treatment included application of sufficient irrigation water on 1 day, during the last week of March for 3 years (1995 through 1997), to mimic a 1,000-year storm event (70 millimeters of water).

Survival rates of the transplanted shrubs have been remarkably high; 97% for sagebrush and 57% for rabbitbrush (PNNL-11367). Heavy invasions of tumbleweed (*Salsola kali*) occurred in 1995 but were virtually absent in 1996. Grass cover, consisting of 12 varieties of annuals and perennials, including cheatgrass, several bluegrasses, and bunch grasses, dominated the surfaces, particularly those that were irrigated. Approximately 75% of the surface was covered by vegetation; a cover value typical of shrub-steppe plant communities.

In all respects, the vegetated cover appeared to be healthy and normal. There was nearly twice as much grass cover on the irrigated surfaces than on the non-irrigated surfaces (PNNL-11367).

Figure 3.3-2 compares temporal changes in mean soil water storage on the irrigated and non-irrigated portions of the prototype barrier through September 1998. All irrigation and natural precipitation plus all available stored soil water were removed via evapotranspiration during the first year of surface barrier operation. By late summer of each year, water was removed from the entire soil profile so that the soil water content of both irrigated and non-irrigated plots reached a relatively uniform lower limit of 5 to 8 volume percent throughout the soil profile. Correspondingly, water storage was reduced to levels of 100 to 150 millimeters (i.e., lower limit of plant-available water), for both the irrigated and non-irrigated soil surfaces. This is approximately one-fifth the amount of water required for drainage. Based on these observations and considering the irrigation treatment to represent the extreme in wet climate, the soil cover would not be expected to drain, even under the wettest Hanford Site climate conditions.

Figure 3.3-2 also shows that all of the water was removed from the soil profile following each simulated 1,000-year storm. Because no drainage occurred, the change in storage is attributed to water loss by evapotranspiration, thus demonstrating the continued positive benefits of having vegetation on the barrier surface. Evapotranspiration for the irrigated plots was nearly double that for the non-irrigated (ambient) plots, suggesting that vegetation is capable of adjusting to water applications. It is apparent that the capacity of vegetation for water consumption has not been exceeded even at three times the long-term annual average precipitation rates. This further supports the hypothesis that the combination of vegetation and soil storage capacity is more than sufficient to remove all applied water under the imposed test conditions.

Drainage did not occur from the soil covered part of the prototype barrier until the third year and then

only in a minute amount (less than 0.2 millimeter) for one of the soil plots subjected to irrigation. The drainage was attributed to lateral flow from water diverted off an adjacent roadway. These observations agree with the results of extensive lysimeter testing of capillary barrier designs (PNL-7209; PNL-8911) and suggest that the water storage capacity of the soil is well in excess of three times the long-term annual average (480 millimeters) precipitation. In contrast, both side-slope configurations drained, though the amount of drainage was significantly less than predicted, based on the lysimeter testing that has been done with coarse materials (PNL-8911).

Figure 3.3-3 compares cumulative drainage from the gravel and riprap slopes through October 31, 1998. On the non-irrigated treatments, the total amount of drainage from the clean fill side-slope was greater than that from the basalt riprap side slopes. A similar trend was observed on the irrigated slopes up until November 1995. Whereas irrigation of the soil surfaces started in February 1995, irrigation of the side slopes did not start until November 1995. A closer look at these results show a seasonal influence on drainage. Whereas drainage from the gravel side slope was continuous, there was essentially no drainage from the riprap in the summer. In the winter, both side-slope configurations drained at similar rates. Advective drying similar to that described by Stormont et al. (1994) and Rose and Guo (1995) may be partly responsible for the lower drainage on the riprap side slopes and may also have an effect on water storage in the fine-soil cover. Additional testing and numerical modeling will be used to test this hypothesis.

The rapid establishment of vegetation on the soil surface was thought to be responsible for at least three positive benefits to surface barrier performance. First, the vegetation was dominant in the water removal process from the soil surfaces. Second, the surface was stabilized against water erosion and runoff. Runoff from the 1,000-year storm in 1995 was 1.8 millimeters (~2% of the 70 millimeters applied). There was no runoff in 1996. The improvement was attributed to

plant growth. Finally, there has been a positive benefit in controlling wind erosion. There has been no measurable loss of soil from the surface of the prototype barrier by wind erosion since the establishment of plants in November 1994.

Four years of testing provide important but limited information for long-term barrier performance estimates. Because only a finite amount of time exists to test a barrier that is intended to function for a minimum of 1,000 years, the testing program has been designed to stress the prototype so that barrier performance can be determined within a reasonable time frame.

3.3.2.2 Conclusions

The study of surface barriers at the Hanford Site has evolved into an integrated demonstration of key features of barriers designed to minimize water intrusion, erosion, and biointrusion. The results of field tests, experiments, and lysimeter studies provide baseline information on which barrier designs can be based. Test results show that a well-designed capillary barrier limits drainage to near-zero amounts in the Hanford Site's arid climate. A subsurface asphalt layer provides additional redundancy. Data collected under extreme conditions (excess precipitation) provide confidence that the barrier has the ability to meet its performance objectives for the 1,000-year design life. Data from the prototype surface barrier confirm earlier observations with lysimeters and field plots and show that virtually all available water can be removed from the soil surfaces by evapotranspiration, under the tested elevated precipitation conditions. Side slopes, in contrast, drain because they are barren. The side-slope drainage is less than predicted because of advective heating and wind action but is non-zero. Thus, this drainage must be accommodated in the final design. Asphalt sublayers can be successful in extending areas of surface protection and can divert drainage water away from underlying waste but the durability of the asphalt must be evaluated.

3.3.3 Measurement of Tritium in Soil Moisture and Helium-3 in Soil Gas at the Old Hanford Townsite and KE Reactor

K. B. Olsen, G. W. Patton, E. P. Dresel,
J. C. Evans

The Hanford Groundwater Monitoring Project sampled and analyzed soil gas and soil moisture in fiscal year 1999 to

- demonstrate the adaptability of soil gas sampling techniques to the measurement of tritium and helium-3 concentrations in Hanford Site soil
- determine tritium and helium-3 concentrations in soil gas at two locations on the Hanford Site
- attempt to extrapolate tritium and helium-3 concentrations in the soil to tritium concentrations in groundwater at the 100 K Area.

In fiscal year 1999, investigators measured tritium and helium-3 in soil vapor at two vadose zone sites. Results indicate helium-3 may be useful to trace vadose zone or groundwater sources of tritium.

Tritium/helium-3 age dating of shallow aquifer groundwater was successfully applied in the late 1980s by Poreda et al. (1988). The technique is based on the presence of the radioactive isotope tritium and its decay to the stable, inert isotope of helium, helium-3. At the Hanford Site, tritium was released to the soil column as effluent from past operations. In some areas of the Hanford Site, the effluent migrated through the vadose zone to mix with groundwater. In other areas, the effluent was retained in the vadose zone. Subsequently, moisture laden with tritium volatilized from the flow path and the water table and began to diffuse upward through the vadose zone toward the surface.

At the same time, helium-3 began to build up in both the groundwater and the vadose zone at the rate

of tritium decay (the half-life of tritium is 12.3 years) and diffuse upward to the surface. Throughout this process, helium-3 is expected to act as a conservative (non-reactive) tracer moving through the vadose zone. Tritium, as tritiated water, would be a reactive tracer freely exchanging with hydroxyl groups on the surface of sediment and thus retard its movement through the vadose zone. Based on the above principles and conceptual model, soil gas and soil moisture samples were collected and analyzed to obtain a better understanding of their vadose zone properties and attempt to map vadose zone and groundwater tritium distribution.

3.3.3.1 Experimental Methods

Two areas of the Hanford Site were chosen to investigate: south of the Old Hanford Townsite and east of the KE Reactor. The Old Hanford Townsite was chosen because it is an area with a known tritium plume at groundwater depths similar to those in the 100 Areas and the site had easy access. The KE Area was chosen to study because there is a known tritium plume but there is some uncertainty as to its distribution. It was hoped that the helium-3/helium-4 method would help better define the existing groundwater contamination.

Eight sampling points, in two clusters, were installed between 1.5 and 9.7 meters below ground surface adjacent to well 699-41-1A, south of the Old Hanford Townsite (Figure 3.3-4). Sixteen sampling points between 2.1 and 3.1 meters below ground surface were installed to the north and east of the KE Reactor (Figure 3.3-5). Soil gas and soil moisture samples were collected in mid-July and in early September from the Old Hanford Townsite and in early September from the KE Reactor.

Soil moisture samples were collected from all eight sampling locations at the Old Hanford Townsite and the eight locations at the KE Reactor. Soil moisture samples were collected using a flexible diaphragm sampling pump. The samples were passed through a single 18-centimeter-long, silica gel column to adsorb soil moisture. Samples were collected at a flow rate of 1 liter per minute for a period of ~24 hours.

Soil gas samples, for helium-3 measurements, were collected at all sampling points using a sampling apparatus constructed from a 30-milliliter stainless steel cylinder. One end of the cylinder was fitted with a high-vacuum needle valve and the other end sealed with a pipe plug. Each cylinder was evacuated to less than 5 torr before sampling.

Two different sampling configurations were used to sample soil gas. During the July sampling at the Old Hanford Townsite, a silica gel trap, identical to that described above for soil moisture samples, was placed in the soil gas stream to remove all soil moisture. The soil gas sampling point was allowed to purge at 1 liter per minute for a minimum of 60 minutes. At the end of the purge period, a hose was connected to the pump and the cylinder was pressurized to the maximum pressure of the pump.

During a subsequent sampling event at the Old Hanford Townsite in September, cluster SG-1 was resampled for helium-3. Silica gel was not used because tritium was not observed in the soil moisture samples previously collected. Instead, a rotometer and pump were hooked in series to the riser tube that extended from the soil gas sampling point to the sampling cylinder. Flow was adjusted to 1 liter per minute, and the sampling point was purged for a minimum of 60 minutes. At the end of the purge, the cylinder was connected to the pump and allowed to pressurize to the pump's maximum pressure.

Soil moisture samples were sent to Quanterra Environmental Services laboratory in Richland, Washington for analysis. In brief, the sample was heated to desorb the soil moisture from the silica gel. The tritium content of the desorbed water was determined by liquid scintillation counting. Detection limit in the liquid, using a 10-milliliter sample aliquot, is estimated at 240 pCi/L.

Soil gas samples were sent to the University of Rochester for helium analysis. Helium isotope ratios and concentrations were analyzed on a VG 5400 Rare Gas Mass Spectrometer fitted with a Faraday cup (resolution of 200 counts) and a Johnston electron

multiplier (resolution of 600 counts) for sequential analyses of the helium-4 (Faraday cup) and helium-3 (multiplier) beams. All helium-3/helium-4 ratios are reported relative to the atmospheric ratio (R_A), using air helium as the absolute standard.

3.3.3.2 Results and Discussion

Analysis of the soil moisture samples found no detectable tritium (minimum detection limit less than 240 pCi/L) in the soil moisture from either the Old Hanford Townsite or KE Reactor sampling points. This suggests that tritiated moisture from groundwater is not migrating upward to the sampling points at the Old Hanford Townsite. This is in spite of the fact that tritium in groundwater from well 699-41-1A, adjacent to the soil moisture sampling points, occurs at a concentration of 117,000 pCi/L at a depth to groundwater of 21 meters. These data indicate that the soil moisture can be attributed to recharge of natural precipitation into the vadose zone at the Old Hanford Townsite, which agrees with work done by Fayer et al. (1997). Concentrations of tritium in natural precipitation normally range from 50 to 100 pCi/L, well below the detection limit of the analytical method used to measure tritium. The lack of tritium in soil moisture at the KE Reactor also suggests that there are no vadose zone sources of tritium in the immediate study area.

Results of the helium analyses of the soil gas samples from the Old Hanford Townsite showed significant enrichment of helium-3 concentrations, compared to ambient air, and an inverse relationship between helium-3 concentration and distance from the source (groundwater). Helium-3/4 ratios at the Old Hanford Townsite location ranged from 1.012 at 1.5 meters below ground surface to 2.157 at 9.7 meters below ground surface (Figure 3.3-6).

Helium-3/4 ratios show a significant variability with time. Figure 3.3-6 shows the helium-3/4 ratios from samples taken at the beginning and at the end of the 24 hour July sampling event. In all but one sample, the ratios at the end of the event are greater than at the beginning of the event. The variability with time

is even more pronounced by comparing the July and September sampling events. The greatest difference is shown by the helium-3/4 ratios from the 5.9 meter samples from the SG-1 cluster nearer well 699-41-1A. Comparing the two results shows a 62% increase in enrichment of helium-3 in the September sample.

The temporal variations might be attributable to atmospheric pumping in the vadose zone because of fluctuations in atmospheric pressure. That is, higher atmospheric pressure may dilute the helium-3 in the vadose zone with low helium-3/4 atmospheric air. This dilution might occur through the soil-atmosphere interface at the surface or through a well if the vadose zone is exposed to perforations or open screen above the water table. At the time of soil gas sampling, there was ~0.3 meters of screened interval open to the atmosphere in well 699-41-1A directly adjacent to one of the sampling clusters SG-1. Thus, atmospheric pumping may have affected the helium-3/4 ratios.

Helium-3/4 ratios in the soil gas samples collected near the KE Reactor ranged from 0.972 to 1.131 (see Figure 3.3-5). The greatest helium-3 enrichment (sample point SG-16) is in the southeastern part of the study area suggesting that there may be a tritium source around that location. Because there was no tritium found in the soil moisture in the immediate area of SG-16, helium-3 must be coming from a source greater than 3 meters from SG-16. This source may be located in the vadose zone or groundwater. The source could possibly be the solid waste burial ground or one or more of several cribs east of the KE Reactor. Alternatively, the source could be from the groundwater plume in the area. However, a groundwater monitoring well, 199-K-111 located adjacent to several soil gas monitoring points at the southeastern end of the study area has no measurable tritium (minimum detection level <240 pCi/L). This suggests that a tritium groundwater plume, if it exists, could be located farther to the south of the study area. Further investigation is necessary to define and identify the source of helium-3 around the southeastern corner of the study area. The helium-3 results from all the sampling points near the KE Reactor suggest no tritium plume is located within the study area.

3.3.3.3 Conclusions

Measurements of tritium in soil moisture do not appear to be useful for delineating tritium groundwater plumes or estimating concentrations of tritium in groundwater. The major source of moisture in the vadose zone at the two investigated sites appears to be natural precipitation and not upward migration of moisture from groundwater into the vadose zone. However, analysis of vadose zone moisture samples for tritium may be helpful in identifying vadose zone sources of tritium near the sampling sites.

Analyses of soil gas from samples collected at the Old Hanford Townsite area show that the gas is enriched in helium-3. This enrichment is due to decay of tritium in the groundwater beneath the site. The amount of enrichment appears to vary with time, most likely because of atmospheric pumping. Nevertheless,

helium-3 can be a useful tracer for either vadose zone or groundwater sources of tritium.

Because atmosphere pumping can affect the results of helium-3 analysis, the entire suite of samples for such analysis should be collected in as short a time span as possible. This is particularly important if samples are to be collected deep in the vadose zone near a groundwater well screened across the water table.

Helium-3 results from samples from the KE Reactor area do not suggest the presence of tritiated groundwater beneath the study area. Based on the relative enrichment factors for helium-3, there may be a groundwater or vadose zone source of tritium southeast of the study area. Potential sources include a groundwater tritium plume, the solid waste burial ground, the 116-KE-1 gas condensate crib east of the KE Reactor, or KE Fuel Storage Basins.

Table 3.3-1. Lysimeters at the Hanford Site

Lysimeter Type and Number	Purpose	Current Status	Potential for Future Use
Field Lysimeter Test Facility			
Drainage, 14 Weighing, 4 Clear tube, 6	Test water balance in layered soils common to engineered barriers	Active, requires minor maintenance	High potential for future infiltration studies
Buried Waste Test Facility			
Drainage, 6 Weighing, 2	Test water balance in coarse-grained sediments	Inactive, requires maintenance, 5 of 6 drainage lysimeters leak	Potential for infiltration studies in coarse sand and no vegetation environment. Potential test environment for sensors
Commercial Waste Lysimeters			
Drainage, 10	Test commercial low-level waste solidification	Inactive	Scheduled to be decommissioned in fiscal year 2000
Solid Waste Landfill			
Drainage, 1	Monitoring	Active	Continued monitoring
Fitzner/Eberhardt Arid Lands Ecology Reserve			
Weighing, 2	Examine water balance in sagebrush and bunchgrass community after a fire	Intermittent data collection	Potential for studies of site conditions but not 200 Areas conditions
Small Tube Lysimeters			
Drainage and Weighing, 105 total	Examine statistical repetition of lysimeter data	Inactive, requires minor maintenance	Too small for most purposes. Potential for small scale tests
S 11 Lysimeters			
Storage, 24	Water balance effects of barriers on plant intrusion and infiltration	Inactive, requires minor maintenance	Possible use for chemical tracer studies
200 East Area Lysimeters			
Drainage, 1	Infiltration studies	Inactive, requires maintenance, limited access in radiological zone	Limited potential for future use because of high expense to operate

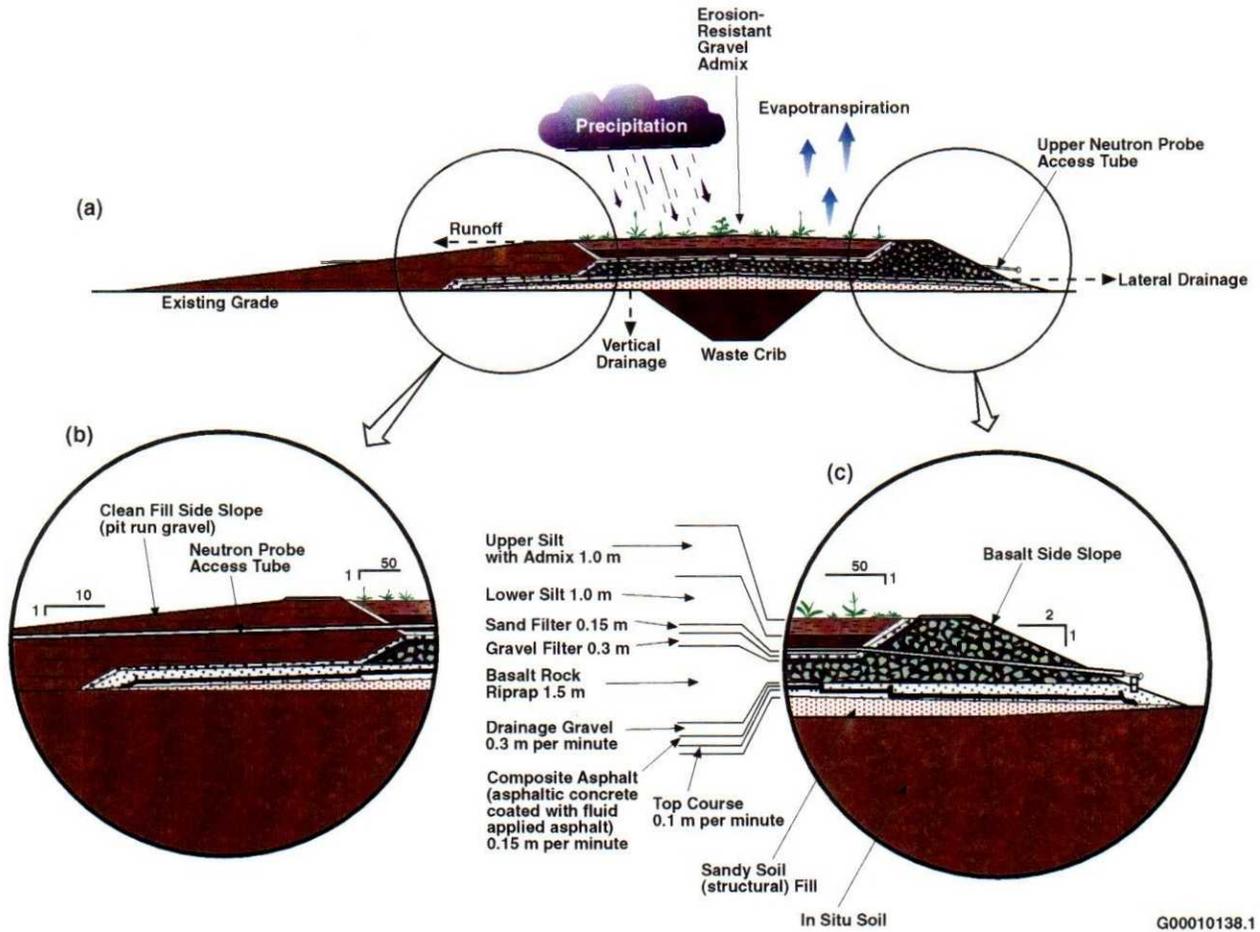


Figure 3.3-1. Cross Section of the Hanford Site Prototype Barrier Showing (a) Interactive Water Balance Processes, (b) Gravel Side Slope, and (c) Basalt Riprap Slope

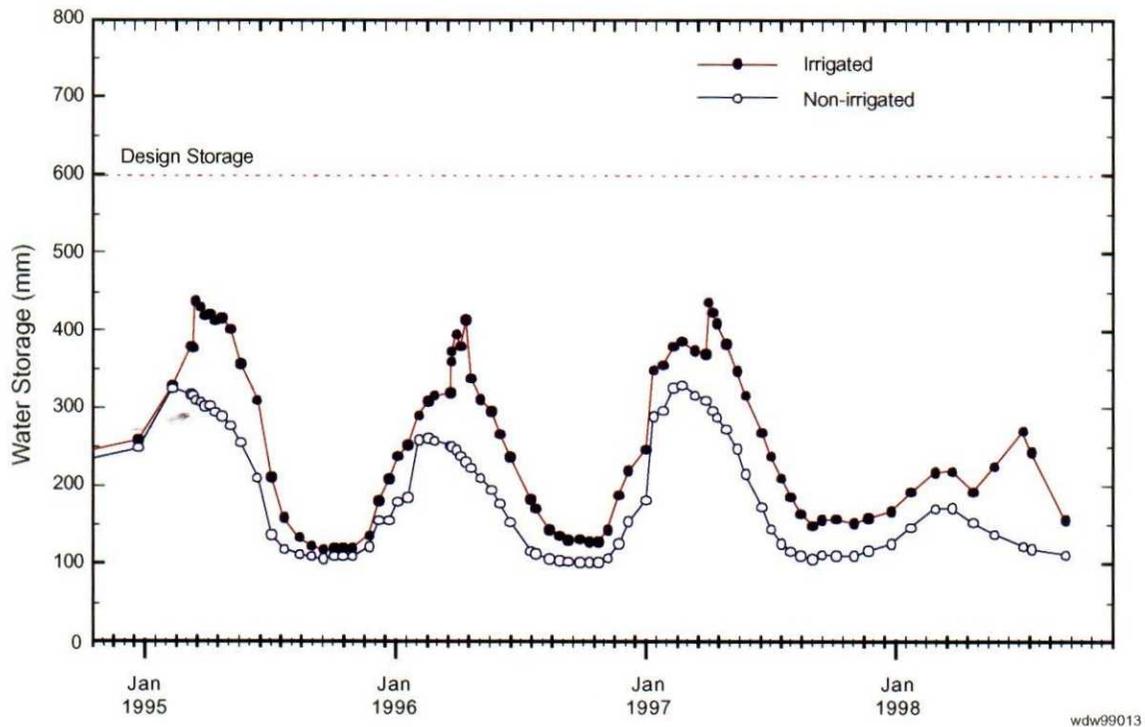


Figure 3.3-2. Temporal Variation in Mean Soil Water Storage at the Prototype Barrier, November 1994 to September 1998

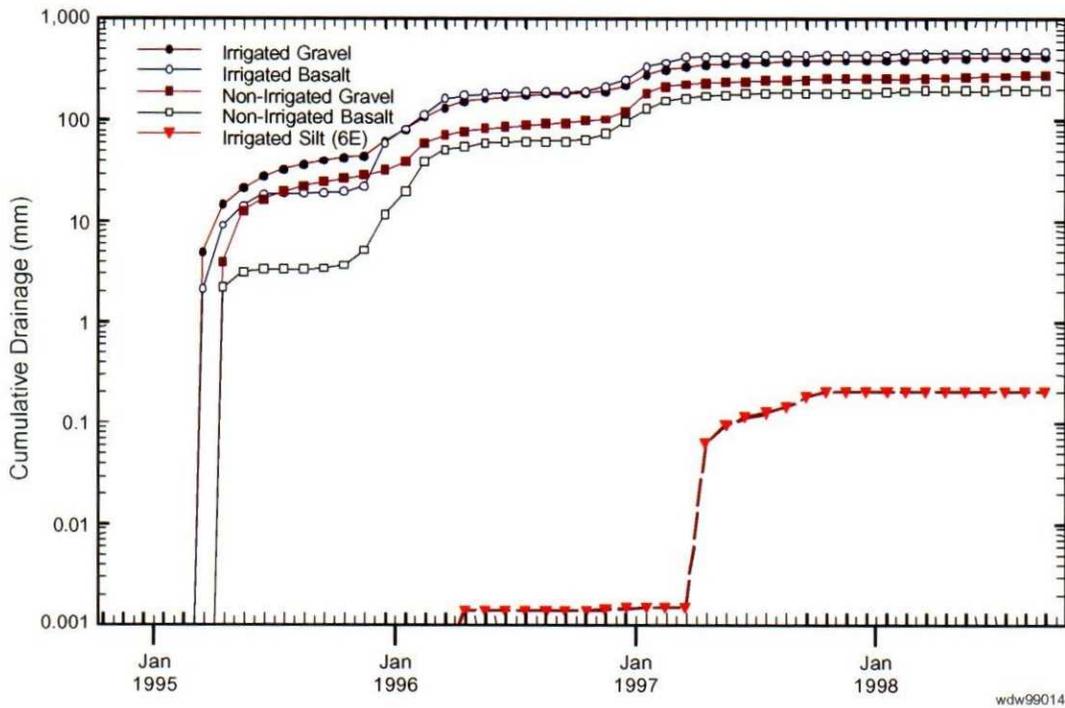
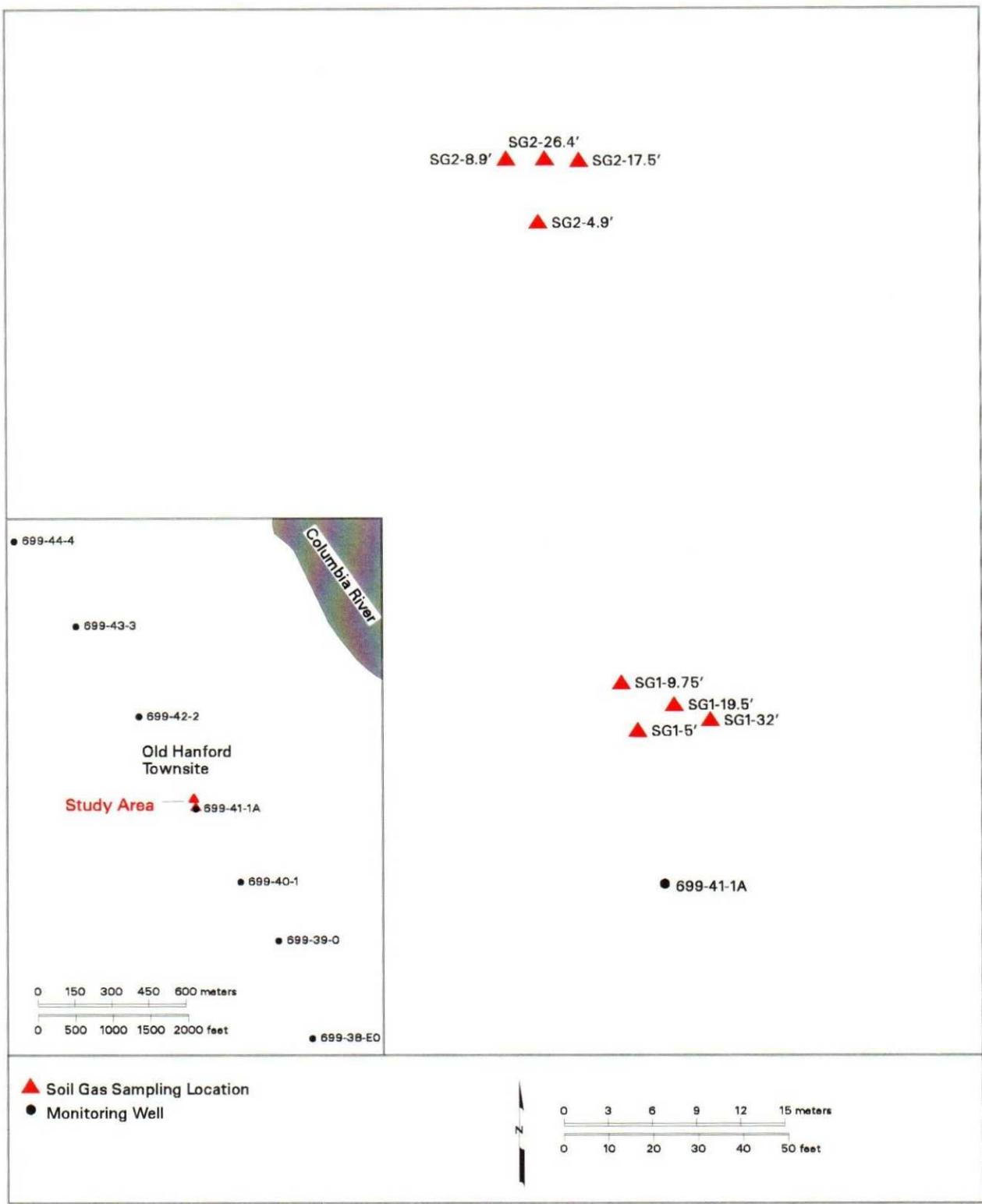
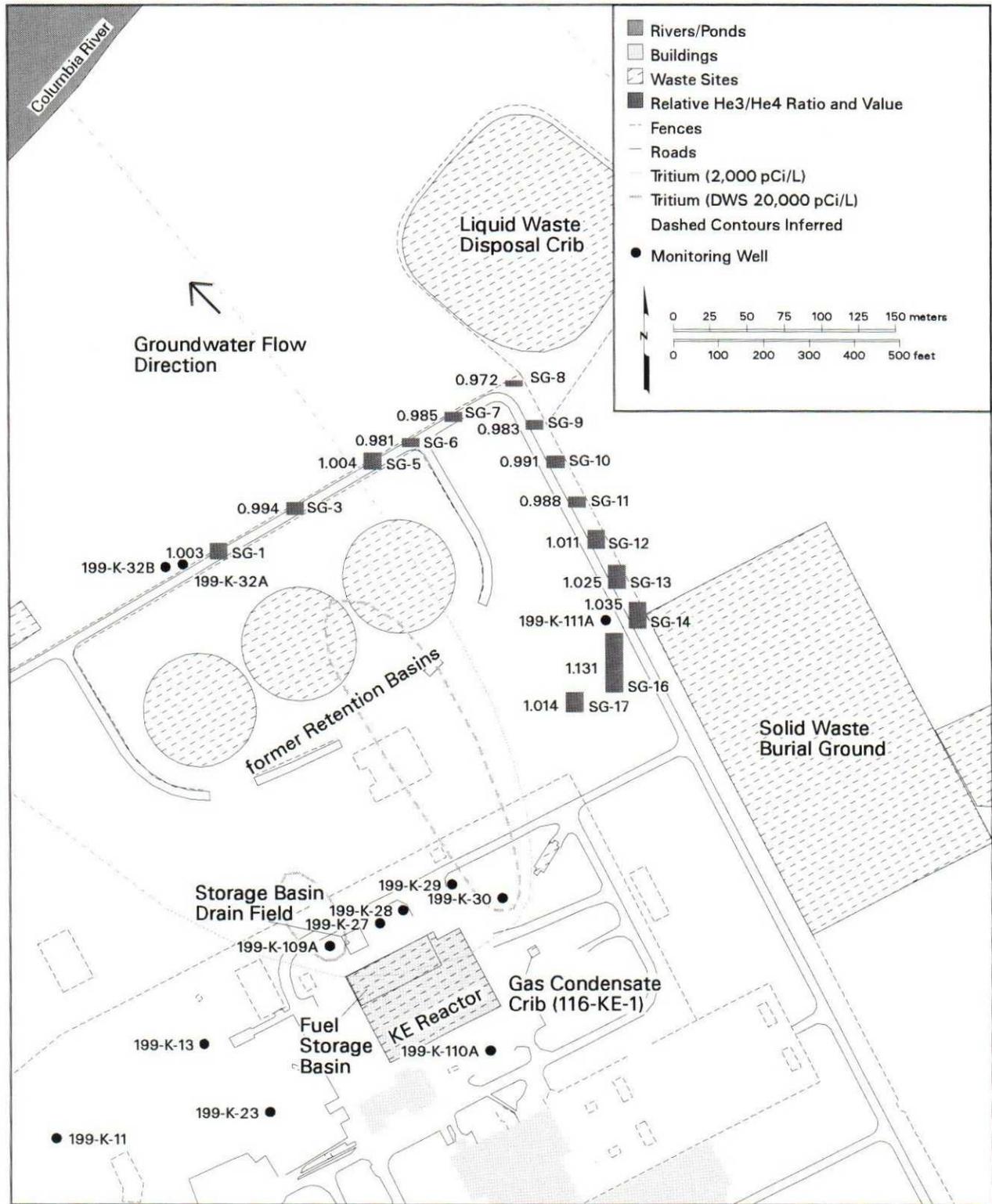


Figure 3.3-3. Cumulative Drainage from November 1994 through September 1998 from Four Side-Slope Plots and One Soil Plot that Drained



can_kolsen_99002 September 30, 1999 5:21 PM

Figure 3.3-4. Location of Soil Gas Sampling Points Adjacent to Well 699-41-1 Near the Old Hanford Townsite



can_kolsen_99003 February 29, 2000 11:52 AM

Figure 3.3-5. Helium-3/Helium-4 Ratios at the Study Site Near KE Reactor

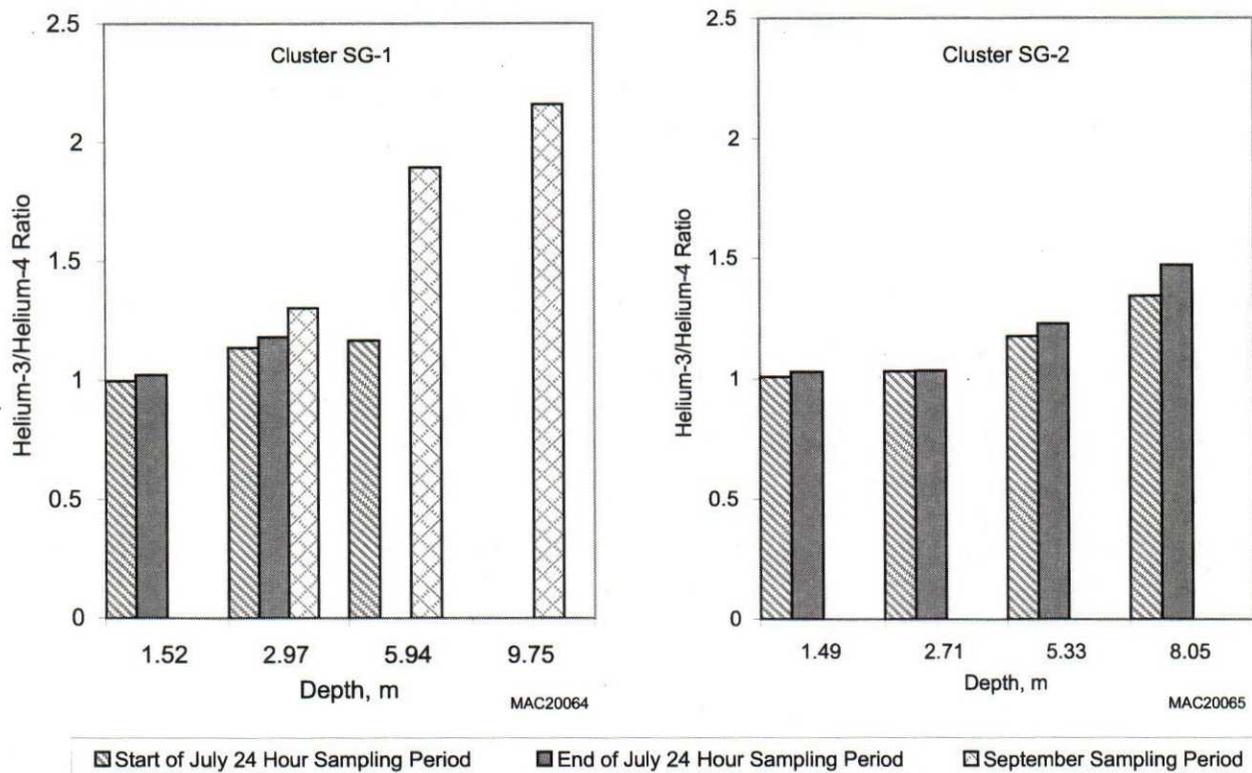


Figure 3.3-6. Comparison of Helium-3/Helium-4 Ratios for Samples Collected at the Old Hanford Townsite. Cluster SG-1 is ~12 meters from well 699-42-1A and cluster SG-2 is ~48 meters from well 699-42-1A

4.0 Groundwater Modeling

This section describes groundwater modeling activities being conducted at the Hanford Site that are relevant to the site-wide Hanford Groundwater Monitoring Project. Recent activities under the groundwater modeling task have focused on efforts to consolidate the site-wide groundwater models into a single model to eliminate redundancies and promote consistency in groundwater modeling analyses at the site. A discussion of this consolidation effort taken from a newly published U.S. Department of Energy (DOE) document (DOE-RL-2000-11, Rev. 1) is described in Section 4.1.

Section 4.1 also provides an overview of ongoing specific applications of the site-wide groundwater flow and transport model developed by the groundwater project.

Section 4.2 describes efforts by the environmental restoration contractor to apply other groundwater models at a local scale to design and evaluate pump-and-treat activities for the remediation of contaminated groundwater. These models were used to describe the capture and injection zones for extraction and injection wells, respectively, and to estimate the area affected by the pump-and-treat operations at different times.

4.1 Site-Wide Groundwater Model Consolidation Process

P. D. Thorne, M. P. Bergeron, S. K. Wurstner

Until recently, the Hanford Site has maintained multiple versions of site-wide groundwater flow and contaminant transport models. These different groundwater models have developed among different contractors since the Hanford Site mission changed from producing special nuclear materials to environmental

Objectives of Hanford Site Groundwater Model

A computer model of Hanford Site groundwater must be able to

- ▶ assess performance of waste-disposal facilities
- ▶ predict movement of contaminants
- ▶ evaluate remediation strategies.

restoration. The Project Hanford Management Contractor, Fluor Hanford, Inc., maintained a vadose zone and groundwater modeling capability to support active and planned disposals in the 200 Areas and operational issues at the site. The environmental restoration contractor, Bechtel Hanford, Inc., implemented a site-wide groundwater model in support of past-practice operable unit investigations and cleanup activities. Pacific Northwest National Laboratory (PNNL) maintains groundwater modeling capabilities to support the site-wide groundwater project and vadose zone modeling capabilities for a variety of site and national programs.

In response to both internal and external recommendations, DOE initiated a site-wide groundwater model-consolidation process, which included the participation of all affected Hanford Site programs. The objective of this process is to eliminate redundancies and promote consistency in groundwater analyses produced for Hanford Site programs. On September 5, 1996, John Wagoner issued a Letter of Instruction to affected programs, and site contractors^(a) that said "... with DOE and contractor customers, tribal and stakeholder participation, PNNL will develop and maintain a predictive Hanford standard groundwater model...."

(a) Letter from U.S. Department of Energy, Richland, Washington, to Pacific Northwest National Laboratory and Westinghouse Hanford Company, dated September 5, 1996, "Single Groundwater Project for the Hanford Site."

In a letter^(b) to regulators and stakeholders dated July 28, 1997, DOE also made a commitment to initiate the model-consolidation process in fiscal year 1998.

The purpose of the model consolidation process is to

- foster consistency in assumptions and applications across programs
- provide model enhancements based on new data/information and improved technical capabilities
- provide model flexibility to meet and support new program needs and decisions.

4.1.1 Recommendations for a Site-Wide Groundwater Flow and Transport Model

As an initial step, DOE established the scope of the model consolidation. This included defining the needs and requirements of a Hanford site-wide groundwater model, an evaluation of current site-wide groundwater models and codes, and specific recommendations for a consolidated site-wide groundwater model. External review of the recommendations for the consolidated site-wide groundwater model was also initiated.

The specific needs and requirements of the site-wide groundwater model were developed based, in part, on a review of current and future groundwater modeling activities conducted for various Hanford Site programs. The needs and requirements also reflect input collected from external stakeholders.

Based on input received from Hanford Site contractors and stakeholders, the consolidated site-wide groundwater model needs to meet a variety of Hanford Site project objectives including

- site-specific performance assessments of proposed waste disposal facilities
- assessment of environmental impact involving the modeling of contaminant transport and exposure prediction

- evaluation of groundwater remediation strategies including natural attenuation, hydraulic control/containment, and contaminant removal/cleanup
- design and evaluation of groundwater-monitoring networks
- risk assessments.

The key uses of the site-wide model over the next 5 years include modeling support to

- the groundwater project
- future iterations of the composite analysis of waste sites located in the 200 Areas plateau
- assessments to support tank farm corrective actions, tank waste retrieval, and tank farm closure for the Office of River Protection
- assessment of the facilities being considered for disposal of immobilized low-activity tank waste and solid waste disposal
- the system assessment capability being developed as part of the Hanford Site Groundwater/Vadose Zone Integration Project

Groundwater modeling analysis may also be needed to support

- the Hanford Canyon Disposition Initiative
- the 200 Areas Soil Characterization and Remediation Project
- assessments of solid low-level waste burial grounds
- permitting for liquid discharge facilities
- updates of the Hanford Site-Wide Groundwater Remediation Strategy (DOE/RL-94-95, Rev. 1)
- the development of final records of decision for contamination being managed by interim remedial measures (e.g., pump-and-treat remediation) in the 100 and 200 areas.

A technical evaluation was conducted of site-wide conceptual and numerical models and preliminary

(b) Letter from U.S. Department of Energy, Richland, Washington, to U.S. Environmental Protection Agency and Washington State Department of Ecology, dated July 28, 1997, "Completion of the Columbia River Comprehensive Impact Assessment (CRCIA) Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) Interim Milestone M-15-80-8."

recommendations for the consolidated site-wide groundwater model were developed in a series of internal workshops attended by representatives of Hanford contractors involved in groundwater modeling. Two most recently used site-wide groundwater modeling efforts were considered. One was conducted for the groundwater project and the other for the development of the Hanford Site-Wide Groundwater Remediation Strategy (DOE/RL-94-95, Rev. 1).

In general, the evaluation showed that both are capable of meeting many of the needs and requirements for a consolidated site-wide groundwater model. However, DOE concluded that the model developed by the groundwater project has broader capabilities to meet the anticipated needs of the site. Therefore, this model was selected for the initial phase of the site-wide groundwater model consolidation process. Capabilities of the groundwater project model include

- **model resolution** - The model contains a higher level of resolution in its representation of the Ringold Formation than used in the groundwater remediation strategy model. This framework can be more easily used to evaluate and investigate the importance of three-dimensional hydrostratigraphic complexity in the Ringold Formation. This is expected to have an increasing influence on future flow and contaminant transport as the water table declines.
- **extent of model** - The areal extent of the model includes the area south of the Hanford Site between the Yakima and Columbia Rivers. Including this area in the model provides the capability to address the potential movement of contaminant plumes off the Hanford Site.
- **natural recharge** - The model incorporates the effect of natural recharge as an upper hydrologic boundary condition. The importance of natural recharge on future groundwater flow conditions and contaminant transport is increasing as the effect of artificial recharge on the water-table dissipates.

DOE also initiated an evaluation of computer codes to implement the consolidated site-wide groundwater model. Only two computer codes were reviewed in this initial phase of the model-consolidation process: (1) the VAM3D-CG code developed by Hydrogeologic, Inc., in Herndon, Virginia, and (2) the CFEST-96 code developed by the CFEST Co. in Irvine, California. The groundwater remediation strategy model is implemented based on the VAM3D-CG code. The groundwater project model is based on the CFEST-96 code. In a qualitative comparison of the two computer codes, both VAM3D-CG and CFEST-96 were found to be technically acceptable.

In the interest of minimizing the impact of initial cost and schedule, DOE selected the CFEST-96 code as an interim code for implementing the consolidated site-wide groundwater model. DOE deferred decisions on final selection of the code until the external peer review of the consolidated site-wide groundwater model and the resulting final refinements and modifications have been completed.

4.1.2 External Peer Review of the Recommended Site-Wide Groundwater Model

As a part of the model consolidation process, the selected site-wide model was reviewed by outside experts in the fall of 1998. The three member review panel consisted of Dr. Steven M. Gorelick of Stanford University, Panel Chair; Dr. Charles Andrews of S. S. Papadopulos and Associates, Inc.; and Dr. James W. Mercer of HSI-Geotrans, Inc. The review panel commented on three specific issues:

- adequacy of the conceptual model and its technical capabilities to meet the anticipated uses and needs
- possible improvements to the modeling framework/implementation
- immediate need for new data.

Computer Modeling Plans

Computer modeling experts reviewed the Hanford Site groundwater model and recommended some improvements. Responses to these recommendations included plans to

- ▶ re-evaluate calibration of the model
- ▶ develop alternative conceptual models
- ▶ analyze uncertainties associated with the model.

The panel's comments and recommendations for each issue summarized from Gorelick et al. (1999a) are described below.

- (1) The panel recommended that the highest priority is to adopt a broader modeling framework that accepts conceptual model uncertainty. Within this new framework, the site-wide model would serve as an important tool to help guide new data collection efforts. First, the degree of potential impact of the various sources of uncertainty can be assessed through analysis of all uncertainties including those introduced by alternate conceptual models. Second, the worth of new data for reducing model uncertainty can be evaluated. The integration of the site-wide model with a geographic information system is an excellent means to preserve the Hanford Site data for applications at a variety of spatial scales. The panel recommended that databases (original field measurements) and information bases (interpretations or interpolations) both be maintained. For example, this would enable details in well logs found in the database to be used to develop a geostatistical model for scales smaller than those found in the interpreted hydrogeologic facies information base. The panel also recommended that the site-wide groundwater model be thought of as a flexible and evolving platform for analyzing groundwater flow and contaminant transport. The model itself

must not be stagnant because, as more data are collected, it is likely that the conceptual model of the groundwater system will change. In addition, new predictive capabilities will be desired. The model framework must be one in which new concepts can be tested and enhancements readily included. The framework must have the capability of being modified to test alternative conceptual models, reflect the most recent consensus conceptual model, and address concerns regarding water resources and water quality.

- (2) The panel recommended that a new modeling framework be established that accepts the inherent uncertainty in model conceptual representations, inputs, and outputs. Given such a framework, the expected values of hydraulic heads and contaminant concentrations, as well as the range (distribution) of predictions, would be products of the site-wide groundwater model. A priority item is to construct a list of alternate conceptual model components and assess each of their potential impact on predictive uncertainty. The panel recommended a series of important improvements to the current site-wide modeling effort:

- The model should be recalibrated using a three-dimensional, transient inverse calibration.
- The existing representation of chemical reactions is limited to first-order decay and linear sorption. Although potentially adequate for some of the prevalent contaminants found in Hanford Site groundwater, for most of the contaminants of concern found in the vadose zone, reactive transport needs to be represented.
- Boundary conditions and boundary fluxes should be re-inspected because of some inconsistencies with existing information and because there is an insufficient conceptual basis for use of these conditions for applications of the site-wide model at both large and small scales.

- The spatial representation of recharge should be represented as a parameter having an expected value and estimated uncertainty.
- (3) The panel commended the modeling team for their efforts in dealing with voluminous data, complex field conditions, and integrated/interdisciplinary approach to model building. With regard to the issue of model adequacy, the spectrum of anticipated uses and needs is so broad (ranging from time scales of less than 1 day to thousands of years and spatial scales of meters to kilometers) that this or any general, site-wide model cannot be expected to be adequate for all potential uses. It was suggested that an initial task should be to specify a narrower, and perhaps more pragmatic, list of model uses.

4.1.3 Response to Peer Review

This section presents an overview of the project plan that will be followed to address technical issues and concerns raised by external stakeholders and the external peer review panel on the site-wide groundwater model.

Based on specific advice provided by the external peer review panel (Gorelick et al. 1999b), the consolidated groundwater model project will focus on high-priority tasks that represent the key model improvements and modifications recommended by the panel:

- re-evaluation of the calibration of the site-wide model using a transient inverse calibration of Hanford Site historical operations, which will provide valuable information on parameter uncertainty and sensitivity coefficients
 - development of realistic alternative conceptual models that will assist in bounding the uncertainty in flow and transport simulation results. Each of the alternative conceptual models will be individually calibrated to Hanford Site historical operations
 - development and implementation of an uncertainty analysis framework that can receive a range
- of uncertain inputs taken primarily from the results of the development and calibration of the several alternative conceptual models and generate a range of related model results.
- In the latter half of fiscal year 1999 and in fiscal year 2000, the consolidated site-wide groundwater modeling task has been performing some work in all three areas outlined above. However, the primary focus of the first effort is on calibration of the site-wide model to observations of hydraulic head, hydraulic testing results, and contaminant concentration data. This is a significant departure from previous approaches to site-wide model calibration that were limited to conditions observed in 1979. The 1979 period was assumed to represent a short period of unchanging hydraulic conditions that was suitable for a steady-state calibration of the site-wide model.
- Efforts that will lead to the transient calibration of the current site-wide groundwater model and the alternative conceptual models involve four broad tasks related to
- gathering and analysis of historical data on hydraulic head, hydraulic testing information, artificial recharge, natural recharge, Columbia River and Yakima River stage changes, and other related information that will be needed to simulate the historical period of Hanford Site operations
 - acquisition and testing of a universal inverse code, called UCODE (Poeter and Hill 1998)
 - linking the UCODE to the current site-wide groundwater model code, CFEST-96, to allow efficient and effective execution of the UCODE/CFEST-96 package in the transient inverse calibration
 - preparing historic observation data and information into required model data input files for use in the transient inverse calibration.
- The consolidated groundwater modeling project plans to complete the transient inverse calibration of the current site-wide groundwater model using the UCODE/CFEST-96 computational framework in fiscal year 2000. Results of this work will be published in September 2000.

The consolidated groundwater model team will also work to define alternative conceptual models. It is anticipated that three to five alternative conceptual models will emerge that will reflect different credible combinations of boundary conditions and interpretations of the hydrogeologic framework.

In fiscal year 2000, a strategy for an uncertainty analysis framework will be developed. Uncertainties associated with prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values will be addressed. This analysis framework will ultimately be used to assess uncertainty in results produced by the range of alternative conceptual models.

Communication with the external peer review panel, regulators, Tribal Nations, stakeholders, and model users is being facilitated by means of an internet-based forum. A web page (available at <http://etd.pnl.gov:2080/gwmodeling/>) has been dedicated to the purpose of tracking technical issues and concerns and posting of other related information. This approach will provide for instant, widely available communication on technical issues and provide concern resolution with all parties, as well as enhancing feedback from concerned parties. The process of regulator and stakeholder interaction has already been initiated in the consolidation process and will continue through the web-based approach.

4.1.4 Model Applications

During fiscal year 1999, PNNL used the site-wide groundwater flow and transport model to predict water quality impact. This work continued into fiscal year 2000, and results will be presented in the Solid Wastes Environmental Impact Statement when it is completed. The purpose of this analysis is to calculate concentrations of contaminants in groundwater from source areas defined in each of the environmental impact alternatives. The analysis also assesses the impact to accessible surface water resources from contaminated groundwater. Calculated concentrations of key contaminants are compared with drinking water

standards and provide the basis for estimates of potential human health risk and ecological risk for comparison between the alternatives.

The site-wide model was applied to an environmental impact statement for solid waste in fiscal year 1999. Results will be available after the work is completed in 2000.

The potential sources of groundwater contamination are solid radioactive and hazardous waste contained in burial grounds located in 200 East and West areas. This waste include past low-level waste buried since 1970, newly generated Category I and III low-level radioactive waste, mixed low-level radioactive waste, and transuranic waste retrievably stored in trenches and caissons located in several of the existing burial grounds.

4.2 Modeling to Support Pump-and-Treat Operations

W. J. McMahon, L. C. Swanson

Groundwater models were used at a local scale in operable units in the 100 and 200 areas to assess the performance of groundwater pump-and-treat systems to remediate contamination within the unconfined aquifer system. These models evaluated system performance and overall progress toward remediation objectives and goals, including evaluating different extraction and injection well configurations, predicting effects of different operational and pumping schedules, assessing extent of hydraulic influence, and evaluating groundwater travel times and extent of the capture zone.

Modeling was conducted using Micro-FEM[®], a two-dimensional finite-element code. The MicroFEM[®] model was used to evaluate the following remedial action sites and contaminants of concern in the 100 K, 100 N, 100 D, 100 H, and 200 West areas:

- 100-KR-4 Operable Unit (100 K Area) - hexavalent chromium

- 100-NR-2 Operable Unit (100 N Area) - strontium-90
- 100-HR-3 Operable Unit (includes both 100 D and 100 H areas) - hexavalent chromium
- 200-UP-1 Operable Unit (200 West Area) - technetium-99 and uranium
- 200-ZP-1 Operable Unit (200 West Area) - carbon tetrachloride.

Additional information on pump-and-treat operations and figures showing the modeled capture zones are presented in Section 2.

4.2.1 Model Results for 100-KR-4, 100-NR-2, and 100-HR-3 Operable Units

Numerical modeling for these pump-and-treat operations provides a quantitative method to evaluate the hydraulic capture and optimize the pumping rates of the pump-and-treat system wells. Results of the modeling indicated that pump-and-treat extraction wells intercepted ~70% of the groundwater flow through the targeted area in the 100-KR-4 Operable Unit (DOE/RL-99-13). The capture zone is shown in Figure 2.3-18. Optimizing the pumping rates increased the capture to ~84%. Much of the uncaptured groundwater passing through the targeted plume area occurs in a culturally sensitive area. The decision to add wells to the network must balance the benefits of improved capture with the consequences of disturbing the sensitive area.

Computer modeling of pump-and-treat systems in the 100 Areas estimate that most of the contaminated groundwater in the target plumes is intercepted before it reaches the Columbia River. In fiscal year 1999, model results were used to optimize pumping rates and recommend locations for new wells to increase the effectiveness of the systems.

At the 100-NR-2 Operable Unit during the same time, the model results indicated that the pump-and-treat system was reducing the net groundwater flow to the Columbia River through the targeted plume area by ~96% (DOE/RL-99-02). The capture zone is shown in Figure 2.4-6.

The 100-HR-3 Operable Unit includes both 100 D and 100 H areas. At 100 D Area, the model results indicated that the extraction wells intercepted over 90% of the groundwater passing through the targeted plume area. At 100 H Area, the model results indicated that the extraction wells intercepted ~82% of the groundwater passing through the targeted plume area (DOE/RL-99-13). The capture zone is shown in Figure 2.6-16.

The analyses were run for the November/December time frame, which corresponds to the low flow time of year in the Columbia River when groundwater discharge to the river is greatest. During other times of the year, when the river stage is higher, the extraction wells intercept a higher percentage of the flow. For additional discussion on the 100-KR-4 and 100-HR-3 models, refer to DOE/RL-99-13. For additional discussion on the 100-NR-2 model, refer to DOE/RL-99-02.

4.2.2 Model Results for 200-UP-1 Operable Unit

Numerical modeling for this pump-and-treat operation was performed to evaluate effectiveness in containing the targeted area of the technetium-99 and uranium plumes and to track the progress of remediation. On the basis of the modeling results, the steady state capture flow lines extend outside and contain the entire targeted area of the plume (see Figure 2.8-40). Thus, the one extraction well (299-W19-39) appears capable of capturing and containing the entire high concentration area of the technetium-99 and uranium plumes. By the end of September 1999, the extraction well had removed at least one pore volume from the entire targeted plume area. The plume capture

efficiency was ~71%, which is the ratio of the amount of water removed from the target area of the plume to the total amount of water removed from the aquifer. For additional discussion on the 200-UP-1 model, refer to DOE/RL-99-02 and DOE/RL-99-79.

Computer models of two pump-and-treat systems in the 200 West Area estimate the capture zone of pumping wells.

4.2.3 Model Results for 200-ZP-1 Operable Unit

Numerical modeling was also performed to evaluate the remedial action at this pump-and-treat operation. The modeling results show the capture flow lines of the extraction wells extending outside the targeted carbon tetrachloride plume area and converging in the areas between the wells (DOE/RL-99-79). Thus,

modeling indicates that the pump-and-treat extraction wells contain the entire high concentration area of the plume, and provide a continuous hydraulic barrier to plume movement. The capture zone is shown in Figure 2.8-17.

The three northernmost extraction wells have operated since 1996, and the areas of capture for individual wells have merged. The numerical modeling predictions indicate that pump-and-treat operations have removed 1 pore volume of water from the upper 15 meters of the aquifer from an area of 332,000 square meters around the northernmost extraction wells. The three southernmost extraction wells began operating in 1997, and the areas of capture for individual wells have not merged. The modeling predictions indicate that wells 299-W15-32, -36, and -37 have removed 1 pore volume of water from an area of 12,000, 24,000, and 31,000 square meters, respectively, around those wells. For a more detailed description of 200-ZP-1 modeling, refer to DOE/RL-99-02 and DOE/RL-99-79.

5.0 Well Installation, Maintenance and Decommissioning

R. B. Mercer, B. A. Williams, J. E. Auten

This section describes well installation, maintenance, and decommissioning activities conducted on the Hanford Site during fiscal year 1999.

5.1 Well Installation

The Hanford Groundwater Monitoring Project defines needs for new monitoring wells in a description of work between Pacific Northwest National Laboratory and Bechtel Hanford, Inc. Each year, the groundwater project installs new wells to maintain network compliance with the *Resource Conservation and Recovery Act of 1976* (RCRA) groundwater monitoring requirements and U.S. Department of Energy (DOE) orders. These compliance issues include ongoing RCRA facility groundwater assessments, replacement of monitoring wells that go dry because of the declining water table, replacement of wells that pose contamination risks to the environment, improvement of spatial coverage of the monitoring networks, and vertical characterization of groundwater contamination. The environmental restoration contractor also determines its needs for new wells annually.

Well Installation

Twenty-six new wells were installed on the Hanford Site in fiscal year 1999:

- ▶ 8 for RCRA monitoring
- ▶ 16 for CERCLA investigations or remediation
- ▶ 1 for a proposed low-level waste site
- ▶ 1 for vadose-zone characterization at a tank farm.

Each year DOE and the Washington State Department of Ecology (Ecology) approve RCRA wells through a process that integrates data quality objectives. This process integrates the data needs of various Hanford Site projects in the proposed wells (i.e., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* and Tank Waste Remediation System).

Milestone M-24-00K (Ecology et al. 1989) required the installation of eight new RCRA groundwater monitoring wells (Table 5.1-1) by February 29, 2000. Well data packages will be published in fiscal year 2000 with more detailed information about these new wells, including the detailed geologic and geophysical descriptions and a complete set of sampling data results. Sixteen new wells were installed in the 100 Areas for activities related to environmental restoration. One well was installed to support characterization for a proposed immobilized low-activity waste repository and another for vadose zone characterization at the SX Tank Farm (see Table 5.1-1).

5.2 Well Maintenance

Maintenance of groundwater wells is performed to meet regulatory requirements as part of a scheduled preventive maintenance cycle (routine) or in response to problems identified in the field (non-routine). Non-routine maintenance includes both surface and subsurface tasks. Surface tasks include conducting field inspections, well labeling, maintenance and replacement of locking well caps, casing repairs, and diagnosis and repair of surface electrical and pump-discharge deficiencies. Subsurface tasks include repairing and replacing sampling pumps; performing camera surveys; brushing casing perforations or screens; developing wells to improve yield, recovery, and sample quality; or removing sediment accumulation. Routine maintenance is performed on a 5-year cycle in support of

groundwater sampling and to minimize non-routine maintenance activities. At a minimum, routine maintenance includes the following tasks:

- removal of groundwater sampling pump system and/or aquifer testing instrumentation/equipment
- inspection and repair or replacement of sampling pump system and/or aquifer testing instrumentation/equipment
- brushing/cleaning of well casing perforations/well screen
- removing debris and fill material
- developing the well
- performing borehole video camera survey
- reinstallation of sampling and/or aquifer-testing instrumentation/equipment
- documenting well conditions and maintenance activities.

About 110 wells were repaired or cleaned and 6 wells were decommissioned in fiscal year 1999.

Non-routine tasks are performed in response to a problem identified in the field. Non-routine maintenance tasks are varied and dependent on the specific problem encountered at a well.

A summary of the number of maintenance activities by regulatory program, on which routine and maintenance tasks were performed in fiscal year 1999, is presented in Table 5.2-1.

5.3 Well Decommissioning

Decommissioning activities result in the permanent removal of a well from service and from the Hanford Site well inventory. Well decommissioning is performed in accordance with 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.

Wells that present the risk of being immediate hazards to the public health or safety are categorized into basic risk groups (high, medium, and low). These categories identify wells that have the potential to provide preferential pathways that allow movement of contaminants deeper into the subsurface strata. Well classifications are shown in Figure 5.3-1.

At this time, well decommissioning is generally driven by the long-range environmental restoration schedule (DOE/RL-96-105, Rev. 1). During fiscal year 1999, six Hanford Site wells were decommissioned (Table 5.3-1). Wells decommissioned to date on the Hanford Site are illustrated also in Figure 5.3-1.

Table 5.1-1. Well Installations for Fiscal Year 1999

<u>Well Number</u>	<u>Well ID</u>	<u>Program</u>	<u>Project</u>
199-D4-19	B8746	CERCLA	100-HR-3 Operable Unit
199-D4-20	B8750	CERCLA	100-HR-3 Operable Unit
199-D4-21	B8755	CERCLA	100-HR-3 Operable Unit
199-D4-22	B8778	CERCLA	100-HR-3 Operable Unit
199-D4-23	B8779	CERCLA	100-HR-3 Operable Unit
199-D5-36	B8744	CERCLA	100-HR-3 Operable Unit
199-D5-37	B8745	CERCLA	100-HR-3 Operable Unit
199-D5-38	B8747	CERCLA	100-HR-3 Operable Unit
199-D5-39	B8748	CERCLA	100-HR-3 Operable Unit
199-D5-40	B8749	CERCLA	100-HR-3 Operable Unit
199-D5-41	B8751	CERCLA	100-HR-3 Operable Unit
199-D5-42	B8752	CERCLA	100-HR-3 Operable Unit
199-D5-43	B8753	CERCLA	100-HR-3 Operable Unit
199-D5-44	B8754	CERCLA	100-HR-3 Operable Unit
199-H4-65	B8759	CERCLA	100-HR-3 Operable Unit
199-K-126	B8760	CERCLA	100-KR-4 Operable Unit
299-E17-21	B8500	ILAW	ILAW
299-E33-334	B8810	RCRA	B-BX-BY tank farms
299-E33-335	B8811	RCRA	B-BX-BY tank farms
299-W15-41	B8815	RCRA	TX-TY tank farms
299-W22-48	B8812	RCRA	S-SX tank farms
299-W22-49	B8813	RCRA	S-SX tank farms
299-W22-50	B8814	RCRA	S-SX tank farms
299-W23-19	B8809	RPP	RPP
299-W26-13	B8817	RCRA	216-S-10 pond and ditch
699-43-44	B8758	RCRA	B Pond

ILAW = Immobilized low-activity waste.

RPP = River Protection Project.

Table 5.2-1. Well Maintenance Summary

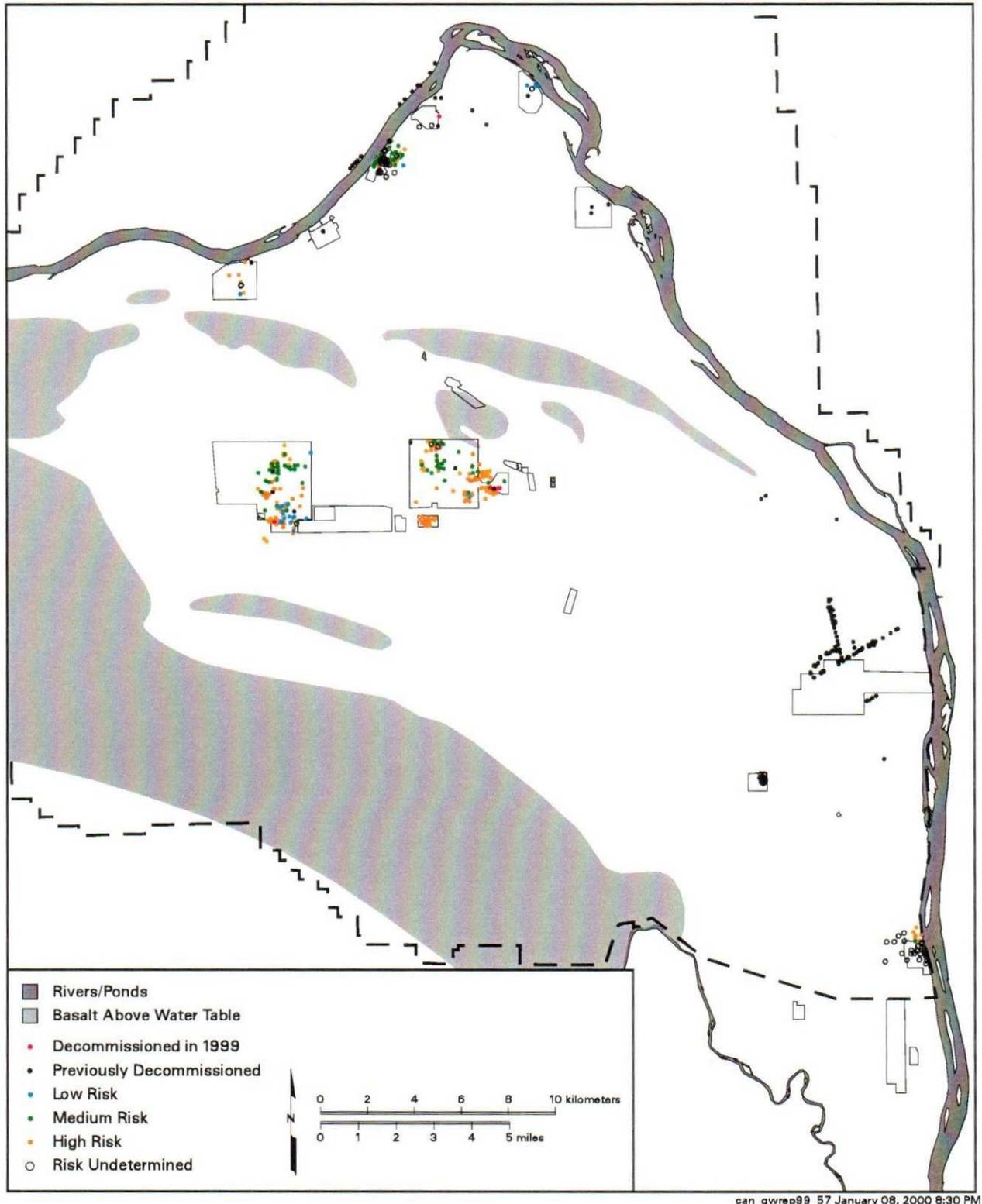
<u>Program</u>	<u>Routine</u>	<u>Nonroutine</u>
RCRA	11	42
CERCLA	5	23
Surveillance	14	16
Total	30	81

RCRA = Resource Conservation and Recovery Act of 1976.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980.

Table 5.3-1. Wells Decommissioned in Fiscal Year 1999

<u>Well Name</u>	<u>Well ID</u>	<u>Location</u>	<u>Date</u>
199-D5-12	A4569	100 D	September 30, 1999
299-E25-27	A4772	200 East	December 9, 1999
299-E25-33	A4781	200 East	December 9, 1999
299-E25-49	A6038	200 East	December 14, 1999
299-E25-50	A6039	200 East	December 10, 1999
299-W23-234	B2828	200 West	August 30, 1999



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Figure 5.3-1. Classification of Wells for Decommissioning

6.0 References

Public Laws

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Appendix A

Supporting Information

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) (Figure A.1). Most of these are regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA) (WAC 173-303), on which this appendix is focused. Three treated effluent disposal facilities (WAC 173-216), one solid waste landfill (WAC 173-304), and various groundwater operable units (*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA]) are also included. Exceedance of drinking water standards and derived concentration guides are also discussed for each geographic region. Information required by the regulations (e.g., assessing the adequacy of the monitoring networks) is included for each RCRA unit.

Table A.1 lists the monitoring status for RCRA facilities at the end of fiscal year 1999. Estimates of groundwater velocity, and supporting data, are shown for RCRA sites in Table A.2. Table A.3 lists wells exceeding drinking water standards for each regulated unit during fiscal year 1999.

The supplemental information includes tables of wells, constituents, and statistical evaluations (Table A.4 through A.51) and maps of well locations (Figures A.2 through A.23). The tables provide references to applicable monitoring plans. Wells that are sampled jointly 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.

A.1 100 B/C Area

The 100 B/C Area continued to be monitored in accordance with CERCLA (100-BC-5 Operable Unit) and the *Atomic Energy Act of 1954*. The CERCLA well network and constituent list were revised in fiscal year 1999 and are documented in Federal Facility Agreement and Consent Order Change Control Form No. M-15-99-03, dated July 14, 1999. Sampling schedules and analyte selection are coordinated to meet the requirements of both regulations.

Monitoring wells in the 100 B/C Area are sampled biannually to quarterly. Strontium-90 and tritium exceeded their interim drinking water standards locally. Gross beta also exceeded its standard, corresponding to the wells with high strontium-90. Chromium exceeded the maximum contaminant level in two wells, nitrate in one well. No radiological contaminants were detected at levels above the derived concentration guides.

A.2 100 K Area

Regulatory compliance issues related to groundwater in the 100 K Area include monitoring associated with the KE and KW Fuel Storage Basins and CERCLA environmental restoration activities.

A.2.1 KW and KE Fuel Storage Basins

Groundwater monitoring in fiscal year 1999 indicated there were no new leaks from these basins. DOE monitors groundwater 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 a groundwater monitoring and assessment plan (WHC-SD-EN-AP-174).

A.2.2 100-KR-4 Operable Unit

The environmental restoration contractor continued to operate a pump-and-treat system for chromium in 100 K Area in fiscal year 1999. The system is an interim action in response to a 1996 record of decision (ROD 1996a).

The specific objectives of the pump-and-treat system are to protect aquatic receptors in the Columbia River bottom substrate from contaminants in groundwater entering the Columbia River, protect human health by preventing exposure to contaminants in the groundwater, and provide information leading to a final remedy. The performance evaluation and annual summary reports indicated that the pump-and-treat system reduces contaminant flux to the Columbia River by creating a hydraulic barrier that extends along the length of the trench. The extraction wells and treatment system capture and remove contaminants from the groundwater passing between the trench and the river that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data all serve to provide the decision basis for the future final remedy. This area is discussed in more detail in Section 2.3 of the main text.

CERCLA characterization of groundwater contamination also continued in fiscal year 1999. The groundwater monitoring schedule consists predominantly of annual sampling of wells, with analyses for anions, metals, and radiological indicators (BHL-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. DOE/RL-96-90 and DOE/RL-96-84 describe sampling and monitoring required as part of the interim action.

A.2.3 Drinking Water Standards and Derived Concentration Guides

In fiscal year 1999, strontium-90 exceeded the 1,000-pCi/L derived concentration guide in well 199-K-109A, near the 116-KE-2 crib. Tritium exceeded the 2 million pCi/L derived concentration guide in well 199-K-30. Wells downgradient of the KW and KE Reactors exceeded the drinking water standards for tritium, strontium-90 (and gross beta), carbon-14, and nitrate. Chromium exceeded the 100- μ g/L maximum contaminant level near the KE Reactor and the 116-K-2 liquid waste disposal trench. Trichloroethylene exceeded the 5- μ g/L maximum contaminant level near the KW Reactor. Two wells upgradient of KE Reactor exceeded the 0.1 mg/L limit for nickel. Single samples exceeded the maximum contaminant levels for cadmium and thallium in filtered samples from wells 199-K-34 and 199-K-36, respectively. Isolated exceedances of secondary limits for iron, manganese, and nickel also were observed.

A.3 100 N Area

Regulatory compliance of the groundwater in the 100 N Area includes RCRA monitoring, CERCLA environmental restoration activities, and a National Pollutant Discharge Elimination System permit under the *Federal Water Pollution Control Act*.

A.3.1 RCRA Units

The 1301-N, 1324-N/NA, and 1325-N liquid waste disposal facilities are monitored in accordance with RCRA interim status indicator evaluation programs (40 CFR 265, WAC 173-303-400). During fiscal year 1999, upgradient and downgradient wells were sampled twice for contamination indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) and once for groundwater quality and site-specific parameters (Table A.4 and Figure A.2). The critical mean values for indicator parameters were all revised in December 1999 for evaluating the data from September 1999 and from fiscal year 2000

(Tables A.5 through A.7). The new values are based on recent data (1997 through 1999) from the upgradient wells.

At the 1301-N facility, total organic carbon in downgradient well 199-N-3 exceeded the critical mean value in January, March, and September 1999. Washington State Department of Ecology (Ecology) was notified in February 1999. Because no organic constituents of concern have been identified in 1301-N waste or sediment, the contamination is assumed to come from another source, and the site remains in indicator evaluation status.

Specific conductance in wells 199-N-59, 199-N-72, and 199-N-73 downgradient of the 1324-N/NA site continued to exceed the critical mean value in fiscal year 1999. A groundwater quality assessment indicated that the high specific conductance is caused by the non-hazardous constituents sulfate and sodium (WHC-SD-EN-EV-003, Rev. 1). Because an assessment has already been completed and non-hazardous constituents caused the high conductance, no further action was needed.

Concentrations of total organic carbon in one downgradient well (199-N-59) continued to exceed the critical mean value in March 1999 at the 1324-N/NA site. Ecology has agreed that the contamination is from another source so assessment monitoring is not required. In accordance with Ecology's instruction, a detection monitoring program continues for this site. Total organic carbon data from September 1999 did not exceed the revised critical mean value.

The revised critical mean value for specific conductance at the 1325-N facility was lower than the previous value, and two of the downgradient wells exceeded the revised mean in September 1999. DOE notified Ecology and submitted an assessment report

that concluded the exceedance did not indicate contamination from the facility (see Section 2.4 of the main text).

Of the dangerous waste constituents or byproduct discharged to these facilities, only nitrate exceeded the maximum contaminant level, and the sources are unclear (see Section 2.4.3 of main text). 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. The 1324-N/NA site has contaminated groundwater with sulfate and sodium, which are not dangerous waste constituents. Table A.3 lists constituents that exceeded drinking water standards in fiscal year 1999.

The closure plans for these facilities were revised and incorporated into a modification of the Hanford Site RCRA Permit (Ecology 1994). The modification became effective in fiscal year 1999. Remedial actions will be integrated with the 100-NR-1 and 100-NR-2 Operable Units. The closure plan (DOE/RL-96-39) states that RCRA monitoring during and after closure activities will continue, according to the existing interim status monitoring plan (WHC-SD-EN-AP-038, Rev. 2). The current well networks adequately monitor the sites, and there are no plans to modify the networks in fiscal year 2000.

A.3.2 100-NR-2 Operable Unit

A pump-and-treat system for strontium-90 continued to operate in 100 N Area in fiscal year 1999. The environmental restoration contractor operates the system in response to an action memorandum^(a) and a record of decision signed in September 1999 (Ecology 1999).

(a) Letter from D. Butler (Washington State Department of Ecology) and R. F. Smith (U.S. Environmental Protection Agency) to R. Izatt (U.S. Department of Energy, Richland Operations Office, Richland, Washington) dated September 23, 1994, "Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy, Hanford Site, Richland, Washington."

The goals of this pump-and-treat system are to:

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

The system met these goals in fiscal year 1999 (see Section 2.4.1 of the main text). The pump-and-treat operation is successfully intercepting and capturing groundwater containing elevated concentrations of strontium-90, and preventing that groundwater from discharging into the Columbia River. The pump-and-treat program collects hydraulic monitoring data, contaminant monitoring data, and treatment system operation data to assess treatment system performance, and to provide the basis for selecting the final remedy.

National Priorities List Agreement/Change Control Form No. 113, dated March 25, 1997, specifies performance monitoring requirements for the N Springs pump-and-treat system. The basic requirement is to sample the process influent and effluent streams monthly for strontium-90 analysis and to place the analytical results in a database to which the regulator has access. An update to the original monitoring plan (i.e., BHI-00164, Rev. 1) identifies and summarizes all current groundwater monitoring being conducted in the 100 N Area (BHI-01165).

The remedial investigation for the 100-NR-2 Operable Unit also collected groundwater data in fiscal year 1999. Monitoring results, along with information gained by operating the pump-and-treat system, will be used to support selection of a final remediation alternative for the operable unit. Federal Facility Agreement and Consent Order Change Control Form No. M-15-96-08, signed on October 9, 1996, lists the wells and analyses to be performed to satisfy groundwater monitoring requirements for the 100-NR-2 Operable Unit (CERCLA) and the 1301-N, 1325-N, and 1324-N/NA facilities (RCRA).

The Sitewide Environmental Surveillance Project collects riverbank seepage annually. Authority for this activity comes from DOE orders for environmental monitoring. The results are presented in an annual report (e.g., Section 4.2 in PNNL-11795). The Near-Facility Environmental Monitoring Program, which is also mandated primarily by DOE orders, conducts additional groundwater and surface water monitoring. Samples are collected from 13 near-river well casings, which have been driven into the shoreline gravels, and also from a near-river monitoring well. The monitoring supports activities for waste management and environmental restoration and helps determine the effectiveness of effluent treatment and control practices. Results are presented annually (e.g., HNF-EP-0573-6).

A.3.3 Pollution Permit

Until May 1999, the National Pollutant Discharge Elimination System permit required 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, the permit was revised to eliminate this requirement.

A.3.4 Drinking Water Standards and Derived Concentration Guides

Strontium-90 continued to exceed the 1,000-pCi/L derived concentration guide in well 199-N-67. Nitrate, strontium-90 (and gross beta), sulfate, and tritium continued to exceed maximum contaminant levels or drinking water standards in the 100 N Area. Filtered manganese exceeded its secondary maximum contaminant level in two wells. Filtered chromium exceeded its maximum contaminant level in one well completed in a locally confined unit.

A.4 100 D Area

RCRA and CERCLA govern groundwater monitoring in the 100 D Area. CERCLA environmental restoration activities include remedial investigations and performance monitoring associated with the groundwater interim action pump-and-treat system.

A.4.1 120-D-1 Ponds

The 120-D-1 ponds well network (Table A.8 and Figure A.3) was sampled once in fiscal year 1999. After that, Ecology implemented modification E of the Hanford Site RCRA Permit (Ecology 1994) and the site was clean closed. This means that all dangerous waste or dangerous waste constituents or residues associated with the operation of the ponds have been removed. The closure plan (DOE/RL-92-71, Rev. 2) is a demonstration of clean closure, and there are no requirements for a landfill cover, postclosure care, or further groundwater monitoring.

Statistical evaluations of indicator parameter data indicated that the ponds have had no adverse impact on groundwater quality. Mercury is the only listed waste that may have been discharged to these ponds and was never detected in any of the downgradient monitoring wells. Chromium and nitrate from upgradient sources exceeded maximum contaminant levels (see Table A.3).

A.4.2 100-HR-3 Operable Unit

The extraction well network in the northern region of the 100 D Area continued to operate through fiscal year 1999. The purpose for the interim remedial action is to decrease the amount of hexavalent chromium that is entering the Columbia River via groundwater. The key documents that pertain to this interim action are the record of decision to proceed (ROD 1996b) and the performance monitoring plan (DOE/RL-96-84).

The specific objectives of the pump-and-treat system are to protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River, protect human health by preventing

exposure to contaminants in the groundwater, and provide information leading to a final remedy. The performance evaluation and annual summary reports indicated that the pump-and-treat reduces contaminant flux to river by creating a hydraulic barrier that extends parallel along the length of the trench. The extraction wells and treatment system capture and remove contaminants from the groundwater passing between the trench and the river that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater, thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data collected in support of the project all serve to provide the decision basis for the future final remedy. It is discussed in more detail in Section 2.5 of the main text.

Groundwater monitoring in other 100-HR-3 wells in 100 D Area also continued during fiscal year 1999. The list of wells to be sampled and the analyses to be performed have been agreed on and are described in National Priorities List Agreement/Change Control Form No. 107, dated November 20, 1996. Most wells are sampled annually, and the samples are analyzed for anions, metals, and radiological indicators. DOE/RL-96-90 and DOE/RL-96-84 describe monitoring required as part of the interim action.

The U.S. Environmental Protection Agency (EPA), Ecology, and DOE signed an amended record of decision for the 100-HR-3 Operable Unit in October 1999 (ROD 1999). The amendment adds a requirement for implementing in situ redox manipulation to remediate the chromium plume in the southwestern 100 D Area. The goal of this treatment system is to reduce concentrations of hexavalent chromium to 20 µg/L or less in compliance wells, which are yet to be determined. A design report/work plan is being prepared to define groundwater monitoring requirements.

A.4.3 Drinking Water Standards and Derived Concentration Guides

Nitrate and chromium exceeded the maximum contaminant levels or drinking water standards during

fiscal year 1999 in a fairly broad area. Strontium-90 and tritium exceeded interim standards in one well in the central 100 D Area and another well in the northern 100 D Area; tritium contamination that migrates from the 100 N Area is present in the southwestern 100 D Area at levels above the drinking water standard. No radiological constituents exceeded the derived concentration guides.

A.5 100 H Area

RCRA and CERCLA govern groundwater monitoring in the 100 H Area. Environmental restoration activities under CERCLA include remedial investigations and performance monitoring associated with the groundwater interim action pump-and-treat system.

A.5.1 183-H Solar Evaporation Basins

This RCRA unit continued to be monitored under a final status corrective-action program during fiscal year 1999 (WAC 173-303-645). The location was incorporated into the Hanford Site RCRA Permit (Ecology 1994) in 1998. Groundwater remediation is integrated with the 100-HR-3 Operable Unit, where remediation for chromium is under way. While the pump-and-treat system is operating, RCRA monitoring consists of annual sampling of four wells for chromium, fluoride, nitrate, technetium-99, and uranium (PNNL-11573; Table A.9 and Figure A.4). The wells were sampled in November 1998.

The current monitoring network was designed to accommodate groundwater flow imposed by the pump-and-treat system. The network remains adequate, and no changes are planned for fiscal year 2000.

A.5.2 100-HR-3 Operable Unit

The extraction and injection well networks in the 100 H Area continued to operate through fiscal year 1999.

The purpose for the interim action is to decrease the amount of hexavalent chromium that is entering the Columbia River via groundwater movement. The

key documents that pertain to this interim action are the record of decision to proceed (ROD 1996a) and the remedial action work plan (DOE/RL-96-84).

The specific objectives of the pump-and-treat system are to protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River, protect human health by preventing exposure to contaminants in the groundwater, and provide information leading to a final remedy. The performance evaluation and annual summary reports indicated that the pump-and-treat system reduces contaminant flux to the river by creating a hydraulic barrier that extends parallel along the length of the trench. The extraction wells and treatment system capture and remove contaminants from the groundwater passing between the trench and the river that otherwise would enter the Columbia River. Institutional controls prevent access to groundwater thereby protecting human health. Water-level, contaminant, system treatment cost and efficiency, and geologic data all serve to provide the decision basis for the future final remedy. The interim action is discussed in more detail in Section 2.6 of the main text.

Groundwater monitoring in other 100-HR-3 wells in the 100 H Area also continued during fiscal year 1999. The list of wells to be sampled and the analyses to be performed have been agreed on and are described in National Priorities List Agreement/Change Control Form No. 107, dated November 20, 1996. Most wells are sampled annually, and the samples are analyzed for anions, metals, and radiological indicators. During fall 1998, aquifer sampling tubes and riverbank seepage were sampled. DOE/RL-96-90 and DOE/RL-96-84 describe additional monitoring that is required as part of the interim action.

A.5.3 Drinking Water Standards and Derived Concentration Guides

Maximum contaminant levels were exceeded in the 100 H Area for the following constituents during fiscal year 1999: chromium and nitrate throughout the 100 H Area, gross beta near the former 183-H

solar evaporation basins and 107-H retention basins, strontium-90 near the former 107-H retention basins, and uranium near the former 183-H basins. In all cases, the fiscal year 1999 values exceeded the limits by relatively small margins. Another contaminant of concern, technetium-99, remained below the 900-pCi/L standard in fiscal year 1999. No radiological constituents exceeded the derived concentration guides.

A.6 100 F Area

CERCLA (100-FR-3 Operable Unit) and the *Atomic Energy Act of 1954* govern groundwater monitoring in the 100 F Area. The CERCLA monitoring network and constituent list were revised in fiscal year 1999 and are documented in Federal Facility Agreement and Consent Order Change Control Form No. M-15-99-02, dated July 14, 1999. The Hanford Groundwater Monitoring Project coordinates sampling schedules and analyte selection to meet the requirements of both regulations. Wells are sampled biannually to quarterly.

Nitrate exceeds its maximum contaminant level beneath most of the 100 F Area and downgradient. Gross beta, strontium-90, trichloroethylene, tritium, and uranium also exceeded standards locally. No radiological constituents exceeded the derived concentration guides.

A.7 200 West Area

RCRA, CERCLA, and state dangerous waste regulations govern groundwater monitoring in the 200 West Area. Groundwater is monitored at eight RCRA sites and two groundwater operable units.

A.7.1 Waste Management Area S-SX

This RCRA site continued to be monitored under an interim status assessment program during fiscal year 1999. DOE initiated the assessment program in response to a directive from Ecology in 1996. The directive cited anomalous trends in technetium-99 and high specific conductance as primary reasons for the

assessment. An assessment plan was submitted in August 1996 (WHC-SD-EN-AP-191). A report on the results of the assessment (PNNL-11810) concluded that this waste management area contributed to groundwater contamination. Accordingly, investigation of the rate and extent of the contamination is required. Current monitoring wells and constituents are listed in Table A.10. Well locations are shown in Figure A.5. Three new wells were installed in 1999 to improve spatial coverage and to replace wells going dry. Additional wells are needed to replace upgradient wells that will be dry in 2000 and in the following years. However, any new drilling for fiscal year 2000 is subject to funding availability.

The rate of movement (see Table A.2) and extent of contamination at this site are discussed in Section 2.8 of the main text.

A.7.2 Waste Management Area T

This RCRA site continued to be monitored under an interim status assessment program during fiscal year 1999 (Table A.11 and Figure A.6). Waste management areas T and TX-TY began assessment monitoring in November 1992 because of high specific conductance in downgradient wells (WHC-SD-EN-AP-132). Assessment findings (PNNL-11809) indicated that contaminants in well 299-W10-15 are a result of sources outside the waste management area. There is strong evidence, however, that contaminants observed in well 299-W11-27, which include chromium, cobalt-60, nitrate, technetium-99, and tritium, are a result of sources within the waste management area, so assessment work has continued. The plume detected in well 299-W11-27 has reached well 299-W11-23, located to the east of 299-W11-27, apparently as a result of changed groundwater flow direction at Waste Management Area T.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8.

The current network of wells is inadequate for assessment monitoring. A minimum of two and probably three new wells are needed along the eastern margin of the waste management area. Two have been proposed, one between wells 299-W11-23 and 299-W11-24, and one between wells 299-W11-24 and 299-W11-12. However, the evidence from the technetium-99 plume (PNNL-11809) indicates that an appropriate well spacing is ~35 meters. Thus, two new wells between 299-W11-24 and 299-W11-12 would be appropriate. In addition, there is inadequate upgradient coverage because of the change in groundwater flow direction.

A.7.3 Waste Management Area TX-TY

This RCRA unit continued to be monitored under an interim status assessment program during fiscal year 1999 (Table A.12 and Figure A.6). Waste Management Area TX-TY began assessment monitoring in November 1991 because of high specific conductance in wells 299-W10-17 and 299-W14-12 (WHC-SD-EN-AP-132). The exceedance in well 299-W14-12 was accompanied by elevated cobalt-60, iodine-129, technetium-99, and tritium. Assessment results (PNNL-11809) indicated that contaminants in well 299-W10-17 are a result of sources outside the waste management area. Assessment results for well 299-W14-12 indicate that the contamination is consistent with a source within the waste management area, though upgradient sources are also possible. Because there was no direct evidence for upgradient sources, assessment continues at the site. Well 299-W15-40 was drilled near the 216-T-25 trench in fiscal year 1999 to evaluate its potential role in providing the observed contamination. Results indicate that the trench is not the source of contamination.

The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8.

The well network is inadequate for assessment monitoring. The average distance between monitoring wells along the southeastern margin of the waste

management area is ~70 meters, and a plume could pass through undetected. In addition, because well 299-W14-12 is expected to go dry, there are no wells located at intermediate or farther distances to track plume movement, and there are no upgradient wells for the northern portion of the waste management area (TY Tank Farm).

A.7.4 Waste Management Area U

Monitoring continued in accordance with RCRA interim status indicator evaluation requirements in fiscal year 1999. The site is sampled quarterly because contaminant concentrations fluctuate rapidly and because of the evidence that low levels of technetium-99 from the waste management area are contaminating groundwater. Quarterly sampling provides assurance that changes will be detected rapidly. The wells are sampled for a broader suite of constituents than specified under the RCRA interim status requirements (Table A.13 and Figure A.5).

Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. Two downgradient wells (299-W18-30 and 299-W19-42) continue to exceed the critical mean value of total organic halides during the first and second quarter of fiscal year 1999. The exceedance is caused by an upgradient source of carbon tetrachloride, and a letter of notification and assessment report were submitted to Ecology in August 1998.

Field specific conductance in two new downgradient wells (299-W19-41 and 299-W19-42) exceeded the critical mean value in December 1998 and February 1999. However, laboratory analyses and relationships between cations/anions and specific conductance did not support the field measurements. Verification sampling was not necessary. Anomalous, high field measurements were attributed to a bad batch of calibration solution and the problem was corrected.

The critical range for pH was exceeded in one downgradient well (299-W19-12) during February 1999. This well was a pre-RCRA well that has had

higher pH historically. A new groundwater monitoring plan is being prepared, recommending that this well be replaced by a new RCRA standard well and during the interim, this well will be used for information only. Background levels were re-established to reflect this change.

Critical mean values were revised in December 1999 based on recent upgradient data (Table A.14). The revised values were applied to data from August 1999. Recent specific conductance values in the upgradient wells have been lower and have had less variability than in the past, so the revised critical mean value is lower. Consequently, downgradient well 299-W19-41 exceeded the revised critical mean in August 1999. An assessment plan is being prepared.

The well network generally is adequate for detection monitoring. Well 299-W19-12, an older non-RCRA well, is being used temporarily to fill a gap in the downgradient network between wells 299-W19-41 and 299-W19-42. This well is used for indication only and a replacement well has been proposed. The upgradient network will be reduced to one well within the next year when the water level in well 299-W18-25 drops too low for sampling.

Only carbon tetrachloride and gross beta exceeded maximum contaminant levels in fiscal year 1999. The carbon tetrachloride is discussed above. The gross beta is caused by technetium-99, which is present in the downgradient wells at concentrations below its 900-pCi/L drinking water standard.

A.7.5 216-S-10 Pond and Ditch

During fiscal year 1999, this facility continued to be monitored semiannually under a RCRA interim status indicator evaluation program (Table A.15 and Figure A.7). Statistical evaluation of indicator parameter data from downgradient wells indicates that the site is not impacting groundwater. Because downgradient well 299-W26-10 could not be sampled during this fiscal year, background concentrations

were re-established using the fiscal year 1999 network of one upgradient and two shallow downgradient wells (Table A.16). A new well was installed for use beginning in fiscal year 2000.

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Chromium remains elevated above the 100- $\mu\text{g/L}$ standard in upgradient well 299-W26-7. Because the upgradient well is located adjacent to the 216-S-10 pond (see Figure A.7), it is unclear if the elevated chromium is from an upgradient source or from past discharges to the pond. To assess the chromium source further, a proposal is being drafted to reclassify this well as a downgradient well and replace it with a new upgradient well in calendar year 2000.

Currently the 216-S-10 pond and ditch are monitored by only one upgradient well and two shallow downgradient wells because other wells have gone dry. The groundwater monitoring network is not adequate for RCRA interim status monitoring. One new downgradient well (299-W26-13) is being installed downgradient of the pond and will provide groundwater data for the continued evaluation of the elevated chromium. Two additional wells, one upgradient and one downgradient, are proposed for installation in calendar year 2000.

A.7.6 216-U-12 Crib

This RCRA unit continued to be monitored under an interim status assessment program in fiscal year 1999. Assessment monitoring began in 1993 because of high specific conductance in two downgradient wells (299-W22-41 and 299-W22-42) (WHC-SD-LEF-EV-001). In fiscal year 1999, network monitoring wells were sampled quarterly for constituents of interest (Table A.17 and Figure A.8).

Based on the results of the assessment investigation (PNNL-11574), the site remains in interim status assessment monitoring because of continued elevated levels of nitrate and technetium-99. However, the

objective of the assessment monitoring, rather than delineating the existing plumes, is focused on (1) determining whether the flux of constituents into the groundwater is increasing, staying the same, or decreasing; (2) monitoring the known constituents until a near-term interim corrective action is defined; and (3) monitoring until a final status plan is implemented. The rate of groundwater flow (see Table A.2) and the extent of contamination at this site is discussed in Section 2.8.

The crib will not receive additional effluents and is scheduled, according to provisions of the Hanford Site RCRA Permit (Ecology 1994), to be closed under RCRA final status regulations in 2005.

Currently the 216-U-12 crib is monitored by only one upgradient well (299-W22-43) and two downgradient wells (299-W22-79, and 699-36-70A). Declining water levels have rendered downgradient wells 299-W22-41 and 299-W22-42 dry in the past year (both wells last sampled in March 1999). The groundwater monitoring network is not adequate for RCRA interim status monitoring. One new well, 299-W22-79, was installed in calendar year 1998 to replace the downgradient wells projected to go dry (PNNL-12127). The upgradient well, 299-W22-43, is now projected to go dry before the end of calendar year 2000. Two additional wells, one upgradient and one downgradient, are proposed for installation in calendar year 2000.

Sample results that exceeded drinking water standards and maximum contaminant levels are presented in Table A.3. Nitrate, which had a source at this crib, remained elevated above the 45-mg/L standard in all downgradient wells.

A.7.7 Low-Level Waste Management Area 3

This RCRA site continued to be monitored under interim status indicator evaluation requirements. Groundwater monitoring wells were sampled twice in fiscal year 1999 (Table A.18 and Figure A.9). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells

were compared to values established from the upgradient wells. Critical mean values for the contamination indicator parameters were not exceeded in any of the wells monitoring this waste management area. Tables A.19 and A.20 list revised critical mean values.

The network continues to adequately monitor this waste management area. Several of the groundwater monitoring wells are approaching the point where representative sampling will no longer be possible because of the declining water table. Additional well installations are planned in calendar year 2000.

A.7.8 Low-Level Waste Management Area 4

Wells are sampled semiannually for contamination indicator parameters in accordance with RCRA interim status regulations (Table A.21 and Figure A.10). Background concentrations for the general contamination indicator parameters were re-established during the second quarter of fiscal year 1999 because the influence of a nearby pump-and-treat system is causing a reversal in the groundwater flow direction. The critical mean value for total organic halides was exceeded in one downgradient well (299-W15-16) in January and July 1999. This well used to be an upgradient well, and the exceedance is believed to be caused by carbon tetrachloride from an upgradient source.

Updated critical mean values are listed in Table A.22. However, indicator parameters will not be evaluated statistically until groundwater flow stabilizes. Meanwhile, wells are sampled semiannually to determine when flow stabilizes and to maintain continuity in the database.

This monitoring network is marginally adequate to detect releases from Low-Level Waste Management Area 4. Additional monitoring wells may be necessary in the future, as the water level continues to decline and to provide greater downgradient coverage. There are tentative plans to change the designation of this waste management area so that it will no longer be a RCRA facility. If this change occurs, additional

monitoring wells will not be installed, and groundwater monitoring will defer to surveillance monitoring.

A.7.9 200-UP-1 Operable Unit

The environmental restoration contractor continued to operate a pump-and-treat system in fiscal year 1999 (Figure A.11).

The interim action objectives (ROD 1997) include the following:

- reduce contamination in the areas of highest concentration of technetium-99 and uranium to below 10 times (480 mg/L) the cleanup level under the *Model Toxics Control Act* (WAC 173-340) for uranium, and 10 times (9,000 pCi/L) the maximum contaminant level for technetium-99
- reduce potential adverse human health risks through reduction of contaminant mass
- prevent further movement of these contaminants from the highest concentration area
- provide information that will lead to the development and implementation of a final remedy that will be protective of human health and the environment.

As of July 1999, the high concentration portions of the technetium-99 and uranium plumes were hydraulically contained. However, they were not remediated to the levels required by the interim action objectives (ROD 1997). Significant progress was made in reducing the size and concentrations of the technetium plume. Less progress has been made in remediating the uranium plume because of its tendency to sorb to the soil. Section 2.8.3 of the main text discusses groundwater remediation in more detail.

A.7.10 200-ZP-1 Operable Unit

The pump-and-treat system continued to operate in fiscal year 1999 (Figure A.12). The purpose of the pump-and-treat system is to prevent further movement of groundwater contamination from the high concentration portion of the carbon tetrachloride

plume and to reduce contaminant mass (ROD 1995). Section 2.8.3 of the main text discusses groundwater remediation in more detail.

The interim action objectives (ROD 1995) include the following:

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

Data through fiscal year 1999 indicate that the plume center (greater than 3,000 µg/L) is moving primarily in a northerly and easterly direction toward the four northernmost extraction wells. The concentrations of carbon tetrachloride east of the extraction wells may be decreasing, as indicated by a decrease in concentrations in monitoring well 299-W14-9 (from ~100 µg/L in mid-1997 to ~20 µg/L at the end of fiscal year 1999). However, the area of the 4,000 µg/L contour has apparently increased in size since 1996. Spreading of the 4,000 µg/L contour is attributed to the effects of pumping.

A.7.11 State-Approved Land Disposal Site

A state waste discharge permit (WAC 173-216) requires groundwater monitoring at this site. The permit was granted in June 1995, and the site began to operate in December 1995. Groundwater monitoring for tritium only is conducted in 17 wells near the facility (Table A.23 and Figure A.13). The permit stipulates requirements for groundwater monitoring and establishes enforcement limits for concentrations of 16 constituents in 3 additional wells immediately surrounding the facility and in background well 299-W8-1 (see Table A.23).

During fiscal year 1999, groundwater monitoring wells immediately downgradient of the facility continued to reflect discharges of high levels of tritium to the facility that occurred from 1996 through 1998. Quantities of tritium discharged to the facility during fiscal year 1999 have been minimal. No permit enforcement limits were exceeded during fiscal year 1999. Evaluation of the well network indicates that well coverage is currently adequate to satisfy groundwater monitoring requirements.

A.7.12 Environmental Restoration Disposal Facility

This facility is a landfill authorized by CERCLA that is designated to meet RCRA requirements of Subpart N, 40 CFR 264. The groundwater monitoring network consists of one upgradient and three downgradient wells that are sampled semiannually (Table A.24). In addition, the facility has a system to collect and remove leachate that helps evaluate whether the liner system is performing within design standards. The groundwater protection plan for this landfill is published in BHI-00079 and the sampling plan for groundwater monitoring is documented in BHI-00873.

Monitoring wells for this facility were sampled twice in fiscal year 1999. Groundwater data collected from the monitoring network indicate that the facility is not contaminating groundwater.

A.7.13 Drinking Water Standards and Derived Concentration Guides

The highest tritium concentration in the 200 West Area was slightly below the derived concentration guide in fiscal year 1999 in well 299-W14-2. This well, located near Waste Management Area TX-TY and associated facilities, exceeded the derived concentration guide in fiscal year 1998. Total uranium analyses of samples from wells near U Plant that indicate the derived concentration guides for uranium-234 and uranium-238 were exceeded. Iodine-129, technetium-99, and tritium were found at levels above the interim

drinking water standards in the 200 West Area. Uranium was found at levels above its proposed maximum contaminant level. Nitrate, carbon tetrachloride, chloroform, chromium, fluoride, manganese, nickel, and trichloroethylene were detected at levels above the maximum contaminant levels.

A.8 200 East Area

Regulatory compliance issues related to groundwater in the 200 East Area include monitoring for RCRA and CERCLA requirements. There is also one state regulated disposal unit in this region.

A.8.1 Waste Management Area A-AX

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 1999. Wells were sampled twice for indicator and site-specific parameters (Table A.25 and Figure A.14). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to those established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during fiscal year 1999. Table A.26 updates the critical mean values based on recent upgradient data.

Because of uncertainty in flow directions, the well network for this site may not be adequate for RCRA monitoring. The aquifer ranges from 2.2 to 4.5 meters thick in RCRA network wells. The rate of water-table decline has increased from 9.1 centimeters per year in 1997 to 30.5 centimeters per year in 1999. If this rate continues, three of the RCRA compliant wells at Waste Management Area A-AX will become unusable in 6 years.

A.8.2 Waste Management Area B-BX-BY

RCRA assessment monitoring continued at this waste management area in fiscal year 1999. Exceedances of the critical mean value for specific conductance in February 1996 at well 299-E33-32 initiated

assessment monitoring. An assessment monitoring plan (WHC-SD-ENV-AP-002) was issued in September 1996, followed by an assessment investigation. Results indicated that tank waste from this waste management area had reached the groundwater (PNNL-11826). The assessment program is continuing to investigate the rate of movement and extent of groundwater contamination at this site (see Section 2.9.1 and Table A.2). Wells are monitored at least quarterly, and in some cases, monthly.

For fiscal year 1999, iodine-129, nitrate, technetium-99, and uranium exceeded maximum contaminant levels or drinking water standards in RCRA compliant wells, with corresponding exceedances of gross beta and gross alpha standards. A further discussion of contaminant trends can be found in Section 2.9.1.

Originally, the RCRA groundwater monitoring network was designed for groundwater flow toward the northwest, based on regional plume maps. This method was used to determine flow direction because the water table is almost flat in the immediate area of the farms. As part of the ongoing studies, a series of steps are being taken to refine water-level measurements to allow a better determination the approximate flow direction based on the local gradient. Although the aquifer is thin through this area, ranging from 2 to 3 meters for RCRA compliant wells, it is anticipated that these wells can be used for at least 5 years.

In fiscal year 1999, the monitoring network was expanded to include surrounding wells (Table A.27 and Figure A.15). Some of these wells are RCRA compliant, while others are older wells installed to monitor past-practice waste disposal sites. The choice of monitoring wells is reviewed either monthly or quarterly to track contamination moving through the site. One new well, 299-E33-44, was installed in fiscal year 1998 on the eastern side of BX Tank Farm in support of the assessment work. A discussion of results from monitoring this well can be found in Section 2.9.1. Two new wells will be drilled in fiscal year 2000 to provide monitoring coverage in the southwestern corner of the site.

A.8.3 Waste Management Area C

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 1999. Monthly sampling began in fiscal year 1999 to assess the potential impact of waste removal and sluicing of tank contents. In addition, the required detection sampling was conducted twice for indicator and site-specific parameters (Table A.28 and Figure A.14). Indicator parameter data from upgradient wells were statistically evaluated. Values from down-gradient wells were compared to values established from the upgradient wells. The indicator parameters (specific conductance, total organic carbon, pH, and total organic halides) did not exceed critical mean values during fiscal year 1999. Table A.29 lists revised critical mean values based on recent data from upgradient wells.

Currently, the well network for this site appears to comply only marginally with the required placement of groundwater monitoring wells because of changes and uncertainty in the direction of flow (see Section 2.9.2).

A.8.4 PUREX Cribs

The 216-A-10, 216-A-36B, and 216-A-37-1 cribs were monitored under a RCRA assessment program in fiscal year 1999 (Table A.30 and Figure A.16). The sites are monitored together 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 evidence of contamination. Combining these cribs into one RCRA groundwater monitoring area saves sampling and analysis costs because the number of near-field wells is reduced.

Many of the far-field wells that formerly were sampled annually are now sampled every 3 years. These wells mainly track the extent and flow rate of the extensive iodine-129, nitrate, and tritium plumes that change very little in a 3-year period. This change was incorporated in two updates of the groundwater monitoring

plan along with corrections to inappropriate procedural references (PNNL-11523 R0.1 and R0.2).

The rate and extent of contamination are discussed in Sections 2.9.2.1 through 2.9.2.7 of the main text. Knowledge of the groundwater flow direction and flow rate in the southeastern portion of the 200 East Area did not change significantly during fiscal year 1999 (see Table A.2). Therefore, the combined near-field and far-field monitoring well networks are adequate to continue to monitor both the extent and rate of flow of the contaminant plumes emanating from the PUREX cribs.

During fiscal year 1999, iodine-129, gross beta, manganese, nitrate, strontium-90, and tritium continue to exceed interim drinking water standards or maximum contaminant levels in areas downgradient of the PUREX cribs (see Table A.3). Strontium-90, a beta emitter, and gross beta exceed the interim drinking water standards only in well 299-E17-14, which is near the 216-A-36B crib. Elevated manganese is found in wells 299-E25-19 and 299-E25-17 (both near the 216-A-37-1 crib). However, manganese exceeded the 50- $\mu\text{g/L}$ maximum contaminant level only in well 299-E25-19. Iodine-129, nitrate, and tritium are major plumes that extend beyond the near-field monitoring well network at the PUREX cribs. These more extensive plumes are monitored by the far-field monitoring well network.

A.8.5 216-B-3 Pond

In fiscal year 1999, groundwater monitoring at B Pond continued under an interim status indicator evaluation program. The RCRA site was monitored under an assessment program from 1990 until January 1998 because of elevated total organic halides in two downgradient wells (699-43-41E and 699-43-41F). Assessment results (PNNL-11604) concluded that no hazardous waste constituents had affected groundwater quality beneath B Pond despite erratic, low levels of total organic halides. Groundwater beneath the site apparently has been affected by tritium and nitrate from past discharges to B Pond. The site was returned to an indicator evaluation program.

The current network includes eight downgradient wells and one upgradient well (Table A.31 and Figure A.17). One new well was drilled near the end of fiscal year 1999 that will be added to the network during fiscal year 2000. The network is designed to intercept potential contamination entrained in groundwater at some distance from the facility (e.g., well 699-44-39B) and contamination potentially entering groundwater from the vadose zone near the facility (e.g., well 699-42-42B). With the addition of the new well in 2000, the network is adequate to detect potential contamination from the facility.

Statistical evaluations of indicator parameters in fiscal year 1999 indicated the site has not adversely affected groundwater quality. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal 1999. Table A.32 lists critical mean values.

A.8.6 216-A-29 Ditch

This RCRA unit continued to be monitored under an interim status indicator evaluation program in fiscal year 1999 (Table A.33 and Figure A.16). Indicator parameter data from upgradient wells were statistically evaluated, and values from downgradient wells were compared to values established from the upgradient wells. All replicate averages for contamination indicator parameters were below critical mean values or limits of quantitation during fiscal year 1999. Critical mean values are listed in Table A.34.

The groundwater monitoring plan was revised in fiscal year 1999 (PNNL-13047). The current network is adequate for detection monitoring.

A.8.7 216-B-63 Trench

In fiscal year 1999, RCRA monitoring continued to provide no evidence that dangerous non-radioactive constituents from the site have entered groundwater. The well network was sampled twice for the indicator parameters pH, specific conductance, total organic carbon, and total organic halides (Table A.35 and Figure A.18). All replicate averages for contamination

indicator parameters were below critical mean values or limits of quantitation during fiscal year 1999. Critical mean values are listed in Table A.36. The network is considered adequate.

A.8.8 Liquid Effluent Retention Facility

This RCRA facility is subject to final status monitoring and is included in the Hanford Site RCRA Permit (Ecology 1994). Until the final status plan is approved by the regulators, groundwater is monitored under the existing interim status plan (WHC-SD-EN-AP-024).

In fiscal year 1999, groundwater monitoring provided no evidence that dangerous, non-radioactive constituents from the site have entered the groundwater. The RCRA indicator parameters are pH, specific conductance, total organic carbon, and total organic halides (Table A.37 and Figure A.19). Specific conductance in two downgradient wells (299-E26-9 and 299-E26-10) exceeded the critical mean value in January 1999. DOE notified Ecology and submitted a groundwater quality assessment plan and report in March 1999. The plan concluded that the Liquid Effluent Retention Facility was not the source of the high specific conductance and detection monitoring should continue.

In June 1999, downgradient well 299-E26-9 was removed from the monitoring network because it went dry. In September 1999, Ecology directed DOE to continue the current monitoring using three wells (one upgradient and two downgradient) for 18 months. During this period, an alternative method of monitoring should be identified. Background conditions were re-established to reflect the most recent site conditions (Table A.38).

A.8.9 Low-Level Waste Management Area 1

Groundwater monitoring under interim status requirements continued at this RCRA site in fiscal year 1999. The well network was sampled twice for

indicator and site-specific parameters (Table A.39 and Figure A.20). Downgradient monitoring well 299-E33-34 exceeded the critical mean for specific conductance in samples from December 1998 and June 1999. This exceedance appears to be related to the nitrate plume and is not related to Low-Level Waste Management Area 1. A letter of notification was submitted to Ecology on March 18, 1999. Because no waste has been placed in the northern portion of this site and there is a known nitrate plume from an upgradient source, no further action is necessary. Critical mean values were updated based on recent upgradient data (Table A.40).

The groundwater monitoring network for Low-Level Waste Management Area 1 is adequate for the RCRA requirements. No new wells are planned for this area.

A.8.10 Low-Level Waste Management Area 2

This RCRA site continued in RCRA interim status indicator evaluation in fiscal year 1999. Wells were sampled twice for indicator and site-specific parameters (Table A.41 and Figure A.18). Statistical evaluations for this area determined that upgradient well 299-E34-7 exceeded the critical mean for specific conductance. The major contributors to the increase are sulfate and calcium. The source of these constituents is not known. However, there is only 0.6 meter of water remaining in this well, which is completed at the top of basalt, and the increase may be related to the basalt chemistry. An additional exceedance occurred in the quadruplicate average for total organic halides at well 299-E34-3 in January 1999. The average result of 42 $\mu\text{g/L}$ is above the critical mean value of 21 $\mu\text{g/L}$. Two of the four reported results (30.4 and 131 $\mu\text{g/L}$) are probably erroneous and have been flagged in the database. The quadruplicate average from April 1999 (2.75 $\mu\text{g/L}$) is well below the critical mean value. Table A.42 updates the critical mean values based on recent data from the upgradient wells.

The monitoring network for Low-Level Waste Management Area 2 is adequate to detect releases from the facility. However, the continued water-level decline may cause additional wells to go dry. Monitoring wells in this area are all completed at the top of basalt and if more wells become dry, alternatives to groundwater monitoring may be required to detect contamination from this facility.

A.8.11 200 Areas Treated Effluent Disposal Facility

A state waste discharge permit (WAC 173-216) governs groundwater sampling and analysis in the three monitoring wells at this facility (Table A.43 and Figure A.17). The constituent list and frequency of sampling are specified in the permit. Wells were sampled quarterly during fiscal year 1999, but may be reduced to semiannually during fiscal year 2000 when a new permit is issued.

No permit criteria for constituents in groundwater were exceeded in fiscal year 1999. The groundwater monitoring network serves to demonstrate that effluent from the facility is not taking a direct route to the uppermost aquifer and to differentiate the potential effects of the facility from those of the 216-B-3 pond facility. The well configuration is adequate for this purpose.

A.8.12 200-PO-1 Operable Unit

This groundwater operable unit, which encompasses the area of the tritium plume southeast of the 200 East Area, has the same monitoring objectives as monitoring for the *Atomic Energy Act of 1954* (surveillance) and RCRA (PUREX cribs assessment). See Section A.8.4 for additional discussion.

A.8.13 200-BP-5 Operable Unit

This groundwater operable unit, which encompasses the northern portion of 200 East Area, has the same monitoring objectives as the *Atomic Energy Act of 1954* (surveillance). See Section A.8.14 for additional discussion.

A.8.14 Drinking Water Standards and Derived Concentration Guides

Tritium was detected at levels above the 2 million pCi/L derived concentration guide at one well south of the PUREX Plant. Tritium contamination at levels above the 20,000-pCi/L interim drinking water standard was found throughout much of the 200 East Area. Strontium-90 was detected at levels above the 1,000-pCi/L derived concentration guide in two wells near the 216-B-5 injection well. Strontium-90 contamination was found at levels above the 8-pCi/L interim drinking water standard in several wells near the 216-B-5 injection well and in one well south of the PUREX Plant. The following constituents also were detected at levels above standards in the 200 East Area: aluminum, cesium-137, cyanide, iodine-129, manganese, nitrate, sulfate, technetium-99, and uranium.

A.9 400 and 600 Areas

This section discusses compliance issues for the 400 Area process ponds, 400 Area water supply wells, Nonradioactive Dangerous Waste Landfill, and Solid Waste Landfill.

A.9.1 400 Area

The 4608 B/C ponds (also called the 400 Area process ponds), are regulated under WAC-173-216. The permit, issued on August 1, 1996, and modified on February 10, 1998, defines groundwater enforcement limitations (Table A.44 and Figure A.21). Groundwater quality met permit conditions in fiscal year 1999.

The water supply in the 400 Area, which comes from wells, is also monitored to maintain compliance with drinking water standards. Tritium was detected at levels above the 20,000-pCi/L standard in the backup water supply wells for this area. Because the backup water supply wells are seldom used, however, the monthly water supply sampling indicates that tritium in the drinking water is maintained at a level below the 4-mrem/yr dose equivalent standard.

A.9.2 Nonradioactive Dangerous Waste Landfill

This RCRA site continued to be monitored under an interim status indicator evaluation program in fiscal year 1999 (Table A.45 and Figure A.22). Statistical evaluations indicated the site has not adversely affected groundwater quality. Table A.46 updates critical mean values based on recent data from upgradient wells. The groundwater monitoring plan for the landfill was rewritten during fiscal year 1999 (PNNL-12227) to update the operating procedures and bring the plan up to date with the current monitoring well network and constituents monitored. It is pending approval from government regulators.

Groundwater flow direction and rate did not change significantly during fiscal year 1999, and the wells in the network are still functioning. Therefore, the monitoring well network is adequate to fulfill the needs of the current groundwater monitoring plan.

A.9.3 Solid Waste Landfill

State dangerous waste regulations (WAC 173-304) govern groundwater monitoring at this landfill. The final closure plan for the site has not been implemented. Wells are sampled quarterly for constituents specified in WAC 173-304 plus the site-specific constituents chlorinated hydrocarbons and tritium (Table A.47 and Figure A.22).

Statistical evaluations of the constituents specified in WAC 173-304 for landfills (Tables A.48 and A.49) revealed that three exceeded their background threshold levels during fiscal year 1999:

- (1) Specific conductance exceeded its 550- μ S/cm threshold level in 9 of the 10 wells in the monitoring network.
- (2) Sulfate exceeded its 51.5-mg/L threshold level in 2 of the 10 wells.
- (3) Filtered zinc exceeded its 34- μ g/L threshold level in one well.

Tritium exceeded its interim drinking water standard at many of the monitoring wells on the eastern side of the landfill, but the source is upgradient. Six chlorinated hydrocarbons exceeded WAC 173-200 groundwater quality criteria in at least one well of the monitoring network. They are as follows, with the numbers of wells having exceedances and the WAC limit:

- Carbon tetrachloride (3) (0.3 μ g/L)
- 1,1-dichloroethane (8) (1.0 μ g/L)
- 1,2-dichloroethane (2) (0.5 μ g/L)
- Tetrachloroethylene (10) (0.8 μ g/L)
- Trichloroethylene (3) (3.0 μ g/L)
- 1,1,1-trichloroethane (10) (0.2 μ g/L).

The monitoring network for the Solid Waste Landfill has two upgradient wells and eight downgradient wells and is adequate for meeting the requirements of WAC 173-304.

A.9.4 Drinking Water Standards and Derived Concentration Guides

No radionuclides exceeded derived concentration guides in the 600 Area. Contamination from other operational areas impacted the 600 Area at levels that exceeded the interim drinking water standards or maximum contaminant levels, as discussed in Section 2.0. Contamination from 600 Area sources at levels exceeding standards 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 southwest of the 200 West Area. Nitrate concentrations that exceeded the maximum contaminant level were found upgradient of the operational areas and probably result from offsite agriculture.

Nitrate exceeded the 45 mg/L maximum contaminant level in the 400 Area. Tritium from upgradient sources exceeded the drinking water standard.

A.10 300 and Richland North Areas

Groundwater in these areas is monitored for one RCRA site and the 300-FF-5 and 1100-EM-1 groundwater operable units.

A.10.1 316-5 Process Trenches

This RCRA site continued to be monitored with a final status corrective-action network. The objective of groundwater monitoring during the corrective-action period 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). A proposed groundwater monitoring plan for corrective action calls for samples from the same wells as in the compliance period, but with fewer independent samples from each well during each sampling period (i.e., four to one). Also, each well showing an exceedance of one of the constituents of concern will be sampled quarterly to better follow the trends of contaminant concentration. The other wells in the network will continue to be sampled semiannually. The proposed plan is still being reviewed by the regulator.

Until the proposed plan is implemented, the final status compliance monitoring program (WHC-SD-EN-AP-185) remains in effect (Table A.50 and Figure A.23). This plan calls for four independent groundwater samples from each network well (eight) during each semiannual sampling period (i.e., 64 well trips per year). The monitoring network for the 316-5 process trenches includes two wells upgradient and six wells downgradient. One of the upgradient wells and three of the downgradient wells monitor the bottom of the unconfined aquifer, and one upgradient well and three downgradient wells monitor the unconfined aquifer near the water table. The monitoring network has eight wells and is adequate to ensure that the 316-5 process trenches complies with a RCRA final status corrective-action network and the current groundwater monitoring plan (WHC-SD-EN-AP-185).

Uranium, trichloroethylene, and cis-1,2-dichloroethylene continued to exceed concentration limits specified in the permit (Table A.51). Uranium, gross alpha, and tetrachloroethylene exceeded maximum contaminant levels in one or more wells monitoring near the water table (see Table A.3). Cis-1,2-dichloroethylene and trichloroethylene exceeded standards in one downgradient well that monitors the base of the unconfined aquifer. Concentrations of uranium and various volatile organics rose sharply in 1995 after the large quantities of relatively clean waste cooling water ceased to be discharged to the 316-5 process trenches. However, since that time, concentrations of those constituents have begun a slight downward trend as was expected.

A.10.2 300-FF-5 Operable Unit

Groundwater in this operable unit is monitored to assess whether the contaminants of concern (uranium, trichloroethylene, and cis-1,2-dichloroethylene) are naturally diminishing over time. The remedial action is an interim action that involves imposing restrictions on the use of the groundwater until these contaminants meet health-based criteria (ROD 1996b). 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.

An operation and maintenance plan for the 300-FF-5 Operable Unit (DOE/RL-95-73) identifies tasks necessary to verify the effectiveness of the remedial action. The plan describes the monitoring program and administrative tasks that are part of the remedial action. The routine operation and maintenance activities include groundwater and river monitoring.

As discussed in Section A.10.1, the constituents of concern actually increased in concentration in the groundwater of the 300-FF-5 Operable Unit immediately after discharges from the process sewers to the

316-5 process trenches stopped. The previously lower concentrations in the groundwater were apparently due to the dilution of the constituents by the large quantities of relatively clean waste cooling water. When the trenches ceased to be used and the dilution no longer occurred, the concentrations rose to the high levels discovered in 1995-1997. More recently the constituents of concern have begun to decrease in concentration slightly, as was predicted (ROD 1996a).

A.10.3 1100-EM-1 Operable Unit

The 1100-EM-1 Operable Unit contains the Horn Rapids Landfill. Results of the CERCLA investigation 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 of volatile organic compounds, with institutional controls on drilling of new water supply wells. Monitoring includes analysis for trichloroethylene, its breakdown products (vinyl chloride and 1,1-dichloroethene), and nitrate in wells downgradient of the Horn Rapids Landfill, as recommended in the sampling plan (DOE/RL-95-50), which was updated in 1999 (PNNL-12220). Pacific Northwest National Laboratory has been responsible for groundwater monitoring at the 1100-EM-1 Operable Unit since 1997. Five years of monitoring are now complete (1995 to 1999), and the data will be reviewed to evaluate the progress of natural attenuation of trichloroethylene (DOE/RL-95-80). Although not specified in the record of decision, chromium is monitored annually in one well downgradient of the 1171 Building.

Trichloroethylene levels did not exceed 5 µg/L at the point of compliance wells 699-S27-E12A, 699-S28-E13A, and 699-S29-E13A in fiscal year 1999. These wells form a line downgradient of the Horn Rapids Landfill that is approximately perpendicular to the prevailing path of the trichloroethylene plume.

A.10.4 Drinking Water Standards and Derived Concentration Guides

No radiological constituents in 300 Area groundwater were detected at levels above their derived concentration guides in fiscal year 1999. Uranium exceeded the proposed maximum contaminant level in much of the eastern part of the 300 Area. Trichloroethylene and cis-1,2-dichloroethylene were found at levels above standards in the deeper part of the unconfined aquifer system at one well (399-1-16B). Trichloroethylene was detected in 22 other wells in the upper portion of the unconfined aquifer of the central and southern parts of the 300 Area, but only wells 399-1-16B and 399-4-1 exceeded the maximum contaminant level. Tetrachloroethylene was detected at 12 wells in the 300 Area, but exceeded its standard in only one well in the upper part of the unconfined aquifer southeast of the 316-5 process trenches. Nitrate exceeded its maximum contaminant level at four wells in the southern portion of the 300 Area.

In the Richland North Area, fluoride, nitrate, and trichloroethylene were detected in groundwater at concentrations above their respective maximum contaminant levels. High levels of gross alpha suggest that uranium may also have been above its standard during fiscal year 1999. Likely sources of these constituents include offsite industry and agriculture.

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Table A.1. RCRA Interim and Final Status Groundwater Monitoring Projects, September 1999

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring			Regulations	Year Scheduled for Part B or Closure
	Indicator Parameter Evaluation ^(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated		
1301-N LWDF, December 1987			X ^(b)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(c)
1324-N/NA LWDF, December 1987			X ^(b)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(c)
1325-N LWDF, December 1987			X ^(b)			40 CFR 265.93(b) WAC 173-303-400	1999 ^(c)
120-D-1 ponds, April 1992	X, clean closed in FY 1999					40 CFR 265.93(b) WAC 173-303-400	1999 ^(d)
183-H solar evaporation basins, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1994 ^(e)
WMA S-SX, October 1991		X, 1996				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)
WMA T, February 1990		X, 1993				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)
WMA TX-TY, September - October 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)
WMA U, October 1990	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(e)
216-S-10 pond and ditch, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(e)
216-U-12 crib, September 1991		X, 1993				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)

Table A.1. (contd)

TSD Units, date initiated	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring			Regulations	Year Scheduled for Part B or Closure
	Indicator Parameter Evaluation ^(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated		
LLWMA 3, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	TBD ^(e,f)
LLWMA 4, October 1988	X					40 CFR 265.93(b) WAC 173-303-400	TBD ^(e,f)
WMA A-AX, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(e)
WMA B-BX-BY, February 1990		X, 1996				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)
WMA C, February 1990	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(e)
PUREX cribs ^(g) 1988		X, 1997				40 CFR 265.93(d) WAC 173-303-400	>2000 ^(e)
216-B-3 pond, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2000 ^(e)
216-A-29 ditch, November 1988	X					40 CFR 265.93(b) WAC 173-303-400	2000 ^(e)
216-B-63 trench, August 1991	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(e)
LERF, July 1991			X, 1998 ^(h)			40 CFR 265.93(b) WAC 173-303-400	1998 ^(e)
LLWMA 1, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	TBD ^(g,h)
LLWMA 2, September 1988	X					40 CFR 265.93(b) WAC 173-303-400	TBD ^(g,h)

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Table A.1. (contd)

TSD Units, date initiated (associated [CERCLA] groundwater operable units)	Interim Status TSD Unit Groundwater Monitoring		Final Status TSD Unit Groundwater Monitoring			Regulations	Year Scheduled for Part B or Closure
	Indicator Parameter Evaluation ^(a)	Groundwater Quality Assessment, date initiated	Detection Evaluation	Compliance Evaluation	Corrective Action, date initiated		
NRDWL, October 1986	X					40 CFR 265.93(b) WAC 173-303-400	>2000 ^(c)
316-5 process trenches, June 1985					X, 1998	40 CFR 264 WAC 173-303-645(10)	1996 ^(e,i)

- (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 (i.e., groundwater quality assessment). An X in the assessment column indicates whether an evaluation was needed or an assessment was required.
- (b) Monitored according to interim status plan as specified in closure plans.
- (c) Closure/postclosure plan; TSD unit will close under final status.
- (d) Closure plan approved in fiscal year 1999; facility groundwater monitoring not required after clean closure.
- (e) Part B permit; TSD unit scheduled to operate under final status regulations beginning in year indicated.
- (f) Facility Part B permit and final status groundwater monitoring plan contingent on completion of solid waste environmental impact statement.
- (g) 216-A-10, -A-36B, and -A-37-1 combined into one RCRA monitoring unit. RCRA monitoring will be performed according to interim status groundwater quality assessment requirements.
- (h) Will monitor groundwater under interim status until final status groundwater monitoring plan is approved.
- (i) Closure plan pending Ecology approval.

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

Table A.2. Estimates of Groundwater Flow Rates at Hanford Site Facilities

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity ^(a)	Gradient ^(b)	Comments
1301-N LWDF	NW	0.045 to 0.82	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0022	Gradient calculated between wells 199-N-34 and 199-N-2.
1324-N/NA	NW	0.086 to 1.6	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0042	Gradient calculated between wells 199-N-72 and 199-N-26.
1325-N LWDF	N	0.021 to 0.38	Darcy	6.1 to 37 (PNL-8335)	0.1 to 0.3	0.0010	Gradient calculated between wells 199-N-28 and 199-N-81.
120-D-1 ponds	NW	0.0021 to 0.22	Darcy	1.2 to 40 (WHC-SD-EN-DP-043)	0.1 to 0.3	0.00055	Gradient calculated between wells 199-D5-13 and 199-D8-4.
183-H solar evaporation basins	E	0.12 to 3.2	Darcy	15 to 140 (PNL-6728)	0.1 to 0.3	0.0023	Gradient calculated between wells 199-H3-2B and 199-H4-12B. 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				
WMA S-SX	ESE	0.0023 to 0.43	Darcy	0.43 to 27 (WHC-SD-EN-DP-042)	0.1 to 0.3	0.0016	Lower bound for hydraulic conductivity and velocity.
		0.07 to 0.14	Contaminant travel time (PNNL-12114)				Average gradient calculated from wells 299-W23-13 and 299-W22-45 at S Tank Farm and wells 299-W23-14 and 299-W22-39 at SX Tank Farm.
WMA T	E	0.04 to 0.13	Darcy	10 (WHC-SD-EN-TI-147)	0.1 to 0.3	0.0013	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W10-12 and 299-W11-27.
WMA TX-TY	E (north half) S or SW (south half)	0.2 to 0.6	Darcy	55 (WHC-SD-EN-DP-042)	0.1 to 0.3	0.001	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W15-12 and 299-W15-4.
WMA U	E	0.028 to 0.52	Darcy	6 to 37 (WHC-SD-EN-DP-042)	0.1 to 0.3	0.0014	Lower bound for hydraulic conductivity and velocity. Gradient calculated between wells 299-W18-31 and 299-W19-32.
216-S-10 pond	ESE	0.04 to 4.8	Darcy	10 (WHC-SD-EN-DP-052) 12 to 150 (BNWL-1709)	0.1 to 0.3	0.0011 to 0.0032	Gradient increases to the south. Gradients calculated between wells 299-W26-8 and average of wells 299-W26-10 and 299-W26-12 (north) and wells 299-W26-7 and 299-W26-9 (south).
216-U-12 crib	ESE, changing to E	0.03 to 0.1	Darcy	6.2 (see comments)	0.1 to 0.3	0.00165	Hydraulic conductivity is geometric mean of values in WHC-MR-0208. Gradient calculated between wells 299-W22-43 and 299-W22-79.

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity ^(a)	Gradient ^(b)	Comments
LLWMA 3	NE	0.0001 to 0.13	Darcy	0.02 to 9.8 (PNL-6820)	0.1 to 0.3	0.0013	
LLWMA 4	E	0.2 to 0.6	Darcy	24 (PNL-6820)	0.1 to 0.3	0.0025	
SALDS	Radial to NE	0.03 to 5.8	Darcy	3.5 to 36.3 (WHC-SD-C018H-RPT-003)	0.25 ^(c)	0.0018 to 0.004	Higher gradient was calculated between wells 699-48-77A and 699-48-77D.
WMA A-AX	E?	0.5 to 0.7	Darcy	2,005 to 2,519 (WHC-SD-EN-TI-019)	0.3	~0.00008	Gradient calculated between wells 299-E25-41 and 299-E24-20. Flow direction unclear because of flat water table.
WMA B-BX-BY	SW?	0.9	Darcy	1,615 (WHC-SD-EN-TI-019)	0.3	~0.00017, September 1999	Gradient calculated between wells 299-E33-33 and 299-E33-42. Flow direction is not well known; based on current contamination migration and water table.
WMA C	SW	0.7 to 1.4	Darcy	1,067 to 2,073 (WHC-SD-EN-TI-019)	0.3	0.00021, September 1999	Gradient calculated between wells 299-E27-7 and 299-E27-13. Flow direction inferred from hydrographs.
216-A-10 crib 216-A-36B	SE	0.004 to 0.60	Darcy	60 to 3,000 (WHC-SD-EN-TI-019; PNNL-11515)	0.1 to 0.3	~0.00002	Gradient estimated from regional water-level contours.
216-A-37-1 crib	SW	~0.018 to 0.18	Darcy	18 to 60 (WHC-SD-EN-DP-047; PNNL-11515)	0.1 to 0.3	~0.0003	Gradient estimated from regional water-level contours.
216-B-3 pond	Radial	0.01 to 19.2	Darcy; plume migration	1 to 640 (WHC-SD-EN-EV-002; PNL-10195)	0.1 to 0.3	~0.003	Gradient calculated between wells 699-44-42 and 699-43-45 (March 1999).
216-A-29 ditch	WSW	~0.02 to ~0.07	Darcy	18 (WHC-SD-EN-DP-047)	0.1 to 0.3	~0.0004	
216-B-63 trench	W	0.01 to 0.1	Darcy	52 to 200 (WHC-SD-EN-EV-002)	0.1 to 0.3	~0.00004	
LERF	W	0.04 to 6.0	Darcy	6.1 to 120 (PNNL-11620)	0.1 to 0.3	0.002 to 0.005	
LLWMA 1	NW	≤0.5	Darcy	73 to 760 (PNL-6820)	0.1 to 0.3	≤0.00006	Uncertainty with gradient and rate of flow. Flow direction inferred from plume maps.

Table A.2. (contd)

Site	Flow Direction	Flow Rate (m/d)	Method	Hydraulic Conductivity (m/d) (source)	Effective Porosity ^(a)	Gradient ^(b)	Comments
LLWMA 2	W	~0.06 to ~0.8	Darcy	430 to 2,000 (PNL-6820)	0.1 to 0.3	~0.00004	Gradient calculated between wells 299-E27-16 and 299-E27-9.
200 Area TEDF	SSW	0.004	Darcy	1.1 (WHC-SD-EN-ES-004)	0.25 ^(c)	~0.001	
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 below 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.
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				
316-5 process trenches	SE	31 (DOE/RL-89-14)	Movement of PCE spill				
	S	0.35 to 105	Darcy	150 to 15,000 (PNL-6716)	0.1 to 0.3	0.0007	Gradient from Plate 2.

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

(b) March 1999 unless noted otherwise.

(c) RHO-ST-42, RHO-RE-ST-12, PNNL-11801.

LERF = Liquid effluent retention facility.

LLWMA = Low-level waste management area.

LWDF = Liquid waste disposal facility.

NA = Not applicable.

NRDWL = Nonradioactive Dangerous Waste Landfill.

PCE = Tetrachloroethylene.

RCRA = Resource Conservation and Recovery Act of 1976.

SALDS = State-Approved Land Disposal Site.

SWL = Solid Waste Landfill.

TEDF = Treated Effluent Disposal Facility.

WMA = Waste management area.

**Table A.3. Monitoring Results Exceeding Maximum Contaminant Levels or Drinking Water Standards
(Regulated Units listed in alphanumeric order)^(a)**

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
100 N Area						
Gross beta, pCi/L	N	199-N-105A	Down	3	3,770	50
	N	199-N-3	Down	1	1,980	50
Nitrate, µg/L	N	199-N-2	Down	1	51,000	45,000
	N	199-N-81	Down	1	52,000	45,000
Nitrogen in Nitrate, µg/L	N	199-N-2	Down	1	20,200	10,000
	N	199-N-59	Down	3	22,900	10,000
	N	199-N-81	Down	1	11,300	10,000
Strontium-90, pCi/L	N	199-N-105A	Down	3	1,870	8
	N	199-N-28	Down	1	85.8	8
	N	199-N-3	Down	3	1,170	8
	N	199-N-34	Up	1	54.9	8
	N	199-N-57	Up	1	14.6	8
	N	199-N-81	Down	2	1,210	8
	Y	199-N-81	Down	1	1,220	8
Tritium, pCi/L	N	199-N-105A	Down	3	23,800	20,000
	N	199-N-28	Down	1	25,800	20,000
	N	199-N-32	Down	2	32,600	20,000
	N	199-N-34	Up	1	24,100	20,000
120-D-1 Ponds						
Chromium, µg/L	N	199-D5-13	Up	1	317	100
	N	199-D8-5	Down	1	228	100
	Y	199-D5-13	Up	2	366	100
	Y	199-D8-4	Down	1	101	100
	Y	199-D8-5	Down	3	251	100
	Y	199-D8-6	Down	1	107	100
Hexavalent Chromium, µg/L	Y	199-D5-13	Up	3	416	100
Nitrogen in Nitrate, µg/L	N	199-D5-13	Up	2	19,000	10,000
	N	199-D8-4	Down	2	15,500	10,000
	N	199-D8-6	Down	1	16,500	10,000
183-H Solar Evaporation Basins						
Chromium, µg/L	N	199-H4-12C	Down	1	244	100
	N	199-H4-3	Down	1	168	100
	Y	199-H4-12A	Down	1	132	100
	Y	199-H4-12C	Down	1	201	100
	Y	199-H4-3	Down	1	150	100
Gross beta, pCi/L	N	199-H4-3	Down	1	63.5	50
Hexavalent Chromium, µg/L	Y	199-H4-12C	Down	2	200	100
	Y	199-H4-3	Down	2	204	100
Nitrogen in Nitrate, µg/L	N	199-H4-12A	Down	1	31,900	10,000
	N	199-H4-3	Down	1	22,700	10,000
	N	199-H4-7	Down	1	10,500	10,000
Uranium, µg/L	N	199-H4-12A	Down	1	33.1	20
	N	199-H4-3	Down	1	21.3	20
216-B-63 Ditch						
Iodine-129, pCi/L	N	299-E33-33	Down	3	4.07	1
	N	299-E33-36	Down	4	6.5	1

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
216-S-10 Pond						
Carbon tetrachloride, µg/L	N	299-W26-12	Down	1	6	5
Chromium, µg/L	Y	299-W26-7	Up	1	175	100
Nickel, µg/L	Y	299-W27-2	Down	1	121	100
216-U-12 Crib						
Carbon tetrachloride, µg/L	N	699-36-70A	Down	1	7	5
Iodine-129, pCi/L	N	299-W22-42	Down	1	9.31	1
Nitrate, µg/L	N	699-36-70A	Down	1	110,000	45,000
Nitrogen in Nitrate, µg/L	N	299-W22-41	Down	2	4,580	10,000
	N	299-W22-42	Down	3	25,100	10,000
	N	299-W22-79	Down	3	18,000	10,000
	N	699-36-70A	Down	3	26,000	10,000
Nitrogen in Nitrite and Nitrate, µg/L	N	699-36-70A	Down	1	24,600	10,000
Tritium, pCi/L	N	299-W22-42	Down	3	49,200	20,000
	N	299-W22-79	Down	2	22,300	20,000
	N	699-36-70A	Down	3	95,000	20,000
316-5 Trenches						
cis-1,2-Dichloroethylene, µg/L	N	399-1-16B	Down	8	180	70
Gross alpha, pCi/L	N	399-1-17A	Down	2	67.3	15
Tetrachloroethylene, µg/L	N	399-1-16A	Down	1	7	5
Trichloroethylene, µg/L	N	399-1-16B	Down	2	6	5
Uranium, µg/L	N	399-1-10A	Down	6	61.1	20
	N	399-1-16A	Down	7	111	20
	N	399-1-17A	Down	6	166	20
400 Area						
Nitrogen in Nitrate, µg/L	N	699-2-7	Down	4	20,800	10,000
Tritium, pCi/L	N	499-S0-7	ND	1	20,200	20,000
	N	499-S0-8	ND	4	33,800	20,000
	N	699-2-6A	Down	1	22,300	20,000
	N	699-8-17	Up	2	68,400	20,000
Low-Level Waste Management Area 1						
Gross beta, pCi/L	N	299-E32-10	Down	3	413	50
	N	299-E33-34	Down	2	1,410	50
	N	299-E33-35	Up	3	441	50
Nitrogen in Nitrate, µg/L	N	299-E28-26	Up	2	10,900	10,000
	N	299-E32-10	Down	3	17,700	10,000
	N	299-E32-2	Down	2	11,600	10,000
	N	299-E32-3	Down	2	11,300	10,000
	N	299-E32-6	Down	2	11,400	10,000
	N	299-E33-34	Down	2	44,600	10,000
	N	299-E33-35	Up	3	20,500	10,000
Technetium-99, pCi/L	N	299-E33-34	Down	1	3,210	900
	N	299-E33-35	Up	2	1,720	900
Uranium, µg/L	N	299-E33-34	Down	1	21.1	20

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
Low-Level Waste Management Area 2						
Nitrogen in Nitrate, µg/L	N	299-E34-7	Up	2	17,200	10,000
Low-Level Waste Management Area 3						
Carbon tetrachloride, µg/L	N	299-W10-13	Up	1	9	5
	N	299-W10-19	Up	1	89	5
	N	299-W10-20	Up	1	1,300	5
	N	299-W10-21	Up	1	400	5
	N	299-W6-2	Down	1	130	5
	N	299-W7-4	Down	1	450	5
	N	299-W7-5	Down	1	110	5
	N	299-W8-1	Down	1	6	5
Nitrogen in Nitrate, µg/L	N	299-W10-19	Up	1	19,500	10,000
	N	299-W10-20	Up	1	25,400	10,000
	N	299-W10-21	Up	1	45,600	10,000
	N	299-W6-2	Down	1	10,900	10,000
	N	299-W7-4	Down	1	21,500	10,000
N	299-W7-5	Down	1	13,800	10,000	
Trichloroethylene, µg/L	N	299-W10-21	Up	1	7	5
Low-Level Waste Management Area 4						
Cadmium, µg/L	Y	299-W18-26	Up	1	10.8	5
Carbon tetrachloride, µg/L	N	299-W15-15	Up	7	510	5
	N	299-W15-16	Down	4	5,800	5
	N	299-W15-17	Down	2	9	5
	N	299-W15-18	Down	4	1,900	5
	N	299-W18-21	Up	6	200	5
	N	299-W18-23	Up	2	190	5
	N	299-W18-24	Down	3	1,400	5
	N	299-W18-26	Up	5	120	5
	N	299-W18-27	Up	5	410	5
	N	299-W18-32	Up	2	13	5
Gross alpha, pCi/L	N	299-W18-21	Up	2	16.5	15
Nitrogen in Nitrate, µg/L	N	299-W15-15	Up	2	20,300	10,000
	N	299-W15-16	Down	2	16,500	10,000
	N	299-W15-18	Down	2	23,100	10,000
	N	299-W18-21	Up	4	18,200	10,000
	N	299-W18-23	Up	1	11,600	10,000
	N	299-W18-24	Up	2	18,100	10,000
N	299-W18-26	Up	1	17,600	10,000	
Trichloroethylene, µg/L	N	299-W15-16	Down	2	6	5
Nonradioactive Dangerous Waste Landfill						
Tritium, pCi/L	N	699-25-34A	Down	2	80,800	20,000
	N	699-25-34B	Down	2	78,800	20,000
	N	699-25-34D	Down	2	75,700	20,000
	N	699-26-33	Down	2	85,600	20,000
	N	699-26-34A	Up	2	73,200	20,000
	N	699-26-34B	Down	3	81,700	20,000
	N	699-26-35A	Up	4	73,700	20,000
	N	699-26-35C	Up	2	31,100	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level	
Plutonium-Uranium Extraction (PUREX) Cribs							
Gross beta, pCi/L	N	299-E17-14	Down	4	110	50	
Iodine-129, pCi/L	N	299-E17-1	Down	1	9.76	1	
	N	299-E17-14	Down	4	12.5	1	
	N	299-E17-17	Down	3	9.41	1	
	N	299-E17-19	Down	2	9.42	1	
	N	299-E17-9	Down	2	11.1	1	
	N	299-E24-16	Down	4	12.2	1	
	N	299-E24-18	Up	1	1.54	1	
	N	299-E25-17	Down	1	3.49	1	
	N	299-E25-19	Down	2	1.91	1	
	N	299-E25-31	Up	1	2.8	1	
	N	699-37-47A	Down	1	2.48	1	
	Nitrogen in Nitrate, µg/L	N	299-E17-1	Down	2	22,000	10,000
		N	299-E17-14	Down	4	26,900	10,000
N		299-E17-19	Down	2	22,400	10,000	
N		299-E17-9	Down	2	43,300	10,000	
Strontium-90, pCi/L	N	299-E17-14	Down	4	17.2	8	
Tritium, pCi/L	N	299-E17-1	Down	2	919,000	20,000	
	N	299-E17-14	Down	4	901,000	20,000	
	N	299-E17-17	Down	3	285,000	20,000	
	N	299-E17-19	Down	2	730,000	20,000	
	N	299-E17-9	Down	2	3,870,000	20,000	
	N	299-E24-16	Down	4	385,000	20,000	
	N	299-E24-18	Up	2	93,800	20,000	
	N	299-E25-19	Down	4	174,000	20,000	
	N	699-37-47A	Down	2	36,000	20,000	
	State-Approved Land Disposal Site						
Carbon tetrachloride, µg/L	N	299-W8-1	ND	1	6	5	
	N	699-48-77C	Down	2	7	5	
Tritium, pCi/L	N	699-48-77A	Down	3	140,000	20,000	
	N	699-48-77C	Down	3	77,000	20,000	
	N	699-48-77D	Down	5	730,000	20,000	
Solid Waste Landfill							
Tetrachloroethylene, µg/L	N	699-23-34A	Down	1	10	5	
	N	699-23-34B	Down	1	7	5	
	N	699-24-33	Down	1	11	5	
	N	699-24-34A	Down	1	9	5	
	N	699-24-34B	Down	1	9	5	
	N	699-24-34C	Down	1	9	5	
	N	699-25-34C	Down	2	7	5	
Tritium, pCi/L	N	699-24-33	Down	4	49,300	20,000	
	N	699-24-34C	Down	4	49,700	20,000	
	N	699-25-34C	Down	5	72,000	20,000	
	N	699-26-35A	Up	4	73,700	20,000	
Waste Management Area A-AX							
Chromium, µg/L	Y	299-E24-19	Down	6	2,820	100	
	Y	299-E25-46	Down	1	131	100	
Iodine-129, pCi/L	N	299-E24-19	Down	2	5.14	1	
	N	299-E24-20	Down	1	4.54	1	
	N	299-E25-40	Up	2	6.65	1	
	N	299-E25-41	Up	2	4.7	1	
	N	299-E25-46	Down	2	4.39	1	
Nickel, µg/L	Y	299-E24-19	Down	6	883	100	

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level	
Waste Management Area B-BX-BY							
Cadmium, µg/L	Y	299-E33-7	Down	1	5.4	5	
Cyanide, µg/L	N	299-E33-7	Down	4	291	200	
Gross alpha, pCi/L	N	299-E33-13	Down	10	37.2	15	
	N	299-E33-18	Down	9	100	15	
	N	299-E33-26	Down	3	31.7	15	
	N	299-E33-38	Down	4	68.9	15	
	N	299-E33-44	Down	12	201	15	
	N	299-E33-5	Down	3	41	15	
Gross beta, pCi/L	N	299-E33-13	Down	12	1,220	50	
	N	299-E33-15	Down	1	59.4	50	
	N	299-E33-16	Down	5	700	50	
	N	299-E33-18	Down	9	476	50	
	N	299-E33-26	Down	3	1,080	50	
	N	299-E33-31	Down	13	609	50	
	N	299-E33-32	Down	11	434	50	
	N	299-E33-34	Down	2	1,410	50	
	N	299-E33-35	Down	3	441	50	
	N	299-E33-38	Down	3	2,460	50	
	N	299-E33-41	Down	12	532	50	
	N	299-E33-42	Down	12	763	50	
	N	299-E33-44	Down	10	2,140	50	
	N	299-E33-5	Down	3	2,220	50	
	N	299-E33-7	Down	8	2,620	50	
	N	299-E33-8	Down	5	541	50	
	N	699-50-53A	Down	1	80.8	50	
	Y	299-E33-8	Down	1	452	50	
	Iodine-129, pCi/L	N	299-E28-8	Down	2	3.54	1
		N	299-E33-15	Down	1	3.88	1
N		299-E33-17	Down	2	6.54	1	
N		299-E33-18	Down	1	5.86	1	
N		299-E33-20	Down	2	5.25	1	
N		299-E33-21	Down	2	3.81	1	
N		299-E33-26	Down	1	4.95	1	
N		299-E33-31	Down	1	4.37	1	
N		299-E33-32	Down	3	4.11	1	
N		299-E33-33	Up	3	4.07	1	
N		299-E33-36	Up	4	6.5	1	
N		299-E33-41	Down	1	4.53	1	
N		299-E33-42	Down	1	4.92	1	
N		299-E33-43	Down	3	4.31	1	
N		299-E33-44	Down	1	4.56	1	
N	299-E33-8	Down	1	4.48	1		
Nitrogen in Nitrate, µg/L	N	299-E33-13	Down	12	58,700	10,000	
	N	299-E33-15	Down	4	71,100	10,000	
	N	299-E33-16	Down	5	116,000	10,000	
	N	299-E33-17	Down	5	49,500	10,000	
	N	299-E33-18	Down	8	31,600	10,000	
	N	299-E33-20	Down	3	50,500	10,000	
	N	299-E33-26	Down	4	39,400	10,000	
	N	299-E33-31	Down	13	26,300	10,000	
	N	299-E33-32	Down	11	15,900	10,000	
	N	299-E33-34	Down	2	44,600	10,000	
	N	299-E33-35	Down	3	20,500	10,000	
	N	299-E33-38	Down	4	47,900	10,000	
	N	299-E33-42	Down	12	16,200	10,000	
	N	299-E33-44	Down	12	31,100	10,000	

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ⁽⁶⁾ Level
Technetium-99, pCi/L	N	299-E33-5	Down	2	42,300	10,000
	N	299-E33-7	Down	8	85,100	10,000
	N	299-E33-8	Down	6	17,200	10,000
	N	699-49-57A	Down	1	26,000	10,000
	N	699-50-53A	Down	1	37,000	10,000
	N	299-E33-13	Down	12	3,660	900
	N	299-E33-16	Down	5	2,200	900
	N	299-E33-18	Down	6	1,490	900
	N	299-E33-26	Down	4	3,750	900
	N	299-E33-31	Down	13	1,860	900
	N	299-E33-32	Down	4	1,210	900
	N	299-E33-34	Down	1	3,210	900
	N	299-E33-35	Down	2	1,720	900
	N	299-E33-38	Down	4	5,750	900
	N	299-E33-41	Down	9	1,450	900
	N	299-E33-42	Down	12	1,730	900
	N	299-E33-44	Down	12	4,700	900
	N	299-E33-5	Down	3	5,000	900
	N	299-E33-7	Down	8	6,850	900
	Uranium, µg/L	N	299-E33-8	Down	5	1,560
N		699-49-57A	Down	1	2,470	900
Y		299-E33-8	Down	1	1,300	900
N		299-E33-13	Down	12	63.7	20
N		299-E33-18	Down	9	186	20
N		299-E33-26	Down	4	45.8	20
N		299-E33-34	Down	1	21.1	20
N		299-E33-38	Down	4	119	20
N		299-E33-41	Down	9	25.3	20
N		299-E33-44	Down	12	350	20
N		299-E33-5	Down	3	85.6	20
Y		299-E33-13	Down	3	66.3	20
Y		299-E33-18	Down	2	156	20
Y	299-E33-26	Down	1	28.3	20	
Y	299-E33-38	Down	1	60.3	20	
Y	299-E33-41	Down	2	25.2	20	
Y	299-E33-44	Down	1	214	20	
Y	299-E33-5	Down	1	52.5	20	
Waste Management Area C						
Gross beta, pCi/L	N	299-E27-13	Down	1	50.8	50
	N	299-E27-14	Up	12	180	50
Iodine-129, pCi/L	N	299-E27-12	Down	1	4.27	1
	N	299-E27-13	Down	1	3.93	1
	N	299-E27-14	Up	1	2.91	1
	N	299-E27-15	Down	1	3.47	1
	N	299-E27-7	Up	1	4.54	1
Waste Management Area S-SX						
Carbon tetrachloride, µg/L	N	299-W23-15	Down	1	120	5
Gross alpha, pCi/L	N	299-W23-7	Down	1	128	15
Gross beta, pCi/L	N	299-W22-45	Down	5	649	50
	N	299-W22-46	Down	4	1,500	50
	N	299-W23-7	Down	1	993	50
Nitrogen in Nitrate, µg/L	N	299-W22-46	Down	1	10,100	10,000
	N	299-W23-14	Up	3	20,600	10,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
Technetium-99, pCi/L	N	299-W22-45	Down	5	1,760	900
	N	299-W22-46	Down	4	3,760	900
Tritium, pCi/L	N	299-W22-39	Down	4	24,800	20,000
	N	299-W22-46	Down	4	41,700	20,000
	N	299-W23-14	Up	4	325,000	20,000
Uranium, µg/L	N	299-W23-7	Down	1	74.3	20
Waste Management Area T						
Carbon tetrachloride, µg/L	N	299-W10-24	Down	6	1,600	5
Chromium, µg/L	Y	299-W10-23	Down	4	153	100
	Y	299-W10-24	Down	4	115	100
	Y	299-W10-4	Up	4	192	100
	Y	299-W10-8	Down	3	115	100
	Y	299-W11-23	Down	2	129	100
Fluoride, µg/L	N	299-W10-12	Down	1	4,290	4000
	N	299-W10-24	Down	2	4,960	4000
	N	299-W10-4	Up	4	5,250	4000
Gross alpha, pCi/L	N	299-W11-27	Down	1	90.1	15
Gross beta, pCi/L	N	299-W10-12	Down	2	77.5	50
	N	299-W10-23	Down	4	106	50
	N	299-W10-24	Down	7	972	50
	N	299-W10-4	Up	4	106	50
	N	299-W10-8	Down	4	115	50
	N	299-W11-12	Down	4	71.7	50
	N	299-W11-23	Down	5	2,460	50
	N	299-W11-24	Down	2	70.7	50
	N	299-W11-27	Down	1	2,050	50
	N	299-W11-28	Down	4	122	50
Y	299-W10-24	Down	2	221	50	
Methylenechloride, µg/L	N	299-W10-24	Down	1	8	5
Nitrogen in Nitrate, µg/L	N	299-W10-1	Up	2	36,100	10,000
	N	299-W10-12	Down	2	85,600	10,000
	N	299-W10-22	Down	5	17,400	10,000
	N	299-W10-23	Down	4	132,000	10,000
	N	299-W10-24	Down	10	120,000	10,000
	N	299-W10-4	Up	4	186,000	10,000
	N	299-W10-8	Down	4	89,300	10,000
	N	299-W11-12	Down	4	28,100	10,000
	N	299-W11-23	Down	5	23,400	10,000
	N	299-W11-24	Down	2	63,400	10,000
	N	299-W11-27	Down	1	16,300	10,000
	N	299-W11-28	Down	4	41,300	10,000
Y	299-W11-24	Down	1	57,000	10,000	
Technetium-99, pCi/L	N	299-W10-24	Down	4	3,660	900
	N	299-W11-23	Down	5	8,540	900
	N	299-W11-27	Down	2	7,010	900
Trichloroethylene, µg/L	N	299-W10-24	Down	4	11	5
Tritium, pCi/L	N	299-W10-12	Down	1	21,700	20,000
	N	299-W10-23	Down	4	25,500	20,000
	N	299-W10-24	Down	5	29,300	20,000
	N	299-W10-4	Up	2	23,700	20,000
	N	299-W10-8	Down	3	23,600	20,000
	N	299-W11-12	Down	4	71,500	20,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
	N	299-W11-24	Down	3	28,200	20,000
	N	299-W11-28	Down	4	41,100	20,000
	Y	299-W10-24	Down	3	29,600	20,000
Waste Management Area T, Assessment Wells						
Carbon tetrachloride, µg/L	N	299-W10-19	Down	1	89	5
	N	299-W10-20	Down	1	1,300	5
	N	299-W10-21	Down	1	400	5
	N	299-W6-2	Down	1	130	5
Gross beta, pCi/L	N	299-W6-10	Up	2	83.2	50
	Y	299-W11-31	Down	1	118	50
Nitrogen in Nitrate, µg/L	N	299-W10-19	Down	1	19,500	10,000
	N	299-W10-20	Down	1	25,400	10,000
	N	299-W10-21	Down	1	45,600	10,000
	N	299-W6-10	Up	2	27,000	10,000
	N	299-W6-2	Down	1	10,900	10,000
	N	299-W6-4	Down	2	19,600	10,000
	N	299-W6-9	Down	2	14,600	10,000
	Y	299-W11-31	Down	1	30,000	10,000
Trichloroethylene, µg/L	N	299-W10-21	Down	1	7	5
Tritium, pCi/L	N	299-W6-10	Up	2	49,400	20,000
	N	299-W6-4	Down	1	21,700	20,000
	Y	299-W11-31	Down	1	52,500	20,000
Waste Management Area TX-TY						
Carbon tetrachloride, µg/L	N	299-W14-14	Down	7	920	5
	N	299-W15-4	Down	3	460	5
	N	299-W15-40	Down	1	950	5
Chromium, µg/L	Y	299-W14-13	Down	4	433	100
Gross alpha, pCi/L	N	299-W14-12	Down	1	26.4	15
Gross beta, pCi/L	N	299-W10-17	Down	4	101	50
	N	299-W10-18	Down	1	52.5	50
	N	299-W10-26	Down	1	55.3	50
	N	299-W14-13	Down	4	1,510	50
	N	299-W14-14	Down	4	117	50
	N	299-W14-2	Down	3	468	50
	N	299-W14-5	Down	4	91.5	50
	N	299-W14-6	Down	3	58.5	50
	N	299-W15-12	Down	2	245	50
	N	299-W15-4	Down	4	418	50
	Y	299-W14-14	Down	1	135	50
	Iodine-129, pCi/L	N	299-W14-13	Down	2	31.1
N		299-W14-2	Down	3	47.4	1
Nickel, µg/L	Y	299-W10-18	Down	3	360	100
Nitrogen in Nitrate, µg/L	N	299-W10-17	Down	4	52,400	10,000
	N	299-W10-18	Down	3	18,500	10,000
	N	299-W10-26	Down	5	19,900	10,000
	N	299-W14-12	Down	1	131,000	10,000
	N	299-W14-13	Down	4	78,500	10,000
	N	299-W14-14	Down	5	51,000	10,000
	N	299-W14-2	Down	4	19,300	10,000
	N	299-W14-5	Down	4	48,600	10,000
	N	299-W14-6	Down	4	20,100	10,000

Table A.3. (contd)

Constituent, units	Filter	Well Name	Upgradient/ Downgradient	Number of Exceedances	Maximum Result	MCL or DWS ^(b) Level
	N	299-W15-12	Down	2	37,100	10,000
	N	299-W15-4	Down	4	29,800	10,000
	N	299-W15-40	Down	4	32,300	10,000
Technetium-99, pCi/L	N	299-W14-12	Down	1	6,200	900
	N	299-W14-13	Down	4	5,130	900
	N	299-W14-2	Down	2	1,450	900
	N	299-W15-4	Down	1	982	900
Trichloroethylene, µg/L	N	299-W14-14	Down	4	10	5
	N	299-W15-40	Down	1	15	5
Tritium, pCi/L	N	299-W10-17	Down	3	27,200	20,000
	N	299-W14-12	Down	1	1,170,000	20,000
	N	299-W14-13	Down	4	2,000,000	20,000
	N	299-W14-2	Down	4	1,970,000	20,000
	N	299-W15-12	Down	2	29,900	20,000
	N	299-W15-4	Down	1	21,400	20,000
Waste Management Area U						
Carbon tetrachloride, µg/L	N	299-W18-30	Down	5	610	5
	N	299-W19-41	Down	1	290	5
	N	299-W19-42	Down	2	510	5
Gross beta, pCi/L	N	299-W19-12	Down	4	78.4	50
	N	299-W19-31	Down	1	57.4	50
	N	299-W19-41	Down	4	148	50
	N	299-W19-42	Down	3	124	50
Treated Effluent Disposal Facility						
Gross beta, pCi/L	N	699-40-36	Down	1	130	50

(a) Samples collected between October 1, 1998 and September 30, 1999. Primary maximum contaminant levels and interim drinking water standards. Excludes constituents where the detection limit is greater than the standard.

(b) MCL = Maximum contaminant level.

DWS = Drinking water standard.

ND = Not determined.

Table A.4. Monitoring Wells and Constituents for 100 N Area Units (adapted from WHC-SD-EN-AP-038, Rev. 2)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
1301-N Liquid Waste Disposal Facility					
199-N-2 ⁶⁴	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2, ERA
199-N-3 ⁶⁴	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2, ERA, Surveillance
199-N-34⁸³	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
199-N-57⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
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	Surveillance
199-N-71⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
199-N-72 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-N-73 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	--
199-N-77 ^{92(b)}	Bottom of unconfined	Semiannual	Semiannual	RCRA	--
1325-N Liquid Waste Disposal Facility					
199-N-28 ^{83(b)}	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
199-N-32 ⁸³	Top of unconfined	Semiannual	Semiannual	PRE	100-NR-2, Surveillance
199-N-41 ⁸⁴	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
199-N-74⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	100-NR-2, Surveillance
199-N-81 ⁹⁵	Top of unconfined	Semiannual	Semiannual	RCRA	100-NR-2, Surveillance
Contamination Indicator Parameters			Site-Specific Parameters		
pH (field)			Alkalinity ^(c)		ICP metals (filtered) ^(c)
Specific conductance (field)			Anions ^(c)		Turbidity
Total organic carbon			Gross alpha ^(d)		
Total organic halides					

(a) Extraction well; screened over entire thickness of aquifer.

(b) Used for supplemental information; no statistical evaluations.

(c) Annually for 1301-N and 1325-N liquid waste disposal facilities.

(d) Gross alpha required for wells 199-N-59 and 199-N-77 only.

Bold italic = Upgradient wells.

Superscript = Year of installation.

ERA = Expedited response action.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.5. Critical Mean Values for 1301-N Liquid Waste Disposal Facility^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	10	9	4.7815	537.69	237.05	1,726.5	1,726.5
Field pH	10	9	5.2912	7.969	0.356	[5.99, 9.94]	[5.99, 9.94]
Total organic carbon, $\mu\text{g}/\text{L}$	10	9	4.7815	623.625	350.836	2,383.0	2,383.0
Total organic halides, ^(b) $\mu\text{g}/\text{L}$	9	8	5.0420	6.162	3.377	24.1	24.1

(a) Based on semiannual sampling events from September 1997 to September 1999 for upgradient wells 199-N-57 and 199-N-34.

(b) Excluding suspect data collected on September 30, 1997 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 A.6. Critical Mean Values for 1324-N/NA Liquid Waste Disposal Facilities^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	5	4	8.1216	305.25	18.694	471.6	471.6
Field pH	5	4	9.7291	8.162	0.095	[7.15, 9.17]	[7.15, 9.17]
Total organic carbon, ^(b) $\mu\text{g}/\text{L}$	5	4	8.1216	237.25	180.157	1,840.1	1,840.1
Total organic halides, $\mu\text{g}/\text{L}$	5	4	8.1216	7.334	2.286	27.7	27.7

(a) Based on semiannual sampling events from September 1997 to August 1999 for upgradient well 199-N-71.

(b) Critical mean calculated from values reported below vendor's specified method detection limit.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table A.7. Critical Mean Values for 1325-N Liquid Waste Disposal Facility^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	5	4	8.1216	349.75	13.621	470.9	470.9
Field pH	5	4	9.7291	8.163	0.149	[6.57, 9.76]	[7.46, 8.79] ^(b)
Total organic carbon, $\mu\text{g}/\text{L}$	5	4	8.1216	307.5	156.774	1,702.3	1,702.3
Total organic halides, $\mu\text{g}/\text{L}$	5	4	8.1216	6.185	2.375	27.3	27.3

(a) Based on semiannual sampling events from September 1997 to September 1999 for upgradient well 199-N-74.

(b) Values calculated using data collected from August 1995 to September 1999 because the critical range calculated using limited 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 A.8. Monitoring Wells and Constituents for 120-D-1 Ponds (adapted from WHC-SD-EN-AP-048)

Well	Hydrogeologic Unit Monitored	Sampling Frequency ^(a)	Water-Level Measurement	Well Standard	Other Networks
199-D5-13⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	100-HR-3, Surveillance
199-D8-4 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	100-HR-3
199-D8-5 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	100-HR-3
199-D8-6 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
Contamination Indicator Parameters			Site-Specific 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)	

(a) Through March 1999. Site clean closed. No further RCRA monitoring required.

Bold italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

Table A.9. Monitoring Wells and Constituents for 183-H Solar Evaporation Basins
(adapted from PNNL-11573)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
199-H4-3 ⁷⁴	Top of unconfined	Annual	Semiannual	PRE	IRA, Surveillance
199-H4-7 ^{86(a)}	Top of unconfined	Annual	Semiannual	RCRA	IRA, Surveillance
199-H4-12A ^{86(a)}	Top of unconfined	Annual	Semiannual	RCRA	IRA
199-H4-12C ⁸⁶	Mid-depth unconfined	Annual	Semiannual	RCRA	IRA
Dangerous Waste Constituents			Site-Specific Parameters		
Chromium (filtered)			Alkalinity	pH	
Nitrate			Anions	Specific conductance	
Fluoride			ICP metals (filtered)	Turbidity	
Technetium-99					
Uranium					

(a) Extraction well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

IRA = Interim response action.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.10. Monitoring Wells and Constituents for Waste Management Area S-SX (adapted from WHC-SD-EN-AP-191)

<u>Well</u>	<u>Hydrogeologic Unit Monitored</u>	<u>Sampling Frequency</u>	<u>Water-Level Measurement</u>	<u>Well Standard</u>	<u>Other Networks</u>
299-W22-39 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W22-44 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W22-45 ⁹²	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W22-46 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W22-48 ⁹⁹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W22-49 ⁹⁹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W22-50 ⁹⁹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W23-7 ⁶⁹	Top of unconfined	Quarterly	Quarterly	PRE	Surveillance
299-W23-9 ⁷²	Top of unconfined	Quarterly	Quarterly	PRE	--
299-W23-13 ⁹⁰	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W23-14 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W23-15 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
<u>Contamination Indicator Parameters</u>			<u>Site-Specific Parameters</u>		
pH			Anions	Strontium-90	
Specific conductance			Cesium-137	Technetium-99	
Total organic carbon			Gross alpha	Tritium	
Total organic halides			Gross beta	Turbidity	
			Hexavalent chromium	Uranium	
			ICP metals (filtered)	Volatile organic compounds	

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.11. 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 Standard	Other Networks
299-W6-2 ^{87(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	LLWMA 3, Surveillance
299-W6-4 ^{91(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W6-9 ^{92(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W6-10 ⁹²	Unconfined	Semiannual	Semiannual	RCRA	--
299-W10-1 ⁴⁷	Unconfined	Semiannual	Semiannual	PRE	Surveillance
299-W10-2 ⁵¹	Unconfined	Semiannual	Semiannual	PRE	--
299-W10-4 ⁵²	Unconfined	Quarterly	Quarterly	PRE	Surveillance
299-W10-8 ⁷³	Top of unconfined	Quarterly	Quarterly	PRE	--
299-W10-12 ⁷⁴	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
299-W10-19 ^{92(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	LLWMA 3
299-W10-20 ^{93(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	LLWMA 3
299-W10-21 ^{93(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	LLWMA 3
299-W10-22 ⁹⁴	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W10-23 ⁹⁸	Unconfined	Quarterly	Quarterly	RCRA	--
299-W10-24 ⁹⁸	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W11-7 ⁵¹	Unconfined	Semiannual	Semiannual	PRE	--
299-W11-12 ⁵³	Unconfined	Quarterly	Quarterly	PRE	--
299-W11-23 ⁷³	Top of unconfined	Quarterly	Quarterly	PRE	--
299-W11-24 ⁷³	Top of unconfined	Quarterly	Quarterly	PRE	--
299-W11-27 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W11-28 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W11-30 ⁹²	Unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
299-W11-31 ^{92(a)}	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W15-12 ⁷³	Unconfined	Semiannual	Semiannual	PRE	--

Contamination Indicator Parameters

pH
 Specific conductance
 Total organic carbon
 Total organic halides

Site-Specific Parameters^(b)

Anions
 Gamma scan (cesium-137, cobalt-60)
 Gross alpha
 Gross beta
 ICP metals (filtered)
 Iodine-129
 Strontium-90
 Technetium-99
 Total dissolved solids
 Tritium
 Turbidity
 Volatile organic compounds

(a) Wells used for expanded assessment monitoring.

(b) Constituent list varies by well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

LLWMA = Low-level waste management area.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.12. Monitoring Wells and Constituents for Waste Management Area TX-TY (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 Standard	Other Networks
299-W10-17 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W10-18 ⁹⁰	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W10-26 ⁹⁹	Unconfined	Quarterly	Quarterly	RCRA	--
299-W14-2 ⁵⁵	Unconfined	Quarterly	Quarterly	PRE	--
299-W14-5 ⁷⁴	Unconfined	Quarterly	Quarterly	PRE	--
299-W14-6 ⁷⁴	Unconfined	Quarterly	Quarterly	PRE	--
299-W14-12 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W14-13 ⁹⁹	Unconfined	Quarterly	Quarterly	RCRA	--
299-W14-14 ⁹⁹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W15-4 ⁵⁶	Unconfined	Quarterly	Quarterly	PRE	200-ZP-1
299-W15-22⁹¹	Top of unconfined	Dry	Dry	RCRA	--
299-W15-40 ⁹⁹	Unconfined	Quarterly	Quarterly	RCRA	--
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity		Iodine-129
Specific conductance			Anions		Strontium-90 ^(a)
Total organic carbon			Gamma scan (cesium-137, cobalt-60)		Technetium-99
			Gross alpha		Total dissolved solids
			Gross beta		Tritium
			ICP metals (filtered)		Turbidity
					Volatile organic compounds ^(a)

(a) Limited wells.

Bold italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.13. Monitoring Wells and Constituents for Waste Management Area U (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W18-25 ⁹⁰	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W18-30 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	200-ZP-1
299-W18-31 ⁹¹	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W19-12 ^{83(a)}	Top of unconfined	Quarterly	Quarterly	PRE	--
299-W19-31 ⁹⁰	Top of unconfined	Dry ^(b)	Dry ^(b)	RCRA	Surveillance
299-W19-41 ⁹⁹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-W19-42 ⁹⁹	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance

Contamination Indicator Parameters		Site-Specific Parameters	
pH		Alkalinity	Iodine-129 ^(c)
Specific conductance		Anions	Phenols ^(d)
Total organic carbon		Gamma scan ^(c)	Technetium-99
Total organic halides		Gross alpha	Total dissolved solids
		Gross beta	Tritium
		ICP metals (filtered)	Turbidity

- (a) Used for supplemental information; no statistical evaluations.
- (b) Last sampled December 1998.
- (c) Wells 299-W19-41 and 299-W19-42 only.
- (d) Annually.
- Bold italic = Upgradient wells.
- Superscript = Year of installation.
- ICP = Inductively coupled plasma emission spectroscopy.
- PRE = Well not constructed to RCRA standards.
- RCRA = Well constructed to RCRA standards.

Table A.14. Critical Mean Values for Waste Management U^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, µS/cm	10	9	4.7815	218.175	10.870	272.7	272.7
Field pH	10	9	5.2912	8.088	0.112	[7.46, 8.71]	[7.46, 8.71]
Total organic carbon, ^(b) µg/L	10	9	4.7815	465.250	125.069	1,092.5	1,153.7
Total organic halides, µg/L	10	9	4.7815	32.938	25.438	160.5	160.5

- (a) Data collected from August 1998 to August 1999 for upgradient wells 299-W18-25 and 299-W18-31.
- (b) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.
- df = Degrees of freedom (n-1).
- n = Number of background replicate averages.
- t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table A.15. Monitoring Wells and Constituents for 216-S-10 Pond and Ditch (adapted from WHC-SD-EN-AP-018)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W26-7⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-W26-8⁹⁰	Top of unconfined	Dry ^(a)	NA	RCRA	Surveillance
299-W26-9⁹⁰	Top of unconfined	Dry ^(b)	NA	RCRA	--
299-W26-10⁹¹	Top of unconfined	Dry ^(c)	NA	RCRA	--
299-W26-12⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-W27-2^{92(d)}	Base of unconfined	Semiannual	Semiannual	RCRA	Surveillance

Contamination Indicator Parameters		Site-Specific Parameters	
pH		Alkalinity	ICP metals (filtered)
Specific conductance		Anions	Phenols
Total organic carbon		Gross alpha	Turbidity
Total organic halides		Gross beta	

- (a) Well dry; last sampled March 1998.
 (b) Well dry; last sampled June 1999.
 (c) Well dry; last sampled March 1999.
 (d) Used for supplemental information; no statistical evaluation.
 Bold italic = Upgradient wells.
 Superscript = Year of installation.
 ICP = Inductively coupled plasma emission spectroscopy.
 NA = Not applicable.
 RCRA = Well constructed to RCRA standards.

Table A.16. Critical Mean Values for 216-S-10 Pond and Ditch^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	5	4	7.5288	276.6	5.504	322.0	322.0
Field pH	5	4	9.0292	8.101	0.089	[7.22, 8.98]	[7.22, 8.98]
Total organic carbon, ^(b) $\mu\text{g}/\text{L}$	5	4	7.5288	274.45	111.93	1,197.6	1,197.6
Total organic halides, $\mu\text{g}/\text{L}$	5	4	7.5288	5.584	2.175	23.5	23.5

- (a) Data collected from December 1996 to December 1997 for upgradient well 299-W26-7, except for total organic carbon that was collected from December 1995 to December 1997.
 (b) Critical mean calculated from values reported below vendor's specified method detection limit.
 df = Degrees of freedom (n-1).
 n = Number of background replicate averages.
 t_c = Bonferroni critical t-value for appropriate df and 12 comparisons.

Table A.17. Monitoring Wells and Constituents for 216-U-12 Crib (adapted from WHC-SD-EN-AP-019 and WHC-SD-EN-AP-108)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-W22-40 ⁹⁰	Top of unconfined	Removed	NA	RCRA	Surveillance
299-W22-41 ⁹⁰	Top of unconfined	Dry ^(a)	NA	RCRA	--
299-W22-42 ⁹⁰	Top of unconfined	Dry ^(a)	NA	RCRA	--
299-W22-43⁹⁰	Top of unconfined	Quarterly	Quarterly	RCRA	--
299-W22-79 ⁹⁸	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-36-70A ⁹⁴	Top of unconfined	Quarterly	Quarterly	RCRA	ERDF

Contamination Indicator Parameters		Site-Specific Parameters	
pH		Alkalinity	Iodine-129 ^(b)
Specific conductance		Anions	Technetium-99
Total organic carbon		Gross alpha	Total dissolved solids
Total organic halides		Gross beta	Tritium
		ICP metals (filtered) ^(b)	Turbidity

(a) Well is dry; last sampled March 1999.

(b) Analyzed annually.

Bold italic = Upgradient well.

Superscript = Year of installation.

ERDF = Environmental Restoration Disposal Facility.

ICP = Inductively coupled plasma emission spectroscopy.

NA = Not applicable.

RCRA = Well constructed to RCRA standards.

Table A.18. 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	WMA T, Surveillance
299-W7-1 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS
299-W7-2 ⁸⁷	Top of unconfined	Dry	Dry	RCRA	--
299-W7-3 ⁸⁷	Deep unconfined	Semiannual	Semiannual	RCRA	SALDS
299-W7-4 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-5 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W7-6 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W7-7 ⁸⁹	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS
299-W7-8 ⁸⁹	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W7-9 ⁹⁰	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS
299-W7-10 ⁹⁰	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-W7-11 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W7-12 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W8-1 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	SALDS, Surveillance
299-W9-1⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-W10-13⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-W10-14⁸⁷	Deep unconfined	Semiannual	Semiannual	RCRA	--
299-W10-19⁹²	Top of unconfined	Semiannual	Semiannual	RCRA	WMA T
299-W10-20⁹³	Top of unconfined	Semiannual	Semiannual	RCRA	WMA T, Surveillance
299-W10-21⁹³	Top of unconfined	Semiannual	Semiannual	RCRA	WMA T, Surveillance

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols
Tritium
Turbidity
Volatile organic compounds

Bold italic = Upgradient wells.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.
SALDS = State-Approved Land Disposal Site.
WMA = Waste management area.

Table A.19. Critical Mean Values for Low-Level Waste Management Area 3 (area not affected by upgradient contamination)^(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	9	8	5.3168	445.472	24.948	585.3	585.3
Field pH	9	8	5.9119	8.287	0.226	[6.88, 9.69]	[6.88, 9.69]
Total organic carbon, ^(b,c) $\mu\text{g}/\text{L}$	8	7	5.7282	169.062	49.945	472.5	1,153.7
Total organic halides, $\mu\text{g}/\text{L}$	8	7	5.7282	9.10	7.137	52.5	52.5

(a) Data collected from December 1994 to September 1995 for upgradient wells 299-W9-1 and 299-W10-13. Critical means calculated for area not impacted by upgradient source of contamination.

(b) Critical means calculated from values reported below vendor's specified method detection limit.

(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table A.20. Critical Mean Values for Low-Level Waste Management Area 3 (area affected by upgradient contamination)^(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	11 ^(b)	10	5.0494	561.296	54.4	848.2	848.2
Field pH	15	14	4.8656	8.059	0.316	[6.47, 9.65]	[6.47, 9.65]
Total organic carbon, ^(c,d) $\mu\text{g}/\text{L}$	15	14	4.4995	336.9167	126.77	926.0	1,153.7
Total organic halides, $\mu\text{g}/\text{L}$	13 ^(b)	12	4.7168	784.492	374.522	2,617.7	2,617.7

(a) Data collected from March 1997 to March 1998 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) Excluded outliers.

(c) Critical means calculated from values reported below vendor's specified method detection limit.

(d) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 40 comparisons.

Table A.21. 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
<i>299-W15-15</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
<i>299-W15-16</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
<i>299-W15-17</i> ⁸⁷	Deep unconfined	Semiannual	Semiannual	RCRA	--
<i>299-W15-18</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
<i>299-W15-19</i> ⁸⁹	Top of unconfined	Dry	Dry	RCRA	200-ZP-1, Surveillance
<i>299-W15-20</i> ⁸⁹	Top of unconfined	Dry	Dry	RCRA	--
<i>299-W15-23</i> ⁹⁰	Top of unconfined	Dry	Dry	RCRA	--
<i>299-W15-24</i> ⁸⁹	Top of unconfined	Dry	Dry	RCRA	--
<i>299-W18-21</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
<i>299-W18-22</i> ⁸⁷	Deep unconfined	Semiannual	Semiannual	RCRA	Surveillance
<i>299-W18-23</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
<i>299-W18-24</i> ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
<i>299-W18-26</i> ⁸⁹	Top of unconfined	Dry	Dry	--	--
<i>299-W18-27</i> ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	200-ZP-1
<i>299-W18-28</i> ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	--
<i>299-W18-29</i> ⁹¹	Perched zone	Dry	Dry	RCRA	--
<i>299-W18-32</i> ⁹²	Top of unconfined	Dry	Dry	RCRA	200-ZP-1
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity		Mercury (filtered)
Specific conductance			Anions		Phenols
Total organic carbon			Gross alpha		Tritium
Total organic halides			Gross beta		Turbidity
			ICP metals (filtered)		Volatile organic compounds
			Lead (filtered)		

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

Table A.22. Critical Mean Values for Low-Level Waste Management Area 4^(a)

<u>Constituent, unit</u>	<u>n</u>	<u>df</u>	<u>t_c</u>	<u>Average Background</u>	<u>Standard Deviation</u>	<u>Critical Mean</u>	<u>Upgradient/Downgradient Comparison Value</u>
Specific conductance, $\mu\text{S}/\text{cm}$	16	15	4.2395	377.156	68.587	676.9	676.9
Field pH	16	15	4.5857	7.958	0.130	[7.34, 8.57]	[7.34, 8.57]
Total organic carbon, ^(b) $\mu\text{g}/\text{L}$	16	15	4.2395	543.438	236.054	1,575.0	1,575.0
Total organic halides, $\mu\text{g}/\text{L}$	16	15	4.2395	262.510	199.616	1,134.8	1,134.8

(a) Based on semiannual sampling events from July 1997 to January 1998 for upgradient wells 299-W15-15, 299-W18-21, 299-W18-23, and 299-W18-26.

(b) Critical means calculated using data below vendor's specified method detection limit.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table A.23. Monitoring Wells, Constituents, and Enforcement Limits for State-Approved Land Disposal Site (adapted from WHC-SD-C018H-PLN-004, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Well Standard	Other Networks
299-W6-6	Top of unconfined	Annual	RCRA	Surveillance
299-W6-7	Top of unconfined	Annual	RCRA	Surveillance
299-W6-8	Top of unconfined	Semiannual	RCRA	--
299-W6-11	Top of unconfined	Annual	RCRA	--
299-W6-12	Top of unconfined	Annual	RCRA	Surveillance
299-W7-1	Top of unconfined	Semiannual	RCRA	LLWMA 3
299-W7-3	Top of unconfined	Annual	RCRA	LLWMA 3
299-W7-5	Top of unconfined	Annual	RCRA	LLWMA 3, Surveillance
299-W7-6	Top of unconfined	Semiannual	RCRA	LLWMA 3, Surveillance
299-W7-7	Top of unconfined	Annual	RCRA	LLWMA 3
299-W7-8	Top of unconfined	Annual	RCRA	LLWMA 3, Surveillance
299-W7-9	Top of unconfined	Annual	RCRA	LLWMA 3
299-W7-11	Top of unconfined	Semiannual	RCRA	LLWMA 3, Surveillance
299-W7-12	Top of unconfined	Annual	RCRA	LLWMA 3, Surveillance
299-W8-1^(a)	Top of unconfined	Quarterly	RCRA	LLWMA 3, Surveillance
699-48-71	Unconfined	Annual	PRE	Surveillance
699-48-77A ^(a)	Confined Ringold unit E; upper	Quarterly	RCRA	--
699-48-77C ^(a)	Confined Ringold unit E; mid to lower	Quarterly	RCRA	Surveillance
699-48-77D ^(a)	Confined Ringold unit E; upper	Quarterly	RCRA	Surveillance
699-49-79	Top of unconfined	Annual	PRE	--
699-51-75	Confined Ringold(?)	Annual	PRE	--
Constituent	Enforcement Limit (µg/L)	Constituent	Enforcement Limit (µg/L)	
Acetone	160	Lead, total	50	
Ammonia	1,100	Mercury, total	2	
Benzene	5	pH	6.5 - 8.5 pH units	
Cadmium, total	10	Strontium-90	Monitor only	
Chloroform	6.2	Sulfate	250,000	
Copper, total	70	Tetrahydrofuran	100	
Gross alpha	Monitor only	Total dissolved solids	500,000	
Gross beta	Monitor only	Tritium	Monitor only	

(a) Monitored for full constituent list. Other wells analyzed for tritium only.

Bold italic = Upgradient well.

LLWMA = Low-level waste management area.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.24. Monitoring Wells and Constituents for Environmental Restoration Disposal Facility
(adapted from BHI-00873)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
699-35-66A ⁵⁷	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
699-36-67 ⁹⁶	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-36-70⁹⁴	Top of unconfined	Semiannual	Semiannual	RCRA	216-U-12
699-37-68 ⁹⁶	Top of unconfined	Semiannual	Semiannual	RCRA	--
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity	ICP metals (filtered)	
Specific conductance			Anions	Iodine-129	
Turbidity			Arsenic (filtered)	Radium	
			Carbon-14	Technetium-99	
			Carbon tetrachloride	Total dissolved solids	
			Gross alpha	Total organic halides	
			Gross beta	Uranium	

Bold italic = Upgradient well.
 Superscript = Year of installation.
 ICP = Inductively coupled plasma emission spectroscopy.
 PRE = Well not constructed to RCRA standards.
 RCRA = Well constructed to RCRA standards.

Table A.25. Monitoring Wells and Constituents for Waste Management Area A-AX
(adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E24-19 ⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E24-20 ⁹¹	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E25-2^{55(a)}	Top of unconfined	--	Quarterly	PRE	--
299-E25-40⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-41⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E25-46 ⁹²	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Anions	Low-level gamma	
Specific conductance			Gross alpha	Phenols	
Total organic carbon			Gross beta	Technetium-99	
Total organic halides			ICP metals (filtered)	Tritium	
			Iodine-129	Turbidity	

(a) Used for supplemental information; no statistical evaluations.
 Bold italic = Upgradient wells.
 Superscript = Year of installation.
 ICP = Inductively coupled plasma emission spectroscopy.
 PRE = Well not constructed to RCRA standards.
 RCRA = Well constructed to RCRA standards.

Table A.26. Critical Mean Values for Waste Management Area A-AX^(a)

<u>Constituent, unit</u>	<u>n</u>	<u>df</u>	<u>t_c</u>	<u>Average Background</u>	<u>Standard Deviation</u>	<u>Critical Mean</u>	<u>Upgradient/Downgradient Comparison Value</u>
Specific conductance, $\mu\text{S}/\text{cm}$	6 ^(b)	5	6.8688	313.50	29.838	534.9	534.9
Field pH	8	7	6.0818	8.066	0.182	[6.89, 9.24]	[6.89, 9.24]
Total organic carbon, $\mu\text{g}/\text{L}$	8	7	5.4079	724.375	168.522	1,691.0	1,691.0
Total organic halides, ^(c,d) $\mu\text{g}/\text{L}$	8	7	5.4079	2.552	0.791	7.1	17.9

(a) Based on semiannual sampling events from February 1998 to June 1999 for upgradient wells 299-E25-40 and 299-E25-41.

(b) Outlier excluded.

(c) Critical mean calculated from values reported below vendor's specified method detection limit.

(d) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 20 comparisons.

Table A.27. Monitoring Wells and Constituents for Waste Management Area B-BX-BY^(a)
(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 Standard	Other Networks
299-E28-8 ⁵⁷	Unconfined	Quarterly	Quarterly	PRE	--
299-E33-5 ⁵⁵	Unconfined	Quarterly ^(b)	Quarterly	PRE	Surveillance
299-E33-7 ⁵⁵	Unconfined	Quarterly ^(c)	Quarterly	PRE	Surveillance
299-E33-8 ⁵³	Unconfined	Quarterly ^(b)	Quarterly	PRE	--
299-E33-13 ⁵³	Unconfined	Quarterly ^(c)	Quarterly	PRE	Surveillance
299-E33-15 ⁵³	Unconfined	Quarterly	Quarterly	PRE	--
299-E33-16 ⁵³	Unconfined	Quarterly	Quarterly	PRE	--
299-E33-17 ⁵³	Unconfined	Quarterly	Quarterly	PRE	--
299-E33-18 ⁵⁰	Unconfined	--	Quarterly	PRE	Surveillance
299-E33-21 ⁵⁷	Unconfined	Quarterly	Quarterly	PRE	--
299-E33-27 ⁷⁰	Unconfined	Quarterly ^(b)	Quarterly	PRE	--
299-E33-28 ⁸⁷	Unconfined	Quarterly ^(b)	Quarterly	RCRA	LLWMA 1
299-E33-29 ⁸⁷	Unconfined	Quarterly ^(b)	Quarterly	RCRA	--
299-E33-31 ⁸⁹	Unconfined	Quarterly ^(b)	Quarterly	RCRA	--
299-E33-32 ⁸⁹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-E33-33⁸⁹	Unconfined	Quarterly	Quarterly	RCRA	216-B-63 trench, Surveillance
299-E33-35 ⁹⁰	Unconfined	Quarterly ^(b)	Quarterly	RCRA	LLWMA 1, Surveillance
299-E33-36⁹⁰	Unconfined	Quarterly	Quarterly	RCRA	216-B-63 trench, Surveillance
299-E33-38 ⁹¹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-E33-39 ⁹¹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-E33-41 ⁹¹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-E33-42 ⁹¹	Unconfined	Quarterly	Quarterly	RCRA	Surveillance
299-E33-43 ⁹¹	Unconfined	Quarterly	Quarterly	RCRA	--
299-E33-44 ⁹⁸	Unconfined	Quarterly ^(c)	Quarterly	RCRA	--
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Anions (nitrate, nitrite)		Low-level gamma (cobalt-60)
Specific conductance			Cyanide		Strontium-90
Total organic carbon			Gross alpha		Technetium-99
Total organic halides			Gross beta		Tritium
			ICP metals (filtered)		Turbidity
			Iodine-129		Uranium

(a) Well list varies, depending on assessment requirements and changes in contaminant conditions.

(b) Not sampled entire year.

(c) Sampled monthly for selected constituents only. Subject to monthly revision.

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

LLWMA = Low-level waste management area.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.28. Monitoring Wells and Constituents for Waste Management Area C^(a) (adapted from WHC-SD-EN-AP-012, Rev. 1)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E27-7^{82(b)}	Top of unconfined	Semiannual	Quarterly	PRE	Surveillance
299-E27-12 ⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-13 ⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-14⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E27-15 ⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Anions		Phenols
Cyanide			Gross alpha		Technetium-99
Specific conductance			Gross beta		Total uranium
Strontium-90			ICP metals (filtered)		Tritium
Total organic carbon			Iodine-129		Turbidity
Total organic halides			Low-level gamma		

(a) Sampling increased January 1999 to monthly with limited constituent list to provide adequate temporal coverage for surface sluicing activities at Tank C-106.

(b) Used for supplemental information; no statistical evaluation.

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.29. Critical Mean Values for Waste Management Area C^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	4 ^(b)	3	11.9838	349.812	15.202	553.5	553.5
Field pH	6	5	7.6037	8.345	0.072	[7.76, 8.93]	[7.76, 8.93]
Total organic carbon, ^(c) $\mu\text{g}/\text{L}$	5 ^(b)	4	8.1216	516.25	128.871	1,662.9	1,662.9
Total organic halides, ^(c,d) $\mu\text{g}/\text{L}$	6	5	6.5414	3.021	1.076	10.6	17.9

(a) Based on semiannual sampling events from February 1997 to June 1999 for upgradient well 299-E27-14.

(b) Outliers removed.

(c) Critical mean calculated from values reported below vendor's specified method detection limit.

(d) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 16 comparisons.

Table A.30. Monitoring Wells and Constituents for PUREX Cribs 216-A-10, 216-A-36B, and 216-A-37-1 (adapted from PNNL-11523)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
Upgradient Wells					
299-E24-18 ⁸⁸	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
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	Surveillance
Near-Field Wells - 216-A-36B Crib					
299-E17-9 ⁶⁸	Top of unconfined	Semiannual	Semiannual	PRE	Surveillance
299-E17-14 ⁸⁸	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
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	PRE	Surveillance
699-37-47A ⁹⁶	Top of unconfined	Semiannual	Semiannual	RCRA	--
Far-Field Wells					
57 wells	Unconfined	Triannual ^(a)	Triannual ^(a)	RCRA, PRE	Sitewide
<u>Contamination Indicator Parameters</u>			<u>Site-Specific Parameters</u>		
pH ^(b)		Alkalinity		ICP metals (filtered)	
Specific conductance ^(b)		Ammonium ion		Iodine-129 ^(b)	
Temperature ^(b)		Anions ^(b)		Phenols	
Turbidity ^(b)		Arsenic (filtered)		Strontium-90	
		Gross alpha		Tritium ^(b)	
		Gross beta			

(a) Some far-field wells sampled annually.

(b) Far-field wells analyzed for these constituents only.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

PUREX = Plutonium-uranium extraction (plant).

RCRA = Well constructed to RCRA standards.

Table A.31. Monitoring Wells and Constituents for 216-B-3 Pond (adapted from WHC-SD-EN-AP-013)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
299-E26-11 ⁸⁹	Bottom of uppermost	Semiannual	Semiannual	RCRA	LERF, Surveillance
299-E32-4⁸⁷	Top of uppermost	Semiannual	Semiannual	RCRA	LLWMA 1
699-40-39	Lower uppermost	Semiannual	Semiannual	RCRA	--
699-41-42 ⁹²	Top of uppermost	Semiannual	Semiannual	RCRA	--
699-42-39B ⁹¹	Lower uppermost	Semiannual	Semiannual	RCRA	--
699-42-42B ⁸⁸	Top of uppermost	Semiannual	Semiannual	RCRA	--
699-43-41G ⁹¹	Top of uppermost	Semiannual	Semiannual	RCRA	--
699-43-45 ⁸⁹	Top of uppermost	Semiannual	Semiannual	RCRA	216-A-29 ditch
699-44-39B ⁹²	Top of uppermost	Semiannual	Semiannual	RCRA	Surveillance
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity	ICP metals (filtered) ^(a)	
Specific conductance			Anions ^(a)	Phenols ^(a)	
Total organic carbon			Gross alpha	Turbidity	
Total organic halides			Gross beta		

(a) Analyzed annually.

Bold italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

LERF = Liquid Effluent-Retention Facility.

LLWMA = Low-level waste management area.

RCRA = Well constructed to RCRA standards.

Table A.32. Critical Mean Values for 216-B-3 Pond^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, µS/cm	15	14	4.4445	417.667	7.215	450.8	450.8
Field pH	15	14	4.8903	7.704	0.262	[6.40, 9.01]	[6.40, 9.01]
Total organic carbon, ^(b,c) µg/L	15	14	4.4445	174.150	123.011	738.8	1,153.7
Total organic halides, ^(b,c) µg/L	14	13	4.5400	3.980	2.242	14.5	17.9

(a) Based on semiannual sampling events from January 1994 to January 1997 for upgradient well 299-E32-4.

(b) Critical means calculated from values reported below vendor's specified method detection limit.

(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 36 comparisons.

Table A.33. Monitoring Wells and Constituents for 216-A-29 Ditch (adapted from WHC-SD-EN-AP-045, Rev. 0-A and WHC-SD-EN-EV-032)

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	Surveillance
299-E25-34 ⁸⁸	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E25-35 ⁸⁸	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
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	--
699-43-43⁸⁸	Top of unconfined	Semiannual	Quarterly	RCRA	216-B-3 pond
699-43-45⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	216-B-3 pond

Contamination Indicator Parameters	Site-Specific Parameters
pH	Alkalinity
Specific conductance	Anions
Total organic carbon	ICP metals (filtered) ^(a)
Total organic halides	Turbidity

(a) Analyzed annually.

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

Table A.34. Critical Mean Values for 216-A-29 Ditch^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	8	7	5.9757	207.50	22.003	347.0	347.0
Field pH	8	7	6.6987	8.364	0.238	[6.68, 10.05]	[7.26, 9.39] ^(b)
Total organic carbon, $\mu\text{g}/\text{L}$	8	7	5.9757	467.03	150.309	1,419.7	1,419.7
Total organic halides, ^(c) $\mu\text{g}/\text{L}$	8	7	5.9757	4.951	1.985	17.5	17.9

(a) Data collected from January 1998 to October 1998 for upgradient wells 699-43-43 and 699-43-45.

(b) Values calculated using data collected from October 1997 to April 1999 (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 discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 36 comparisons.

Table A.35. 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-E27-8⁸⁷	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA 2
299-E27-9⁸⁷	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA 2
299-E27-11⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA 2
299-E27-16 ⁹⁰	Top of unconfined	Semiannual	Quarterly	RCRA	--
299-E27-17⁹¹	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA 2, Surveillance
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	WMA B-BX-BY, Surveillance
299-E33-36 ⁹⁰	Top of unconfined	Semiannual	Quarterly	RCRA	WMA B-BX-BY
299-E33-37 ⁹⁰	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E34-8 ⁹⁰	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E34-10⁹¹	Top of unconfined	Semiannual	Quarterly	RCRA	LLWMA 2, Surveillance

Contamination Indicator Parameters

pH
 Specific conductance
 Total organic carbon
 Total organic halides

Site-Specific Parameters

Alkalinity^(a)
 Anions^(a)
 Gross alpha
 Gross beta
 ICP metals (filtered)^(a)
 Phenols^(a)
 Turbidity

- (a) Analyzed annually.
 Bold italic = Upgradient wells.
 Superscript = Year of installation.
 ICP = Inductively coupled plasma emission spectroscopy.
 LLWMA = Low-level waste management area.
 RCRA = Well constructed to RCRA standards.
 WMA = Waste management area.

Table A.36. Critical Mean Values for 216-B-63 Trench^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, µS/cm	18 ^(b)	17	4.371	360.889	23.830	467.9	467.9
Field pH	20	19	4.572	8.029	0.179	[7.19, 8.87]	[7.19, 8.87]
Total organic carbon, µg/L	20	19	4.267	474.375	200.588	1,351.5	1,351.5
Total organic halides, ^(c) µg/L	20	19	4.267	3.520	1.549	10.3	17.9

(a) Based on semiannual sampling events from November 1997 to April 1999 for upgradient wells 299-E27-8, 299-E27-9, 299-E27-11, 299-E27-17, and 299-E34-10.

(b) Excluded outliers.

(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table A.37. 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 Networks
299-E26-9 ⁸⁷	Top of unconfined	Semiannual ^(a)	Quarterly ^(a)	RCRA	Surveillance
299-E26-10 ⁹⁰	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
299-E26-11⁸⁹	Top of unconfined	Semiannual	Quarterly	RCRA	216-B-3 pond, Surveillance
299-E35-2 ⁸⁷	Top of unconfined	Semiannual	Quarterly	RCRA	Surveillance
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity ^(b)	ICP metals (filtered) ^(b)	
Specific conductance			Ammonium ^(b)	Phenols ^(a)	
Total organic carbon			Anions ^(b)	Temperature	
Total organic halides			Gross alpha ^(b)	Turbidity	
			Gross beta ^(b)	Volatile organic compounds	

(a) Well dry in June 1999.

(b) Analyzed annually.

Bold italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

Table A.38. Critical Mean Values for Liquid Effluent Retention Facility^(a)

<u>Constituent, unit</u>	<u>n</u>	<u>df</u>	<u>t_c</u>	<u>Average Background</u>	<u>Standard Deviation</u>	<u>Critical Mean</u>	<u>Upgradient/ Downgradient Comparison Value</u>
Specific conductance, $\mu\text{S}/\text{cm}$	6	5	6.1384	382.833	9.617	446.6	446.6
Field pH	6	5	7.1464	8.131	0.092	[7.42, 8.85]	[7.42, 8.85]
Total organic carbon, ^(b) $\mu\text{g}/\text{L}$	5	4	7.5287	362.00	191.788	1,943.7	1,943.7
Total organic halides, ^(b) $\mu\text{g}/\text{L}$	4	3	10.8688	3.15	1.912	26.4	26.4

(a) Based on semiannual sampling events from July 1997 to June 1999 for upgradient well 299-E26-11.

(b) Critical means calculated from values reported below vendor's specified method detection limit.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 12 comparisons.

Table A.39. 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 Networks
299-E28-26⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E28-27⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	WMA B, Surveillance
299-E28-28⁹⁰	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E32-2 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-3 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-4⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-3 pond
299-E32-5 ⁸⁹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E32-6 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E32-7 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E32-8 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E32-9 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E32-10 ⁹²	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E33-28⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	WMA B
299-E33-29⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	WMA B
299-E33-30 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	--
299-E33-34 ⁹⁰	Top of unconfined	Semiannual	Semiannual	RCRA	WMA B
299-E33-35⁹⁰	Top of unconfined	Semiannual	Semiannual	RCRA	WMA B, Surveillance

Contamination Indicator Parameters

pH
Specific conductance
Total organic carbon
Total organic halides

Site-Specific Parameters

Alkalinity
Anions
Gross alpha
Gross beta
ICP metals (filtered)
Lead (filtered)
Mercury (filtered)
Phenols
Tritium
Turbidity

Bold italic = Upgradient wells.
Superscript = Year of installation.
ICP = Inductively coupled plasma emission spectroscopy.
RCRA = Well constructed to RCRA standards.
WMA = Waste management area.

Table A.40. Critical Mean Values for Low-Level Waste Management Area 1^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/ Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	27 ^(b)	26	4.1774	390.259	53.332	617.1	617.1
Field pH	28	27	4.4138	7.968	0.216	[7.00, 8.94]	[7.00, 8.94]
Total organic carbon, ^(c) $\mu\text{g}/\text{L}$	28	27	4.1542	465.625	263.589	1,580	1,580
Total organic halides, ^(d) $\mu\text{g}/\text{L}$	27 ^(b)	26	4.1774	3.132	1.891	11.2	17.9

(a) Based on semiannual sampling events from December 1997 to June 1999 for upgradient wells 299-E28-26, 299-E28-27, 299-E28-28, 299-E32-4, 299-E33-28, 299-E33-29, and 299-E33-35.

(b) Excluding outlier or data exceeding the holding time requirement.

(c) Critical mean calculated from values reported below vendor's specified method detection limit.

(d) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 68 comparisons.

Table A.41. Monitoring Wells and Constituents for Low-Level Waste Management Area 2
(adapted from WHC-SD-EN-AP-015)

<u>Well</u>	<u>Hydrogeologic Unit Monitored</u>	<u>Sampling Frequency</u>	<u>Water-Level Measurement</u>	<u>Well Standard</u>	<u>Other Networks</u>
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, Surveillance
299-E34-2 ⁸⁷	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
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	Surveillance
299-E34-6 ⁸⁷	Top of unconfined	Dry	Dry	RCRA	--
299-E34-7 ⁸⁹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E34-9 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
299-E34-10 ⁹¹	Top of unconfined	Semiannual	Semiannual	RCRA	216-B-63 trench, Surveillance
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	--
<u>Contamination Indicator Parameters</u>			<u>Site-Specific Parameters</u>		
pH			Alkalinity		Mercury (filtered)
Specific conductance			Anions		Phenols
Total organic carbon			Gross alpha		Polychlorinated biphenyls
Total organic halides			Gross beta		Tritium
			ICP metals (filtered)		Turbidity
			Lead (filtered)		

Bold italic = Upgradient wells.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

Table A.42. Critical Mean Values for Low-Level Waste Management Area 2^(a)

Constituent, unit	n	df	t _c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	7	6	7.0210	448.321	46.78	799.4	799.4
Field pH	12	11	5.4261	8.0246	0.126	[7.31, 8.74]	[7.31, 8.74]
Total organic carbon, $\mu\text{g}/\text{L}$	12	11	4.9785	554.375	253.489	1,867.9	1,867.9
Total organic halides, ^(b,c) $\mu\text{g}/\text{L}$	12	11	4.9785	3.013	1.148	9.0	17.9

(a) Data collected from January 1998 to April 1999 for upgradient wells 299-E27-10, 299-E34-3, and 299-E34-7, except for specific conductance that included data collected in the same period for upgradient wells 299-E27-10 and 299-E34-3.

(b) Critical mean calculated from values below vendor's specified method detection limit.

(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 48 comparisons.

Table A.43. Monitoring Wells, Constituents, and Enforcement Limits for 200 Areas Treated Effluent Disposal Facility (adapted from WHC-SD-EN-WP-012, Rev. 1)

Well	Hydrogeologic Unit	Sampling Frequency	Well Standard	Other Networks
699-40-36 ⁹²	Ringold confined	Quarterly	RCRA	--
699-41-35 ⁹²	Ringold confined	Quarterly	RCRA	--
699-42-37⁹²	Ringold confined	Quarterly	RCRA	--
Constituent ^(a)	Enforcement Limit ($\mu\text{g}/\text{L}$)			
Cadmium	5			
Cyanide	50			
Lead	10			
Total trihalomethanes	66			
Trichloroethane	5			
pH	6.5 - 8.5 pH units			

(a) Also monitored for ICP metals, anions, trace metals, volatile and semivolatile organic compounds, total petroleum hydrocarbons, ammonia, alkalinity, specific conductance, total dissolved solids, turbidity, total organic carbon, oil and grease, gross alpha, gross beta, radium-226, and radium-226/228. No enforcement limits for those constituents.

Italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

**Table A.44. Monitoring Wells, Constituents, and Enforcement Limits for 400 Area
Process Ponds (specified in state waste discharge permit)**

<u>Well</u>	<u>Hydrogeologic Unit Monitored</u>	<u>Sampling Frequency</u>	<u>Water-Level Measurement</u>	<u>Well Standard</u>	<u>Other Networks</u>
699-2-6A ⁹⁷	Unconfined aquifer	Quarterly	Annual	RCRA	--
699-2-7 ⁷⁸	Unconfined aquifer	Quarterly	Annual	PRE	--
699-8-17⁵⁰	Unconfined aquifer	Quarterly	Semiannual	PRE	--
<u>Constituent</u>	<u>Enforcement Limit (µg/L)^(a,b)</u>				
Cadmium (unfiltered)	10				
Chromium (unfiltered)	50				
Lead (unfiltered)	50				
Manganese (unfiltered)	50				
Mercury (unfiltered)	2				
pH	Monitor only				
Specific conductance	Monitor only				
Sulfate	Monitor only				
Temperature	Monitor only				
Total organic carbon	Monitor only				
Turbidity	Monitor only				

(a) Defined as the average of four quarterly measurements from a well. Average to be calculated using the four most recent quarterly measurements from a well.

(b) Enforcement limit in groundwater shall be met in point-of-compliance well 699-2-7.

Bold italic = Upgradient well.

Superscript = Year of installation.

ICP = Inductively coupled plasma emission spectroscopy.

PRE = Well not constructed to RCRA standards.

RCRA = Well constructed to RCRA standards.

Table A.45. Monitoring Wells and Constituents for Nonradioactive Dangerous Waste Landfill
(adapted from WHC-SD-EN-AP-026)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurement	Well Standard	Other Networks
699-25-33A ⁸⁷	Top of LPU ^(a)	Semiannual	Semiannual	RCRA	--
699-25-34A ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-25-34B ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-25-34D ⁹²	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-26-33 ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance, DOH
699-26-34A⁹²	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-26-34B ⁹²	Top of unconfined	Semiannual	Semiannual	RCRA	--
699-26-35A⁸⁶	Top of unconfined	Quarterly	Quarterly	RCRA	SWL
699-26-35C⁸⁷	Top of LPU ^(a)	Semiannual	Semiannual	RCRA	--
Contamination Indicator Parameters			Site-Specific Parameters		
pH			Alkalinity	Tritium	
Specific conductance			ICP metals (filtered)	Turbidity	
Total organic carbon			Phenols	Volatile chlorinated hydrocarbons	
Total organic halides					

(a) Low-permeability unit in upper Ringold Formation.

Bold italic = Upgradient wells.

Superscript = Year of installation.

DOH = Washington State Department of Health.

ICP = Inductively coupled plasma emission spectroscopy.

RCRA = Well constructed to RCRA standards.

SWL = Solid Waste Landfill.

Table A.46. Critical Mean Values for Nonradioactive Dangerous Waste Landfill^(a)

Constituent, unit	n	df	t_c	Average Background	Standard Deviation	Critical Mean	Upgradient/Downgradient Comparison Value
Specific conductance, $\mu\text{S}/\text{cm}$	11	10	4.8092	452.89	29.427	600.7	600.7
Field pH	11	10	5.2814	7.450	0.164	[6.55, 8.35]	[6.55, 8.35]
Total organic carbon, ^(b) $\mu\text{g}/\text{L}$	11	10	4.8092	308.682	242.278	1,597.7	1,597.7
Total organic halides, ^(b,c) $\mu\text{g}/\text{L}$	11	10	4.8092	4.278	2.054	14.6	17.9

(a) Data collected based on semiannual sampling events from August 1997 to February 1999 for upgradient wells 699-26-34A and 699-26-35A.

(b) Critical means calculated from values reported below vendor's specified method detection limit.

(c) Upgradient/downgradient comparison value is the limit of quantitation discussed in Appendix B.

df = Degrees of freedom (n-1).

n = Number of background replicate averages.

t_c = Bonferroni critical t-value for appropriate df and 28 comparisons.

Table A.47. 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 Standard	Other Networks
699-22-35 ⁹³	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
699-23-34A ⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-23-34B ⁹³	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-24-33 ⁴⁸	Top of unconfined	Quarterly ^(a)	Quarterly	PRE	--
699-24-34A ⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-24-34B ⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-24-34C ⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	Surveillance
699-24-35⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-25-34C ⁸⁷	Top of unconfined	Quarterly	Quarterly	RCRA	--
699-26-35A⁸⁶	Top of unconfined	Quarterly	Quarterly	RCRA	NRDWL
Parameters/Constituents Required by WAC 173-304-490			Site-Specific Parameters		
Ammonia as nitrogen	Nitrate		Gross alpha	1,1,1-Trichloroethane	
Chemical oxygen demand	Nitrite		Gross beta	Trichloroethylene	
Chloride	pH		Total organic halides	Tritium	
Specific conductance	Sulfate				
Dissolved iron	Temperature				
Dissolved zinc	Total coliform				
Manganese	Total organic carbon				

(a) Well sampled for supporting data.

Bold italic = 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.48. Sampling Results for Required Constituents^(a) at Solid Waste Landfill

Constituent, unit	Tolerance Interval ^(b)	Date	Well 699-22-35	Well 699-23-34A	Well 699-23-34B	Well 699-24-34A
Temperature, °C	21.0	December 1998	18.1	17.9	17.4	17.3
		February 1999	17.3	18.0	17.6	18.1
		May 1999	18.5	19.0	18.2	19.0
		August 1999	18.4	18.8	19.3	--
Specific conductance, µS/cm	550	December 1998	801 ^(c,d)	613 ^(c,d)	714 ^(c,d)	581 ^(c,d)
		February 1999	809 ^(c,d)	663 ^(c,d)	747 ^(c,d)	630 ^(c,d)
		May 1999	826 ^(c,d)	675 ^(c,d)	766 ^(c,d)	641 ^(c,d)
		August 1999	822 ^(c)	686 ^(c)	772 ^(c)	--
Field pH	[6.2, 8.46]	December 1998	6.8	6.7	6.8	6.8
		February 1999	7.1	6.7	6.9	6.6
		May 1999	6.8	6.6	6.7	6.6
		August 1999	7.0	6.7	6.8	--
Total organic carbon, µg/L	1,154	December 1998	330	390	588	368
		February 1999	250	965	901	565
		May 1999	<220	480	580	355
		August 1999	455	315	342	498
Chloride, µg/L	9,045	December 1998	5,190	5,680	6,360	5,840
		February 1999	5,790	5,270	5,645	5,540
		May 1999	5,430	5,280	5,560	5,420
		August 1999	5,620	5,540	5,570	5,700
Nitrate, µg/L	33,800	December 1998	14,900	12,400	13,900	12,100
		February 1999	15,600	11,700	15,100	12,700
		May 1999	13,700	10,500	13,500	11,600
		August 1999	15,500	11,700	15,200	12,300
Nitrite, µg/L	109	December 1998	<70	<70	<70	<70
		February 1999	<70	<70	<70	<70
		May 1999	<70	<70	<70	<70
		August 1999	<70	<70	<70	<70
Ammonium, µg/L	165	December 1998	<37	<37	<37	<37
		February 1999	<37	<37	<37	<37
		May 1999	<37	<37	<37	<37
		August 1999	<37	<37	<37	<37
Sulfate, µg/L	51,500	December 1998	49,300	45,600	56,400 ^(c)	44,500
		February 1999	56,400 ^(c)	43,900	54,650 ^(c)	42,500
		May 1999	54,200 ^(c)	43,600	53,200 ^(c)	40,900
		August 1999	56,100 ^(c)	46,400	55,000 ^(c)	44,600
Iron, filtered, µg/L	137	December 1998	89.4	44.9	71.1	90.5
		February 1999	51.3	38.9	46.5	47.1
		May 1999	84.3	65.5	78.0	91.1
		August 1999	51.1	70.4	58.8	117.0
Zinc, filtered, µg/L	34	December 1998	13.9	6.7	8.8	6.1
		February 1999	3.9	6.6	5.0	3.7
		May 1999	7.4	9.3	7.4	12.2
		August 1999	6.6	10.4	4.9	25.8
Manganese, filtered, µg/L	11	December 1998	9.2	4.8	6.1	4.5
		February 1999	3.9	4.2	3.4	2.9
		May 1999	5.7	5.2	6.3	5.6
		August 1999	4.8	5.1	5.1	5.0

Table A.48. (contd)

Constituent, unit	Tolerance Interval ^(b)	Date	Well	Well	Well	Well	
			699-22-35	699-23-34A	699-23-34B	699-24-34A	
Chemical oxygen demand, µg/L	5,000	December 1998	<3,820	<3,820	<3,820	<3,820	
		February 1999	<3,820	<3,820	<3,820	<3,820	
		May 1999	33,000 ^(c,e)	<3,820	25,000 ^(c,e)	26,000 ^(c,e)	
		August 1999	<3,820	<3,820	<3,820	<3,820	
Coliform bacteria, most probable number	16	December 1998	0	0	0	0	
		February 1999	0	0	0	0	
		May 1999	0	0	0	0	
		August 1999	0	0	0	0	
			Well	Well	Well	Well	Well
			699-24-34B	699-24-34C	699-24-35	699-25-34C	699-26-35A
Temperature, °C	21.0	December 1998	18.3	18.1	16.9	18.8	19.8
		February 1999	17.8	18.7	17.1	18.5	19.4
		May 1999	19.0	19.2	17.8	19.9	19.6
		August 1999	19.5	19.3	18.9	19.6	20.1
Specific conductance, µS/cm	550	December 1998	612 ^(c,d)	638 ^(c,d)	510 ^(c,d)	576 ^(c,d)	454 ^(d)
		February 1999	632 ^(c,d)	672 ^(c,d)	538 ^(c,d)	593 ^(c,d)	471 ^(d)
		May 1999	645 ^(c,d)	684 ^(c,d)	553 ^(c,d)	601 ^(c,d)	484 ^(d)
		August 1999	663 ^(c)	708 ^(c)	565 ^(c,d)	616 ^(c)	507
Field pH	[6.2,8.46]	December 1998	6.7	7.1	6.9	7.2	7.3
		February 1999	6.7	7.0	7.1	7.4	7.5
		May 1999	6.7	6.9	7.0	7.2	7.4
		August 1999	6.7	7.1	6.9	7.3	7.3
Total organic carbon, µg/L	1,154	December 1998	458	292	525	203	532
		February 1999	290	600	328	155	538
		May 1999	360	400	390	330	430
		August 1999	488	465	342	505	348
Chloride, µg/L	9.045	December 1998	5,910	7,090	5,520	7,230	7,040
		February 1999	5,650	6,890	5,640	7,430	7,120
		May 1999	5,360	6,310	5,220	7,000	7,100
		August 1999	5,540	6,620	5,840	6,520	7,500
Nitrate, µg/L	33,800	December 1998	12,800	19,300	11,200	21,800	21,600
		February 1999	12,700	18,500	12,000	20,800	22,700
		May 1999	11,600	16,200	10,900	19,500	19,700
		August 1999	12,200	16,700	11,300	18,100	21,000
Nitrite, µg/L	109	December 1998	<70	<70	<70	<70	<70
		February 1999	<70	<70	<70	<70	<70
		May 1999	<70	<70	<70	<70	<70
		August 1999	<70	<70	<70	<70	<70
Ammonium, µg/L	165	December 1998	<37	<37	<37	<37	<37
		February 1999	<37	<37	<37	<37	<37
		May 1999	<37	<37	<37	<37	<37
		August 1999	<37	<37	<37	<37	<37
Sulfate, µg/L	51,500	December 1998	44,300	45,100	45,700	43,550	41,800
		February 1999	43,100	42,000	45,000	41,500	39,400
		May 1999	41,000	40,000	42,400	39,300	36,800
		August 1999	44,000	42,700	44,100	39,200	40,100

Table A.48. (contd)

Constituent, unit	Tolerance Interval ^(b)	Date	Well	Well	Well	Well	Well
			699-24-34B	699-24-34C	699-24-35	699-25-34C	699-26-35A
Iron, filtered, µg/L	137	December 1998	56.4	76.4	56.8	49.9	38.4
		February 1999	33.0	53.1	36.0	31.2	34.7
		May 1999	77.9	103	57.8	54.1	55.2
		August 1999	70.3	70.6	44.7	39.6	37.9
Zinc, filtered, µg/L	34	December 1998	6.7	36.2 ^(c)	12.4	10.1	8.6
		February 1999	4.4	10.5	4.8	7.9	5.1
		May 1999	9.9	8.7	6.2	11.2	9.5
		August 1999	14.6	13.5	11.2	6.6	6.6
Manganese, filtered, µg/L	11	December 1998	4.7	5.1	4.4	4.4	4.5
		February 1999	2.1	4.9	1.8	2.3	3.4
		May 1999	5.3	5.7	4.8	5.0	4.1
		August 1999	4.4	4.5	4.0	<3	4.5
Chemical oxygen demand, µg/L	5,000	December 1998	<3,820	<3,820	<3,820	<3,820	<3,820
		February 1999	<3,820	<3,820	<3,820	<3,820	<3,820
		May 1999	25,000 ^(c,e)	24,000 ^(c,e)	41,000 ^(c,e)	50,000 ^(c,e)	38,000 ^(c,e)
		August 1999	<3,820	<3,820	<3,820	<3,820	<3,820
Coliform bacteria, most probable number	16	December 1998	0	0	0	0	0
		February 1999	0	0	0	0	0
		May 1999	0	0	0	0	0
		August 1999	0	0	0	0	0

(a) WAC 173-304.

(b) Numbers obtained from Table A.49, background threshold value column.

(c) Exceeding background threshold values.

(d) Field measurements were suspect; values reported were laboratory analysis results.

(e) Suspect data.

< = Data values less than the method detection limit; number given is the respective limit.

Table A.49. Results of Lilliefors Test for Normality and Background Threshold Values for Solid Waste Landfill

Constituent, unit	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	0.140 ns	NA	[5.7, 8.75] ^(b)	[6.2, 8.46]
Field pH ^(d)	0.089 ns	NA	[6.2, 8.46] ^(b)	
Total organic carbon, µg/L	0.191 s	0.181 s	750 ^(c) 1,568 ^(e)	1,568
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	109 ^(e)	109
Ammonium, µg/L	NC	NC	100 ^(e) 165 ^(e)	165
Sulfate, µg/L	0.179 s	0.190 s	51,500 ^(c)	51,500
Iron, filtered, µg/L	NC	NC	78 ^(c) 137 ^(e)	137
Zinc, filtered, µg/L	NC	NC	34 ^(c) 19 ^(e)	34
Manganese, filtered, µg/L	NC	NC	11 ^(c) 2.3 ^(e)	11
Coliform, most probable number	NC	NC	16 ^(c) 3.7 ^(f)	16
Chemical oxygen demand, µg/L	NC	NC	5,000 ^(g)	5,000

(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.

(d) Outliers removed.

(e) Based on limit of quantitation discussed in Appendix B.

(f) Based on method detection limit.

(g) Based on laboratory practical quantitation limit.

NA = Not applicable.

NC = Not calculated; insufficient measured values.

ns = Not significant at 0.05 level of significance.

s = Significant at 0.05 level of significance.

Table A.50. Monitoring Wells and Constituents for 316-5 Process Trenches (adapted from WHC-SD-EN-AP-185)

Well	Hydrogeologic Unit Monitored	Sampling Frequency ^(a)	Water-Level Measurement	Well Standard	Other Networks
399-1-10A ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-10B ⁹¹	Bottom of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-16A ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-16B ⁸⁷	Bottom of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-17A ⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance, DOH
399-1-17B ⁸⁶	Bottom of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-18A⁸⁶	Top of unconfined	Semiannual	Semiannual	RCRA	Surveillance
399-1-18B⁸⁷	Bottom of unconfined	Semiannual	Semiannual	RCRA	Surveillance

Field-Measured Parameters		Site-Specific Parameters	
pH		cis-Dichloroethylene	Trichloroethylene
Specific conductance		Tetrachloroethylene	Uranium
Total organic carbon		Thallium	
Total organic halides			

(a) Sampled and measured monthly for 4 months for each semiannual sampling period.

Bold italic = Upgradient wells.

Superscript = Year of installation.

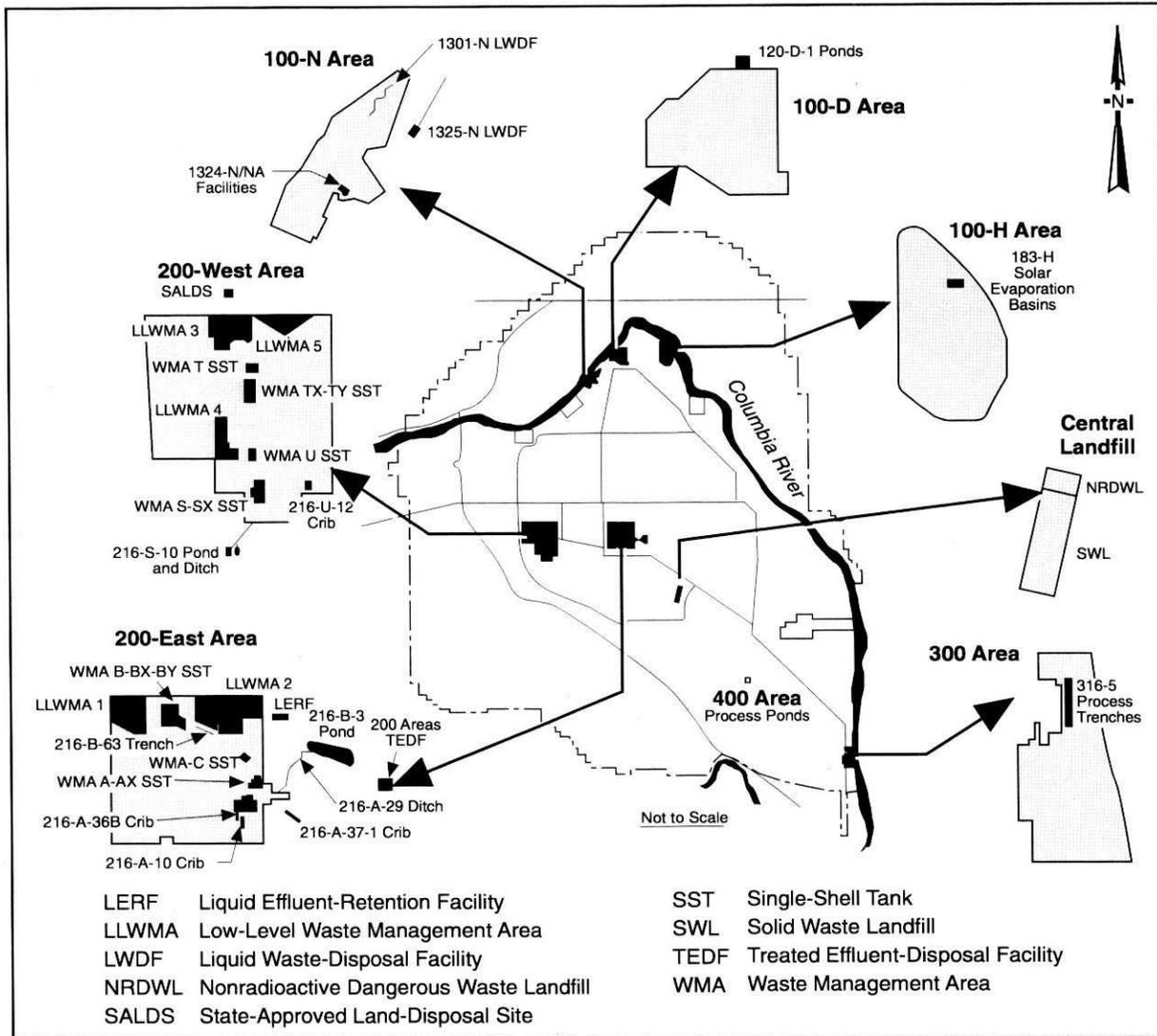
DOH = Washington State Department of Health.

RCRA = Well constructed to RCRA standards.

Table A.51. Summary of Groundwater Sampling Results for 316-5 Process Trenches

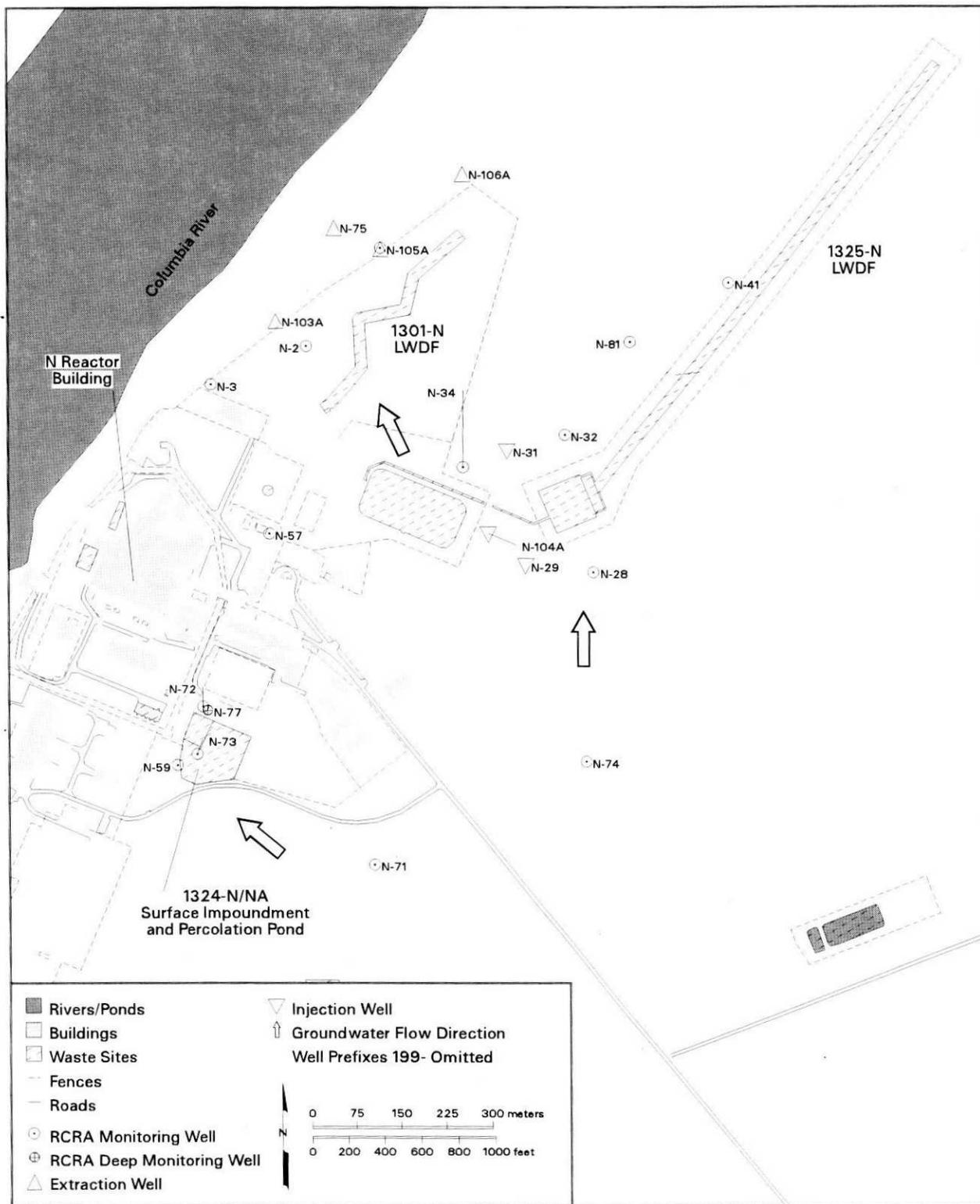
Sampling Time	Constituent of Concern	Concentration Level ($\mu\text{g/L}$)	Well Exceeding Concentration Limit (Range, $\mu\text{g/L}$)
December 1998, January, February, March, June, July, August, September 1999	Trichloroethylene	5	399-1-16B ^(a) (4 - 6)
	cis-1,2-Dichloroethylene	70	399-1-16B (120 - 180)
	Uranium	20	399-1-10A ^(a) (23.6 - 61.1) 399-1-16A (52.3 - 111) 399-1-17A (88.8 - 166)

(a) Excluded outliers.



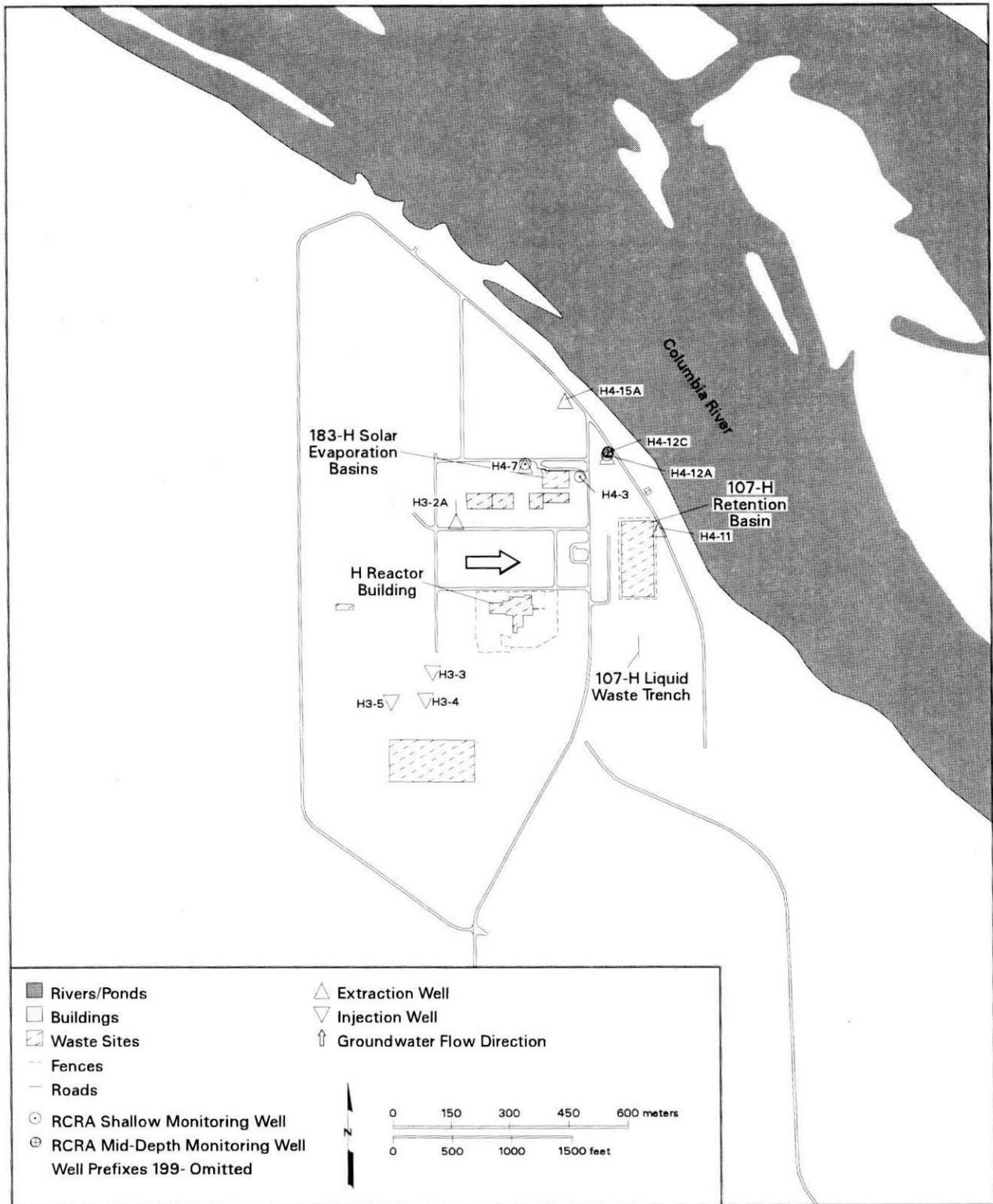
RG98120214.13

Figure A.1. Regulated Units on the Hanford Site Requiring Groundwater Monitoring



jpm98125 February 12, 1999 1:08 PM

Figure A.2. Monitoring Well Locations for 100 N Area



can_gwrep98_47 February 12, 1999 5:33 PM

Figure A.4. Monitoring Well Locations for 183-H Solar Evaporation Basins

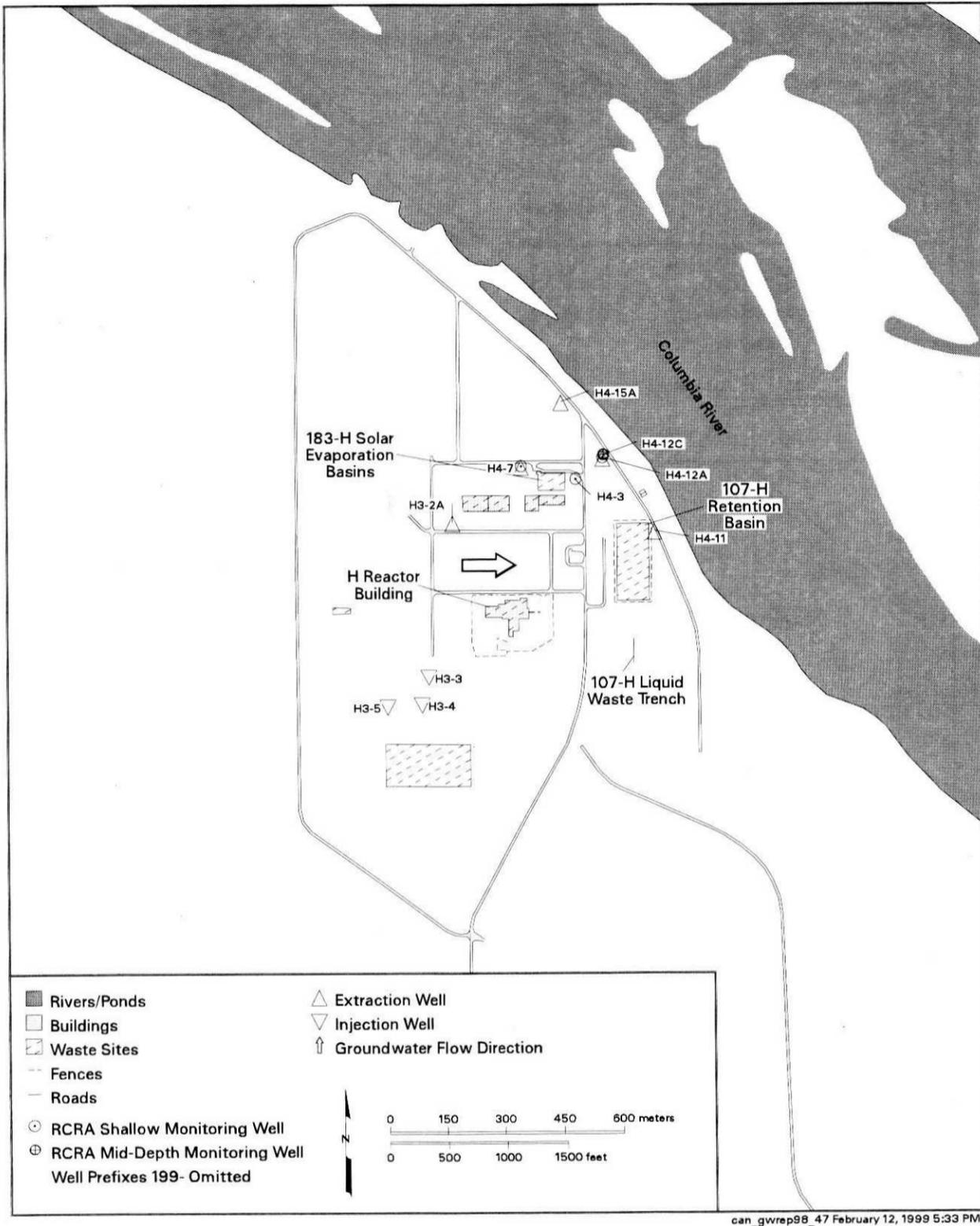
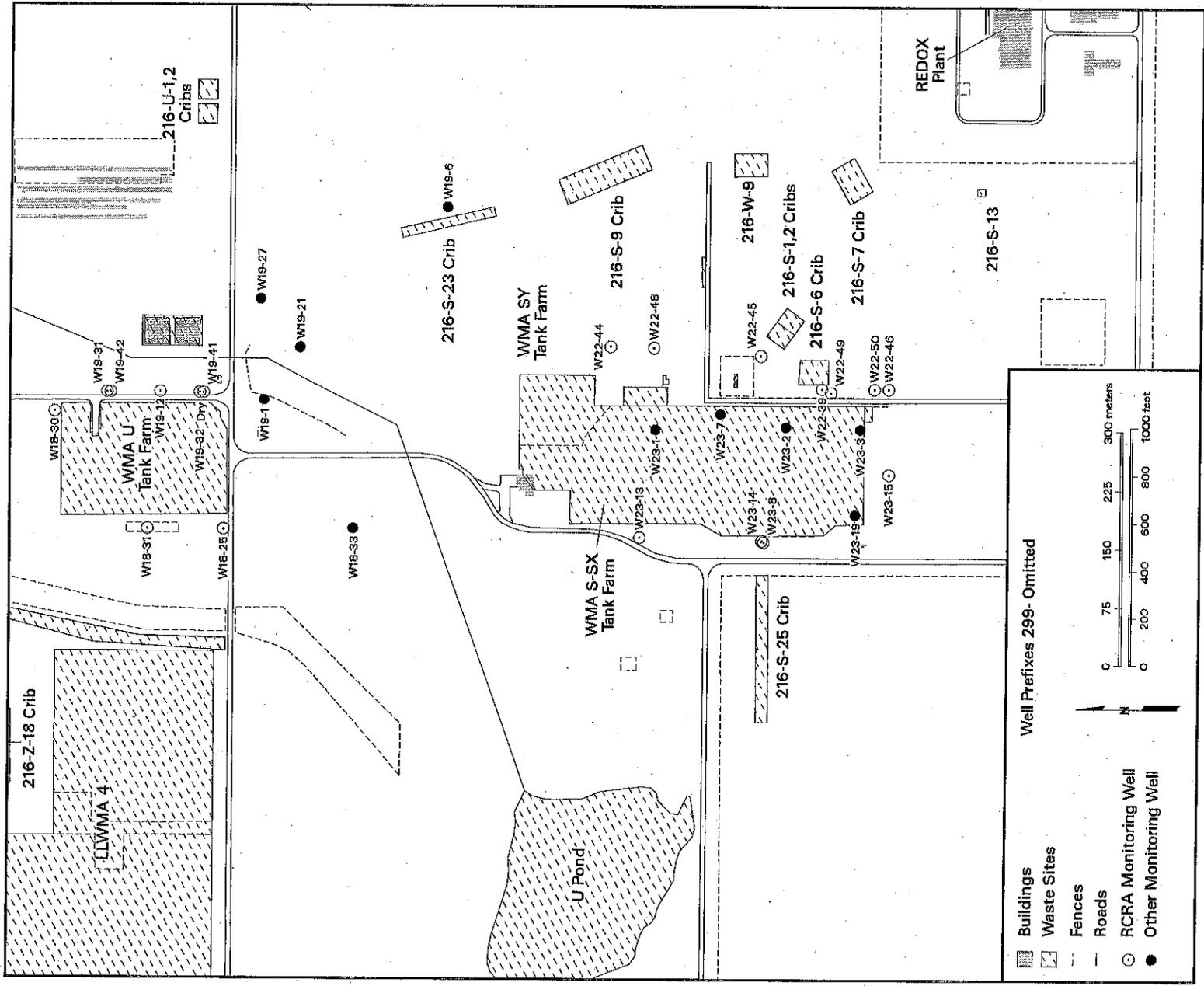
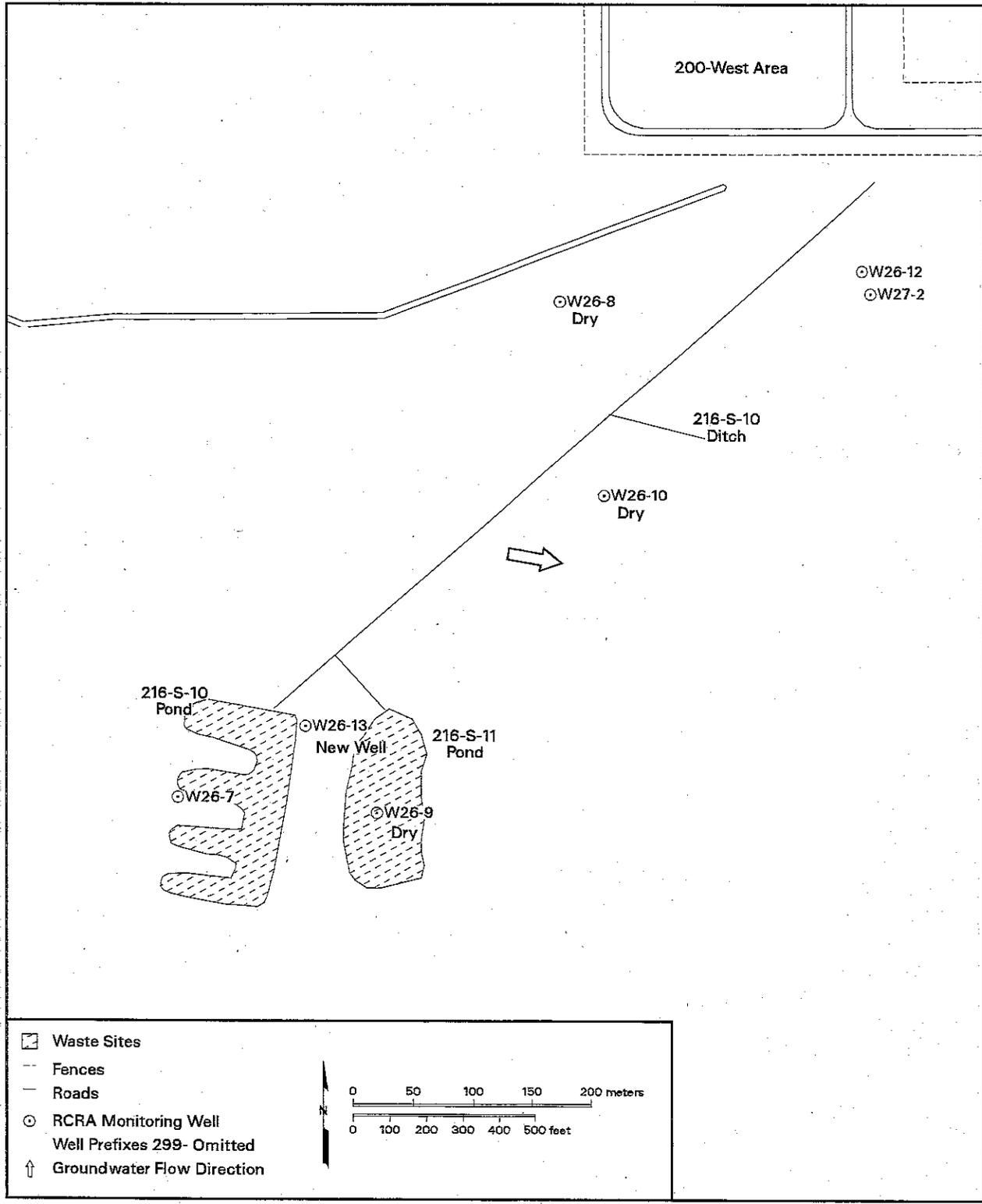


Figure A.4. Monitoring Well Locations for 183-H Solar Evaporation Basins



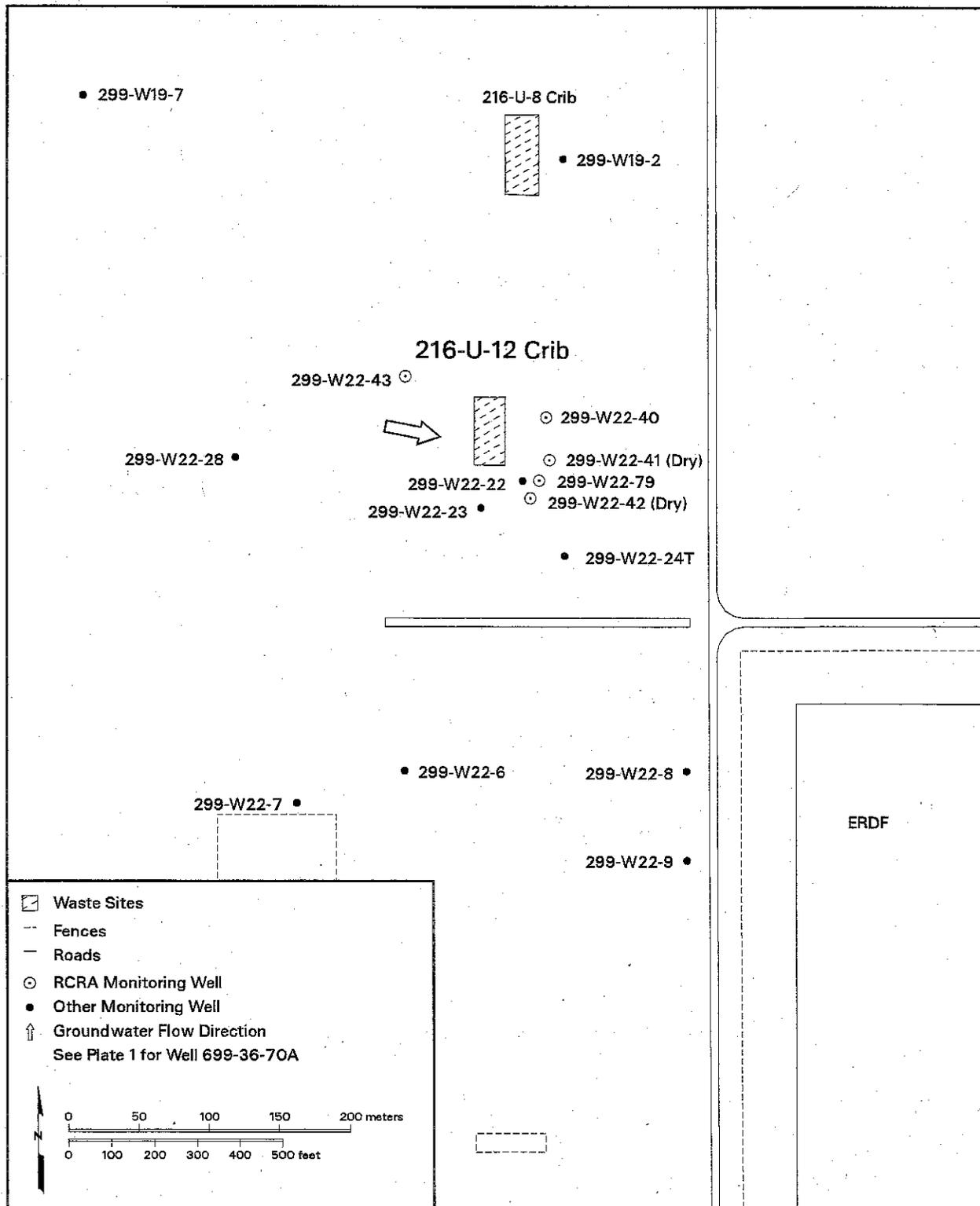
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Figure A.5. Monitoring Well Locations for Waste Management Areas S-SX and U



can_gwrep99_58 January 11, 2000 1:50 PM

Figure A.7. Monitoring Well Locations for 216-S-10 Pond and Ditch



can_gwrep99_59 January 11, 2000 12:19 PM

Figure A.8. Monitoring Well Locations for 216-U-12 Crib

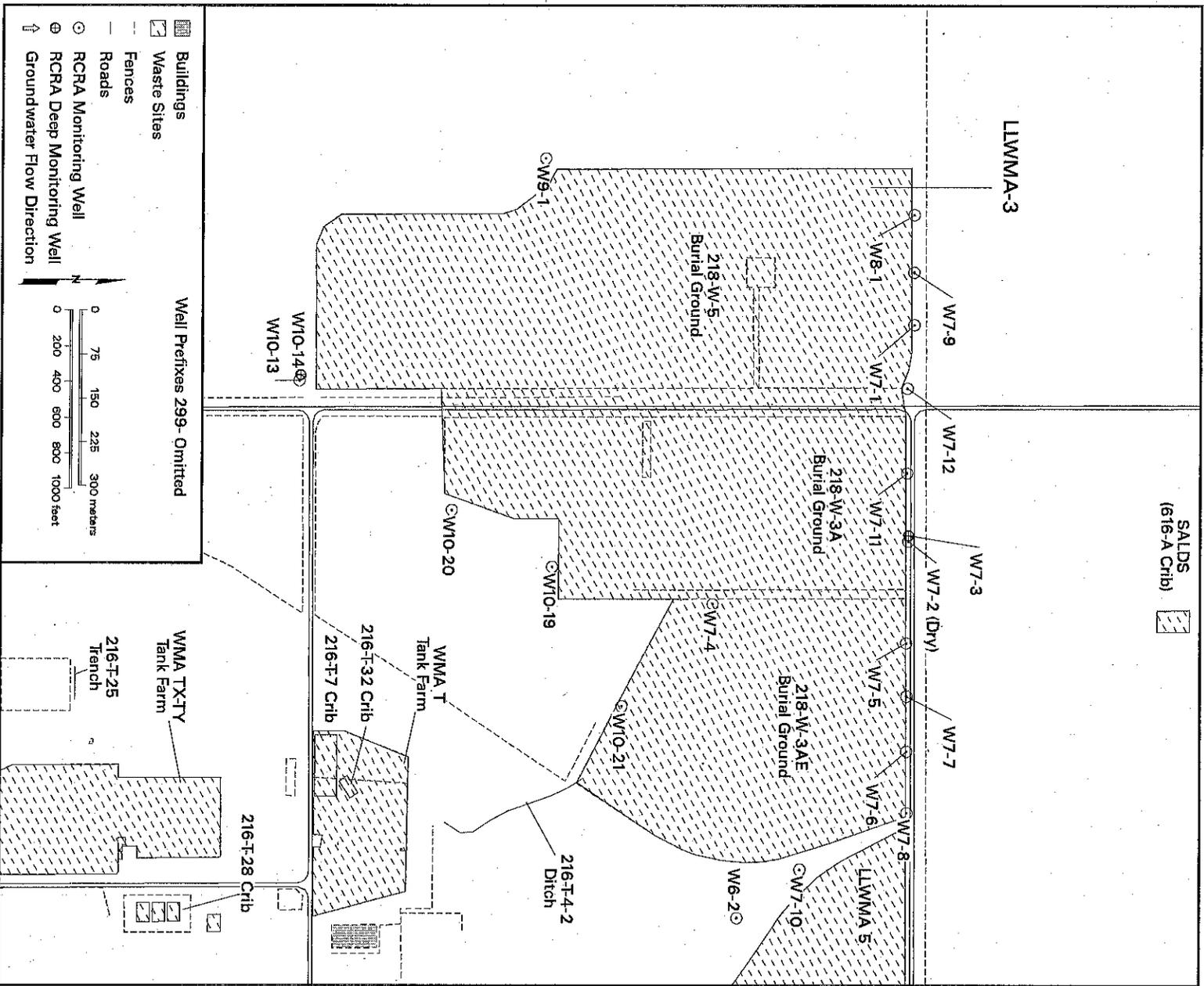


Figure A.9. Monitoring Well Locations for Low-Level Waste Management Area 3

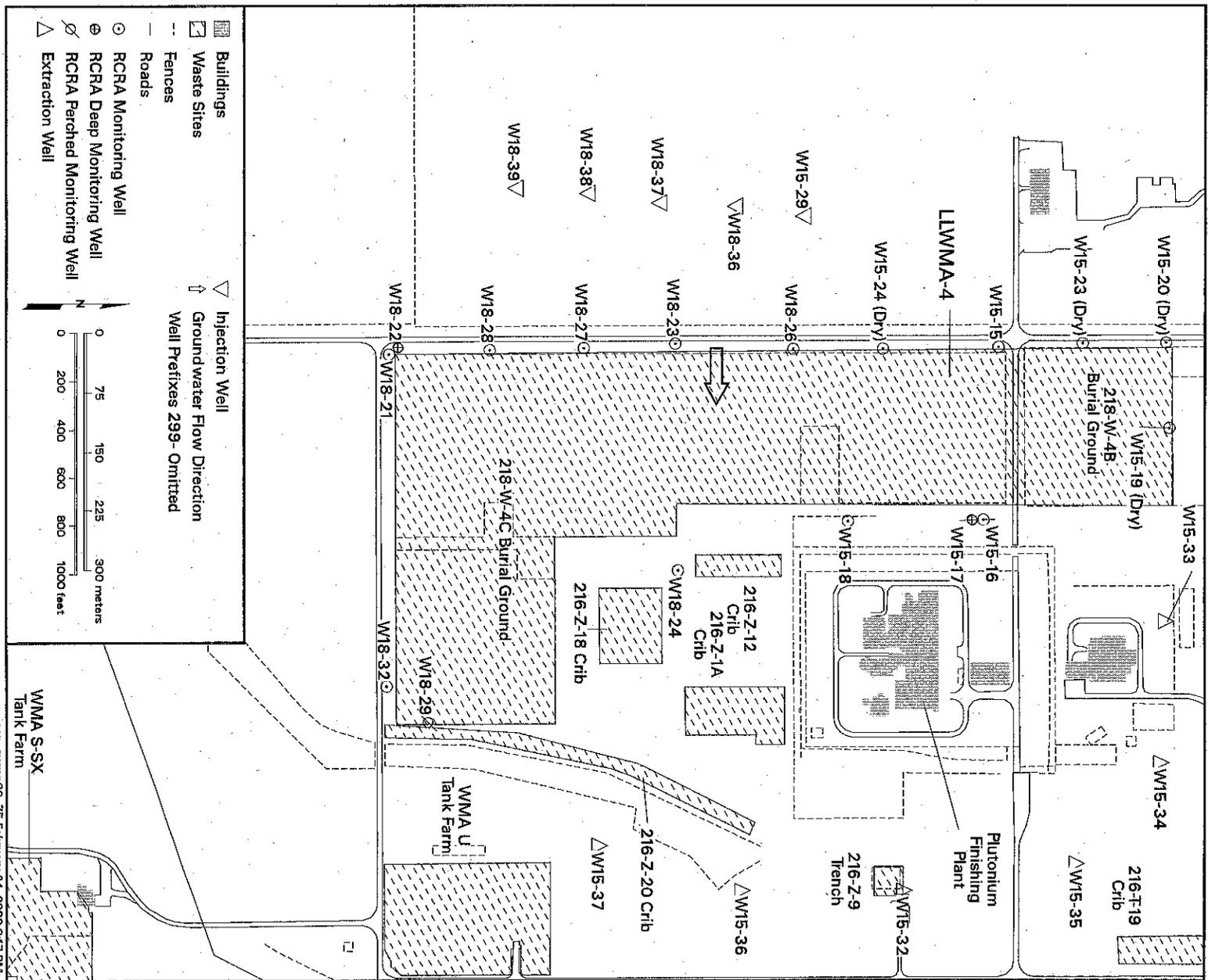


Figure A.10. Monitoring Well Locations for Low-Level Waste Management Area 4

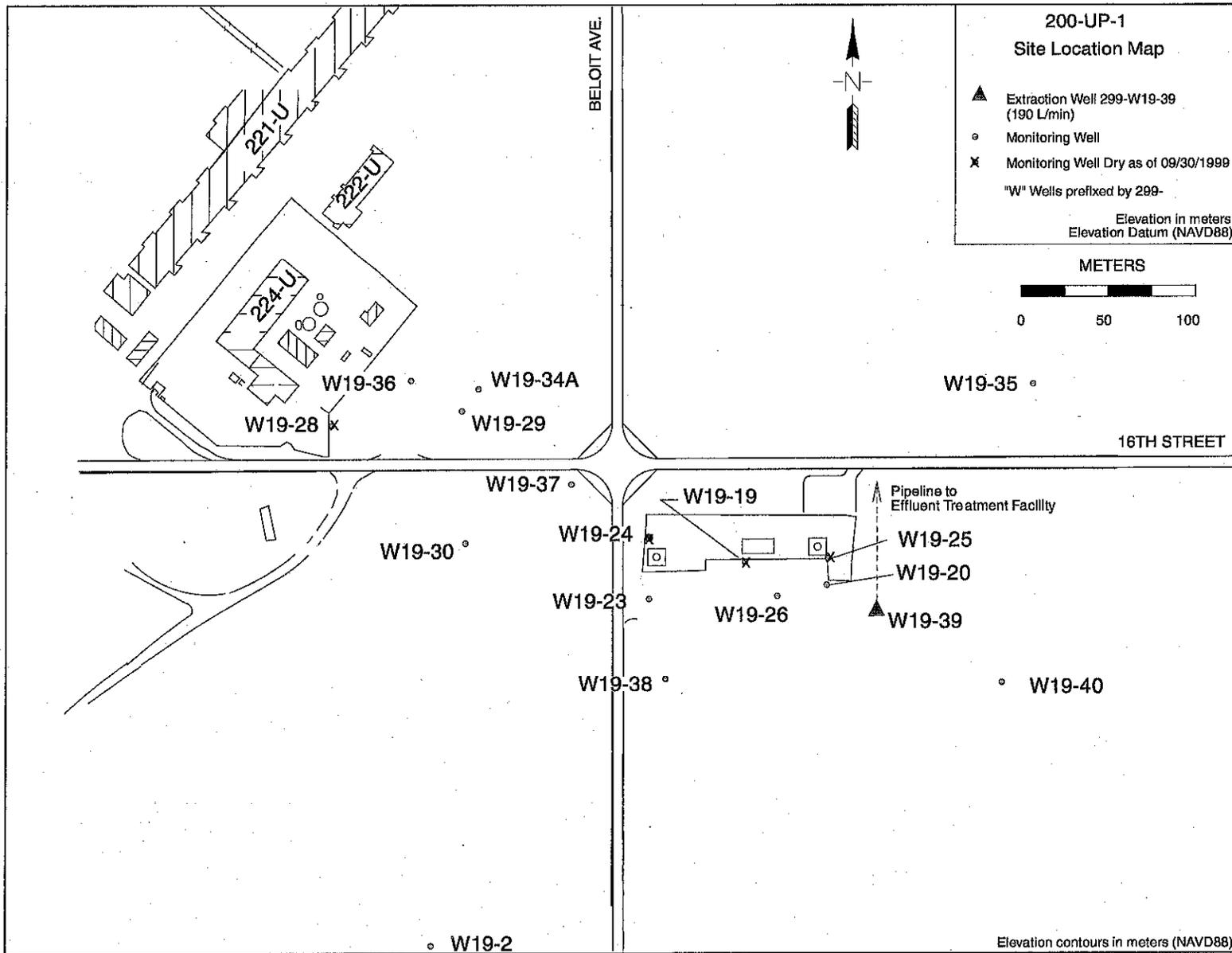


Figure A.11. Well Locations for 200-UP-1 Groundwater Operable Unit

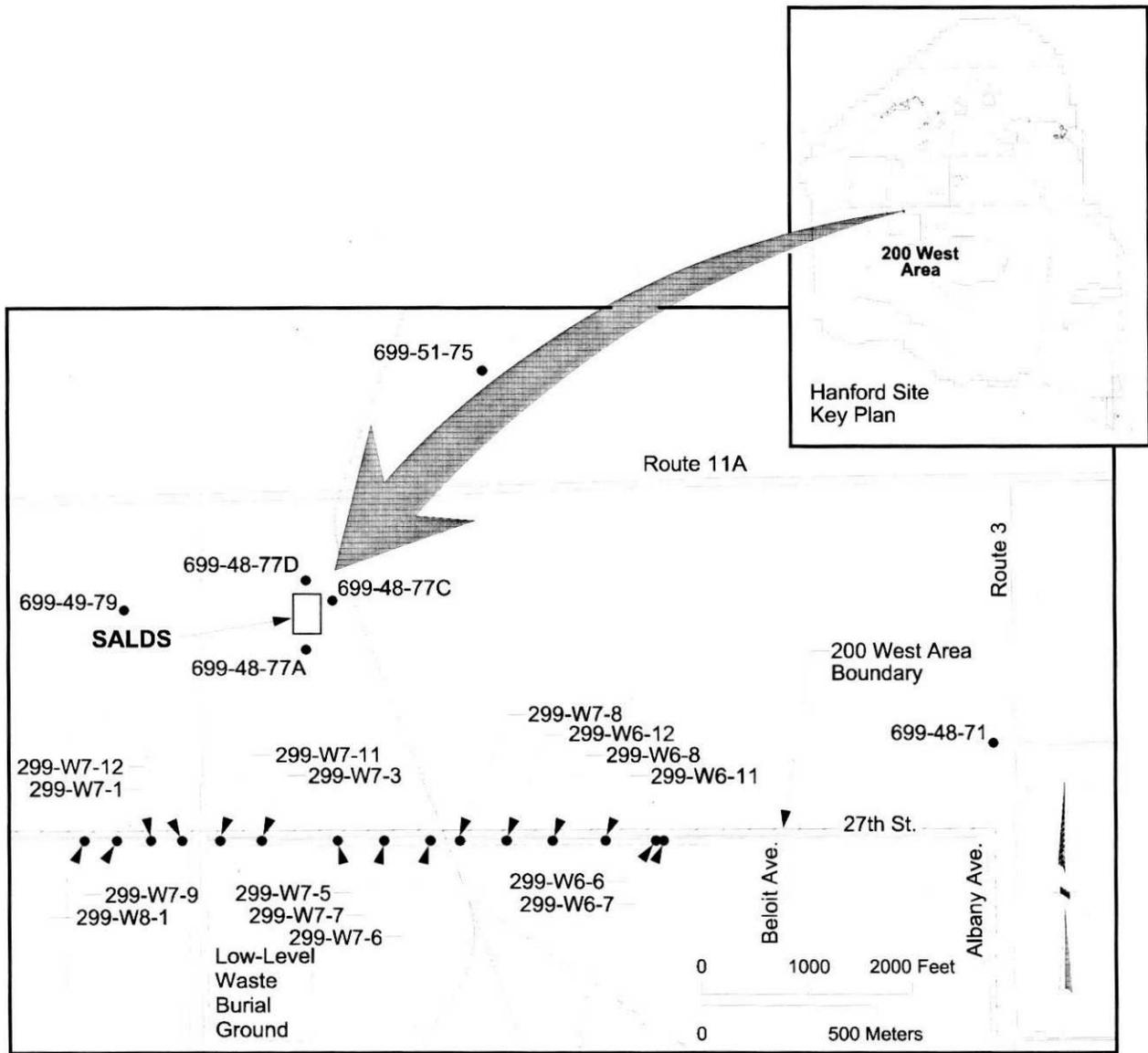


Figure A.13. Monitoring Well Locations for State-Approved Land Disposal Site

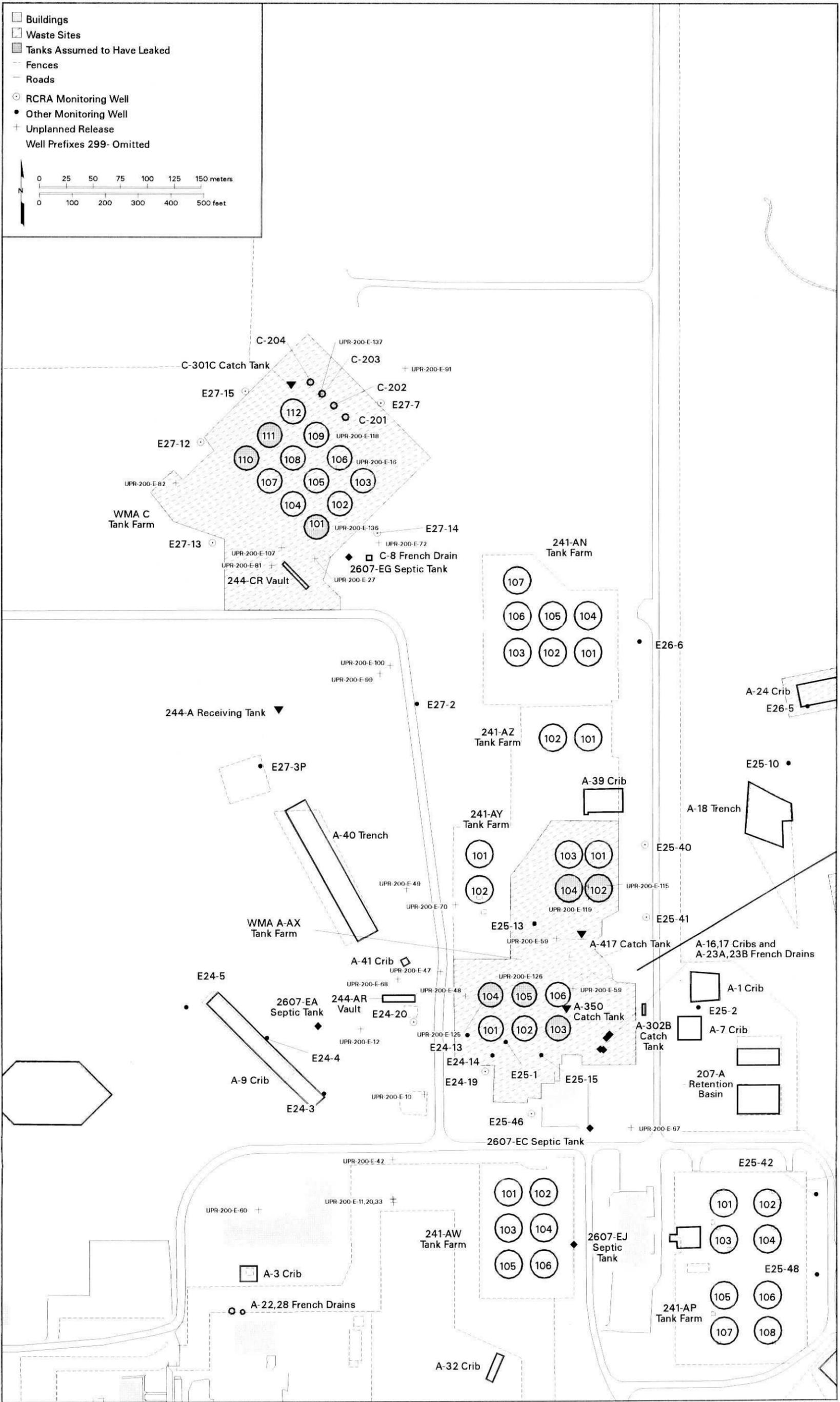
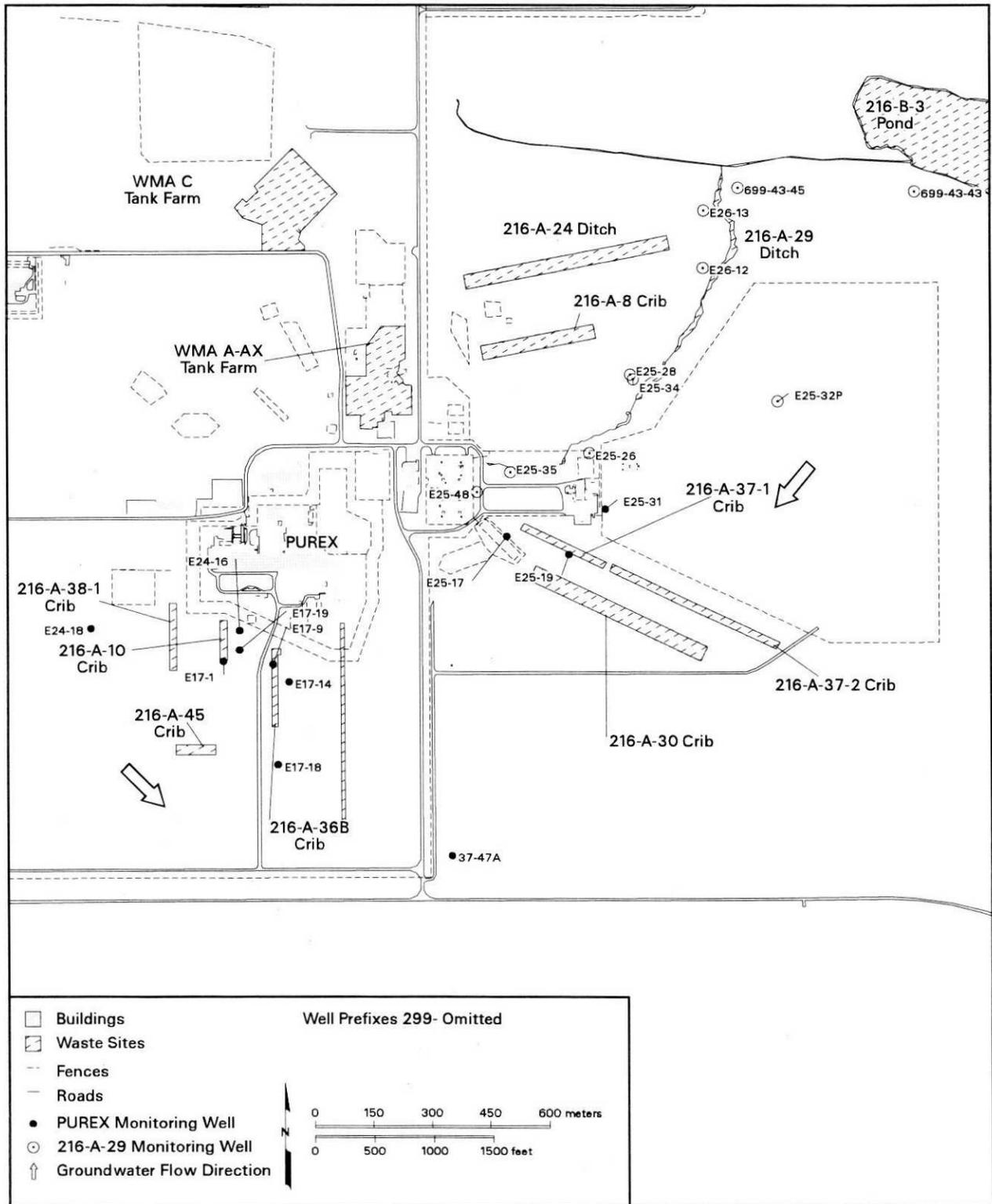
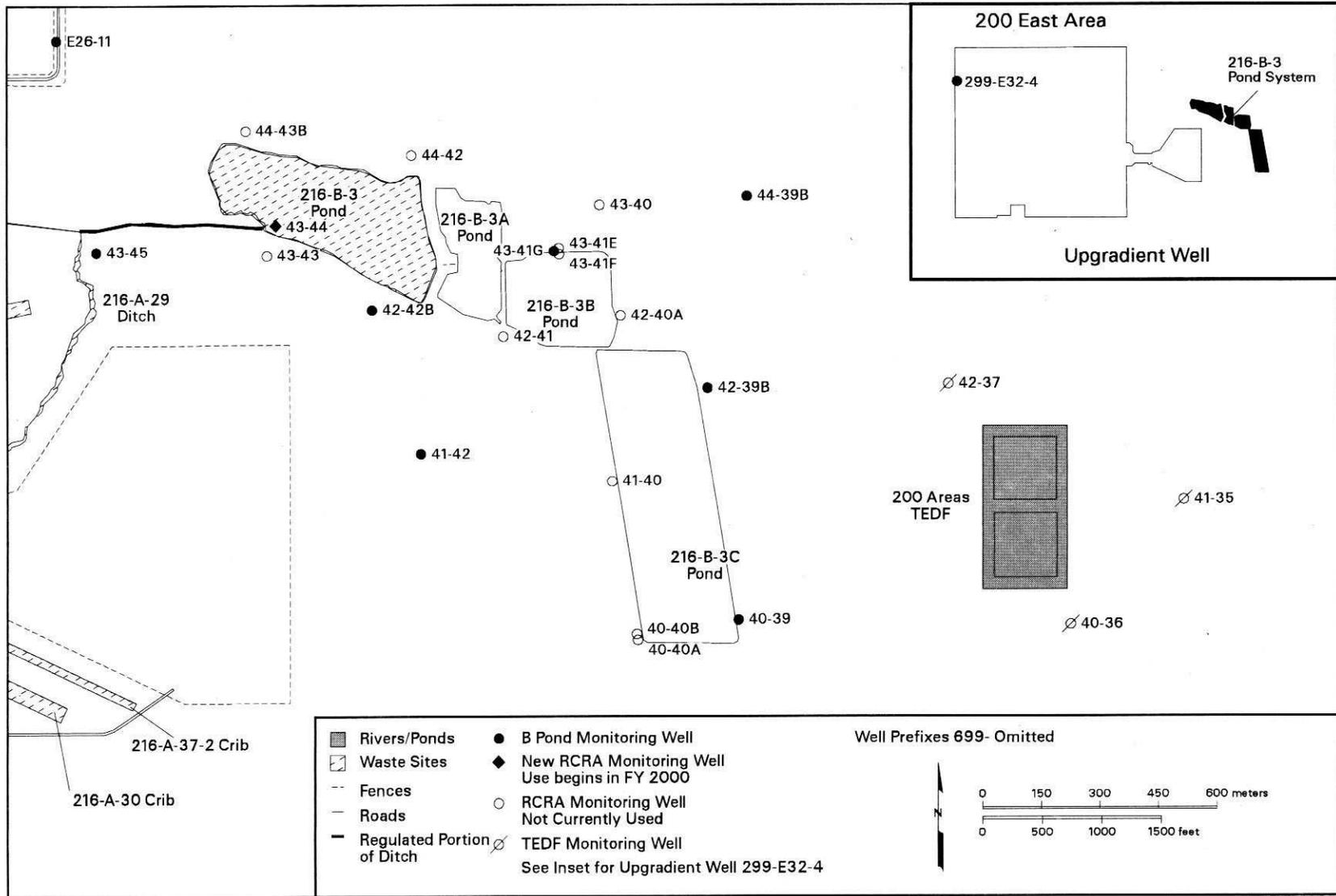


Figure A.14. Monitoring Well Locations for Waste Management Areas A-AX and C



can_gwrep99_60 January 11, 2000 2:32 PM

Figure A.16. Monitoring Well Locations for PUREX Cribs and 216-A-29 Ditch



A.100

Figure A.17. Monitoring Well Locations for 216-B-3 Pond and 200 Areas Treated Effluent Disposal Facility

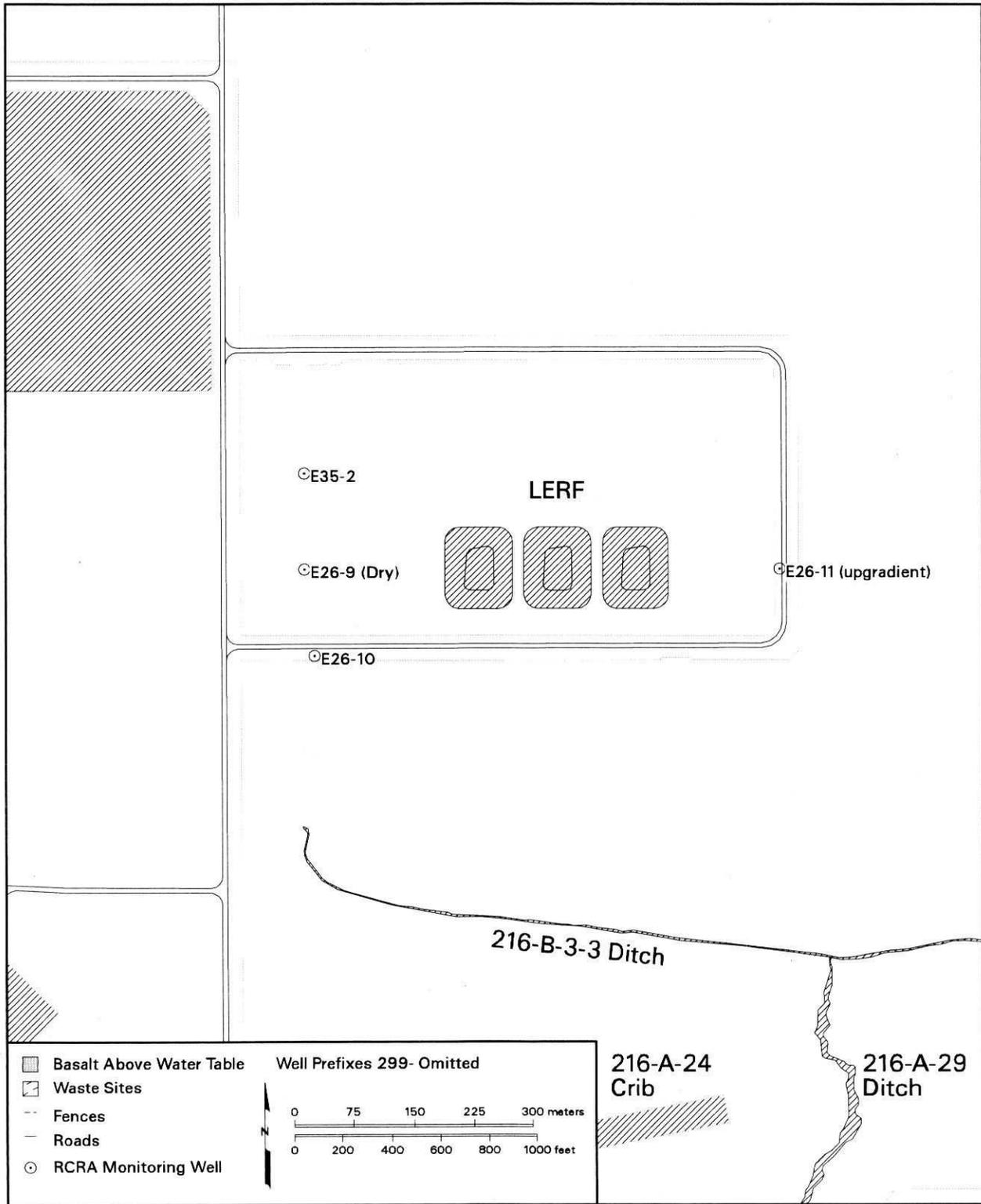
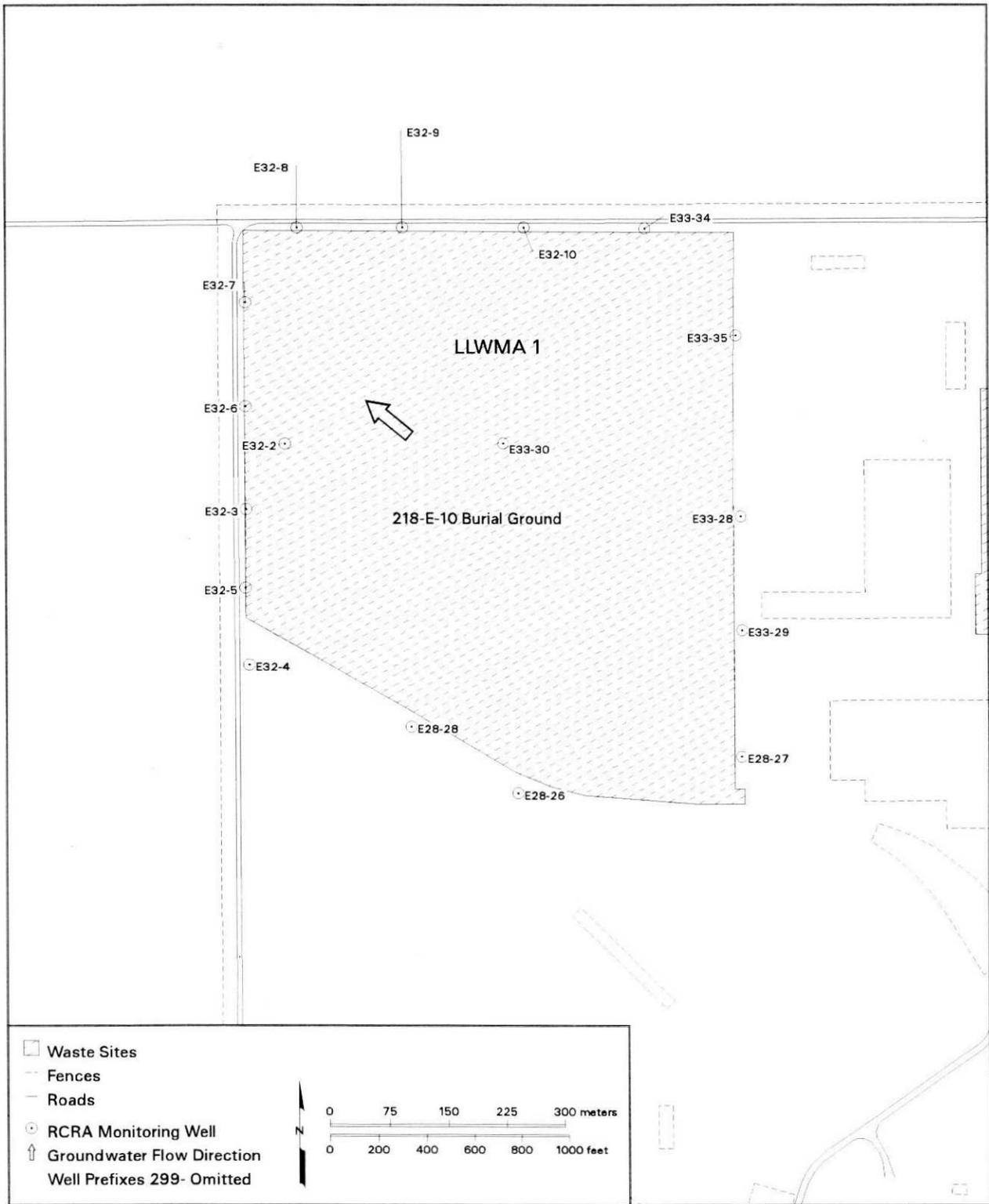
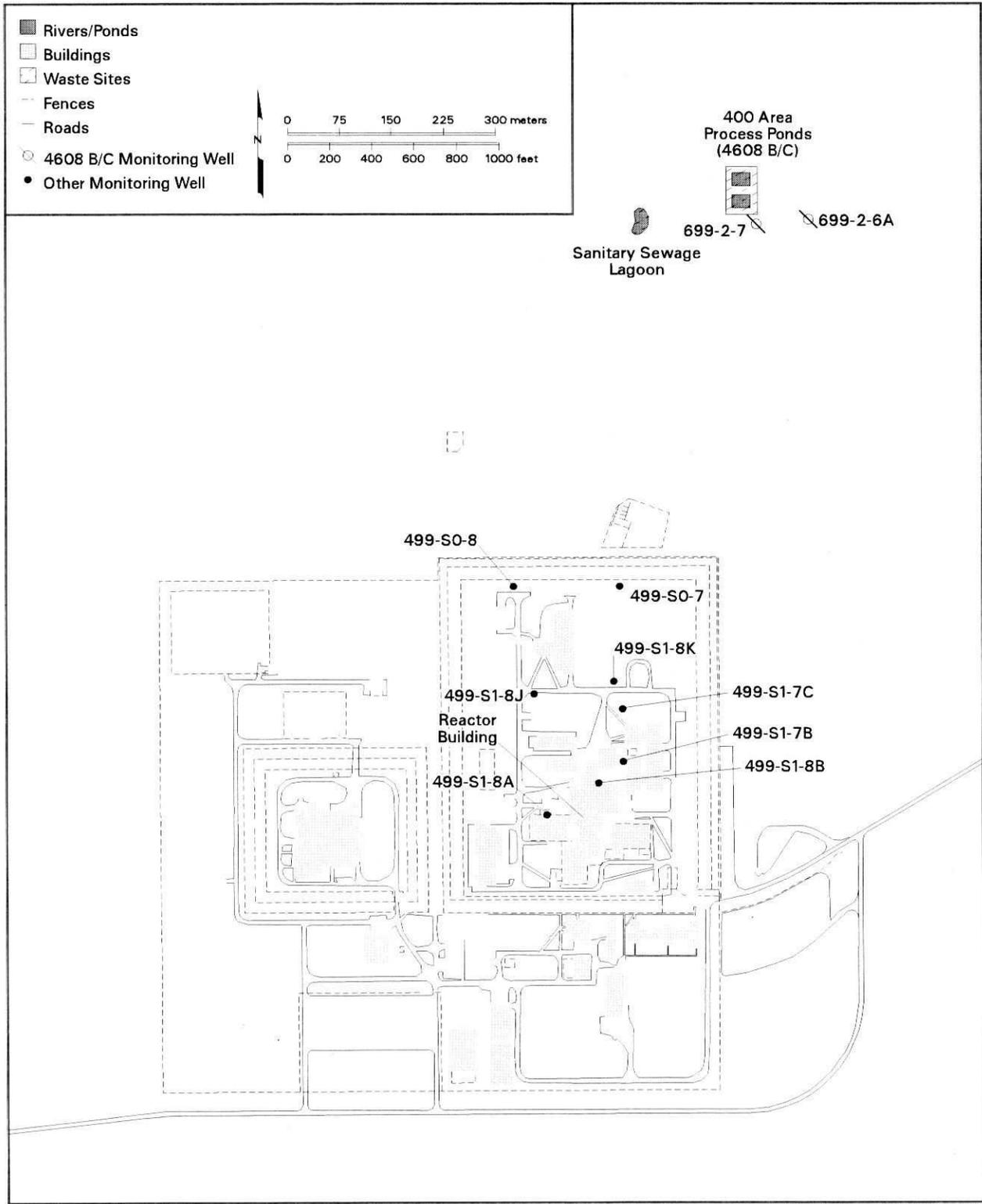


Figure A.19. Monitoring Well Locations for Liquid Effluent Retention Facility



jpm98115 February 12, 1999 3:04 PM

Figure A.20. Monitoring Well Locations for Low-Level Waste Management Area 1



jpm98052 February 12, 1999 5:49 PM

Figure A.21. Monitoring Well Locations for 400 Area Process Ponds

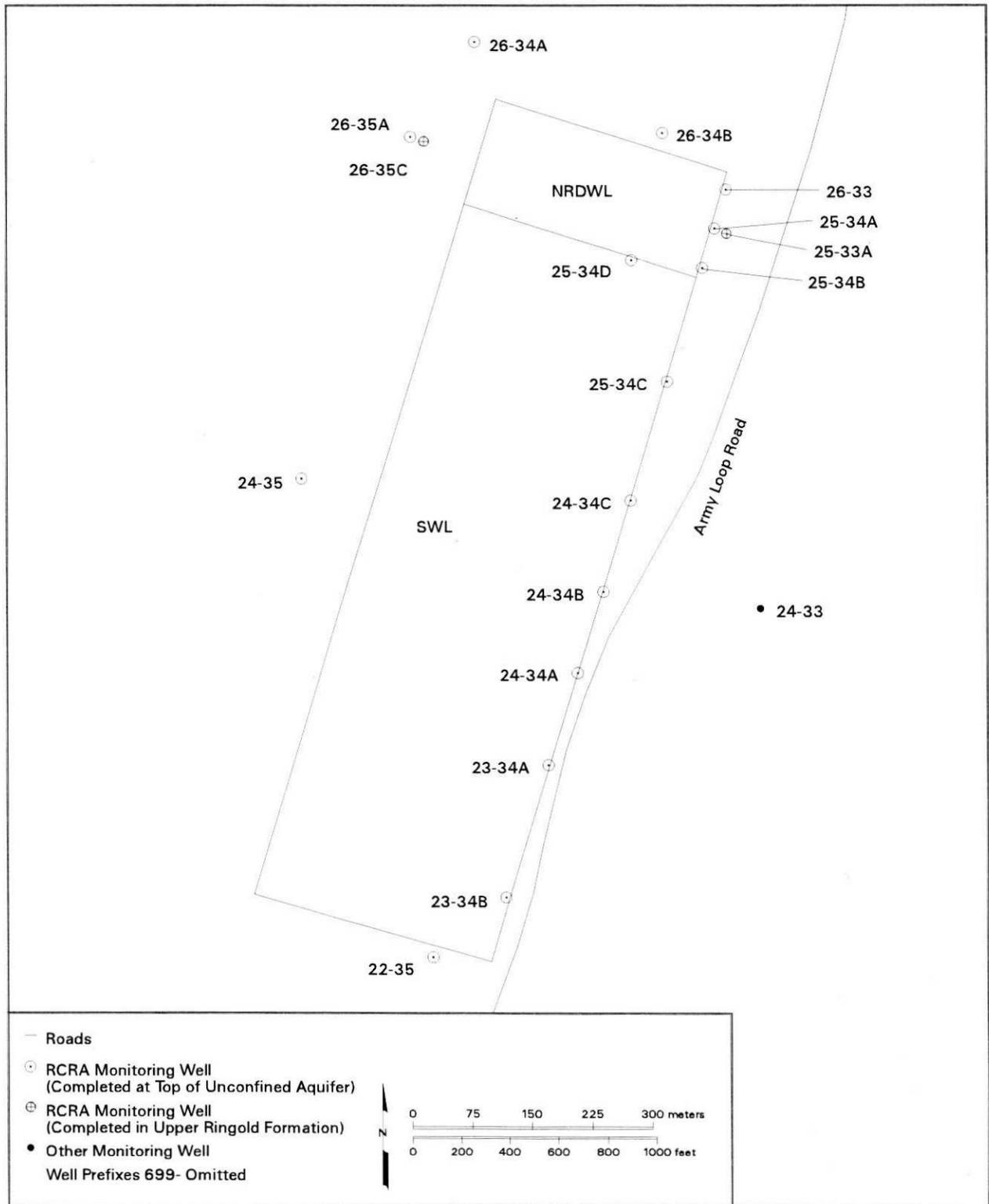


Figure A.22. Monitoring Well Locations for Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill

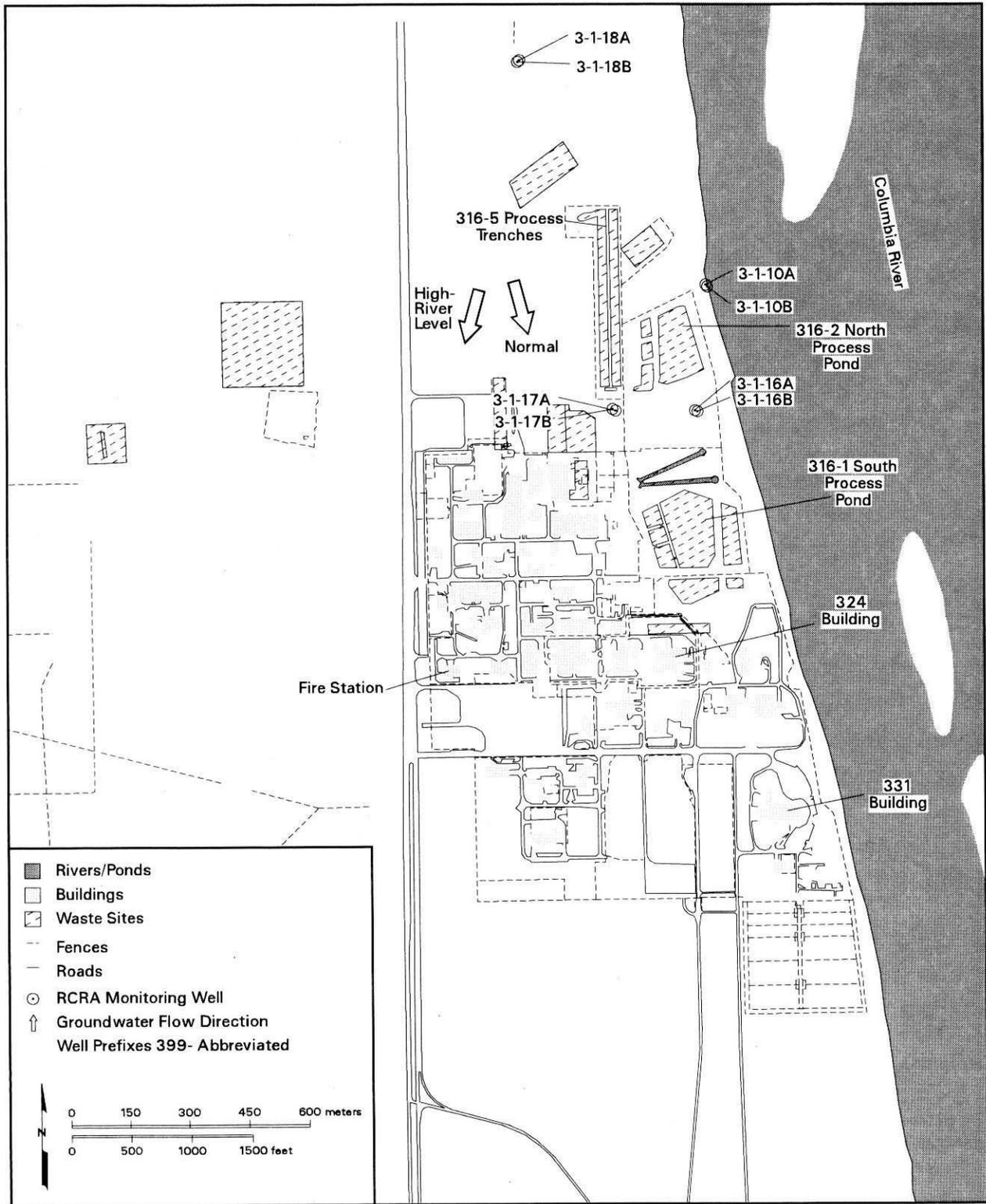


Figure A.23. Monitoring Well Locations for 316-5 Process Trenches

Appendix B

Quality Assurance and Quality Control

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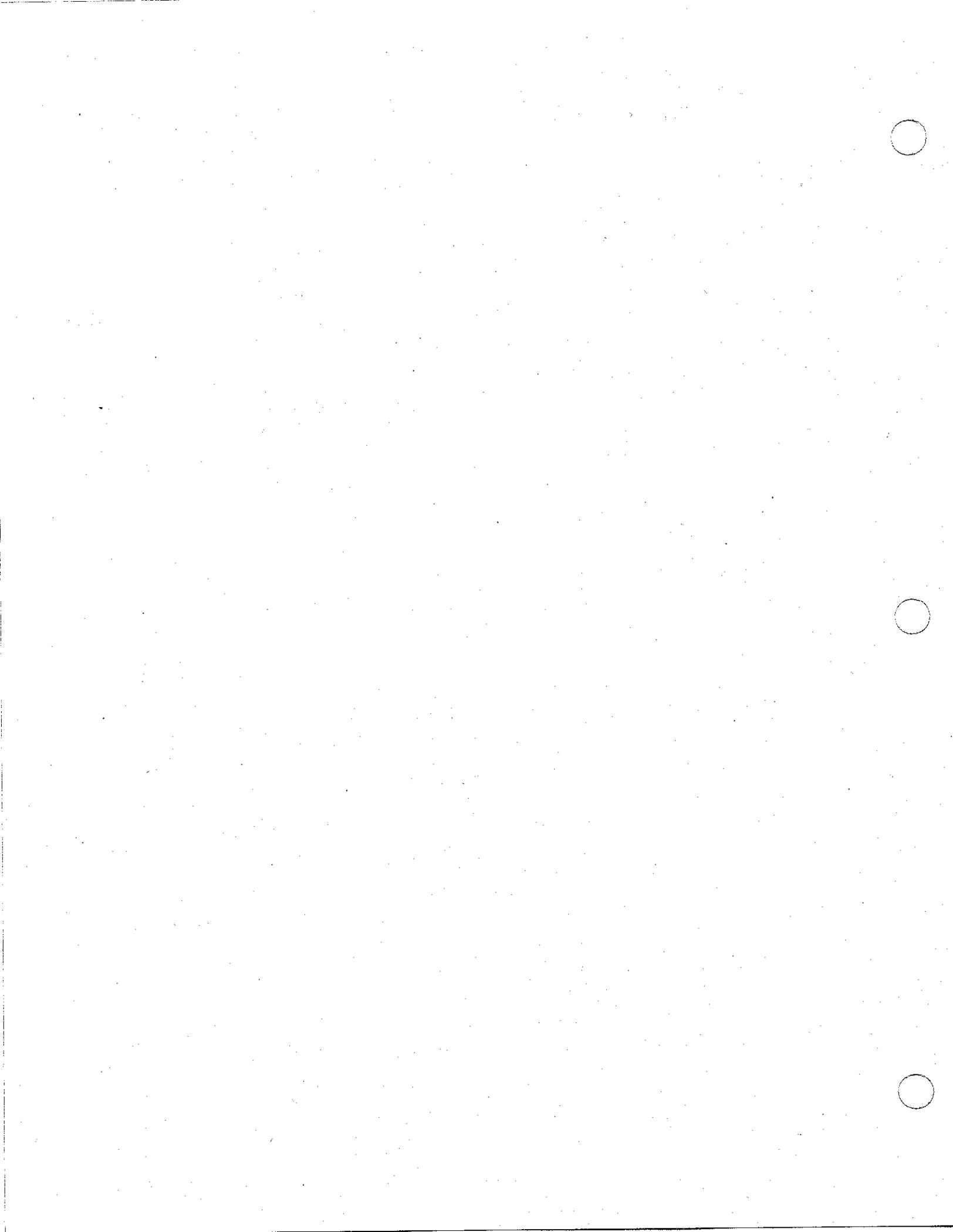
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Appendix B

Quality Assurance and Quality Control

This appendix presents fiscal year 1999 quality assurance/quality control (QA/QC) information for long-term and interim action groundwater monitoring at the Hanford Site. The phrase "long-term monitoring" refers to monitoring performed to meet the requirements of the *Resource Conservation and Recovery Act of 1976 (RCRA)* and the *Atomic Energy Act of 1954*. Long-term monitoring also includes monitoring performed at *Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)* sites with no groundwater remediation. Pacific Northwest National Laboratory (PNNL) manages long-term monitoring via the Hanford Groundwater Monitoring Project (groundwater project). Interim action monitoring encompasses monitoring at sites with active groundwater remediation under CERCLA. Bechtel Hanford, Inc. manages interim action groundwater monitoring.

The QA/QC practices used by the groundwater project assess and enhance the reliability and validity of field and laboratory measurements conducted to support these programs. Accuracy, precision, and detection are the primary parameters used to assess data quality (Mitchell et al. 1985). Representativeness, completeness, and comparability may also be evaluated for overall quality. These parameters are evaluated through laboratory QC checks (e.g., matrix spikes, laboratory blanks), replicate sampling and analysis, analysis of blind standards and blanks, and interlaboratory comparisons. Acceptance criteria have been established for each of these parameters. When a parameter is outside the criteria, corrective actions are taken to prevent a future occurrence.

The QA/QC practices for RCRA samples are based on guidance from the U.S. Environmental Protection Agency (EPA) (OSWER-9950.1; SW-846).

U.S. Department of Energy (DOE) orders and internal requirements provide the guidance for the collection and analysis of samples for long-term monitoring. The QA/QC practices for the groundwater project are described in the project-specific QA plan. Guidance for interim action monitoring QA/QC practices is provided in project-specific documents (e.g., 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 provided in PNNL-13080.

B.1 Sample Collection and Analysis

C. J. Thompson

B.1.1 Sample Collection

Waste Management Federal Services, Inc., Northwest Operations conducted groundwater sampling for fiscal year 1999. Their tasks included bottle preparation, sample set coordination, field measurements, sample collection, sample shipping, well pumping, and coordination of purgewater containment and disposal. Waste Management's statement of work defines quality requirements for sampling activities. Groundwater project staff review all sampling procedures before the procedures are implemented.

B.1.2 Sample Analysis

Quanterra Incorporated, St. Louis, Missouri (Quanterra, St. Louis) performed most routine analyses of hazardous and non-hazardous chemicals for the groundwater project. Recra Environmental, Inc.,

Lionville, Pennsylvania (Recra) served as the project's secondary laboratory for chemical analyses of split samples and blind standards. In contrast, Recra performed the majority of chemical analyses for interim action groundwater monitoring. Quanterra, St. Louis also analyzed samples from sites with active groundwater remediation.

Quanterra Incorporated, Richland, Washington (Quanterra, Richland) served as the primary radiological laboratory for the groundwater project. Thermo NUtech, Richmond, California also performed radiological analyses on long-term monitoring samples. The roles of these laboratories were reversed for interim action groundwater monitoring (i.e., Thermo NUtech served as the primary laboratory, while Quanterra, Richland was used as a backup laboratory).

B.2 Field Quality Control Samples

C. J. Thompson, R. W. Weiss

Field QC samples include field duplicates and three types of field blanks. Field duplicates are used to assess sampling and measurement precision, while field blanks provide an overall measure of contamination introduced during the sampling and analysis process.

B.2.1 Long-Term Monitoring (Hanford Groundwater Monitoring Project)

The groundwater project considers analytical results of field QC samples 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 those field duplicates with at least one result greater than five times the method detection limit or minimum detectable activity are evaluated.
- field blanks – Three kinds of blanks are used to check for contamination that may result from field activities and/or bottle preparation: full trip, field transfer, and equipment blanks. For most chemical constituents, results above two

times the method detection limit are identified as suspected contamination. However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, toluene, and phthalate esters, the limit is five times the method detection limit. For radiological data, blank results are flagged if they are greater than two times the total propagated analytical uncertainty.

If a field blank does not meet the established criteria, it is assumed that there are potential problems with the data for all associated samples. For full-trip and field-transfer blanks, an associated sample is one that was collected on the same day and analyzed by the same method as a full-trip or field-transfer blank. For equipment blanks, an associated sample is one that has all of the following in common with an equipment blank:

- collection date
- collection method/sampling equipment
- analysis method.

Data associated with out-of-limit field blanks are flagged with a Q in the database to indicate a potential contamination problem. A Q is also applied to both duplicate results when their precision exceeds the QC limits.

The percentages of acceptable field blank (92%) and duplicate (98%) results evaluated in fiscal year 1999 were very high, indicating little problem with contamination and good precision overall. Tables B.1 through B.4 summarize the field blank and field duplicate results that exceeded QC limits. To assist with their evaluation, the tables are divided into the following categories, where applicable: general chemical parameters, ammonia and anions, metals, volatile organic compounds, semivolatile organic compounds, and radiological parameters. Constituents not listed in the tables had 100% acceptable field blanks and/or field duplicates.

With the exception of semivolatile organic compounds, all classes of constituents had results that were

flagged as potentially contaminated because of out-of-limit field blank results. Generally, the out-of-limit blank results were less than five times the method detection limit (i.e., below quantifiable limits). However, the majority of the flagged blank results for volatile organics were more than five times greater than the method detection limits, resulting in quantifiable contamination of 2-butanone, carbon disulfide, carbon tetrachloride, chloroform, methylene chloride, and tetrahydrofuran. In general, these compounds had low frequencies of detection (i.e., less than 10%) in field blanks, and the impact on the data is minor. Chloroform and methylene chloride had relatively high percentages of unacceptable field-transfer blanks results (25% and 41%, respectively). Chloroform may have been present in the water used to prepare the field blanks because of incomplete removal by the water-purification system. Methylene chloride is a common laboratory contaminant that was also detected at similar concentrations in several laboratory method blanks. Thus, laboratory contamination is the suspected source of the methylene chloride.

Near the end of fiscal year 1998 and early in fiscal year 1999, PNNL staff observed that the field blank results for total organic carbon were slightly higher than had been observed previously. Twenty-seven percent of the fiscal year 1999 field blank results for total organic carbon were out of limits, though none of the results exceeded the method detection limit by more than a factor of four. Based on this finding, it was postulated that the elevated results were caused by degraded performance of the water-purification system used to prepare reagent water for the field blanks. To test this hypothesis, seven replicate samples of certified, organic-free water, along with seven samples of water from the sampler's water-purification system, were collected throughout the second quarter of fiscal year 1999 and submitted in blind fashion to Quanterra, St. Louis. The samplers also collected additional samples by filling sample bottles with the certified water at the site where full-trip blanks are normally prepared. The purpose of these latter samples was to determine whether field blanks were being contaminated as a result of conditions at the preparation site. The results

from this study were somewhat inconclusive, because the total organic carbon values for each sample type were highly variable and the laboratory changed total organic carbon analyzers approximately midway through the study. However, the data suggest that the water from the water-purification system was not significantly different from the certified, organic-free water. Although the cause of the elevated readings has not been discovered, total organic carbon concentrations in field blanks from the latter half of the year were ~15% lower than values from the first half. Moreover, the number of field blanks with detectable total organic carbon dropped from 65% in the first half of the year to 37% in the second half.

Equipment-blank and full-trip blank results were similar. This suggests that the use of non-dedicated sampling equipment at some wells did not have a significant impact on data quality. However, equipment blanks had higher percentages of out-of-limit results than full-trip blanks for anions and most metals.

The chemical class with the greatest number of out-of-limit field blank results was metals. Most of the unacceptable results were within a factor of two of the QC limits. Many of the out-of-limit values were probably false detections, resulting from the use of the instrument detection limit as a reporting limit for metals. Instrument detection limits do not take into account sample-matrix effects, which can have a negative impact on analyte detection.

Duplicate results were flagged for oil and grease, seven metals, six volatile organic compounds, and two radiological parameters. Overall, the total number of flagged duplicate results was very low, but the percentages of unacceptable results were high for several metals and volatile organic compounds based on the number of duplicates that met the evaluation criteria. Most of the out-of-limit duplicate results appear to be anomalous instances of poor precision based on other QC indicators such as the results from the blind standards and laboratory duplicates (discussed in Sections B.4.2 and B.4.3). In several cases, the laboratory was asked to reanalyze or investigate duplicate results with a very

high relative percent difference, but the checks did not reveal the source of the problem. Especially poor agreement was observed between one or more pairs of results for the following: 25,900 and 2,380 µg/L oil and grease; non-detection and 11.7 µg/L copper; 2,150 and 5,880 µg/L; 1,010 and 350 µg/L iron; and non-detection and 2 µg/L; 0.2 and 4 µg/L chloroform. Mislabeled samples or procedural deviations at the laboratory may have caused the unmatched results.

B.2.2 Interim Action Monitoring

Trained staff collected samples in accordance with approved procedures. Field QC samples were collected and evaluated according to site-specific requirements (e.g., BHI-00038, Rev. 2; DOE/RL-90-08; DOE/RL-91-03; DOE/RL-91-46; DOE/RL-92-76; DOE/RL-96-07; DOE/RL-96-90, Draft A; DOE/RL-97-36, Rev. 2). In general, field QC samples consisted of field duplicates, splits, equipment blanks, and trip blanks. Field QC data are evaluated as necessary to make decisions that may modify or terminate a remedial action. In fiscal year 1999, no evaluations were necessary for decision-making purposes.

Field QC data were examined to monitor laboratory operations and to identify potential problem areas where improvements were necessary. Evaluation criteria were essentially the same as those used for the groundwater project, with the following exceptions:

- The 20% relative percent difference criterion for field duplicate and split sample results was relaxed for sample analytical results near (i.e., typically within five times) the method detection limits.
- Bechtel Hanford, Inc. sent no blind standards as part of interim action monitoring to the commercial laboratories in fiscal year 1999. The great similarity of matrices between the long-term and interim action monitoring samples and common use of the same laboratories make additional analysis of blind standards redundant.

For field blank samples, ~84% of all results were returned as non-detected. Greater than 80% of the reported detected blank results were common metals

(e.g., calcium, iron, manganese, sodium) measured by the inductively coupled plasma method (ICP) at levels close to analysis procedure detection limits. All detected organic constituents (i.e., ~10% of all reported detected results) were common laboratory contaminants seen at very low levels (1 to 4 µg/L). Minimal radioactive contamination was reported, and the results for all detected constituents except tritium were very near analysis detection limits. Two of seven tritium results were above detection limits (values of ~600 and 6,000 pCi/L). Tritium is a known contaminant in some water sources used for preparation of blanks. However, the elevated result of 6,000 pCi/L was probably the result of a swapped sample. Evaluation of other field blank sample results shows no evidence of unexpected or excessive contamination of blanks in the field or by the laboratory. The constituents and levels of contamination found should have no impact on decision making for interim action monitoring. No changes were noted from evaluation of the previous year's blank samples.

Field duplicate and split results showed ~8.5% exceeding the criteria used for evaluation. It should be noted that the criteria used are likely more restrictive than necessary because they are based on similar criteria for laboratory replicate evaluation (i.e., analysis of multiple aliquots from the same sample container by the same laboratory in the same analytical batch). Over one-half of the high relative percent difference results were from iron and vanadium analyses performed by the commercial laboratories. Poor agreement was noted for iron in both interlaboratory and intralaboratory comparisons. Most of the comparisons are at low levels (less than 50 µg/L), and all of the greater concentration samples were on unfiltered samples. Unfiltered samples would be expected to show greater variability because of suspended solids. The vanadium differences were all intralaboratory split samples and were manifested in all but one sample. All results reported were less than 30 µg/L, but in every case, results reported by Quanterra, St. Louis were greater than the split laboratory (Recra). Slightly different analytical technology is being used by the

commercial laboratories (i.e., traditional ICP spectroscopy at Quanterra, St. Louis versus super trace [low detection limits] ICP at Recra). If vanadium analysis at low concentrations becomes of interest, the differences between analytical technology should be investigated. The other differences between the laboratories appear to be essentially random (i.e., the high or low laboratories often switch places for the same analysis on different samples), with the following exception: field volatile organic analysis consistently showed slightly higher results than reported by the commercial laboratories. Most of the results met the criteria, and it would be expected that field analysis, typically performed much closer to the time of sampling, show less loss of volatile components.

Overall evaluation indicates no significant issues between procedures and analyses performed by the laboratories providing services to Bechtel Hanford, Inc. The overall performance for fiscal year 1999 appeared essentially unchanged from the previous year.

B.3 Holding Times

D. S. Sklarew

Holding time is the elapsed time period between sample collection and analysis. Samples should be analyzed within recommended holding times to minimize the possibility of changes in constituent concentrations caused by volatilization, decomposition, or other chemical changes. Samples are also refrigerated to slow potential chemical reactions within the sample matrix. Maximum recommended holding times for constituents frequently analyzed for the groundwater project are listed in Table B.5. Radiological constituents do not have recommended maximum holding times because these constituents do not typically change chemically under ambient temperatures when appropriate preservatives are used. Results of radionuclide analysis are corrected for decay from sampling date to analysis date.

Of the 4,065 non-radiological samples analyzed by Quanterra, St. Louis in fiscal year 1999 for the

groundwater project, holding times were exceeded for 137 samples (3%). The constituents with the most missed holding times were 136 phenols, 118 anions, 37 alkalinity, 25 total dissolved solids, 16 total organic halides, 12 coliform, and 11 total organic carbon. This information was discussed with Quanterra, St. Louis to help the laboratory identify areas where improvements are needed. Recra did not exceed holding times for any of the samples that they analyzed for the groundwater project.

Specific evaluation of adherence to analytical holding times for interim action monitoring was not performed for this report. Analytical holding times are monitored as part of ongoing sample and data management activities throughout the year. No remediation decisions were affected by missed holding times in fiscal year 1999.

B.4 Laboratory Performance

D. S. Sklarew, D. L. Stewart, C. J. Thompson

Laboratory performance is measured by several indicators, including nationally based performance evaluation studies, double-blind standard analyses, laboratory audits, and internal laboratory QA/QC programs. This section provides a detailed discussion of the performance indicators for Quanterra, St. Louis and Richland. Brief summaries of performance measures for Recra and Thermo NUtech are also presented throughout this section.

B.4.1 Nationally Based Performance Evaluation Studies

During fiscal year 1999, EPA, Environmental Resources Associates, and DOE conducted nationally based studies to evaluate laboratory performance for chemical and radiological constituents. Quanterra, St. Louis and Recra participated in the EPA's Water Pollution and Water Supply Performance Evaluation Studies, which ended in December 1998. Environmental Resource Associates is currently conducting similar, EPA sanctioned water pollution and water

supply studies. Although fewer laboratories are participating, both Quanterra, St. Louis and Recra are among the participants. Quanterra, Richland and Thermo NUtech take part in DOE's Quality Assessment Program and EPA's National Exposure Research Laboratory Performance Evaluation Studies. The latter study ended in December 1998. Quanterra, Richland participates in the Environmental Resource Associates' InterLaB RadChem Proficiency Testing Program, which has replaced the National Exposure Research Laboratory studies. All four laboratories take part in DOE's Mixed Analyte Performance Evaluation Program. Results of those studies related to groundwater monitoring at the Hanford Site are described in this section.

B.4.1.1 Water Pollution and Water Supply Studies

The purpose of water pollution and water supply studies is to evaluate the performance of laboratories in analyzing selected organic and inorganic compounds. Every month, standard water samples are distributed as blind standards to participating laboratories. These samples contain specific organic and inorganic analytes at concentrations unknown to the participating laboratories. After analysis, the laboratories submit results to the study's sponsor (i.e., EPA or Environmental Resources Associates). The sponsor uses regression equations to determine acceptance and warning limits for the study participants. The results of these studies, expressed in this report as a percentage of the results that EPA or Environmental Resources Associates found acceptable, independently verify the level of laboratory performance.

For the four studies in which Quanterra, St. Louis participated this year (WS030, WS035, WP040, WP050), the percentage of acceptable results ranged from 84% to 94% (Table B.6). Of the 30 constituents with unacceptable results, 7 were out of limits twice and 1 was out of limits 3 times. This discussion focuses on the results for the eight constituents that were out of limits more than once. Orthophosphate results were unacceptable in both water supply studies and

one water pollution study; the latter was caused by a reporting error. The method required by the EPA for orthophosphate (i.e., Method 365.1, EPA-600/4-79-020, a colorimetric method) is not routinely used for analysis of Hanford Site groundwater samples, which are analyzed by an ion chromatography method. Because the two methods are very different, the unacceptable results should have no effect on the interpretation of data for Hanford Site samples. Alkalinity and Aroclor 1016 were unacceptable in two cases because of reporting errors. Mercury and two volatile organics were unacceptable because of analyst errors. Hardness results were probably unacceptable in one case because the sample was not freshly prepared for analysis and slight evaporation may have caused the high bias. The cause of the second unacceptable hardness result is not known. No reason has been found for the unacceptable kjeldahl nitrogen results; however, no kjeldahl nitrogen determinations were performed on Hanford Site groundwater samples during fiscal year 1999. The other 22 constituents were within limits three out of four times; thus, Quanterra, St. Louis has shown that it can achieve acceptable results for these constituents.

Recra participated in four water pollution and water supply studies this year, WS030, WS035, WP040, and WP048. The percentage of Recra's acceptable results ranged from 90% to 95% (Table B.7). Of the 26 constituents with unacceptable results, 4 were out of limits twice. Total organic carbon was unacceptable in one of the two cases because of a sample preparation error. Recra found no obvious causes for the two unacceptable results for dichlorodifluoromethane, pentachlorophenol, and 1,1-dichloroethylene.

B.4.1.2 DOE Quality Assessment and Mixed Analyte Performance Evaluation Programs

DOE's Quality Assessment Program evaluates how laboratories perform when they analyze radionuclides in water, air filter, soil, and vegetation samples. This discussion considers only water samples. The program is coordinated by the Environmental Measurements Laboratory (EML) in New York. EML provides blind

standards that contain specific amounts of one or more radionuclides to participating laboratories. Constituents analyzed can include americium-241, cesium-137, cobalt-60, gross alpha, gross beta, iron-55, manganese-54, nickel-63, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, and total uranium. After sample analysis, each participating laboratory forwards the results to EML for comparison with known values and with results from other laboratories. EML evaluates the accuracy of the results based on the historical analytical capabilities for the individual analyte/matrix pairs. Using a cumulative normalized distribution, acceptable performance yields results between the 15th and 85th percentiles. Acceptable with warning results are between the 5th and 15th percentile and between the 85th and 95th percentile. Not acceptable results include the outer 10% (less than 5th percentile or more than 95th percentile) of historical data (EML-600, EML-604).

For the two studies conducted this year, QAP49 and QAP50 (EML-600 and EML-604), the percentages of Quanterra, Richland's acceptable results were 100% and 92%, respectively (Table B.8). Uranium-238 was the only constituent that had a result that was not acceptable. However, one constituent (7%) in the first study and five constituents (38%) in the second study had results that were evaluated as acceptable with warning (Table B.8).

The percentages of Thermo NUtech's results that were acceptable for the two studies were 80% and 100%, respectively (Table B.9). Constituents with unacceptable results in the first study were cesium-137, cobalt-60, and manganese-54. Gross alpha results were acceptable with warning in this study.

DOE's Mixed Analyte Performance Evaluation Program examines laboratory performance in the analysis of soil and water samples containing metals, volatile and semivolatile organic compounds, and radionuclides. This report considers only water samples. The program is conducted at the Radiological and Environmental Sciences Laboratory in Idaho Falls, Idaho, and is similar in operation to DOE's Quality

Assessment Program discussed above. DOE evaluates the accuracy of the Mixed Analyte Performance Evaluation Program results for radiological and inorganic samples by determining if they fall within a 30% bias of the reference value.

All fiscal year 1999 results (MAPEP-98-W6) for Quanterra, Richland and St. Louis were acceptable (Table B.8). All results for Thermo NUtech were also acceptable, but plutonium-239/240 was acceptable with warning. Two results (8%) were not acceptable for Recra: acenaphthylene and 2,6-dinitrotoluene (see Table B.9).

B.4.1.3 National Exposure Research Laboratory and InterLaB RadChem Proficiency Testing Program Studies

As of January 1, 1999, the InterLaB RadChem Proficiency Testing Program study, conducted by the Environmental Resources Associates, replaced the EPA's National Exposure Research Laboratory performance evaluation studies, which were conducted at the National Exposure Research Laboratory, Las Vegas, Nevada. Thus, fiscal year 1999 samples were evaluated under either the EPA or the Environmental Resource Associates program. The purpose of the studies was and is to evaluate the performance of laboratories in analyzing selected radionuclides. Both programs provide blind standards that contain specific amounts of one or more radionuclides in a water matrix to participating laboratories. National Exposure Research Laboratory standards and Environmental Resources Associates standards were prepared for the following radionuclides/parameters: barium-133, cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, radium-226, radium-228, strontium-89, strontium-90, tritium, uranium, and zinc-65. In addition, National Exposure Research Laboratory standards were prepared for iodine-131 and plutonium. After sample analysis, the results were forwarded to EPA or Environmental Resources Associates for comparison with known values and with results from other laboratories. EPA evaluated the accuracy of the results by determining if they fell within ± 3 standard deviations of the mean of all

results reported in the intercomparison study (EPA-600/4-81-004). Environmental Resources Associates bases its control limits on the EPA's National Standards for Water Proficiency Testing Studies Criteria Document (NERL-Ci-0045).

All National Exposure Research Laboratory results submitted by Quanterra Richland this year (see Table B.8) were acceptable (95%) with the exception of cesium-134 in one study. However, cesium-134 was below the control limit for 43% of the laboratories reporting for this study. All Environmental Resources Associates results from Quanterra, Richland except one set of data for natural uranium, were within the control limits (94%). Four constituents (24%) in the Environmental Resources Associates study had results that were evaluated as acceptable with warning (see Table B.8).

All National Exposure Research Laboratory results from Thermo NUtech this year were acceptable see Table B.9). Thermo NUtech does not participate in the Environmental Resources Associates program.

B.4.2 Double-Blind Standard Evaluation

The groundwater project forwarded blind QC standards to Quanterra, Richland and St. Louis, Recra, and Thermo NUtech during fiscal year 1999. Blind spiked standards were generally prepared in triplicate and submitted to the laboratories to check the accuracy and precision of analyses. For most constituents, the standards were prepared in a groundwater matrix from a background well. Cyanide standards and one set of volatile organic compound standards in the first quarter of fiscal year 1999 were prepared in organic free, deionized water. In all cases, the standards were submitted to the laboratories in double-blind fashion (i.e., the standards were disguised as regular groundwater samples).

Tables B.10 and B.11 list the number and types of blind standards along with the control limits used in fiscal year 1999. Overall, 84% of the blind spike determinations were acceptable. For Quanterra, 90% of the results were within the control limits, which represents an improvement over fiscal year 1998 (i.e.,

80% were within limits in fiscal year 1998). This improvement is significant, considering that the fiscal year 1999 blind standard program was more focused on those constituents that have had poor results in the past. Fiscal year 1999 was the first year that the groundwater project submitted a complete set of blind standards to Recra and Thermo NUtech. This was done to provide performance information for the project's secondary laboratories.

Quanterra's blind standard results are listed in more detail in Table B.12. One or more results were unacceptably high for gross alpha, gross beta, plutonium-239, total organic carbon, and tritium. Similarly, one or more results were biased low for carbon tetrachloride, cyanide, total organic halides, trichloroethylene, and tritium. Three constituents, carbon tetrachloride, plutonium-239, and trichloroethylene, were out of limits only once; the anomalous results appear to reflect isolated instances of poor analytical precision. Two tritium results were out-of-limits. One was a non-detection result for a standard that had allegedly been spiked at 211,600 pCi/L. Since a re-analysis of the standard confirmed the original result, it is believed that the sample was either mislabeled or was not spiked with tritium. Quanterra, St. Louis' most problematic constituents were gross alpha, gross beta, total organic carbon, and total organic halides. Results for these constituents are discussed below.

Three of sixteen of Quanterra, St. Louis total organic carbon results were out of limits, but most of the total organic carbon results were biased high. The out-of-limit results were from the third and fourth quarters of the fiscal year, and the out-of-limit recoveries ranged from 127% to 133%. The laboratory performed data rechecks on the results and reanalyses on the samples but was unable to identify a reason for the discrepancies. Unlike other blind standard constituents, all of the total organic carbon standards were prepared at concentrations near the laboratory's practical quantitation limit (1,000 µg/L), so a small percentage of out-of-limit results is not unexpected. In the future, the groundwater project will continue to closely monitor Quanterra's performance for this important analysis.

An additional backup laboratory for total organic carbon will also be evaluated if necessary.

Half of Quanterra's total organic halide results were out of limits for the standards that were spiked with volatile organic compounds. Individual out-of-limit recoveries for these standards ranged from 55% to 71%. The groundwater project performed in-house analyses on splits of the standards and confirmed that the standards were spiked at the proper concentrations. Because all of the results for the 2,4,6-trichlorophenol standards were acceptable, the reason for the low bias appears to be volatilization or weak retention of the volatile analytes on the charcoal cartridges used in the analysis. The laboratory investigated the out-of-limit results but was unable to determine the source of error. Low-biased total organic halide results are of concern because of the potential for not detecting halogenated organics at RCRA sites. However, even with a 50% negative bias, detection should occur at concentrations well below the limit of quantitation (discussed in Section B.5).

Quanterra's gross alpha results were acceptable for all but the third quarter. Similarly, all of the gross beta results were within limits except for the second quarter results. For both parameters, the blind standards may have been spiked incorrectly. Splits of the beta standards had similar results at Thermo NUtech, while reanalysis of the gross alpha standards by Quanterra, Richland confirmed two out of three of the results. In general, the results for both parameters exhibited relatively poor precision, but the average results tended to be close to the expected concentrations.

Table B.13 provides a detailed summary of Recra and Thermo NUtech's blind standard results. Seventy-one percent of the results for these laboratories were within control limits, representing good performance overall. However, several high-biased results were reported for total organic carbon, total organic halides, and gross beta. In addition, the labs had two or more unacceptably low results for cyanide and iodine-129. Cyanide results were consistently low for Recra and Quanterra, St. Louis; the problem is believed to be

associated with the standards because both laboratories have had acceptable water supply and water pollution performance-evaluation results for cyanide. The low iodine-129 results were non-detections that were caused by an error at the laboratory. Subsequent iodine-129 standards in the second quarter were spiked at lower concentrations, and all of Thermo NUtech's results were acceptable. Recra's total organic halide results were acceptable, except for the third quarter results that were biased high, and one of the fourth quarter results that was a non-detection. The reasons for these abnormal results are unknown. All of Recra's total organic carbon results were biased high and two-thirds were out of limits. Recra re-analyzed all of the standards with unacceptable results; the re-analysis results were also out of limits. Due to the large number of out-of-limit results, the groundwater project does not plan to submit additional samples to Recra for total organic carbon analyses. Finally, half of Thermo NUtech's gross beta results were unacceptably high. The second quarter results are believed to be high because of incorrectly spiked standards, but the high bias in the first quarter results appears to be a laboratory problem. Quanterra, Richland analyzed splits of the standards and achieved acceptable results.

B.4.3 Laboratory Internal QA/QC Programs

Quanterra, Richland and St. Louis, Thermo NUtech, and Recra maintain internal QA/QC programs that generate data on analytical performance by analyzing method blanks, laboratory control samples, matrix spikes and matrix spike duplicates, matrix duplicates, and surrogates (see PNNL-13080 for definitions of these terms). An assessment of the laboratory QC data for fiscal year 1999 is summarized in this section. Quanterra data are discussed in detail first and presented in Tables B.14 through B.17. Constituents not listed in these tables did not exceed Quanterra's QC limits. A brief summary of Recra and Thermo NUtech data is presented at the end of the section.

Evaluation of results for method blanks was based on the frequency of detection above the blank QC

limits. In general, these limits are two times the method detection limit or instrument detection limit for chemical constituents and two times the total propagated error for radiological components. For common laboratory contaminants such as 2-butanone, acetone, methylene chloride, phthalate esters, and toluene, the QC limit is five times the method detection limit. Table B.14 summarizes Quanterra's method blank results. The general chemical parameters, ammonia and anions, and metals categories had the greatest percentage of method blank results exceeding the QC limits. For the general chemical parameters, only specific conductance showed high method blank results, with 100% above the method detection limit. These high method blanks for conductance do not appear to be a significant problem because 94% of groundwater samples have conductance values that are at least 100 times higher than the highest blank value. For ammonia and anions, only chloride had greater than 10% of the method blanks outside the QC limits. The highest method blank for chloride was 0.194 mg/L, or 2.8 times the QC limit. For metals, the laboratory's instrument detection limits for Method 6010 (the ICP method SW-846) are believed to be unrealistically low, which resulted in the large number of method blanks that exceeded the limits for this method. For volatile organic compounds, only acetone and methylene chloride had greater than 10% of method blanks outside the QC limits. Fewer than 4% of the method blanks for acetone and 1% for methylene chloride exceeded three times the QC limits. Acetone and methylene chloride show frequent blank problems because of low-level background contamination in the laboratories.

To assess the laboratory control samples, QC limits for general chemical parameters, ammonia and anions, and metals were between 80% and 120%; those for radiological parameters were between 70% and 130%. Table B.15 summarizes Quanterra's results for the laboratory control samples. For constituents with 10 or more measurements, none had greater than 10% of laboratory control samples outside of QC limits. Fewer than 3% of the volatile or semivolatile organics were out of limits based on the QC limits that were effective in July. Previous limits were similar but were

not used for statistical data evaluation because the limits were not reported electronically by the laboratory until July.

Table B.16 summarizes Quanterra's results for the matrix spikes and matrix spike duplicates. Matrix spike and matrix spike duplicate QC limits were between 75% and 125% for general chemical parameters, ammonia and anions, and metals. Matrix spike QC limits were between 70% and 130% for radiological parameters. These limits are based on those incorporated into the database starting in July 1999. For the volatile and semivolatile organic compounds, the QC limits that were effective in July were used to evaluate the results, as described above. Fewer than 5% of the volatile or semivolatile organic matrix spikes and matrix spike duplicates were out of limits.

Matrix duplicates were evaluated by comparing the relative percent difference to the QC limit for results that were five times greater than the method detection limit or the minimum detectable activity for general chemical parameters, ammonia and anions, and radiological parameters. The QC limit was 20% for all three categories. Table B.17 lists the constituents that exceeded the relative percent difference limits. Matrix duplicates were not analyzed for volatile organic compounds, semivolatile organic compounds, or metals.

Surrogate data included seven compounds for volatile organics and two for semivolatile organics. Applying the QC limits electronically available from Quanterra as of July 1999, none of the volatile organic surrogate compounds and 16% of the semivolatile organic compounds were outside the QC limits.

QC data for Thermo NUtech and Recra were limited for fiscal year 1999 because these laboratories did not analyze many samples for the groundwater project. Recra analyzed method blanks, laboratory control samples, matrix spikes, and matrix duplicates for total organic carbon, total organic halides, selected anions, metals, and selected volatile organic compounds. Most results were within QC limits. However, the following data were outside limits: one total organic halide laboratory control sample, one trichloroethylene

matrix spike, one silicon matrix spike, one boron and one molybdenum matrix duplicate, and five metal method blanks (barium, calcium, magnesium, sodium, and silicon). Thermo NUtech analyzed method blanks, laboratory control samples, matrix spikes, and matrix duplicates for gross alpha, gross beta, and iodine-129. One iodine-129 matrix duplicate was outside limits.

B.4.3.1 Issue Resolution

Issue resolution forms are documents for recording and resolving problems encountered with sample receipt, sample analysis, and data reporting. The forms are generated by the laboratory and forwarded to the groundwater project as soon as possible after a potential problem is identified. The forms indicate if direction on the part of the project is required. The documentation is intended to identify occurrences, deficiencies, and/or issues that may potentially have an adverse effect on data integrity. Table B.18 indicates the specific issues identified during fiscal year 1999 and the number of times these occurred.

B.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.

Assessments of Quanterra, Richland and St. Louis were conducted December 7 to 10, 1998 and May 6 to 8, 1999, respectively. The Hanford Site's Integrated Contractor Assessment Team, consisting of representatives from Bechtel Hanford, Inc. and Waste Management Federal Services of Hanford, Inc. conducted the audits. The purpose of the assessments was to evaluate the continued readiness of both Quanterra laboratories to analyze and process samples for the Hanford Site. Specific work requirements for the laboratories are specified in the statement of work between Waste Management Federal Services of Hanford, Inc. and Quanterra (RFSH-SOW-93-003, Rev. 5).

The assessment scope for these audits was based on the analytical and QA requirements for both groundwater and multi-media samples as specified in

the statement of work. The primary focus of the Quanterra, Richland audit was personnel training, procedure compliance, sample receipt and tracking, instrument operation and calibration, equipment maintenance, instrumentation records and logbooks, and the implementation of Quanterra's QA management plan. For Quanterra, St. Louis, the focus was on the implementation of their QA program, compliance to their technical operating procedures, and verification of the corrective actions initiated in response to the previous audit (May 1998). The specific areas reviewed included sample preparation, instrument calibration, QC sample data and acceptance criteria, logbook review, and preventive maintenance.

Seven findings and five observations were noted in the assessment of Quanterra, Richland, and ten findings and five observations were identified during the assessment of Quanterra, St. Louis. These findings and observations related to deficiencies in four specific programmatic areas: document control, quality improvement, work processes, and calibration. Corrective-action responses to the assessment findings and observations have been evaluated. The laboratories have addressed all findings and observations, and the audits have been closed.

The Hanford Integrated Contractor Assessment Team conducted an assessment of Quanterra, Richland's sample disposal practices on May 13, 1999. This targeted system assessment was part of the continuing assessments required by the DOE, Richland Operations Office Waste Programs division as a condition of continuance of the commercial laboratory disposal program. General waste handling processes were reviewed, as well as sample handling, personnel qualifications, records, and requirements for waste. Results of the audit indicated that the commercial laboratory has systems in place for processing and managing waste streams. Laboratory staff were knowledgeable and well trained.

Assessments of Thermo NUtech and its subcontractor laboratory, Recra, were conducted by an assessment team consisting of representatives from Bechtel

Hanford, Inc., PNNL, and Waste Management Federal Services of Hanford, Inc., March 18 to 20, 1999 and June 22 to 24, 1999. The scope of these audits focused on the analytical and QA requirements for sample analyses as specified in the contract with the laboratories.

Four findings and eight observations were identified during the audit conducted at Thermo NUtech. The findings and observations were related to lack of procedures, use of instruments past the calibration dates, incomplete training records, and incomplete followup to previous corrective-action responses for past audits. All corrective-action responses have been accepted, and the findings have been closed.

Five findings and ten observations were noted for Recra. These findings and observations were related to procedural non-compliance, lack of procedures, incomplete training records, and reporting and software deficiencies. Closure of this audit is still pending.

Continued assessments of the laboratories are planned for the upcoming year to further evaluate performance and to ensure those corrective actions for the past findings and observations have been implemented.

B.4.3.3 Sample Collection Contractor Surveillances

Groundwater project staff regularly reviewed sample collection activities performed by the sampling sub-contractor, Waste Management Technical Services. The purpose of the reviews was to ensure that samples were collected and submitted to the laboratories in accordance with high-quality standards. Monthly surveillances were conducted in the following areas: sample delivery and shipping, bottle preparation, sample collection, calibration of instruments, standard certifications, procedure implementation, training, and paperwork processing. All issues identified during the surveillances have been corrected.

B.4.4 Data Completeness and Comparability

Data judged to be complete are data that are not suspect, rejected, associated with a missed holding

time, out-of-limit field duplicate or field blank, or qualified to indicate laboratory blank contamination. For fiscal year 1999, 85% of the groundwater project data were considered complete. Potentially invalid data was flagged in the database. The percentages of data flagged were 2.7% for field QC problems, 0.6% for exceeded holding times, 0.2% for rejected results, 0.3% for support values, and 13% for laboratory blank contamination.

For comparability, samples are split in the field (i.e., collected in duplicate) and forwarded to two or more laboratories when problems arise that require confirmation of analytical results. During fiscal year 1999, 10 samples were split for one or more analyses of alkalinity, anions, iodine-129, metals, strontium-90, total dissolved solids, and tritium (27 constituents total). Samples were analyzed for hazardous and non-hazardous chemicals by Quanterra, St. Louis and Recra. Radiological analyses were performed by Quanterra, Richland and Thermo NUtech. None of the split sample results had a relative percent difference greater than 20% for concentrations that were more than five times greater than the analyzing laboratories' detection limits. Thus, the laboratories showed excellent agreement for constituents at mutually quantifiable concentrations, and the split samples were useful for confirming out-of-trend results.

Specific evaluation of completeness and comparability issues for interim action groundwater monitoring was not performed for this report. Completeness and comparability issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in fiscal year 1999.

B.5 Limit of Detection, Limit of Quantitation, and Method Detection Limit

C. J. Chou, C. J. Thompson

Detection and quantitation limits are essential for evaluating data quality and usefulness because they

provide the limits of a method's measurement. The detection limit is the lower limit at which a measurement can be differentiated from background. The quantitation limit is the lower limit where a measurement becomes quantifiably meaningful. The limit of detection, limit of quantitation, and method detection limit are useful for evaluating groundwater data.

The limit of detection is defined as the lowest concentration level statistically different from a blank (Currie 1988). The concentration at which an analyte can be detected depends on the variability of the blank response. For the purpose of this discussion, the blank is taken to be a method blank.

In general, the limit of detection is calculated as the mean concentration in the blank plus three standard deviations of that concentration (EPA/540/P-87/001, OSWER 9355.0-14): The blank-corrected limit of detection is simply three times the blank standard deviation. At three standard deviations from the blank mean, the false-positive and the false-negative error rates are each ~7% (Miller and Miller 1988). A false-positive error is an instance when an analyte is declared to be present but is, in fact, absent. A false-negative error is an instance when an analyte is declared to be absent but is, in fact, present.

The limit of detection for a radionuclide is typically computed from the counting error associated with each reported result (e.g., EPA 520/1-80-012) and represents instrumental or background conditions at the time of analysis. In contrast, the limit of detection and limit of quantitation for the radionuclides shown in Table B.19 are based on variabilities that result from both counting errors and uncertainties introduced by sample handling. In the latter case, distilled water, submitted as a sample, is processed as if it were an actual sample. Thus, any random cross-contamination of the blank during sample processing will be included in the overall error, and the values shown in Table B.17 are most useful for assessing long-term variability in the overall process.

The limit of quantitation is defined as the level above which quantitative results may be obtained

with a specified degree of confidence (Keith 1991). The limit of quantitation is calculated as the blank mean plus 10 standard deviations of the blank (EPA/540/P-87/001, OSWER 9355.014). The blank-corrected limit of quantitation is simply 10 times the blank standard deviation. The limit of quantitation is most useful for defining the lower limit of the useful range of concentration measurement technology. When the analyte signal is 10 times larger than the standard deviation of the blank measurements, there is a 95% probability that the true concentration of the analyte is within $\pm 25\%$ of the measured concentration.

The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero. The method detection limit is determined from analysis of a sample in a given matrix containing the analyte (Currie 1988). The method detection limit is 3.14 times the standard deviation of the results of 7 replicates of a low-level standard. Note that the method detection limit, as defined above, is based on the variability of the response of low-level standards rather than on the variability of the blank response.

For this report, total organic carbon, total organic halides, and radionuclide field blank data are available for limit of detection and limit of quantitation determinations. The field blanks are QC samples that are introduced into a process to monitor the performance of the system. The use of field blanks to calculate the limit of detection and the limit of quantitation is preferred over the use of laboratory blanks because field blanks include error contributions from sample preparation and handling, in addition to analytical uncertainties. Methods to calculate the limit of detection and the limit of quantitation are described in detail in Appendix A of DOE/RL-91-03. The results of the limit of detection and limit of quantitation determinations are listed in Table B.17.

Because of the lack of blank data for other constituents of concern, it was necessary to calculate approximate limit of detection and limit of quantitation values

by using variability information obtained from low-level standards. The data from the low-level standards are obtained from laboratory method detection limit studies. If low-level standards are used, the variability of the difference between the sample and blank response is increased by a factor of $\sqrt{2}$ (Currie 1988, p. 84). The formulas are summarized below:

$$\text{MDL} = 3.14 \times s$$

$$\begin{aligned} \text{LOD} &= 3 \times (\sqrt{2} \times s) \\ &= 4.24 \times s \end{aligned}$$

$$\begin{aligned} \text{LOQ} &= 10 \times (\sqrt{2} \times s) \\ &= 14.14 \times s \end{aligned}$$

where s = standard deviation from the seven replicates of the low-level standard.

The results of limit of detection, limit of quantitation, and method detection limit calculations for most non-radiological constituents of concern (besides total organic carbon and total organic halides) are listed in Table B.20. The values in the table apply to Quanterra, St. Louis only.

Specific evaluation of detection-limit issues for the interim action groundwater monitoring program was not performed for this report. Detection-limit issues are primarily assessed as part of site-specific validation activities. No validation activities were performed on interim action groundwater monitoring data in fiscal year 1999.

B.6 Conclusions

Overall, assessments of fiscal year 1999 QA/QC information indicate that groundwater monitoring data are reliable and defensible. Sampling was conducted in accordance with reviewed procedures. Few contamination or other sampling-related problems were encountered that affected data integrity. Likewise, laboratory performance was excellent in most respects, based on the large percentages of acceptable field and laboratory QC results. Satisfactory laboratory audits and generally acceptable results in nationally-based performance evaluation studies also demonstrated good laboratory

performance. However, the following areas of concern were identified and should be considered when interpreting groundwater monitoring results:

- A few QC samples were probably swapped in the field or at the laboratory based on a small number of unusually high field-blank results and duplicate results with poor precision. The same problem likely occurred for a small number of groundwater samples.
- Several indicator parameters, metals, and volatile organic compounds were detected at low levels in field and/or laboratory method blanks. Some of these constituents were found at similar levels in groundwater samples.
- Maximum recommended holding times were exceeded for ~3% of groundwater project samples. Anions and phenols were the primary analyses affected, though the data impacts are considered minor.
- Quanterra, St. Louis' double-blind standard results for total organic carbon were typically biased ~15% high, while the results for total organic halides (volatiles only) were biased low by ~25%. On average, Recra's total organic carbon results were biased ~40% high.
- Quanterra, Richland's double-blind standard results for gross alpha and gross beta were inconsistent with biases ranging from 16% low to 88% high. Thermo NUtech's results for gross beta were biased high by up to 51%.

B.7 References

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Table B.1. Full-Trip Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits ^(a)	Range of Out-of-Limit Results
General Chemical Parameters					
Alkalinity	1	27	3.7	598 - 4,460 µg/L	8,000 µg/L
Chemical oxygen demand	1	3	33.3	7,638 µg/L	34,000 µg/L
Specific conductance	42	45	93.3	0.09 µS/cm	0.571 - 13 µS/cm
Total carbon	2	3	66.7	512 - 1,416 µg/L	1,520 - 1,960 µg/L
Total dissolved solids	8	14	57.1	8,456 µg/L	9,000 - 31,000 µg/L
Total organic carbon	22	82	26.8	444.4 - 512 µg/L	446 - 1,030 µg/L
Total organic halides	3	74	4.1	4.76 - 8.54 µg/L	5.8 - 15.2 µg/L
Ammonia and Anions					
Chloride	12	47	26.5	69.2 - 70 µg/L	70 - 167 µg/L
Nitrogen in nitrate	4	47	8.5	4 - 21.2 µg/L	22 - 124 µg/L
Sulfate	3	47	6.4	194 - 216 µg/L	239 - 329 µg/L
Metals					
Antimony	1	38	2.6	39.4 - 54.6 µg/L	63.3 µg/L
Beryllium	2	38	5.3	0.4 - 1.4 µg/L	0.52 - 1.4 µg/L
Calcium	11	38	28.9	130.6 - 249 µg/L	250 - 833 µg/L
Copper	4	38	10.5	4.6 - 8 µg/L	4.6 - 9.2 µg/L
Iron	3	38	7.9	60.6 - 71.2 µg/L	78.2 - 528 µg/L
Magnesium	16	38	42.1	68.2 - 201.4 µg/L	73.1 - 1,080 µg/L
Manganese	17	38	44.7	1 - 1.4 µg/L	1.1 - 8.1 µg/L
Potassium	1	38	2.6	1,152 - 3,355.2 µg/L	2,690 µg/L
Sodium	27	38	71.1	88.4 - 239.6 µg/L	245 - 1,120 µg/L
Strontium (elemental)	4	38	10.5	0.8 - 1.4 µg/L	3.2 - 4.9 µg/L
Vanadium	9	38	23.7	7.4 - 9.4 µg/L	8.1 - 25 µg/L
Zinc	13	38	34.2	8.2 - 8.4 µg/L	8.8 - 45.6 µg/L
Volatile Organic Compounds					
Carbon tetrachloride	1	14	7.1	0.05 - 0.904 µg/L	0.4 µg/L
Radiological Parameters					
Gross beta	4	39	10.3	2.2 - 6.36 pCi/L ^(b)	3.15 - 22.7 pCi/L
Tritium	3	41	7.3	30 - 602 pCi/L ^(b)	129 - 1,280 pCi/L

(a) Because method detection limits may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

(b) The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

Table B.2. Field Transfer Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits ^(a) (µg/L)	Range of Out-of-Limit Results (µg/L)
2-Butanone	1	79	1.3	0.84 - 1.78	4
Carbon disulfide	1	79	1.3	0.26 - 0.296	0.4
Carbon tetrachloride	5	88	5.7	0.284 - 0.904	0.4 - 1
Chloroform	22	88	25.0	0.18 - 0.572	0.2 - 4
Methylene chloride	36	88	40.9	1.425 - 3.8	3 - 38
Tetrahydrofuran	1	75	1.3	3.14 - 3.92	17

(a) Because method detection limits may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

Table B.3. Equipment Blanks Exceeding Quality Control Limits

Constituent	Number Out of Limits	Number of Analyses	Percent Out of Limits	Range of QC Limits ^(a)	Range of Out-of-Limit Results
General Chemical Parameters					
Specific conductance	18	20	90.0	0.09 µS/cm	0.865 - 11.7 µS/cm
Total dissolved solids	3	4	75.0	8,456 µg/L	10,000 - 23,000 µg/L
Total organic carbon	6	20	30.0	444.4 - 512 µg/L	460 - 815 µg/L
Total organic halides	2	16	12.5	4.76 - 8.54 µg/L	4.8 - 15.2 µg/L
Ammonia and Anions					
Chloride	11	20	55.0	69.2 - 70 µg/L	71 - 276 µg/L
Fluoride	3	20	15.0	20.8 - 24 µg/L	61 - 86 µg/L
Nitrogen in nitrate	6	20	30.0	4 - 21.2 µg/L	13 - 150 µg/L
Sulfate	2	20	10.0	194 - 216 µg/L	215 - 220 µg/L
Metals					
Barium	2	17	11.8	1.8 - 2.2 µg/L	5.6 - 5.9 µg/L
Calcium	7	17	41.2	130.6 - 249 µg/L	254 - 439 µg/L
Copper	5	17	29.4	4.6 - 8 µg/L	5.7 - 39.7 µg/L
Iron	1	17	5.9	60.6 - 71.2 µg/L	132 µg/L
Magnesium	7	17	41.2	68.2 - 201.4 µg/L	195 - 588 µg/L
Manganese	10	17	58.8	1 - 1.4 µg/L	1.7 - 5.4 µg/L
Nickel	1	17	5.9	20 - 28.6 µg/L	103 µg/L
Sodium	14	17	82.4	88.4 - 239.6 µg/L	234 - 838 µg/L
Strontium (elemental)	1	17	5.9	0.8 - 1.4 µg/L	3.3 µg/L
Vanadium	7	17	41.2	7.4 - 9.4 µg/L	9.7 - 35.6 µg/L
Zinc	7	17	41.2	8.2 - 8.4 µg/L	8.3 - 14.5 µg/L
Volatile Organic Compounds					
Acetone	1	3	33.3	1.65 - 9.7 µg/L	2 µg/L
Carbon disulfide	1	3	33.3	0.26 - 0.296 µg/L	1 µg/L
Chloroform	1	3	33.3	0.18 - 0.344 µg/L	11 µg/L
Radiological Parameters					
Tritium	2	15	13.3	34.8 - 432 pCi/L ^(b)	142 - 147 pCi/L

(a) Because method detection limits may change throughout the year, the limits are presented as a range. However, each result was evaluated according to the method detection limit in effect at the time the sample was analyzed.

(b) The limit for radiological analyses is determined by the sample-specific total propagated uncertainty.

Table B.4. Field Duplicates Exceeding Quality Control Limits

Constituent	Total Number of Duplicates	Number of Duplicates Evaluated ^(a)	Number Out of Limits	Percent Out of Limits	Range of Relative Percent Differences ^(b)
General Chemical Parameters					
Oil and grease	1	1	1	100.0	166.3
Metals					
Chromium	61	27	2	7.4	22.2 - 41.4
Copper	55	1	1	100.0	100
Iron	55	11	6	54.6	37.2 - 97.1
Manganese	55	32	7	21.9	22.8 - 68.9
Potassium	55	17	3	17.7	20.4 - 26.2
Vanadium	55	33	2	6.1	27.4 - 32.8
Zinc	55	14	4	28.6	43.6 - 95.6
Volatile Organic Compounds					
1,1,1-Trichloroethane	17	2	1	50.0	22.2
Acetone	14	1	1	100.0	162
Carbon tetrachloride	17	4	1	25.0	107.7
Chloroform	17	4	2	50.0	181
cis-1,2-Dichloroethylene	17	2	2	100.0	40
Methylene chloride	17	1	1	100.0	28.6
Radiological Parameters					
Gross alpha	42	9	3	33.3	20.2 - 28.5
Technetium-99	17	10	2	20.0	24.3 - 50.0

- (a) Duplicates with both results less than five times the method detection limit or minimum detectable activity were excluded from the evaluation.
- (b) In cases where a non-detected result was compared with a measured value, the method detection limit or minimum detectable activity was used for the non-detected concentration.

Table B.5. Hanford Groundwater Monitoring Project Maximum Recommended Holding Times

Methods	Constituents	Holding Times
8010/8020/8260 (SW-846)	Volatile organics	14 days
8270 (SW-846)	Semivolatile organics	7 days before extraction; 40 days after extraction
8080 (SW-846)	Pesticides	7 days before extraction; 40 days after extraction
8080 (SW-846)	Polychlorinated biphenyls	7 days before extraction; 40 days after extraction
8040 (SW-846)	Phenols	7 days before extraction; 40 days after extraction
6010 (SW-846)	Inductively coupled-plasma metals	6 months
7060 (SW-846)	Arsenic	6 months
7421 (SW-846)	Lead	6 months
7470 (SW-846)	Mercury	28 days
7740 (SW-846)	Selenium	6 months
7841 (SW-846)	Thallium	6 months
9012 (SW-846)	Cyanide	14 days
9020 (SW-846)	Total organic halides	28 days
9060 (SW-846)	Total organic carbon	28 days
300.0 (EPA-600/4-81-004)	Bromide	28 days
300.0 (EPA-600/4-81-004)	Chloride	28 days
300.0 (EPA-600/4-81-004)	Fluoride	28 days
300.0 (EPA-600/4-81-004)	Nitrate	72 hours
300.0 (EPA-600/4-81-004)	Nitrite	72 hours
300.0 (EPA-600/4-81-004)	Phosphate	72 hours
300.0 (EPA-600/4-81-004)	Sulfate	28 days
310.1 (EPA-600/4-81-004)	Alkalinity	14 days
410.4 (EPA-600/4-81-004)	Chemical oxygen demand	28 days

Table B.6. Results of U.S. Environmental Protection Agency Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies

Laboratory	WP030 February 1999 Percent Acceptable	WS035 August 1999 Percent Acceptable	WP040 November 1998 Percent Acceptable	WS050 May 1999 Percent Acceptable
Quanterra Incorporated, St. Louis, Missouri	84 ^(a)	94 ^(b)	85 ^(c)	91 ^(d)

(a) Unacceptable results were for alkalinity, orthophosphate, hardness, turbidity, boron, fluoride, nitrate, nitrite, 2,4,5-T, 2,4-D, 2,4-DB, chlorobenzene, 1,2-dichloroethane, and 1,1,2-trichloroethane.

(b) Unacceptable results were for orthophosphate, mercury, carbon tetrachloride, 1,1,1,2-tetrachloroethane, and 1,2,3-trichloropropane.

(c) Unacceptable results were for alkalinity, kjeldahl-nitrogen, Aroclor 1016/1242 in oil, Aroclor 1254 in oil, benzene, ethylbenzene, toluene, three dichlorobenzenes, and total phenolics.

(d) Unacceptable results were for hardness, orthophosphate, mercury, Aroclor 1016, kjeldahl nitrogen, 1,2-dichlorobenzene, 1,3-dichlorobenzene, tetrachloroethylene, and total suspended solids.

Table B.7. Results of Water Pollution (WP) and Water Supply (WS) Performance Evaluation Studies for Recra Environmental, Inc.

Laboratory	WP040 November 1998 Percent Acceptable	WS030 February 1999 Percent Acceptable	WP048 March 1999 Percent Acceptable	WS035 August 1999 Percent Acceptable
Recra LabNet, Philadelphia	95 ^(a)	94 ^(b)	93 ^(c)	90 ^(d)

- (a) Unacceptable results were for silver, total organic carbon, chemical oxygen demand, and Aroclor 1016/1242 in oil.
- (b) Unacceptable results were for hardness, bis-(2-ethylhexyl)adipate, dichlorodifluoromethane, 1,1,1,2-perchloroethylene, 1,2,3-trichlorobenzene, 1,1-dichloroethylene, methyl-t-butyl ether, dinoseb, pentachlorophenol, 2,4-D, and dicamba.
- (c) Unacceptable results were for cyanide, conductivity, and total organic carbon.
- (d) Unacceptable results were for aluminum, chloride, fluoride, carbon tetrachloride, 1,2-dichlorobenzene, 1,1-dichloroethylene, 1,1,2,2-tetrachloroethane, chloroform, toxaphene, pentachlorophenol, and dichlorodifluoromethane.

Table B.8. Summary of Quanterra Incorporated Interlaboratory Performance, Fiscal Year 1999

Radionuclides	Number of Results Reported for Each	Number Within Acceptable Control Limits
DOE Quality Assessment Program (EML-600, EML-604) Environmental Measurements Laboratory		
Americium-241, cobalt-60, cesium-137, gross alpha, gross beta, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium	2	2 ^(a,b)
Uranium-238	2	1 ^(a)
Manganese-54, nickel-63	1	1 ^(a)
DOE Mixed Analyte Performance Evaluation Program (MAPEP-98-W6) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-137, cobalt-57, manganese-54, nickel-63, plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-235, uranium-238, zinc-65	1	1 ^(c)
Anthracene, antimony, barium, beryllium, chromium, copper, 1,3-dichlorobenzene, 2,4-dichlorophenol, diethylphthalate, 2,4-dimethylphenol, 2,4-dinitrotoluene, 2,6-dinitrotoluene, fluoranthene, fluorene, lead, 2-methylphenol, naphthalene, 4-nitrophenol, phenanthrene, phenol, selenium, thallium, zinc	1	1 ^(d)
EPA Laboratory Intercomparison Studies National Exposure Research Laboratory		
Cesium-137, cobalt-60, gross alpha, gross beta, radium-226, radium-228, uranium	2	2 ^(e)
Cesium-134	2	1 ^(e)
Barium-133, iodine-131, strontium-89, strontium-90, tritium, zinc-65	1	1 ^(e)
EPA InterLaB RadChem Proficiency Testing Program Environmental Resource Associates		
Gross alpha, gross beta, radium-226, radium-228, strontium-90	2	2 ^(f,g)
Uranium	2	1 ^(f)
Cesium-134, cesium-137, cobalt-60, strontium-89, tritium	1	1 ^(f,g)

(a) Control limits from EML-600 and EML-604.

(b) One result each for americium-241, cesium-137, cobalt-60, gross alpha, gross beta, and plutonium-238 was acceptable but outside warning limits.

(c) Results from Quanterra, Richland.

(d) Results from Quanterra, St. Louis.

(e) Control limits from EPA-600/4-81-004.

(f) Control limits from National Standards for Water Proficiency Testing Studies Criteria Document.

(g) One result each for cesium-137, cobalt-60, gross beta, and strontium-89 was acceptable but outside warning limits.

Table B.9. Summary of Recra Environmental, Inc. and Thermo NUtech Interlaboratory Performance, Fiscal Year 1999

<u>Radionuclides</u>	<u>Number of Results Reported for Each</u>	<u>Number Within Acceptable Control Limits</u>
DOE Quality Assessment Program (EML-600, EML-604) Environmental Measurements Laboratory		
Americium-241, gross alpha, gross beta, iron-55, nickel-63, plutonium-238, plutonium-239, strontium-90, tritium, uranium-234, uranium-238, uranium	2	2 ^(a,b)
Cobalt-60, cesium-137	2	1 ^(a)
Manganese-54	1	0 ^(a)
DOE Mixed Analyte Performance Evaluation Program (MAPEP-98-W6) Radiological and Environmental Sciences Laboratory		
Americium-241, cesium-137, cobalt-57, cobalt-60, iron-55, manganese-54, nickel-63, plutonium-238, plutonium-239/240, strontium-90, uranium-234/233, uranium-238, zinc-65	1	1 ^(c,d)
Anthracene, antimony, barium, beryllium, chromium, copper, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 2,4-dichlorophenol, diethylphthalate, 2,4-dimethylphenol, 2,4-dinitrotoluene, fluoranthene, fluorene, lead, 2-methylphenol, 4-nitrophenol, phenanthrene, phenol, selenium, thallium, zinc	1	1 ^(e)
Acenaphthylene	1	0 ^(e)
EPA Laboratory Intercomparison Studies National Exposure Research Laboratory		
Cesium-134, cesium-137, cobalt-60, gross alpha, gross beta, strontium-89, strontium-90	2	2 ^(f)
Barium-133, iodine-131, radium-226, radium-228, uranium, zinc-65	1	1 ^(f)

(a) Results from Thermo NUtech, Richmond, California. Control limits from EML-600 and EML-604.

(b) One result each for gross alpha was acceptable but outside warning limits.

(c) Results from Thermo NUtech, Richmond, California.

(d) One result for plutonium-239/240 was acceptable but outside warning limits.

(e) Results from Recra LabNet, Philadelphia.

(f) Results from Thermo NUtech, Richmond, California. Control limits from EPA-600/4-81-004.

Table B.10. Summary of Quanterra Incorporated Double-Blind Spike Determinations

Constituent	Sample Frequency	Number of Results Reported ^(a)	Number of Results Outside QC Limits ^(b)	Control Limits ^(c) (%)
General Chemical Parameters				
Specific conductance	Annually	3	0	±25
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	16	3	±25
Total organic halides (2,4,6-trichlorophenol spike)	Quarterly	14	0	±25
Total organic halides (carbon tetrachloride, chloroform, and trichloroethene spike)	Quarterly	14	7	±25
Anions				
Cyanide	Quarterly	14	3	±25
Fluoride	Quarterly	12	0	±25
Nitrate	Semiannually	6	0	±25
Metals				
Chromium	Semiannually	6	0	±20
Volatile Organic Compounds				
Carbon tetrachloride	Quarterly	16	1	±25
Chloroform	Quarterly	16	0	±25
Trichloroethylene	Quarterly	16	1	±25
Radiological Parameters				
Gross alpha (plutonium-239 spike)	Quarterly	16	3	±25
Gross beta (strontium-90 spike)	Quarterly	16	3	±25
Cesium-137	Semiannually	6	0	±30
Cobalt-60	Semiannually	6	0	±30
Iodine-129	Semiannually	6	0	±30
Plutonium-239	Quarterly	16	1	±30
Strontium-90	Semiannually	6	0	±30
Technetium-99	Quarterly	16	0	±30
Tritium	Quarterly	9	2	±30
Uranium-238	Quarterly	16	0	±30

(a) Blind standards were submitted in triplicate or quadruplicate.

(b) Quality control limits are given in the Hanford Groundwater Monitoring Project's QA plan.

(c) Each result must be within the specified percentage of the known value to be acceptable.

Table B.11. Summary of Recra Environmental, Inc. and Thermo NUtech Double-Blind Spike Determinations

Constituent	Sampling Frequency	Number of Results Reported ^(a,b)	Number of Results Outside QC Limits ^(c)	Control Limits ^(d) (%)
General Chemical Parameters				
Total organic carbon (potassium hydrogen phthalate spike)	Quarterly	15	10	±25
Total organic halides (2,4,6-trichlorophenol spike)	Quarterly	10	4	±25
Total organic halides (carbon tetrachloride, chloroform, and trichlorethylene spike)	Quarterly	11	4	±25
Anions				
Cyanide	Semiannually	6	4	±25
Fluoride	Annually	3	0	±25
Metals				
Chromium	Annually	3	0	±20
Volatile Organic Compounds				
Carbon tetrachloride	Annually	3	0	±25
Chloroform	Annually	3	0	±25
Trichlorethylene	Annually	3	0	±25
Radiological Parameters				
Gross alpha (plutonium-239 spike)	Semiannually	6	0	±25
Gross beta (strontium-90 spike)	Quarterly	12	6	±25
Cesium-137	Annually	3	0	±30
Cobalt-60	Annually	3	0	±30
Iodine-129	Semiannually	6	2	±30
Plutonium-239	Annually	3	0	±30
Strontium-90	Annually	3	0	±30
Technetium-99	Annually	3	0	±30
Tritium	Annually	3	0	±30
Uranium-238	Annually	3	0	±30

(a) Blind standards were submitted in triplicate or quadruplicate.

(b) Recra Environmental, Inc. performed chemical analyses, and Thermo NUtech performed radiological analyses.

(c) Control limits are given in the Hanford Groundwater Monitoring Project's QA plan.

(d) Each result must be within the specified percentage of the known value to be acceptable.

Table B.12. Quanterra Incorporated Blind Standard Results

Constituent	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
General Chemical Parameters ($\mu\text{g/L}$)					
Specific conductance	Fourth	445	425	96	1
Total organic carbon ^(a)	First	805	808	100	19
	Second	1,002	1,155	115	5
	Third	1,500	1,930	129	4
	Fourth	1,998	2,440	122	4
Total organic halides ^(b) (phenol)	First	1,02.3	86.3	84	0
	Second	1,052	1,023	97	19
	Third	12.9	14.7	114	3
	Fourth	130	113	87	6
Total organic halides ^(c) (volatile organic mixture)	First	103.5	64.3	62	11
	Second	1,088	752.8	69	11
	Third	13.2	12.1	91	13
	Fourth	130	94.7	73	4
Anions ($\mu\text{g/L}$)					
Cyanide	First	100	70.6	71	1
	Second	100	77.6	78	1
	Third	300	237	79	2
	Fourth	400	307	77	1
Fluoride	First	1,000	1,237	124	1
	Second	1,000	1,190	119	1
	Third	5,000	5,283	106	2
	Fourth	2,000	2,353	118	2
Nitrate	First	10,166	10,220	101	2
	Second	10,166	10,600	104	1
Metals ($\mu\text{g/L}$)					
Chromium	First	300	288	96	1
	Second	300	296	99	1
Volatile Organic Compounds ($\mu\text{g/L}$)					
Carbon tetrachloride	First	9.8	9.0	92	11
	Second	414	387	93	6
	Third	5.1	4.3	85	13
	Fourth	51	42.7	84	16
Chloroform	First	98.9	96.7	98	1
	Second	435	460	106	9
	Third	5.1	4.3	85	13
	Fourth	50	47.3	95	1
Trichloroethylene	First	7.9	7.3	93	8
	Second	394	383	97	8
	Third	5	5.3	107	11
	Fourth	50	40.3	81	10

Table B.12. (contd)

Constituent	Fiscal Year Quarter	Spike Amount	Average Result	Average Recovery (%)	Relative Standard Deviation (%)
Radiological Parameters (pCi/L)					
Gross alpha (plutonium-239)	First	21.22	20.8	98	23
	Second	292.22	272	93	6
	Third	6.98	13.1	188	14
	Fourth	101.45	107	106	13
Gross beta (strontium-90) ^(d)	First	13.08	10.9	84	13
	Second	21.29	37.8	178	5
	Third	58.86	64.9	110	24
	Fourth	105.85	121.0	114	4
Cesium-137	First	614.8	643.7	105	6
	Second	197.8	201.0	102	6
Cobalt-60	First	200.46	201.3	100	3
	Second	398.95	399.0	100	1
Iodine-129	First	30.49	29.9	98	14
	Second	24.59	18.8	76	5
Plutonium-239	First	21.224	24.0	113	5
	Second	1.482	1.81	122	18
	Third	6.978	7.02	101	4
	Fourth	1.939	2.38	123	5
Strontium-90	First	7.98	8.99	113	12
	Second	20.15	21.3	106	6
Technetium-99	First	471.5	393.7	83	5
	Second	910.1	880.7	97	7
	Third	202.1	211.3	105	8
	Fourth	97.1	103.4	107	5
Tritium	Second	38,080	36,867	97	1
	Third	211,600	134,310	63	87
	Fourth	199	246	124	18
Uranium-238	First	61.881	61.4	99	5
	Second	144.48	144.0	100	2
	Third	915.726	908.3	99	1
	Fourth	318.21	330.0	104	2

(a) Total organic carbon standards were submitted in quadruplicate each quarter.

(b) Total organic halide (phenol) standards were submitted in quadruplicate during the first and fourth quarters. The standards were submitted in triplicate in the second and third quarters.

(c) Total organic halide (volatile) standards were submitted in triplicate during the first and fourth quarters. The standards were submitted in quadruplicate in the second and third quarters.

(d) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

Table B.13. Recra Environmental, Inc. and Thermo NUtech Blind Standard Results

Constituent	Fiscal Year Quarter	Spike Amount	Average Result ^(a)	Average Recovery (%)	Relative Standard Deviation (%)
General Chemical Parameters (µg/L)					
Total organic carbon ^(b)	First	805	978	121	3
	Second	1,002	1,600	160	7
	Third	1,500	1,933	129	13
	Fourth	1,998	2,975	149	8
Total organic halides ^(c) (phenol)	Second	1,052	1,150	109	8
	Third	12.9	21.9	170	10
	Fourth	130	88.8	68	59
Total organic halides ^(d) (volatile organic mixture)	Second	1,088	1,063	98	8
	Third	13.2	21.4	162	19
	Fourth	130	102	78	4
Anions (µg/L)					
Cyanide	Second	100	74.0	74	5
	Fourth	400	277	69	17
Fluoride	Second	1,000	1,100	110	0
Metals (µg/L)					
Chromium	Second	300	302	101	2
Volatile Organic Compounds (µg/L)					
Carbon tetrachloride	Second	414	383	93	6
Chloroform	Second	435	410	94	2
Trichlorethylene	Second	394	333	85	2
Radiological Parameters (pCi/L)					
Gross alpha (plutonium-239)	Second	292.22	278.3	95	8
	Fourth	101.45	94.6	93	15
Gross beta (strontium-90) ^(e)	First	13.08	19.8	151	8
	Second	21.29	30.5	143	8
	Third	58.86	68.9	117	1
	Fourth	104.52	114.7	110	4
Cesium-137	Second	197.8	193.7	98	3
Cobalt-60	Second	398.95	361.0	90	5
Iodine-129	First	30.49	14.8	49	73
	Second	24.59	24.6	100	13
Plutonium-239	Second	1.482	1.26	85	7
Strontium-90	Second	20.15	19.8	98	5
Technetium-99	Second	910.1	998.7	110	2
Tritium	Second	38,080	39,030	103	1
Uranium-238	Second	144.48	167.0	116	1

(a) Recra Environmental, Inc. performed chemical analyses, and Thermo NUtech performed radiological analyses.

(b) Total organic carbon standards were submitted in quadruplicate each quarter.

(c) Total organic halide (phenol) standards were submitted in triplicate during the second and third quarters and in quadruplicate during the fourth quarter.

(d) Total organic halide (volatile) standards were submitted in quadruplicate during the second and third quarters and in triplicate during the fourth quarter.

(e) Assuming strontium-90 and yttrium-90 are in equilibrium, spike amount is strontium-90 + yttrium-90.

Table B.14. Quanterra Incorporated Method Blank Results

Constituent	Percent Out of Limit	Number of Analyses	Concentration Range of Out-of-Limit Results
General Chemical Parameters			
Total general chemical parameters	15.6	688	--
Alkalinity	0.9	112	5.6 mg/L
Specific conductance	100	105	0.317 - 1.04 μ S/cm
Total dissolved solids	1.4	74	39 mg/L
Ammonia and Anions			
Total ammonia and anions	5.7	1,104	--
Chloride	26.2	210	0.07 - 0.194 mg/L
Fluoride	2.0	204	0.037 - 0.063 mg/L
Sulfate	1.9	213	0.234 - 0.277 mg/L
Metals			
Total metals	14.4	2,028	--
Aluminum	55.9	102	39 - 161 mg/L
Calcium	51.0	102	27.1 - 492 mg/L
Chromium	0.9	106	7.1 mg/L
Copper	11.8	102	5.9 - 11.7 mg/L
Iron	89.2	102	12.8 - 91.8 mg/L
Magnesium	11.8	102	123 - 276 mg/L
Manganese	5.9	102	1.1 - 2.5 mg/L
Sodium	24.5	102	59.4 - 241 mg/L
Vanadium	5.9	102	6.1 - 14.3 mg/L
Zinc	29.4	102	3.2 - 17 mg/L
Volatile Organic Compounds			
Total volatile organic compounds	2.0	2,696	--
Acetone	33.0 ^(b)	106	2 - 19 mg/L
2-Butanone	0.9 ^(b)	106	4 mg/L
1,4-Dichlorobenzene	0.8	123	0.4 mg/L
Methylene chloride	12.6 ^(b)	119	2 - 15 mg/L
Vinyl chloride	1.7	119	0.3 mg/L
Semivolatile Organic Compounds			
Total semivolatile organic compounds	0	832	--
Radiological Parameters			
Total radiological parameters	0.2	1,076	--
Technetium-99	1.4	70	54.9 pCi/L
Tritium	1.2	82	23.6 pCi/L

(a) Control limits are twice the method detection limit.

(b) Control limits for footnoted compounds are five times the method detection limit.

Table B.15. Quanterra Incorporated Laboratory Control Samples

Constituent	Percent Out of Limit ^(a)	Number of Analyses
General Chemical Parameters		
Total general chemical parameters	0	706
Ammonia and Anions		
Total ammonia and anions	0	1,101
Metals		
Total metals	0.1	2,030
Silver	2.0	102
Radiological Parameters		
Total radiological parameters	2.1	708
Cesium-137	1.8	56
Cobalt-60	1.8	57
Gross alpha	6.8	73
Technetium-99	5.7	70
Tritium	0.9	109
Uranium	1.6	61
Uranium-235	28.6	7

(a) QC limits are 80% to 120% for general chemical parameters, ammonia and anions, and metals; 70% to 130% for radiological parameters.

Table B.16. Quanterra Incorporated Matrix Spikes and Matrix Spike Duplicates

Constituent	Percent Out of Limit ^(a)	Number of Analyses
General Chemical Parameters		
Total general chemical parameters	4.2	212
Total carbon	83.3	6
Total organic carbon	0.9	115
Total organic halides	3.3	91
Ammonia and Anions		
Total ammonia and anions	16.2	468
Chloride	10.8	83
Cyanide	6.9	29
Fluoride	12.0	83
Nitrogen in nitrate	33.7	83
Nitrogen in nitrite	18.1	83
Sulfate	12.6	87
Sulfide	100	1
Metals		
Total metals	0.5	3,147
Cadmium	0.6	161
Chromium	1.2	163
Copper	1.3	157
Iron	1.3	157
Lead	11.1	54
Selenium	50.0	4
Sodium	0.6	157
Zinc	0.6	157
Radiological Parameters		
Total radiological parameters	15.6	122
Technetium-99	6.3	64
Uranium	25.9	58

(a) Control limits are 75% to 125% for general chemical parameters, ammonia and anions, and metals; 70% to 130% for radiological parameters.

Table B.17. Quanterra Incorporated Matrix Duplicates

Constituent	Percent Out of Limit ^(a)	Number of Analyses
General Chemical Parameters		
Total general chemical parameters	0.5	400
Specific conductance	1.3	75
Total carbon	16.7	6
Total organic halides	1.1	91
Ammonia and Anions		
Total ammonia and anions	0.6	459
Fluoride	1.2	81
Nitrogen in nitrate	1.2	81
Sulfate	1.2	85
Radiological Parameters		
Total radiological parameters	0.9	1,128
Gross alpha	1.4	70
Gross beta	1.4	71
Iodine-129	5.9	34
Plutonium-239/240	8.3	12
Strontium-90	1.8	56
Technetium-99	1.5	68
Uranium-234	14.3	7
Uranium-235	14.3	7
Uranium-238	14.3	7

(a) For values five times greater than the method detection limit, control limits for relative percent difference are 20% for general chemical parameters, ammonia and anions, and radiological parameters.

Table B.18. Summary of Issue Resolution Forms Received for Fiscal Year 1999

Issue	Number of Occurrences
Hold time missed	34
Broken bottles ^(a)	11
Missing samples ^(a)	6
Temperature deviation ^(a)	7
pH variance ^(a)	3
Bottle size/type (insufficient volume)	4
Chain of custody forms incomplete ^(a)	16
Laboratory QC out of limits	29
Analytical preparation deviations	5
Method failures/discontinued analyses	7

(a) Issue always originated before samples were received at the laboratory.

Table B.19. Summary of Quanterra Incorporated Detection/Quantitation Limits Determined from Field Blanks Data

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Total Organic Carbon ($\mu\text{g/L}$)					
10/01/98 - 12/29/98	22 ^(a)	225.89	121.44	590 ^(b)	1,440 ^(b)
01/19/99 - 02/23/99	8 ^(a)	325.47	80.80	568	1,133
02/24/99 - 03/18/99	12 ^(a)	141.21	166.36	499 ^(c)	1,664 ^(c)
04/19/99 - 06/28/99	14 ^(a)	163.03	156.78	470	1,568
07/14/99 - 08/24/99	13	122.89	115.37	346	1,154
Summary	69	190.55	165.93	400	1,334
Constituent: Total Organic Halides ($\mu\text{g/L}$)					
10/01/98 - 12/29/98	25	0.18	2.24	6.7 ^(c)	22.4 ^(c)
01/19/99 - 03/18/99	25 ^(a)	1.37	1.40	4.2	14.0
04/19/99 - 06/28/99	16	-0.38	1.62	4.8	16.2
07/14/99 - 08/24/99	13	0.66	1.79	5.4	17.9
Summary	79	0.52	1.81	5.4	18.1
Constituent: Antimony-125 (pCi/L)					
10/13/98 - 12/16/98	6	-1.52	3.43	10.28 ^(c)	34.26 ^(c)
04/01/99 - 06/02/99	6	0.47	5.10	15.29	50.98
07/13/99 - 08/16/99	3	1.59	3.96	11.88	39.62
Summary	15	-0.10	4.28	12.8	42.8
Constituent: Cesium-134 (pCi/L)					
10/13/98 - 12/16/98	6	-1.61	0.91	2.74 ^(c)	9.14 ^(c)
04/01/99 - 06/02/99	6	-0.29	0.81	2.43	8.09
07/13/99 - 08/16/99	3	-2.15	2.40	7.20	23.99
Summary	15	-1.19	1.26	3.77	12.57
Constituent: Cesium-137 (pCi/L)					
10/13/98 - 12/16/98	6	0.92	0.54	1.62 ^(c)	5.40 ^(c)
04/01/99 - 06/02/99	6	0.01	1.33	3.98	13.28
07/13/99 - 08/16/99	3	-0.54	1.06	3.19	10.63
Summary	15	0.26	1.02	3.07	10.22
Constituent: Cobalt-60 (pCi/L)					
10/13/98 - 12/16/98	6	0.00	0.45	1.34 ^(c)	4.46 ^(c)
04/01/99 - 06/02/99	6	0.59	1.52	4.56	15.2
07/13/99 - 08/16/99	3	-0.23	1.09	3.27	10.89
Summary	15	0.19	1.11	3.34	11.5
Constituent: Europium-154 (pCi/L)					
10/13/98 - 12/16/98	6	0.13	3.23	9.69 ^(c)	32.30 ^(c)
04/01/99 - 06/02/99	6	1.14	2.64	7.91	26.37
07/13/99 - 08/16/99	3	-2.36	3.97	11.90	39.66
Summary	15	0.03	3.14	9.42	31.41
Constituent: Gross Alpha (pCi/L)					
10/01/98 - 12/29/98	15	0.143	0.233	0.70 ^(c)	2.33 ^(c)
01/06/99 - 03/16/99	11	0.065	0.164	0.49	1.64
04/12/99 - 06/28/99	11	0.051	0.168	0.5	1.68
07/13/99 - 08/19/99	6	0.061	0.168	0.5	1.68
Summary	43	0.088	0.193	0.58	1.93

Table B.19. (contd)

Period	Number of Samples	Mean	Standard Deviation	Limit of Detection	Limit of Quantitation
Constituent: Gross Beta (pCi/L)					
10/01/98 - 12/29/98	14 ^(a)	0.79	0.83	2.50 ^(c)	8.34 ^(c)
01/06/99 - 03/31/99	11	0.96	0.84	2.51	8.36
04/07/99 - 06/28/99	12 ^(a)	1.00	0.87	2.61	8.72
07/13/99 - 08/24/99	7	0.93	1.05	3.16	10.53
Summary	44	0.91	0.88	2.64	8.81
Constituent: Iodine-129 (pCi/L)					
10/13/98 - 11/19/98	5	0.028	0.167	0.50 ^(c)	1.67 ^(c)
01/06/99 - 03/16/99	3	0.045	0.097	0.29	0.97
04/12/99 - 06/23/99	5	0.001	0.056	0.17	0.56
07/13/99 - 07/14/99	2	0.059	0.022	0.07	0.22
Summary	15	0.026	0.114	0.34	1.14
Constituent: Strontium-90 (pCi/L)					
10/13/98 - 12/16/98	6	0.096	0.145	0.43 ^(c)	1.45 ^(c)
01/06/99 - 02/01/99	3	-0.005	0.058	0.17	0.58
04/12/99 - 05/25/99	2	0.137	0.001	0.00	0.01
08/11/99 - 08/24/99	2	0.129	0.010	0.03	0.10
Summary	13	0.084	0.111	0.33	1.11
Constituent: Technetium-99 (pCi/L)					
10/01/98 - 12/29/98	8	3.01	3.41	10.23 ^(c)	34.12 ^(c)
02/01/99 - 03/31/99	3	11.60	7.81	23.43	78.09
04/07/99 - 06/23/99	7	1.67	4.32	12.95	43.16
07/13/99 - 08/24/99	5	-2.85	6.49	19.47	64.90
Summary	23	2.45	5.05	15.14	50.50
Constituent: Tritium (pCi/L)					
10/13/98 - 12/29/98	15	188.4	162.2	486.5 ^(c)	1,621.8 ^(c)
01/06/99 - 03/16/99	13 ^(a)	169.4	71.5	214.4	714.7
04/01/99 - 06/23/99	12	76.4	83.8	251.5	838.3
07/13/99 - 08/24/99	7	146.9	153.8	461.4	1,538.1
Summary	47	148.4	122.8	368.5	1,228.3
Constituent: Uranium (µg/L)					
10/01/98 - 12/29/98	6	0.0137	0.0141	0.056 ^(b)	0.155 ^(b)
01/14/99 - 03/31/99	5	0.0104	0.0117	0.045	0.127
04/07/99 - 06/09/99	4	0.0079	0.0055	0.024	0.063
08/16/99 - 08/24/99	2	0.0030	0.0006	0.005	0.009
Summary	17	0.010	0.011	0.044	0.122

(a) Excluded outliers.

(b) Limit of detection equals the mean blank concentration plus 3 standard deviations; limit of quantitation equals the mean blank concentration plus 10 standard deviations.

(c) Limit of detection (blank corrected) equals 3 times the blank standard deviation; limit of quantitation (blank corrected) equals 10 times the blank standard deviation.

Table B.20. Summary of Quanterra Incorporated, St. Louis Detection and Quantitation Limits

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
General Chemical Parameters								
EPA-600/4-81-004, 160.1	Total dissolved solids	4,228	5,713	19,042				
EPA-600/4-81-004, 310.1	Alkalinity	299	404	1,347	11/16/98	2230	3013	10044
EPA-600/4-81-004, 410.4	Chemical oxygen demand	3,819	5,160	17,200				
EPA-600/4-81-004, 413.1	Oil and grease	699	944	3,148				
Ammonia and Anions								
EPA-600/4-81-004, 300.0	Bromide	15	20.3	67.6	12/22/98	17.4	23.5	78.4
EPA-600/4-81-004, 300.0	Chloride	35	47.3	157.6	12/22/98	34.6	46.8	155.8
EPA-600/4-81-004, 300.0	Fluoride	12	16.2	54.0	12/22/98	10.4	14.1	46.8
EPA-600/4-81-004, 300.0	Nitrogen in nitrate	2	2.7	9.0	12/22/98	10.6	14.3	47.7
EPA-600/4-81-004, 300.0	Nitrogen in nitrite	17	23.0	76.6	12/22/98	7.4	10.0	33.3
EPA-600/4-81-004, 300.0	Phosphate	42	56.7	189	12/22/98	34.8	47.0	157
EPA-600/4-81-004, 300.0	Sulfate	97	131	437	12/22/98	108	146	486
EPA-600/4-81-004, 350.1	Nitrogen in ammonia	8.76	11.8	39.5	12/10/98	30.1	40.67	135.6
SW-846, 9012	Cyanide	1.33	1.80	5.99	12/7/98	1.59	2.15	7.16
Metals								
SW-846, 6010	Aluminum	38	51.3	171	7/25/99	26.5	35.8	119
SW-846, 6010	Antimony	27.3	36.9	123	7/25/99	19.7	26.6	88.7
SW-846, 6010	Barium	1.1	1.5	5.0	7/25/99	0.9	1.2	4.1
SW-846, 6010	Beryllium	0.7	0.9	3.2	7/25/99	0.2	0.3	0.9
SW-846, 6010	Cadmium	2.2	3.0	9.9	7/25/99	2	2.7	9.0
SW-846, 6010	Calcium	124.5	168.2	560.7	7/25/99	65.3	88.2	294
SW-846, 6010	Chromium	2.7	3.6	12.2	7/25/99	2.7	3.6	12.2
SW-846, 6010	Cobalt	2.3	3.1	10.4	7/25/99	2.5	3.4	11.3
SW-846, 6010	Copper	2.3	3.1	10.4	7/25/99	4	5.4	18.0
SW-846, 6010	Iron	35.6	48.1	160	7/25/99	30.3	40.9	137
SW-846, 6010	Lead	37.3	50.4	168	7/25/99	9	12.2	40.5
SW-846, 6010	Magnesium	34.1	46.1	154	7/25/99	100.7	136.1	453.5
SW-846, 6010	Manganese	0.7	0.9	3.2	7/25/99	0.5	0.7	2.3
SW-846, 6010	Nickel	14.3	19.3	64.4	7/25/99	10	13.5	45.0
SW-846, 6010	Potassium	1,677.6	2,266.7	7,555.7	7/25/99	576	778	2,594
SW-846, 6010	Silver	3.8	5.1	17.1	7/25/99	8	10.8	36.0
SW-846, 6010	Sodium	119.8	161.9	539.6	7/25/99	44.2	59.7	199
SW-846, 6010	Strontium (elemental)	0.7	0.9	3.2	7/25/99	0.4	0.5	1.8
SW-846, 6010	Tin	70	94.6	315	7/25/99	27	36.5	122
SW-846, 6010	Vanadium	3.7	5.0	16.7	7/25/99	4.7	6.4	21.2
SW-846, 6010	Zinc	4.1	5.5	18.5	7/25/99	4.2	5.7	18.9

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 7060	Arsenic	2	2.70	9.01				
SW-846, 7131	Cadmium	0.2	0.27	0.90				
SW-846, 7191	Chromium	0.3	0.41	1.35				
SW-846, 7421	Lead	0.8	1.08	3.60				
SW-846, 7470	Mercury	0.011	0.015	0.050				
SW-846, 7740	Selenium	0.9	1.22	4.05				
SW-846, 7841	Thallium	0.6	0.81	2.70				
Volatile Organic Compounds								
SW-846, 8010	1,1,1-Trichloroethane	0.028	0.038	0.126				
SW-846, 8010	1,1,2-Trichloroethane	0.036	0.049	0.162				
SW-846, 8010	1,1-Dichloroethane	0.024	0.032	0.108				
SW-846, 8010	1,2-Dichloroethane	0.018	0.024	0.081				
SW-846, 8010	1,4-Dichlorobenzene	0.026	0.035	0.117				
SW-846, 8010	Carbon tetrachloride	0.025	0.034	0.113				
SW-846, 8010	Chloroform	0.028	0.038	0.126				
SW-846, 8010	cis-1,2-Dichloroethylene	0.025	0.034	0.113				
SW-846, 8010	Methylene chloride	0.207	0.280	0.932				
SW-846, 8010	Tetrachloroethylene	0.031	0.042	0.140				
SW-846, 8010	trans-1,2-Dichloroethylene	0.031	0.042	0.140				
SW-846, 8010	Trichloroethylene	0.028	0.038	0.126				
SW-846, 8010	Vinyl chloride	0.294	0.397	1.324				
SW-846, 8020	1,4-Dichlorobenzene	0.028	0.038	0.126	11/16/98	0.52	0.703	2.342
SW-846, 8020	Benzene	0.042	0.057	0.189	11/16/98	0.26	0.351	1.171
SW-846, 8020	Ethylbenzene	0.033	0.045	0.149	11/16/98	0.31	0.419	1.396
SW-846, 8020	Toluene	0.089	0.120	0.401	11/16/98	0.81	1.094	3.648
SW-846, 8020	Xylenes (total)	0.065	0.088	0.293	11/16/98	0.59	0.797	2.657
SW-846, 8260	1,1,1,2-Tetrachloroethane	0.1134	0.153	0.511	1/27/99	0.2	0.270	0.901
SW-846, 8260	1,1,1-Trichloroethane	0.178	0.241	0.802	1/27/99	0.14	0.189	0.631
SW-846, 8260	1,1,2,2-Tetrachloroethane	0.3	0.405	1.351	1/27/99	0.13	0.176	0.586
SW-846, 8260	1,1,2-Trichloroethane	0.1	0.135	0.450	1/27/99	0.23	0.311	1.036
SW-846, 8260	1,1-Dichloroethane	0.2	0.270	0.901	1/27/99	0.13	0.176	0.586
SW-846, 8260	1,1-Dichloroethylene	0.194	0.262	0.874	1/27/99	0.15	0.203	0.676
SW-846, 8260	1,2,3-Trichloropropane	0.1546	0.209	0.696	1/27/99	0.24	0.324	1.081
SW-846, 8260	1,2-Dibromo-3-chloropropane	0.24	0.324	1.081	1/27/99	0.32	0.432	1.441
SW-846, 8260	1,2-Dibromoethane	0.068	0.092	0.306	1/27/99	0.13	0.176	0.586
SW-846, 8260	1,2-Dichloroethane	0.144	0.195	0.649	1/27/99	0.14	0.189	0.631
SW-846, 8260	1,2-Dichloroethylene (total)	0.1028	0.139	0.463	1/27/99	0.24	0.324	1.081
SW-846, 8260	1,2-Dichloropropane	0.2	0.270	0.901	1/27/99	0.1	0.135	0.450

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8260	1,4-Dichlorobenzene	0.184	0.249	0.829	1/27/99	0.17	0.230	0.766
SW-846, 8260	1-Butanol	2.52	3.405	11.35	1/27/99	7	9.458	31.53
SW-846, 8260	2-Butanone	0.42	0.567	1.892	1/27/99	0.89	1.203	4.008
SW-846, 8260	2-Hexanone	0.36	0.486	1.621	1/27/99	0.44	0.595	1.982
SW-846, 8260	4-Methyl-2-pentanone	0.19	0.257	0.856	1/27/99	0.15	0.203	0.676
SW-846, 8260	Acetone	1.94	2.621	8.737	1/27/99	0.33	0.446	1.486
SW-846, 8260	Acetonitrile	4.7	6.350	21.17	1/27/99	4.4	5.945	19.82
SW-846, 8260	Acrolein	4.28	5.783	19.28	1/27/99	5.07	6.850	22.83
SW-846, 8260	Acrylonitrile	1.7	2.297	7.66	1/27/99	1.01	1.365	4.55
SW-846, 8260	Benzene	0.168	0.227	0.757	1/27/99	0.13	0.176	0.586
SW-846, 8260	Bromodichloromethane	0.0998	0.135	0.449	1/27/99	0.08	0.108	0.360
SW-846, 8260	Bromoform	0.072	0.097	0.324	1/27/99	0.14	0.189	0.631
SW-846, 8260	Bromomethane	0.28	0.378	1.261	1/27/99	0.11	0.149	0.495
SW-846, 8260	Carbon disulfide	0.148	0.200	0.667	1/27/99	0.13	0.176	0.586
SW-846, 8260	Carbon tetrachloride	0.142	0.192	0.640	1/27/99	0.15	0.203	0.676
SW-846, 8260	Chlorobenzene	0.15	0.203	0.676	1/27/99	0.25	0.338	1.126
SW-846, 8260	Chloroethane	0.2	0.270	0.901	1/27/99	0.23	0.311	1.036
SW-846, 8260	Chloroform	0.172	0.232	0.775	1/27/99	0.09	0.122	0.405
SW-846, 8260	Chloromethane	0.66	0.892	2.973	1/27/99	0.03	0.041	0.135
SW-846, 8260	cis-1,2-Dichloroethylene	0.1	0.135	0.450	1/27/99	0.15	0.203	0.676
SW-846, 8260	cis-1,3-Dichloropropene	0.102	0.138	0.459	1/27/99	0.07	0.095	0.315
SW-846, 8260	Dibromochloromethane	0.066	0.089	0.297	1/27/99	0.16	0.216	0.721
SW-846, 8260	Dichlorodifluoromethane	0.4626	0.625	2.083	1/27/99	0.21	0.284	0.946
SW-846, 8260	Ethyl cyanide	0.96	1.297	4.324	1/27/99	1.47	1.986	6.621
SW-846, 8260	Ethylbenzene	0.26	0.351	1.171	1/27/99	0.23	0.311	1.036
SW-846, 8260	Methylene chloride	0.76	1.027	3.423	1/27/99	0.41	0.554	1.847
SW-846, 8260	Styrene	0.128	0.173	0.576	1/27/99	0.17	0.230	0.766
SW-846, 8260	Tetrachloroethylene	0.184	0.249	0.829	1/27/99	0.29	0.392	1.306
SW-846, 8260	Tetrahydrofuran	1.96	2.648	8.828	1/27/99	1.57	2.121	7.071
SW-846, 8260	Toluene	0.158	0.213	0.712	1/27/99	0.26	0.351	1.171
SW-846, 8260	trans-1,2-Dichloroethylene	0.13	0.176	0.586	1/27/99	0.11	0.149	0.495
SW-846, 8260	trans-1,3-Dichloropropene	0.058	0.078	0.261	1/27/99	0.2	0.270	0.901
SW-846, 8260	Trichloroethylene	0.4	0.540	1.802	1/27/99	0.16	0.216	0.721
SW-846, 8260	Trichloromonofluoromethane	0.406	0.549	1.829	1/27/99	0.13	0.176	0.586
SW-846, 8260	Vinyl acetate	0.72	0.973	3.243	1/27/99	0.17	0.230	0.766
SW-846, 8260	Vinyl chloride	0.68	0.919	3.063	1/27/99	0.1	0.135	0.450
SW-846, 8260	Xylenes (total)	0.142	0.192	0.640	1/27/99	0.79	1.067	3.558

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
Semivolatile Organic Compounds								
SW-846, 8040	2,3,4,6-Tetrachlorophenol	1.43	1.93	6.44	11/12/98	2.09	2.82	9.41
SW-846, 8040	2,4,5-Trichlorophenol	1.81	2.44	8.14	11/12/98	4.7	6.35	21.2
SW-846, 8040	2,4,6-Trichlorophenol	2.42	3.27	10.9	11/12/98	4.96	6.70	22.3
SW-846, 8040	2,4-Dichlorophenol	1.93	2.60	8.67	11/12/98	1.23	1.66	5.54
SW-846, 8040	2,4-Dimethylphenol	1.82	2.46	8.18	11/12/98	2.87	3.88	12.9
SW-846, 8040	2,4-Dinitrophenol	0.53	0.72	2.39	11/12/98	1.82	2.46	8.20
SW-846, 8040	2,6-Dichlorophenol	1.90	2.57	8.57	11/12/98	1.1	1.49	4.95
SW-846, 8040	2-Chlorophenol	1.94	2.62	8.75	11/12/98	2.13	2.88	9.59
SW-846, 8040	2-Methylphenol (cresol, o-)	1.79	2.42	8.06	11/12/98	2.43	3.28	10.9
SW-846, 8040	2-Nitrophenol	1.51	2.04	6.80	11/12/98	1.92	2.59	8.65
SW-846, 8040	2-secButyl-4,6-dinitrophenol (DNBP)	0.52	0.71	2.35	11/12/98	2	2.70	9.01
SW-846, 8040	3,4 methyl phenol	3.54	4.79	15.96				
SW-846, 8040	4,6-Dinitro-2-methylphenol	0.46	0.63	2.09	11/12/98	1.36	1.84	6.13
SW-846, 8040	4-Chloro-3-methylphenol	2.03	2.75	9.15	11/12/98	1.01	1.37	4.55
SW-846, 8040	4-Nitrophenol	0.70	0.94	3.14	11/12/98	0.92	1.24	4.14
SW-846, 8040	Pentachlorophenol	2.16	2.92	9.72	11/12/98	1.5	2.03	6.76
SW-846, 8040	Phenol	0.94	1.28	4.25	11/12/98	0.54	0.73	2.43
SW-846, 8080	4,4'-DDD	0.007	0.009	0.032				
SW-846, 8080	4,4'-DDE	0.005	0.007	0.023				
SW-846, 8080	4,4'-DDT	0.01	0.014	0.045				
SW-846, 8080	Aldrin	0.011	0.015	0.050				
SW-846, 8080	Alpha-BHC	0.006	0.008	0.027				
SW-846, 8080	Aroclor-1016	0.08	0.108	0.360				
SW-846, 8080	Aroclor-1221	0.08	0.108	0.360				
SW-846, 8080	Aroclor-1232	0.08	0.108	0.360				
SW-846, 8080	Aroclor-1242	0.08	0.108	0.360				
SW-846, 8080	Aroclor-1248	0.08	0.108	0.360				
SW-846, 8080	Aroclor-1254	0.03	0.041	0.135				
SW-846, 8080	Aroclor-1260	0.03	0.041	0.135				
SW-846, 8080	Beta-BHC	0.019	0.026	0.086				
SW-846, 8080	Chlordane	0.098	0.132	0.441				
SW-846, 8080	Delta-BHC	0.004	0.005	0.018				
SW-846, 8080	Dieldrin	0.008	0.011	0.036				
SW-846, 8080	Endosulfan I	0.007	0.009	0.032				
SW-846, 8080	Endosulfan II	0.009	0.012	0.041				
SW-846, 8080	Endosulfan sulfate	0.039	0.053	0.176				

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8080	Endrin	0.005	0.007	0.023				
SW-846, 8080	Endrin aldehyde	0.01	0.014	0.045				
SW-846, 8080	Gamma-BHC (Lindane)	0.009	0.012	0.041				
SW-846, 8080	Heptachlor	0.011	0.015	0.050				
SW-846, 8080	Heptachlor epoxide	0.005	0.007	0.023				
SW-846, 8080	Methoxychlor	0.017	0.023	0.077				
SW-846, 8080	Toxaphene	0.136	0.184	0.613				
SW-846, 8150	2,4,5-T	0.257	0.347	1.157				
SW-846, 8150	2,4,5-TP	0.064	0.086	0.288				
SW-846, 8150	2,4-Dichlorophenoxyacetic acid	3.98	5.38	17.9				
SW-846, 8150	2-secButyl-4,6-dinitrophenol (DNBP)	0.095	0.128	0.428				
SW-846, 8270	1,2,4,5-Tetrachlorobenzene	4.9	6.62	22.1	11/17/98	1.03	1.39	4.64
SW-846, 8270	1,2,4-Trichlorobenzene	1.13	1.53	5.09	11/17/98	0.97	1.31	4.37
SW-846, 8270	1,2-Dichlorobenzene	1.07	1.45	4.82	11/17/98	0.89	1.20	4.01
SW-846, 8270	1,3-Dichlorobenzene	1.51	2.04	6.80	11/17/98	0.9	1.22	4.05
SW-846, 8270	1,4-Dichlorobenzene	0.959	1.30	4.32	11/17/98	0.93	1.26	4.19
SW-846, 8270	1,4-Naphthoquinone	1.9	2.57	8.56				
SW-846, 8270	1-Naphthylamine	4.4	5.95	19.8				
SW-846, 8270	2,2'-Oxybis(1-chloropropane)	1.59	2.15	7.16	11/17/98	1.18	1.59	5.31
SW-846, 8270	2,3,4,6-Tetrachlorophenol	3.7	5.00	16.7				
SW-846, 8270	2,4,5-Trichlorophenol	1.15	1.55	5.18	11/17/98	0.78	1.05	3.51
SW-846, 8270	2,4,6-Trichlorophenol	1.55	2.09	6.98	11/17/98	0.66	0.89	2.97
SW-846, 8270	2,4-Dichlorophenol	1.53	2.07	6.89	11/17/98	1	1.35	4.50
SW-846, 8270	2,4-Dimethylphenol	1.36	1.84	6.13	11/17/98	0.97	1.31	4.37
SW-846, 8270	2,4-Dinitrophenol	1.15	1.55	5.18	11/17/98	0.97	1.31	4.37
SW-846, 8270	2,4-Dinitrotoluene	0.949	1.28	4.27	11/17/98	0.68	0.92	3.06
SW-846, 8270	2,6-Dichlorophenol	5	6.76	22.5				
SW-846, 8270	2,6-Dinitrotoluene	0.968	1.31	4.36	11/17/98	0.71	0.96	3.20
SW-846, 8270	2-Acetylaminofluorene	4.3	5.81	19.4				
SW-846, 8270	2-Chloronaphthalene	1.65	2.23	7.43	11/17/98	0.98	1.32	4.41
SW-846, 8270	2-Chlorophenol	1.07	1.45	4.82	11/17/98	1.12	1.51	5.04
SW-846, 8270	2-Methylnaphthalene	1.25	1.69	5.63	11/17/98	1	1.35	4.50
SW-846, 8270	2-Methylphenol (cresol, o-)	0.854	1.15	3.85	11/17/98	1	1.35	4.50
SW-846, 8270	2-Naphthylamine	4.4	5.95	19.8				
SW-846, 8270	2-Nitroaniline	1.07	1.45	4.82	11/17/98	0.59	0.80	2.66
SW-846, 8270	2-Nitrophenol	1.22	1.65	5.49	11/17/98	1.18	1.59	5.31
SW-846, 8270	2-Picoline	5.7	7.70	25.7				

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	2-secButyl-4,6-dinitrophenol (DNBP)	4.2	5.67	18.9				
SW-846, 8270	3,3'-Dichlorobenzidine	1.046	1.41	4.71	11/17/98	0.55	0.74	2.48
SW-846, 8270	3-Methylcholanthrene	17	23.0	76.6				
SW-846, 8270	3-Nitroaniline	0.998	1.35	4.49	11/17/98	0.5	0.68	2.25
SW-846, 8270	4,6-Dinitro-2-methylphenol	0.459	0.62	2.07	11/17/98	1.74	2.35	7.84
SW-846, 8270	4-Aminobiphenyl	3.7	5.00	16.7				
SW-846, 8270	4-Bromophenylphenyl ether	1.44	1.95	6.49	11/17/98	0.78	1.05	3.51
SW-846, 8270	4-Chloro-3-methylphenol	1.44	1.95	6.49	11/17/98	0.84	1.13	3.78
SW-846, 8270	4-Chloroaniline	1.37	1.85	6.17	11/17/98	0.88	1.19	3.96
SW-846, 8270	4-Chlorophenylphenyl ether	1.18	1.59	5.31	11/17/98	1.02	1.38	4.59
SW-846, 8270	4-Methylphenol (cresol, p-)	0.735	0.99	3.31	11/17/98	0.77	1.04	3.47
SW-846, 8270	4-Nitroaniline	0.532	0.72	2.40	11/17/98	0.87	1.18	3.92
SW-846, 8270	4-Nitrophenol	0.845	1.14	3.81	11/17/98	0.48	0.65	2.16
SW-846, 8270	4-Nitroquinoline-1-oxide	2.8	3.78	12.6				
SW-846, 8270	5-Nitro-o-toluidine	4.4	5.95	19.8				
SW-846, 8270	7,12-Dimethylbenz[a]anthracene	4.4	5.95	19.8				
SW-846, 8270	Acenaphthene	1.1	1.49	4.95	11/17/98	0.87	1.18	3.92
SW-846, 8270	Acenaphthylene	1.3	1.76	5.86	11/17/98	0.98	1.32	4.41
SW-846, 8270	Acetophenone	3.4	4.59	15.3				
SW-846, 8270	alpha,alpha-Dimethylphene- thylamine	50	67.6	225				
SW-846, 8270	Aniline	0.977	1.32	4.40	11/17/98	0.87	1.18	3.92
SW-846, 8270	Anthracene	0.929	1.26	4.18	11/17/98	0.48	0.65	2.16
SW-846, 8270	Azobenzene	0.736	0.99	3.31	11/17/98	0.45	0.61	2.03
SW-846, 8270	Benzidine	2.52	3.40	11.4	11/17/98	0.87	1.18	3.92
SW-846, 8270	Benzo(a)anthracene	0.258	0.35	1.16	11/17/98	0.58	0.78	2.61
SW-846, 8270	Benzo(a)pyrene	0.585	0.79	2.63	11/17/98	0.6	0.81	2.70
SW-846, 8270	Benzo(b)fluoranthene	0.462	0.62	2.08	11/17/98	0.88	1.19	3.96
SW-846, 8270	Benzo(ghi)perylene	0.938	1.27	4.22	11/17/98	0.95	1.28	4.28
SW-846, 8270	Benzo(k)fluoranthene	0.869	1.17	3.91	11/17/98	0.74	1.00	3.33
SW-846, 8270	Benzoic acid	28	37.8	126	11/17/98	0.96	1.30	4.32
SW-846, 8270	Benzyl alcohol	0.917	1.24	4.13	11/17/98	1.1	1.49	4.95
SW-846, 8270	Bis(2-Chloroethoxy)methane	1.2	1.62	5.40	11/17/98	1.14	1.54	5.13
SW-846, 8270	Bis(2-chloroethyl) ether	0.518	0.70	2.33	11/17/98	1.12	1.51	5.04
SW-846, 8270	Bis(2-ethylhexyl) phthalate	0.45	0.61	2.03	11/17/98	1.29	1.74	5.81
SW-846, 8270	Butylbenzylphthalate	0.484	0.65	2.18	11/17/98	0.72	0.97	3.24
SW-846, 8270	Carbazole	1.392	1.88	6.27				
SW-846, 8270	Chlorobenzilate	4.1	5.54	18.5				

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Chrysene	0.229	0.31	1.03	11/17/98	0.42	0.57	1.89
SW-846, 8270	Di-n-butylphthalate	0.823	1.11	3.71	11/17/98	1.05	1.42	4.73
SW-846, 8270	Di-n-octylphthalate	0.426	0.58	1.92	11/17/98	1.35	1.82	6.08
SW-846, 8270	Diallylate	7.3	9.86	32.9				
SW-846, 8270	Dibenz[a,h]anthracene	0.74	1.00	3.33	11/17/98	1.43	1.93	6.44
SW-846, 8270	Dibenzofuran	1.19	1.61	5.36	11/17/98	0.77	1.04	3.47
SW-846, 8270	Diethylphthalate	0.789	1.07	3.55	11/17/98	1.5	2.03	6.76
SW-846, 8270	Dimethoate	3.7	5.00	16.7				
SW-846, 8270	Dimethyl phthalate	0.98	1.32	4.41	11/17/98	3.04	4.11	13.7
SW-846, 8270	Disulfoton	3.3	4.46	14.9				
SW-846, 8270	Ethyl methanesulfonate	3.3	4.46	14.9				
SW-846, 8270	Famphur	49	66.21	221				
SW-846, 8270	Fluoranthene	0.135	0.18	0.61	11/17/98	0.6	0.81	2.70
SW-846, 8270	Fluorene	0.846	1.14	3.81	11/17/98	0.72	0.97	3.24
SW-846, 8270	Hexachlorobenzene	1.57	2.12	7.07	11/17/98	0.58	0.78	2.61
SW-846, 8270	Hexachlorobutadiene	1.98	2.68	8.92	11/17/98	0.91	1.23	4.10
SW-846, 8270	Hexachlorocyclopentadiene	1.66	2.24	7.48	11/17/98	0.91	1.23	4.10
SW-846, 8270	Hexachloroethane	1.42	1.92	6.40	11/17/98	0.86	1.16	3.87
SW-846, 8270	Hexachlorophene	100	135	450				
SW-846, 8270	Hexachloropropene	5.2	7.03	23.4				
SW-846, 8270	Indeno(1,2,3-cd)pyrene	0.841	1.14	3.79	11/17/98	0.61	0.82	2.75
SW-846, 8270	Isodrin	4.1	5.54	18.5				
SW-846, 8270	Isophorone	1.03	1.39	4.64	11/17/98	0.86	1.16	3.87
SW-846, 8270	Isosafrole	4.1	5.54	18.5				
SW-846, 8270	Kepone	30	40.5	135				
SW-846, 8270	m-Dinitrobenzene	3.8	5.13	17.1				
SW-846, 8270	Methapyrilene	26	35.1	117				
SW-846, 8270	Methyl methanesulfonate	1.5	2.03	6.76				
SW-846, 8270	Methyl parathion	3.5	4.73	15.8				
SW-846, 8270	N-Nitroso-di-n-dipropylamine	2.22	3.00	10.0	11/17/98	0.9	1.22	4.05
SW-846, 8270	N-Nitrosodi-n-butylamine	5.3	7.16	23.9				
SW-846, 8270	N-Nitrosodiethylamine	2.9	3.92	13.1				
SW-846, 8270	N-Nitrosodimethylamine	1.86	2.51	8.38	11/17/98	0.74	1.00	3.33
SW-846, 8270	N-Nitrosodiphenylamine	0.588	0.79	2.65	11/17/98	0.45	0.61	2.03
SW-846, 8270	N-Nitrosomethylethylamine	5.2	7.03	23.4				
SW-846, 8270	N-Nitrosomorpholine	2.9	3.92	13.1				
SW-846, 8270	N-Nitrosopiperidine	4.2	5.67	18.9				
SW-846, 8270	Naphthalene	1.59	2.15	7.16	11/17/98	1.09	1.47	4.91
SW-846, 8270	Nitrobenzene	1.19	1.61	5.36				

Table B.20. (contd)

Method	Constituent	Initial MDL ^(a) (µg/L)	Initial LOD (µg/L)	Initial LOQ (µg/L)	Ending Values, Effective Date	Ending MDL ^(a) (µg/L)	Ending LOD (µg/L)	Ending LOQ (µg/L)
SW-846, 8270	Nitrosopyrrolidine	3.2	4.32	14.4				
SW-846, 8270	O,O,O-Triethyl phosphorothioate	5	6.76	22.5				
SW-846, 8270	O,O-Diethyl O-2-pyrazinyl phosphorothioate	3.5	4.73	15.8				
SW-846, 8270	o-Toluidine	3.2	4.32	14.4				
SW-846, 8270	p-Dimethylaminoazobenzene	4.8	6.49	21.6				
SW-846, 8270	p-Phenylenediamine	100	135	450				
SW-846, 8270	Parathion	3.7	5.00	16.7				
SW-846, 8270	Pentachlorobenzene	3.4	4.59	15.3				
SW-846, 8270	Pentachloronitrobenzene (PCNB)	4	5.40	18.0				
SW-846, 8270	Pentachlorophenol	0.84	1.13	3.78	11/17/98	0.87	1.18	3.92
SW-846, 8270	Phenacetin	3.5	4.73	15.8				
SW-846, 8270	Phenanthrene	0.679	0.92	3.06	11/17/98	0.46	0.62	2.07
SW-846, 8270	Phenol	0.7	0.95	3.15	11/17/98	0.55	0.74	2.48
SW-846, 8270	Phorate	4.2	5.67	18.9				
SW-846, 8270	Pronamide	3.9	5.27	17.6				
SW-846, 8270	Pyrene	0.521	0.70	2.35	11/17/98	0.71	0.96	3.20
SW-846, 8270	Pyridine	0.96	1.30	4.32				
SW-846, 8270	Safrol	4.4	5.95	19.8				
SW-846, 8270	sym-Trinitrobenzene	22	29.7	99.1				
SW-846, 8270	Tetraethyl dithiopyrophosphate	4.6	6.22	20.7				
SW-846, 8270	Tributyl phosphate	21	28.4	94.6				

(a) MDLs for many constituents changed during the fiscal year. For these constituents, the initial MDL, LOD, and LOQ were in effect until the date the values were updated (ending values, effective date). In cases where the MDL did not change, no ending values are listed.

MDL = Method detection limit.

LOD = Limit of detection.

LOQ = Limit of quantitation.

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Grant County P.U.D.
30 "C" Street S.W.
P.O. Box 878
Ephrata, WA 98823

P P. Sobotta
Nez Perce Tribe
Environmental Restoration/Waste
Management
P.O. Box 365
Lapwai, ID 83540-0365

I South Columbia Basin Irrigation District
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Pasco, WA 99301

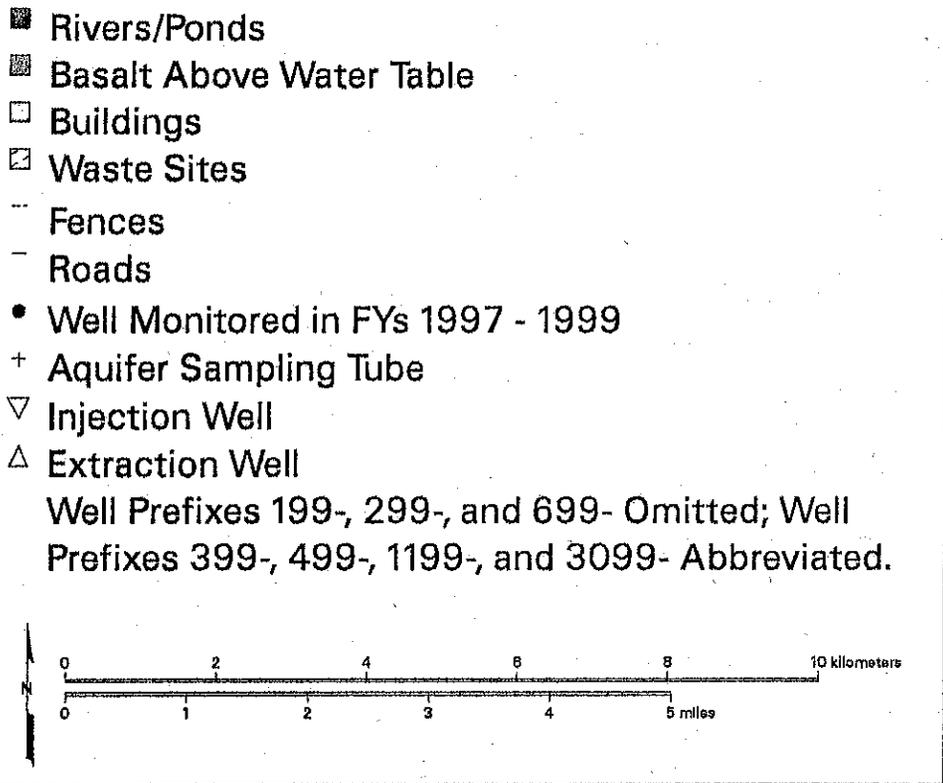
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■ Rivers/Ponds

■ Basalt Above Water Table

□ Buildings

▣ Waste Sites

- Fences

- Roads

• Well Monitored in FYs 1997 - 1999

+ Aquifer Sampling Tube

▽ Injection Well

△ Extraction Well

Well Prefixes 199-, 299-, and 699- Omitted; Well Prefixes 399-, 499-, 1199-, and 3099- Abbreviated.

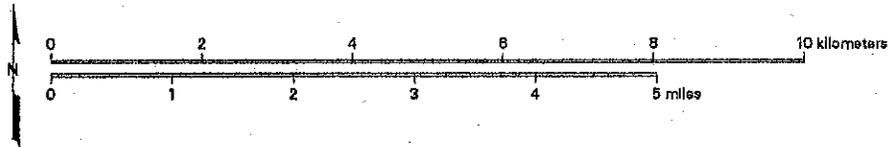


Plate 1. Locations of Hanford Site Monitorir

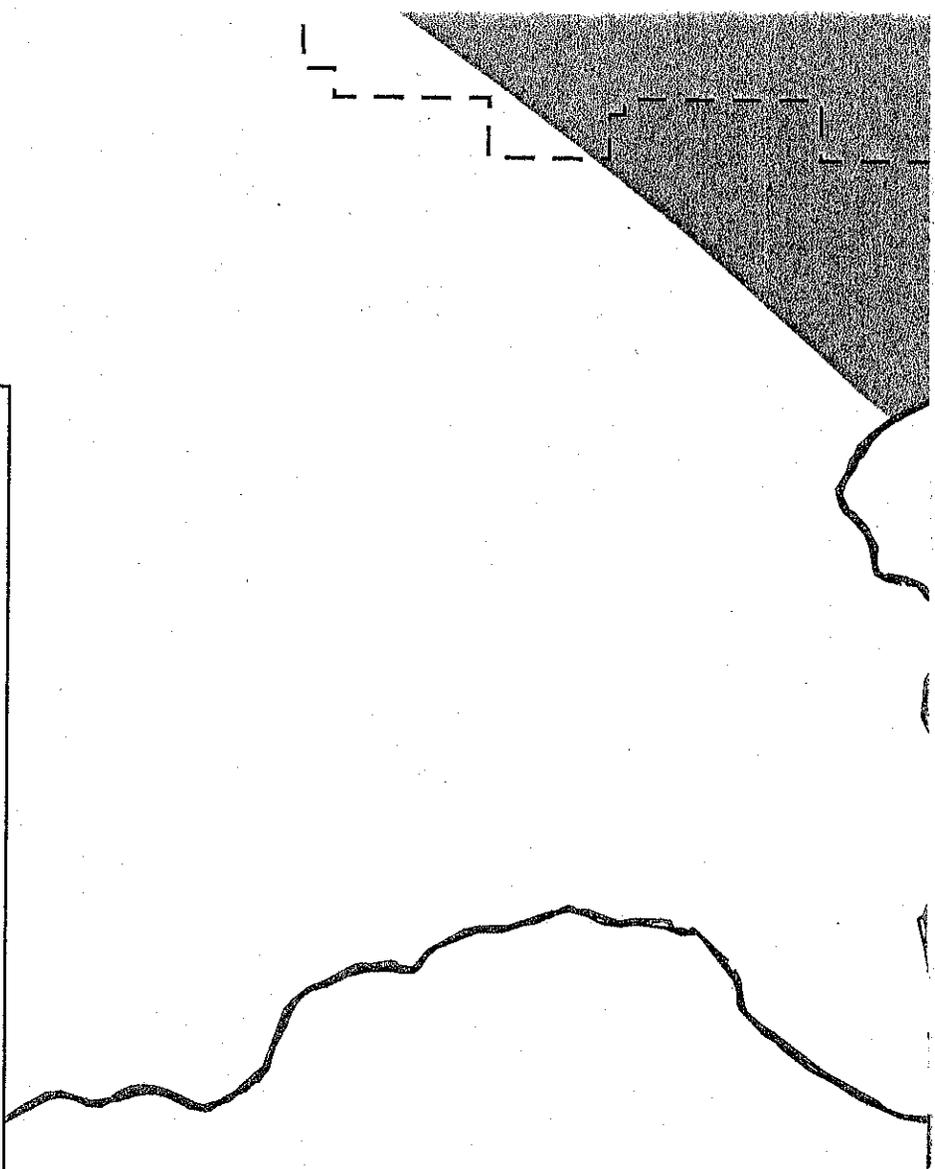
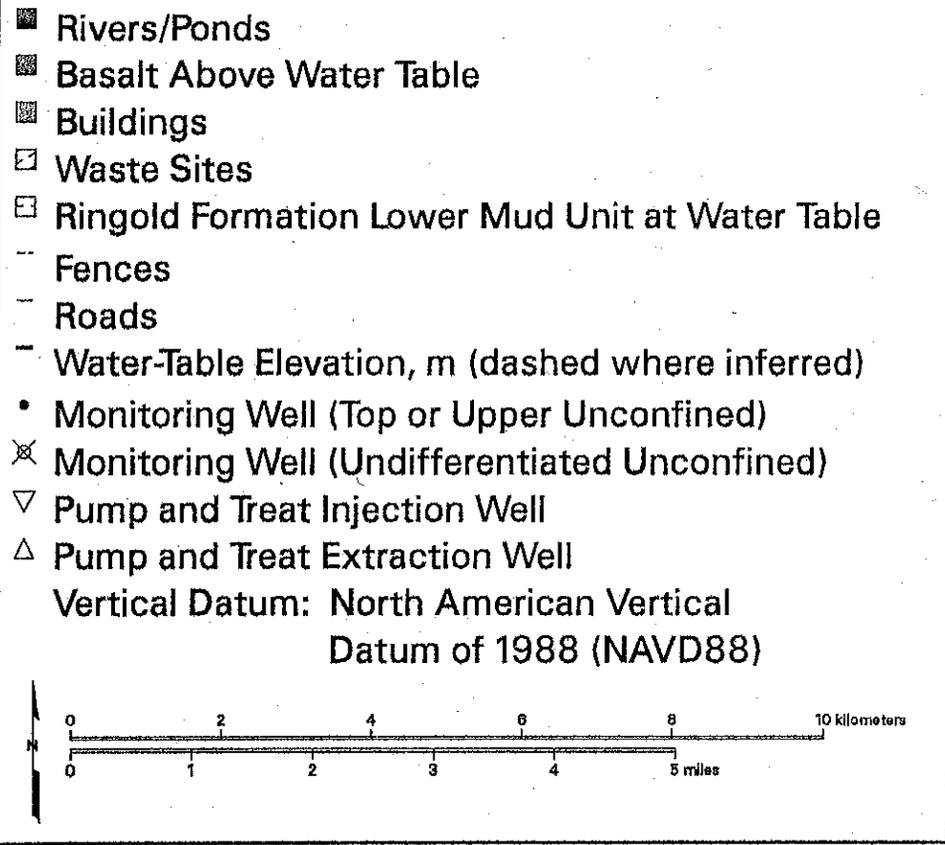


Plate 2. Hanford Site Water-Table Map, March 1994

- Rivers/Ponds
- Basalt Above Water Table
- Buildings
- ⊠ Waste Sites
- Ringold Formation Lower Mud Unit at Water Table
- Fences
- Roads
- Tritium, pCi/L (DWS 20,000 pCi/L)
(Dashed Where Inferred)
- Well Monitored in FY 1999
- ▲ Well Monitored in FY 1998
- ▼ Well Monitored in FY 1997
- + Aquifer Sampling Tube
- △ Extraction Well
- ▽ Injection Well
- nd = Non Detect

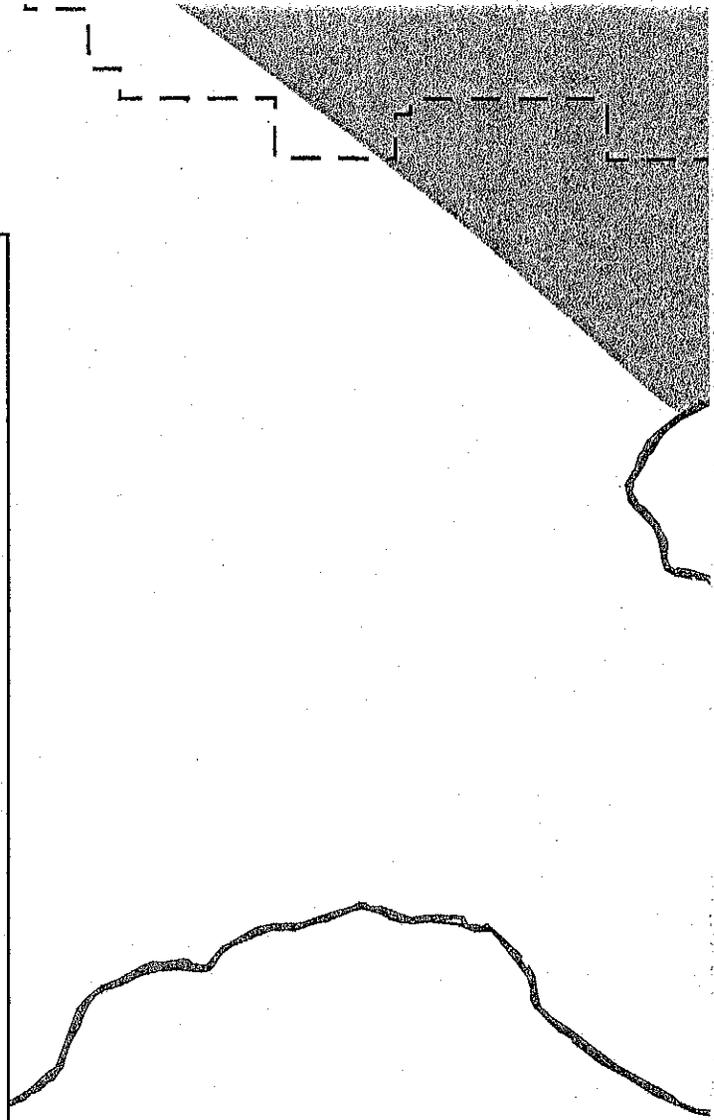
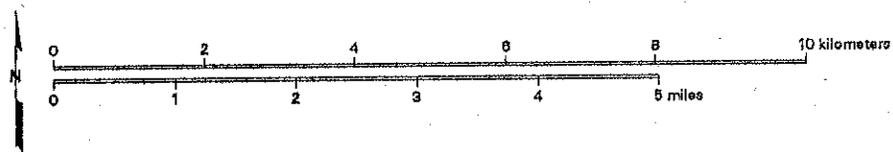


Plate 3. Sitewide Distribution of Tritium in (