3.1 Vadose Zone Characterization

D. G. Horton

This section describes significant vadose zone characterization activities that occurred during fiscal year (FY) 2004. These characterization activities were done to further the understanding of physical and chemical properties of the vadose zone and vadose zone contamination and to delimit existing vadose zone contamination. During the year, geophysical logging, and laboratory analysis of chemical and radiological contaminants in soil samples were done to characterize existing vadose zone contaminant plumes and help plan future remedial actions.

Characterization activities further the understanding of physical and chemical properties of the vadose zone.

During FY 2004, baseline spectral gamma logging and neutron moisture logging of boreholes continued at selected past-practice liquid disposal facilities. The results of this characterization will provide a baseline against which to compare subsequent logging events to monitoring for subsurface contaminant movement.

The results of extensive geochemical characterization of core samples from Waste Management Area C and Waste Management Area T became available in FY 2004. These data allow comparison of contaminated vadose zone sediment with uncontaminated sediment and descriptions of contaminant plumes beneath the single-shell tanks in the vicinity of the boreholes.

3.1.1 Characterization to Support Remedial Investigations

D. G. Horton

The results of laboratory analyses for chemicals and radionuclides in support of remedial investigation at the 200-CS-1 Chemical Sewer Group Operable Unit (200-CS-1 Operable Unit), 200-CW-5 U Pond/Z Ditches Cooling Water Group Operable Unit (200-CW-5 Operable Unit), 200-PW-2 Uranium-Rich Process Waste Operable Unit (200-PW-2 Operable Unit), and 200-PW-4 General Process Condensate and Process Waste Operable Unit (200-PW-4 Operable Unit) became available in 2004. These operable units are not defined geographically, but instead, are defined by waste type. The characterization results will support remediation of past-practice liquid disposal facilities in the 200 Areas.

3.1.1.1 Vadose Zone Characterization at the 200-CS-1 Operable Unit

C. S. Cearlock

A remedial investigation was conducted from 1999 to 2003 for the 200-CS-1 Operable Unit. A remedial investigation report was issued in 2004 (DOE/RL-2004-17). This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section, and the reader is referred to the remedial investigation document.

Twelve test pits were excavated and four boreholes were drilled at four *Resource Conservation and Recovery Act* (RCRA) treatment, storage, and disposal units: 216-A-29 ditch, 216-B-63 trench, 216-S-10 ditch, and 216-S-10 pond. Details concerning borehole drilling and test pit excavation can be found in WMP-17755. One hundred and forty-six sediment samples were collected and analyzed for radionuclides, metals, anions, polychlorinated biphenyls, volatile and semivolatile organics, and physical properties. In addition, the four boreholes were logged with spectral gamma-ray and neutron moisture tools. Supplemental

data were collected earlier at the 216-A-29 ditch and 216-B-63 trench and were included in the remedial investigation. The data were compared to background concentrations from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

The analytical results from samples taken from the three test pits at the 216-A-29 ditch and one test pit at the 216-B-63 ditch were summarized during 2003 in PNNL-14187 from activities described in BHI-01651. Part of that summary is included in this section for completeness.

216-A-29 Ditch. Borehole B8826 was drilled to 83.2 meters below ground surface near the head end of the 216-A-29 ditch. (The depth to groundwater in the area is ~86 meters below ground surface.) Perched water was encountered in the borehole at depths of ~78.6 to 78.9 meters overlying a dense, compacted silt and clay layer in the Hanford formation. Test pit AD-1 was excavated nearby at the head end of the ditch. Test pit AD-3 was excavated ~240 meters from the head end and test pit AD-2 was located at the far end of the ditch. Each test pit was excavated to depths between 4.6 and 5.2 meters. The location of the 216-A-29 ditch is shown on Figure 2.11-1 in Section 2.11, and the locations of the borehole and test pits are shown on Figure 3.1-1.

Generally, contamination is highest near the head end of and close to the surface of ditches and trenches used for past-practice liquid waste disposal.

Cesium-137 was the only manmade radionuclide detected in borehole B8826 by spectral gamma-ray logging. Cesium-137 was found between depths of 0.91 and 1.98 meters at concentrations between 0.5 and 62 pCi/g with the highest concentration at 1.5 meters depth.

Table 3.1-1 lists the highest concentrations and associated locations and depths for selected constituents. Maximum contaminant concentrations tended to be near the 1.2 to 1.8 meters level below the surface for most metals. In the test pits, all detected radionuclides (except tritium) with concentrations greater than 2 pCi/g were found between 0 and 2 meters below ground surface. The only radionuclide at a concentration greater than 2 pCi/g below 3.4 meters was tritium. The maximum tritium concentration was 7.05 pCi/g at 79.3 meters.

Metal concentrations in samples from the borehole exceeded background concentrations only at depths of 79.3 to 79.9 meters (except vanadium, which also exceeded background at 7.5 to 8.1 meters). This corresponds to the depth of a contact between sand and clay, which is probably responsible for the encountered perched water. Total chromium, copper, lead, nickel, and zinc exceeded background at 79 meters.

The highest concentrations of most constituents were in a sample from depths of 1.2 to 1.5 meters in test pit AD-1. Shallow samples from nearby borehole B8826 also had high radionuclide concentrations, and the same radionuclides were elevated at both locations (i.e., americium-241 and plutonium-239/240). The test pit and borehole are near the inlet to the ditch and are expected to have similar levels of contamination. Contaminant concentrations were lower at test pit AD-3 near the ditch center and even less at pit AD-2 near the far end of the ditch. However, cadmium and lead are elevated at test pit AD-2.

In addition to the constituents listed in Table 3.1-1, several organic compounds were detected in the test pit samples and borehole.

216-B-63 Trench. Borehole B8827 was drilled to 31.4 meters below ground surface near the inlet to the 216-B-63 trench. (The depth to groundwater at the 216-B-63 trench is ~78 meters below ground surface.) Test pit BT-1 was excavated near the middle of the trench and test pit BT-2 was excavated near the far end of the trench. Each test pit was excavated to between 5.5 and 7.6 meters. The location of the 216-B-63 trench is shown on Figure 2.11-1 in Section 2.11, and the locations of the borehole and test pits are shown on Figure 3.1-2.

Cesium-137 was the only manmade radionuclide detected in borehole B8826 by spectral gamma-ray logging. Cesium-137 was found between depths of 1.2 and 3.4 meters at concentrations between 0.5 and 22.4 pCi/g with the highest concentration at 2.7 meters.

Table 3.1-2 lists the highest concentrations and associated locations and depths for selected constituents. The only radionuclides in the test pits with concentrations greater than 2 pCi/g were cesium-137 and strontium-90. Strontium-90 was detected in sporadic locations throughout both test pits, whereas cesium-137 was found in only test pit BT-1 (with the exception of 0.817 pCi/g in the shallowest sample from pit BT-2). The only radionuclide with concentrations greater than 2 pCi/L in borehole B8827 was nickel-63 that was found throughout the borehole at concentrations between 2 and 15 pCi/g.

The highest concentrations of most constituents occurred at the bottom of the ditch, 3 meters below the surface, and tended to decrease with depth. High heavy metal concentrations tended to be near the ditch inlet in samples from borehole B8827 and just below the ditch's historic bottom. More soluble constituents, such as nitrate, tended to be found throughout the ditch. The largest nitrate concentration was 188 mg/kg in test pit BT-2 at the far end of the ditch.

In addition to the constituents listed in Table 3.1-2, several organic compounds were detected in the test pit samples and borehole.

216-S-10 Pond. Borehole B8817 was drilled to 73.4 meters below ground surface near the 216-S-10 pond. (The depth to groundwater at the 216-S-10 pond and ditch is ~70 meters below ground surface.) Four test pits, SP-1 through SP-4, were excavated in various parts of the pond. Each test pit was excavated to a depth of 7.6 meters. The location of the 216-S-10 pond and ditch is shown on Figure 2.9-1 in Section 2.9, and the location of the borehole and test pits are shown on Figure 3.1-3.

In addition to borehole B8817, wells 299-W26-6 and 699-32-77 were logged with a spectral gamma tool. No manmade radionuclides were found in B8817. Cesium-137 was detected near the surface of the other two wells with a maximum concentration of 2.5 pCi/g in well 299-W26-6.

Analytical results from samples from borehole B8817 showed nickel-63 to be the only radionuclide present. There was very little metal and anion contamination in the borehole samples. Table 3.1-3 shows the maximum concentrations of analytes exceeding background at the 216-S-10 pond. There appeared to be no discernible pattern with respect to lateral trends in contamination. Radionuclides, metals, soluble salts, and organics appear to be randomly distributed in the 216-S-10 pond.

216-S-10 Ditch. Borehole B8828 was drilled to 81.1 meters below ground surface near the center of the 216-S-10 ditch. Three test pits were excavated. Test pit SD-1 was excavated to a depth of 5.2 meters at the outflow end of the ditch where effluent from the ditch entered the 216-S-10 and 216-S-11 ponds. Test pit SD-2 was excavated to 0.9 meter at the inlet end of the ditch and test pit SD-3 was excavated to 4.6 meters at the middle of the ditch near borehole B8828.

The only manmade radionuclide detected by spectral gamma logging of borehole B8828 was cesium-137, which was found at several depths at a concentration near the 0.2 pCi/g detection limit. Nickel-63 was the only radionuclide found in the laboratory samples from the borehole. The only manmade radionuclides found in the test pit samples were cesium-137 and plutonium-239/240. However, nickel-63 was not an analyte for the test pit samples. The maximum concentration of radionuclides and non-radionuclide analytes exceeding background are listed in Table 3.1-4. Most of the maximum concentrations were associated with a single sample from depths of 0 to 0.5 meter in test pit SD-2, near the inlet to the ditch. This suggests most contamination associated with the 216-S-10 ditch is near the head end of the ditch and close to the surface.

Boreholes and test pits helped characterize the nature and vertical extent of contamination in the vadose zone underlying the 216-A-29 ditch, 216-B-63 trench, and 216-S-10 ditch and pond.

3.1.1.2 Vadose Zone Characterization at the 200-CW-5 Operable Unit

J. C. Bower

A remedial investigation was conducted from January to October 2002 for the 200-CW-5 Operable Unit. A remedial investigation report was issued in 2004 (DOE/RL-2003-11) fulfilling the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) Milestone M-15-40B (Ecology et al. 1989). The remedial investigation report includes the 200-CW-2 S pond and ditches, 200-CW-4 T pond and ditches, and the 200-SC-1 Steam Condensate Operable Units because they received similar waste as the 200-CW-5 Operable Unit, and the contaminant distribution beneath all these waste sites was expected to be the similar. The basis for this grouping is given in DOE/RL-96-81 and DOE/RL-98-28.

This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section and the reader is referred to the remedial investigation document.

The 216-Z-11 ditch is located south and southeast of the Plutonium Finishing Plant, 200 West Area (see Figure 2.9-1 in Section 2.9). Twenty GeoProbe®[(a)] soil probes were installed at the 216-Z-11 ditch in five transits. The locations of the five transits were at portions of the ditch where the highest transuranic contamination was expected. Each probe was logged with a gross gamma/passive neutron logging system to determine the gross concentration and type of gamma-emitting constituent present. The logging results were used to locate one borehole (C3808) in the area of the highest contamination in the ditch. The borehole was drilled through the 216-Z-11 ditch to a depth of 68.6 meters below ground surface and 33 soil samples were collected during drilling for physical property, chemical, and radionuclide analyses. Details on the drilling of borehole C3808 can be found in CP-12134. Borehole C3808 was also logged with gross gamma and passive neutron tools and soil gas was sampled. The location of the borehole is shown on Figure 3.1-4.

Samples from several boreholes adjacent to three ditches contained very little contamination and concentrations were <1 pCi/g.

Contamination was found in the vadose zone beneath the 216-Z-11 ditch to a depth of 12 meters below ground surface. Americium-241 and plutonium-239/240 were the dominant contaminants detected at the bottom of the ditch at ~2.3 to 2.6 meters below ground surface. Concentrations were 468 and 2,780 pCi/g, respectively. Maximum concentrations of americium-241 (919 pCi/g) and plutonium-239/240 (4,840 pCi/g) were detected ~1.2 meters beneath the bottom of the ditch.

Other radiological contaminants detected in borehole C3808 between 2.3 and 5.3 meters below ground surface include plutonium-238 (58.4 pCi/g), radium-226 (1.07 pCi/g), strontium-90 (2.73 pCi/g), and thorium-230 (8.43 pCi/g). At depths greater than 5.3 meters, the concentrations were less than 1 pCi/g.

Nitrite and total petroleum hydrocarbon exceeded screening levels in soil samples collected from borehole C3808. Nitrite was found between 3 and 5.3 meters below ground surface with a maximum concentration of 43 mg/kg at a depth of 3 meters. Concentrations decreased with depth to 5.3 meters. Total petroleum hydrocarbon was detected 3.0 to 3.8 meters below ground surface at 27 mg/kg.

Molybdenum was the only metal to exceed screening levels in soil sample from borehole C3808. Molybdenum was found at a concentration of 0.82 mg/kg between 46 and 47 meters below ground surface.

(a) GeoProbe is a registered trademark of Kejr, Inc., Salina, Kansas.

Contaminant concentrations found in borehole C3808 were lower than expected. Comparison of the data from the 216-Z-11 ditch with previously collected data from the adjacent 216-Z-1D and 216-Z-19 ditches showed significantly higher contaminant concentration in the latter two ditches. Because of that and because the 216-Z-11, 216-Z-1D, and 216-Z-19 ditches were known to converge in the area of the borehole, the remedial investigation included data from samples previously collected from the 216-Z-1D and 216-Z-19 ditches.

In 1959, nine surface grab samples were collected along the length of the 216-Z-1D ditch and analyzed for plutonium-239 and alpha activity. The plutonium-239 concentrations ranged from 24,000 to 780,000 pCi/g and alpha activity ranged from 26,000 to 860,000 pCi/g in the 216-Z-1D ditch samples. Additional samples from the ditch collected in 1959 had plutonium-239 concentrations between 1.27 million and 4.46 million pCi/g and alpha activity between 15,000 and 27.1 million pCi/g.

In 1981, boreholes drilled through the 216-Z-1D ditch found a major zone of contamination between 0.9 and 4.3 meters below ground surface where the maximum concentrations were plutonium-239/240 (380,000 pCi/g), plutonium-238 (5,252 pCi/g), and americium-241 (34,809 pCi/g). Contaminant concentrations decreased to less than 1 pCi/g at 6 meters below ground surface.

Most contamination is confined to within 0.5 to 1.2 meters of ditch bottoms in the 200-CW-5 Operable Unit.

Also in 1981, soil samples were collected from the 216-Z-19 ditch to a depth of 4.9 meters. Data from those samples indicated that contaminants were present to 4.9 meters, and the highest levels of contamination were associated with the bottom of the ditch. Contaminant levels generally were higher near both ends of the ditch, and the maximum contaminant concentrations were near the end of the ditch near the 216-U-10 pond. Maximum plutonium-239/240 concentration was 13 million pCi/g and maximum americium-241 concentration was 7.86 million pCi/g. Also in 1981, samples from several boreholes located adjacent to the three ditches contained very little contamination and concentrations were less than 1 pCi/g.

Based on all the data considered in the remedial investigation, the 216-Z-1D ditch contains the highest concentrations of contaminants, primarily plutonium-239/240. Most of the contamination is confined to within 0.5 to 1.2 meters of the ditch bottoms. Boreholes drilled in the vicinity of the Z ditches suggest that contamination is largely confined laterally to within a few meters of the ditch boundaries. The data also suggest that contamination is distributed over the entire length of the ditches and there is significant variability in concentrations among closely spaced samples.

3.1.1.3 Vadose Zone Characterization at the 200-PW-2 and 200-PW-4 Operable Units

L. C. Hulstrom

A total of 175 samples were collected in the vadose zone at the 200-PW-2 and 200-PW-4 Operable Units as part of a remedial investigation.

A remedial investigation was conducted from April to November 2003 for the 200-PW-2 and 200-PW-4 Operable Units. A remedial investigation report was issued in 2004 (DOE/RL-2004-25) fulfilling Tri-Party Agreement Milestone M-15-43B. This section summarizes the results of the vadose zone characterization sampling and analysis. The remedial investigation went further than characterization by using the site-specific data to develop a health-based risk assessment. The risk assessment is not summarized in this section, and the reader is referred to the remedial investigation document.

Four boreholes were drilled for the 200-PW-2 Operable Unit (one each at the 216-A-10 crib, 216-A-19 trench, 216-A-36B crib, and the 216-B-12 crib) and one was drilled at the 216-A-37-1 crib for the 200-PW-4 Operable Unit. Four large-diameter push holes were placed at the 216-A-10 crib and one at the 207-A south retention basin. Two auger holes were also drilled in the 207-A south retention basin. Details concerning borehole drilling

and sampling activities can be found in CP-18666. The four boreholes and five push holes were logged with spectral gamma and neutron moisture tools.

A total of 175 samples were collected from the boreholes. Samples were analyzed for ammonia, anions, hexavalent chromium, cyanide, metals, oil, grease, pesticides, herbicides, polychlorinated biphenyls, semivolatile organics, total petroleum hydrocarbons, radionuclides, volatile organics, moisture content, particle size distribution, and bulk density. The data were compared to background concentrations from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).

The concentrations of most constituents tended to decrease with depth below the bottom of the 216-A-19 trench.

The remedial investigation report included data collected in the early 1990s at the 216-U-8 and 216-U-12 cribs. A discussion of those data can be found in DOE/RL-95-13.

216-A-19 Trench. The 216-A-19 trench is located between the 216-A-8 and 216-A-24 cribs, east of 200 East Area. The location of borehole C3245 is shown on Figure 3.1-5. Borehole C3245 was drilled through the 216-A-19 trench to 78.2 meters below ground surface total depth. (The depth to groundwater in the area is ~80 meters below ground surface.) The sediment encountered include 5.2 meters of trench backfill materials underlain by the sand and gravel of the Hanford formation. Cesium-137, uranium-235, and uranium-238 were the only manmade radionuclides found by geophysical logging. The cesium-137 concentration was up to 40 pCi/g between depths of 0.3 to 3.4 meters. The high cesium-137 concentrations at relatively shallow depths may have resulted from waste discharged to the 216-A-34 ditch, which may have overflowed into the 216-A-19 trench.

Geophysical logging of borehole C3245 showed that the uranium-238 concentrations were between 18 and 560 pCi/g in the depth interval 2 to 9.3 meters. The maximum concentrations of both cesium-137 and uranium-238 occurred at 2.4 meters below the surface. Uranium-235 at a concentration of 8 pCi/g was detected at 2.4 meters.

Samples were collected from ten depths in borehole C3245. Laboratory analysis of the samples showed that contamination is in the vadose zone beneath the 216-A-19 trench to a depth of 75.6 meters below ground surface. Table 3.1-5 shows the radionuclides detected with concentrations above 1 pCi/g and the non-radionuclides that exceeded screening levels. The table gives the maximum concentrations encountered and the associated depth. All detected radionuclides with concentrations greater than 1 pCi/g were found between 4.4 and 5.3 meters below ground surface. The bottom of the ditch was at 4.6 meters. The concentrations of most constituents decrease with depth below the bottom of the trench.

216-A-10 Crib. The location of the 216-A-10 crib is shown on Figure 2.10-1 in Section 2.10. Borehole C3247 was drilled near the center of the 216-A-10 crib to a total depth of 98.8 meters below ground surface. The location of the borehole is shown on Figure 3.1-6. (The depth to groundwater at the crib is ~98 meters below ground surface.) Crib fill materials were encountered to 13.7 meters. The Hanford formation sands and gravels were drilled from 13.7 meters to total depth. Two palesols were noted: one at 16.2 to 16.5 meters and the other at 88.5 to 89.3 meters below ground surface. Twelve samples were collected from the borehole. Five large-diameter push holes also were installed through the crib to depths between 18.3 and 27.8 meters. All of the push holes (as well as borehole C3247) were logged with a spectral gamma tool.

Spectral gamma logging found cesium-137 in all holes. The maximum cesium-137 concentration ranged from 1,300 to 3,600 pCi/g between 14 and 18.6 meters. Cesium-137 was found as deep as 25.6 meters in borehole C3247 but at levels near the minimum detection limit of 0.3 pCi/g.

For most radionuclides with concentrations greater than 2.5 pCi/g, the maximum concentrations were between 15.8 and 18.9 meters below ground surface. The exceptions are tritium and strontium-90, which were found deeper. Table 3.1-6 lists the maximum concentrations of radionuclides present at concentrations greater than 2.5 pCi/g.

216-A-36B Crib. The location of the 216-A-36B crib is shown on Figure 2.10-1 in Section 2.10. Borehole C4160 was drilled through the 216-A-36B crib to a depth of 97.8 meters. The location of borehole C4160 is shown on Figure 3.1-6. (The depth to groundwater at the crib is ~98 meters below ground surface.) The crib bottom was penetrated at ~8 meters below ground surface. Ammonia vapors were detected in the drill cutting during drilling. The ammonia content tended to increase with increasing silt and carbonate cement and decrease with increasing sand content. Twelve soil samples were collected from the borehole during drilling.

The high concentrations of plutonium-239/240 and americium-241 indicate that some of the soil from the 216-A-36B crib may be designated as transuranic waste.

The spectral gamma log identified cesium-137 between 0 and 1.5 meters depth at concentrations of less than 10 pCi/g and between 6.1 and 29 meters depth with a maximum concentration of 2 million pCi/g at 8.2 meters. Cobalt-60 was detected between 11.5 and 18.2 meters below ground surface with a maximum concentration of 1.5 pCi/g at 15.2 meters.

Laboratory analyses of samples from borehole C4160 showed that radionuclide contamination was beneath the 216-A-36B crib to a depth of 96.5 meters. With two exceptions, the radionuclide contaminants with maximum concentrations greater than 3 pCi/g are found between the depths of 7.6 and 9.1 meters near the crib bottom. The exceptions are tritium, with a maximum concentration of 121 pCi/g at 87.6 meters, and potassium-40 with a maximum concentration of 19.4 pCi/g at 16.3 meters below ground surface. Table 3.1-7 gives the maximum concentrations for radionuclides with concentrations greater than 3 pCi/g and concentrations for non-radionuclides that exceeded the screening limit. The high concentrations of plutonium-239/240 and americium-241 indicate that some of the soil from this crib may be designated as transuranic waste.

216-A-37-1 Crib. The location of the 216-A-37-1 crib is shown on Figure 2.10-1 in Section 2.10. Borehole C4106 was drilled through the 216-A-37-1 crib to a total depth of 84.8 meters. The location of the borehole is shown on Figure 3.1-7. (The depth to groundwater at the crib is ~85 meters below ground surface.) The bottom of the crib was found at 3.8 meters. Eleven samples were collected from the borehole during drilling.

Cesium-137 was the only manmade radionuclide detected by spectral gamma logging. Cesium-137 was detected at concentrations between 0.2 and 30 pCi/g between 2.7 and 11 meters.

Laboratory analysis of the eleven samples showed that three radionuclides were present at concentrations greater than 1 pCi/g and four metals and anions exceeded the screening limit. Table 3.1-8 provides the analytical results.

216-B-12 Crib. The 216-B-12 crib is located ~400 meters south of Low-Level Waste Management Area 1. Borehole C3246 was drilled through the 216-B-12 crib to a total depth of 93.3 meters below ground surface. The location of the borehole is shown on Figure 3.1-8. (The depth to groundwater at the crib is ~92 meters below ground surface.) The bottom of the crib was encountered at 9.8 meters. Nine samples for analytical testing were collected from the borehole. High levels of radiation and ammonia were detected during drilling.

Cesium-137, europium-154, and uranium-238 were found by spectral gamma logging. Cesium-137 was identified between the surface and 2.1 meters at concentrations between 0.3 and 12 pCi/g and between 9.1 and 33.6 meters at concentrations between 0.6 and 121,000 pCi/g. The maximum concentration of cesium-137 was at 10.7 meters depth, which corresponds with the maximum cesium-137 found in soil samples (Table 3.1-9). Europium-154 was detected at 9.4 meters with a concentration of 9 pCi/g; uranium-238 was found at 35.8 meters with a concentration of 13 pCi/g.

Laboratory analyses of samples from borehole C3246 showed that most radionuclides with concentrations greater than 1 pCi/g had maximum values at or above a depth of 12.1 meters. Table 3.1-9 gives the maximum concentrations of radioisotopes with concentrations greater than 1 pCi/g and non-radionuclides that exceeded the screening limit.

Little radionuclide contamination was detected in the vadose zone beneath the 207-A south retention basin.

207-A South Retention Basin. The 207-A south retention basin is located south of Waste Management Area A-AX. Three types of samples were collected at the 207-A south retention basin: three samples of the concrete and polyurethane sealant, four soil samples from each of three borehole drilled through the basin floor, and composite samples of soil and water from residual runoff in the basin.

Relatively little radionuclide contamination was detected in the vadose zone beneath the basin. The only radionuclides with concentrations greater than 1.5 pCi/g were thorium-234 (3.16 pCi/g) and tritium (16.6 pCi/g). No non-radionuclide exceeded screening levels.

Organics related to the polyurethane sealant were found in the concrete samples. Also, tributyl phosphate, which was in the process condensates stored in the basin, was present in small amounts in the concrete. The composite soil and water had gross beta at 15 pCi/L, gross alpha at 2 pCi/L and total organic carbon at 18.9 mg/L in the water. No other measurements were elevated above normal levels.

3.1.2 Characterization at Waste Management Area T

R. J. Serne, B. N. Bjornstad, D. G. Horton, D. C. Lanigan, C. W. Lindenmeier, M. J. Lindberg, R. E. Clayton, V. L. LeGore, K. N. Geiszler, S. R. Baum, M. M. Valenta, I. V. Kutnyakov, T. S. Vickerman, R. D. Orr, and C. F. Brown

The Vadose Zone Project managed by CH2M HILL Hanford Group, Inc. drilled two characterization boreholes (C4104 and C4105) in the T Tank Farm, 200 West Area, during 2003. The boreholes were sampled, and the samples analyzed during 2003 and 2004. The details of drilling and sampling can be found in RPP-16340 and RPP-17275. The details of the analytical work and the interpretation of the results can be found in PNNL-14849. This section summarizes the more important findings in PNNL-14849.

Two boreholes were extended from the ground surface down to refusal in the Ringold Formation member of Wooded Island and were located to evaluate the 1973 leak from tank T-106. Borehole C4104 was drilled as close as possible (~4 meters south) to the existing borehole, 299-W10-196, which was drilled through the T-106 leak in 1992 and 1993, to allow comparisons of the extent of vertical migration that occurred over the 10-year period. Borehole C4105 was drilled ~26.8 meters west of borehole C4104. The bottom of tank T-106 is ~13 meters below ground surface. The water table at the T Tank Farm is ~71 meters below ground surface.

Nitrate distribution suggests that fluid leaked from tank T-106 has spread at least 26 meters laterally in the Cold Creek unit and Ringold Formation.

Sediment samples from both boreholes were analyzed for the following parameters: moisture content, gamma-emitting radionuclides, 1:1 water extracts (which provides soil pH, electrical conductivity, cation, trace metal, radionuclide, and anion data), total and inorganic carbon, and 8 M nitric acid extracts.

Moisture content, pH, electrical conductivity, nitrate, technetium-99, sodium, and uranium concentrations were selected as the main indicators of the leading edge of the contaminant plume. Of these parameters, the moisture content, pH, sodium, and uranium were not indicative of the extent of contamination. The moisture content turned out to be more a function of grain size than a direct measure of leaked tank liquid. The pH never exceeded 10, which was unexpected based on the assumption that the tank liquid was caustic to very caustic (>1 M hydroxide). The uranium data suggested that only small quantities were present in the leaked liquid, and the sodium data showed obvious ion exchange with the sediments that retarded its migration.

The nitrate water extract concentrations from borehole C4104 were elevated from 19.5 meters below ground surface to the bottom of the borehole at 38.7 meters below ground surface. The highest nitrate concentration was 2,565.63 μg/g at 35 meters below ground

surface, which is 1,000 times background. The nitrate concentrations in water extracts from borehole C4105 were elevated between ~26.5 and 39.6 meters below ground surface with the highest nitrate concentration of 1,511 μg/g occurring at a depth of 26.8 meters.

The distribution of contaminants in the vadose zone in 1973 suggested that the leak occurred near the southeast quadrant of tank T-106 in the vicinity of borehole C4104. The current distribution of nitrate suggests that the leaked liquid has penetrated as deep as the Ringold Formation member of Taylor Flat (upper contact 32.9 to 33.8 meters below ground surface) and has spread at least 26.5 meters laterally in the Cold Creek unit and Ringold Formation member of Taylor Flat to borehole C4105. Comparing the nitrate concentrations in samples from borehole C4104 with the concentrations in samples from nearby borehole 299-W10-196 suggests that the maximum concentration of nitrate may be ~1.8 meters deeper in C4104 than it was in borehole 299-W10-196 in 1993. This could be the result of vertical migration during the last 10 years or could represent simultaneous deposition of nitrate from a non-planar wetting front.

The technetium-99 water extract concentrations from borehole C4104 were elevated from 12 meters below ground surface to the bottom of the borehole. The highest technetium-99 concentrations were in the Ringold Formation member of Taylor Flat and reached 6,110 pCi/g. The high concentrations of technetium-99 between 29 and 32 meters below ground surface in the lower Cold Creek unit found in borehole 299-W10-196 in 1993 are not present in borehole C4104 in 2004. This may indicate vertical redistribution of technetium-99 during the last 10 years. The maximum concentrations of technetium-99 in borehole C4105 were in the upper Cold Creek unit and reached 1,650 pCi/g. The upper Cold Creek unit is a silt-rich unit, which may perch water in some areas.

Neither the nitrate nor the technetium-99 distribution identifies the leading edge of the contamination because neither borehole penetrated the bottom of the plume. The profiles do suggest that the center of mass of the tank-related liquid resides in the fine-grained sediments of the Ringold Formation member of Taylor Flat.

Site-specific desorption K_d values for technetium-99, uranium, chromium, and cobalt-60 (borehole C4104 only) were calculated from the data from boreholes C4104 and C4105 by dividing the mass per gram of sediment by the estimated pore water concentration of the constituent obtained from the dilution-corrected 1:1 water extract concentrations. The full suite of data can be found in PNNL-14849. The K_d data show two trends. First, where there are significant concentrations of contaminants in the sediments (between depths of 14.12 and 38.1 meters in borehole C4104 and between 21.34 and 39.62 meters in borehole C4105), the K_d values for uranium and chromium are smaller (i.e., the contaminants are more mobile) than their values at shallower and deeper depths. This is caused both by (1) more saline pore water (competing ions) and (2) higher contributions of waste species for chromium and uranium being present, which are generally more water leachable than naturally present species.

The second trend shows that the desorption K_d values for technetium-99 and cobalt-60 in the main portion of the vadose zone plumes are very close to 0 mL/g, whereas the desorption K_d values for uranium in the main portion of the plumes varies between 0.06 and 2 mL/g in borehole C4104 and between 30 and 80 mL/g in borehole C4105. The desorption K_d values for chromium in the zones where elevated chromium are present vary between 0.5 and 5 mL/g in both boreholes. The in situ desorption K_d results suggest that technetium-99 and cobalt-60 are very mobile, uranium is considerably less mobile, and chromium is the least mobile. These variations in K_d results have applications in modeling. However, these variations are only applicable to these boreholes in this specific geochemical environment.

The in situ desorption K_d results suggest that technetium-99 and cobalt-60 are very mobile, uranium is considerably less mobile, and chromium is the least mobile.

3.1.3 Vadose Zone Characterization at Waste Management Area C

C. F. Brown and R. J. Serne

The magnitude of contamination found in borehole C4297 at the C Tank Farm is not as great as that found in boreholes at other tank farms.

The Vadose Zone Project managed by CH2M Hill Hanford Group, Inc. drilled one characterization borehole (C4297) in the C Tank Farm during FY 2004 (see Figure 2.10-1 in Section 2.10 for location of Waste Management Area C). The borehole was placed southwest of tank C-105 to investigate: (1) a liquid level drop, believed to be due to evaporation, which occurred in tank C-105 between 1963 and 1967 and (2) vadose zone monitoring data (spectral gamma data from drywell 30-05-07) that indicate two high cesium-137 zones located near and just below the bottom of tank C-105. This section summarizes the results of the characterization effort. The complete results will be published in FY 2005.

Total depth of the borehole was based on rapid turnaround analysis of key mobile contaminants (technetium-99 and nitrate) in grab samples collected as part of the drilling activities. Previous research had shown that technetium-99 and nitrate profiling accurately identifies the maximum vertical penetration of tank waste leaks into the vadose zone (PNNL-13757-2; PNNL-13757-4; PNNL-14083). Advancement of the borehole was halted in the Hanford formation sand sequence (H2 subunit of WHC-SD-EN-TI-290) at a total depth of 59.9 meters below ground surface after technetium-99 was no longer identified in water extracts from seven grab samples representing the final 9 meters of borehole depth. In all, 10 cores (35 samples) were retrieved from borehole C4297 between depths of 7.8 and 41.1 meters. Additionally, 112 grab samples were collected between depths of 0.8 and 63.8 meters. All of the core samples were submitted for radiological, chemical, and geochemical analyses; a summary of the analyses is presented here.

Field measurements included geophysical logging of the characterization borehole using a spectral gamma tool. Cesium-137, cobalt-60, and europium-154 were identified on the log. The maximum cesium-137 concentration was 1,700 pCi/g at ~4.3 meters depth; the maximum cobalt-60 concentration was 1 pCi/g at ~4.5 meters depth; and the maximum europium-154 concentration was 400 pCi/g at ~ 4 meters depth.

Laboratory tests were conducted to characterize the sediment and identify water-leachable constituents. Testing consisted primarily of 1:1 sediment:water extractions that were used to calculate the elemental concentrations of water soluble constituents in the solid and estimate in situ pore water chemistry conditions. Additionally, 8 M nitric acid extractions were used to provide a measure of the total leachable sediment content of contaminants. Radioanalytical analyses of the sediment samples consisted of gamma energy analysis as well as total beta and alpha measurements of the 1:1 sediment:water and 8 M nitric acid extracts.

Of the geochemical parameters measured in the core samples, pH and electrical conductivity, as well as concentrations of nitrate, sodium, uranium, and technetium-99 in water extracts are the main indicators of vadose zone contamination. A spike was observed in both pH (2 pH unit increase) and electrical conductivity (a factor of 5 increase) in water extracts of sediment samples associated with the bottom of the tank. Similarly, sodium levels were elevated by up to a factor of 6 in water extracts of sediment samples from this depth (13 to 14.6 meters below ground surface). Evaluation of these data suggests that chemical reactions between alkaline fluids (possibly tank related) and the native sediment has created an ion exchange front, whereby sodium has replaced calcium and magnesium on the sediments' exchange sites, extending from ~13 meters to as deep as 20 meters below ground surface.

Water-extractable technetium-99 was observed in borehole C4297 grab and core samples from 13.3 to 52.3 meters below ground surface, with a peak water-extractable sediment activity of 5.84 pCi/g at 47.8 meters below ground surface. The profile of water-extractable nitrate from C4297 grab and core samples correlates well with the technetium-99 profile, with a peak

water-extractable nitrate concentration of 17.3 µg/g occurring at 43.8 meters below ground surface. Water-extractable uranium was observed in C4297 grab and core samples from 13.3 to 18.6 meters below ground surface, with a peak water-extractable sediment concentration of 0.022 µg/g at 5.6 meters below ground surface. Minor amounts of beta activity were measured in the C4297 splitspoon acid-extract samples, with peak activities of 33.5 and 31.5 pCi/g occurring at 8.1 and 13 meters below ground surface, respectively. Gamma energy analysis of C4297 splitspoon samples resulted in the detection of no manmade gamma emitters in the sediment profile above concentrations of a few tenths of a picocurie per gram.

The magnitude of contamination found in borehole C4297 is not as great as that found in boreholes at other tank farms. Specifically, the peak water extractable technetium-99 concentration (5.84 pCi/g) measured in sediment samples from C4297 is three orders of magnitude less than the peak concentration measured in cores collected beneath tank SX-108 (10,300 pCi/g). Similarly, the peak acid-extractable uranium concentration (0.958 µg/g) measured in sediment samples from C4297 is three orders of magnitude less than the peak concentration measured in cores collected in the vicinity of tank BX-102 (1,787 µg/g).

3.1.4 Borehole Geophysics for Vadose Zone Characterization

R. G. McCain

As the prime contractor for the U.S. Department of Energy (DOE) Grand Junction Office, the S.M. Stoller Corporation (Stoller) provides geophysical logging services and technical support for the Hanford Site. Geophysical logging in new and existing boreholes is used for stratigraphic correlation and to detect and quantify radioactive contaminants.

Log data, log plots, and reports are accessible via the Internet at http://www.gj.em.doe.gov/hanf.

3.1.4.1 Available Logging Equipment

Borehole logging equipment currently in use for vadose zone characterization at the Hanford Site includes the spectral gamma logging system (SGLS) and the neutron moisture logging system (NMLS). The SGLS uses a cryogenically cooled, high-purity germanium detector to detect, identify, and quantify gamma-emitting radionuclides in the subsurface. Identification of naturally occurring and manmade radionuclides is based on detection of characteristic gamma rays emitted during decay of specific radionuclides. The SGLS is calibrated by measuring detector response to gamma rays from potassium, thorium, and uranium, resulting in a continuous detector response over an energy range from 180 KeV to 2.6 MeV. Minimum detection limits are provided for typical counting times and borehole environments. Corrections are available for dead time, well casing thickness, and the presence of water. A variation of the SGLS, known as the high-rate logging system, uses a much smaller detector than the SGLS and can collect log data in zones of very high gamma activity where the spectral gamma logging detector is saturated. When used in combination, the SGLS and high-rate logging system provide a measurement capability from ~0.1 to 10^9 pCi/g cesium-137.

Geophysical logging allows scientists to determine the characteristics of subsurface, geology, and contaminant distribution through cased or uncased boreholes.

Spectral gamma and total gamma logs are used for stratigraphic correlation, as well as for detection of manmade gamma-emitting radionuclides. Evaluation of high-resolution gamma energy spectra allows identification of radon accumulation in boreholes and differentiation between manmade and naturally occurring uranium. Long-lived radionuclides identifiable by spectral gamma logging include cobalt-60, cesium-137, europium-152 and europium-154, and neptunium-237. Plutonium-239 and americium-241 can also be detected, albeit at much higher concentrations because of the relatively low intensity of their characteristic gamma-ray emissions. In some cases, it is possible to qualitatively detect beta-emitting

radionuclides (i.e., strontium-90) by the bremsstrahlung generated from interaction of beta particles and the steel casing. (Bremsstrahlung is electromagnetic radiation emitted when a charged particle changes its velocity.)

The NMLS uses a 50-mCi americium/beryllium source and helium-3 detector. Neutrons emitted from the source bombard the surrounding formation and are scattered back to the detector. In geologic media, the dominant mechanism for neutron scattering is interaction with hydrogen atoms, and the count rate at the detector is a function of the amount of hydrogen in the formation, which is generally an indicator of the moisture content. Neutron moisture logs are useful as an indication of in situ moisture content and for stratigraphic correlation. The NMLS is calibrated for moisture content in 15-centimeter- and 20-centimeter-diameter cased holes. For other borehole diameters, it can be used qualitatively to identify differences in moisture content. Neutron moisture logs are useful in correlation because fine-grained layers tend to have higher moisture content.

The passive neutron log measures the ambient neutron flux in the borehole. This log is a qualitative indicator of the presence of alpha-emitting radionuclides. Alpha particles emitted from decay of transuranic elements such as plutonium-239 or americium-241 interact with light elements in the soil (primarily oxygen), generating secondary neutrons by (alpha, n) reactions. These neutrons may penetrate the steel casing and be detected by the passive neutron log, or they may be slowed by interactions with the formation and eventually captured. Of the elements commonly present in soil, hydrogen is the most likely to interact with neutrons. Hydrogen has a high capture cross section and promptly emits a gamma ray at 2223.25 KeV, with an intensity of 1 gamma per capture. These gamma rays are detectable with the SGLS and subject to relatively little interference. Thus, the presence of the hydrogen capture line in passive gamma spectra is a qualitative indication of the presence of both soil moisture and alpha-emitting radionuclides.

3.1.4.2 Baseline Characterization Program

The baseline characterization program establishes data against which future data can be compared to assess the movement of contaminants.

The primary goal of the baseline characterization program is to collect initial SGLS data at waste sites in the Hanford 200 Area. These data are used to establish a baseline against which future log data are compared to assess contaminant mobility in the subsurface. The intent of the baseline characterization program is to log boreholes in a specific area, review and update historical log data, integrate the log results, and report the findings for that area. This approach is described in GJO-HGLP 1.7.1. A prioritized list of areas to be investigated and available boreholes organized by waste site is maintained by Stoller. This list is subject to change, depending on remedial investigation activities and the borehole decommissioning project.

During FY 2004, baseline characterization logging was performed at the 216-A-27 crib, in the B/C crib area, and in the vicinity of the 216-T-6 crib. The B/C cribs area is also the subject of remedial investigation activities, and the seven existing boreholes logged in this area could also be considered under remedial investigation support.

For the most part, the baseline characterization logging was superceded by logging for remedial investigation support in FY 2004. Priority for baseline logging operations was also subject to change as boreholes were identified for decommissioning. Boreholes selected for decommissioning are reviewed by Stoller and those in or near known waste sites are logged as part of the baseline program prior to decommissioning. In two cases, Stoller ran total gamma logs in two 600 Area boreholes scheduled for decommissioning. The purpose of these logs was to determine depths for multiple casing strings where as-built drawings were not available.

3.1.4.3 Remedial Investigation Support

In addition to baseline characterization, borehole geophysical logging also supports remedial investigations and feasibility studies for the Groundwater Remediation Project's assessment of the Central Plateau operable units. Geophysical logging is also performed in

new and existing boreholes as requested by the responsible Hanford Site contractors. Log data plots and reports are provided to project representatives.

During FY 2004, logging operations to support remedial investigation activities were performed in 91 boreholes. In addition to spectral gamma logging, high rate logging, neutron moisture logging, and passive neutron logging were also performed in selected boreholes. Areas in which logging was performed included the 216-A-4, 216-A-8, and 216-A-10 cribs; the B/C cribs area; 216-S-7 and 216-S-20 cribs; the 216-T-28 crib; and the U Plant area. In the U Plant area, drive casings were driven specifically for geophysical logging to determine the maximum extent of lateral contaminant migration in the shallow vadose zone to support cover design.

During FY 2004, geophysical logging was performed at 91 boreholes to support remedial investigation activities.

In addition to logging operations in the 200 Area and vicinity, three existing extraction wells in the 100-D Area in situ redox manipulation project were logged to assess the ability of geophysical logs to detect subtle variations in stratigraphy which may affect contaminant migration in the shallow aquifer.

3.1.4.4 Groundwater Well Development

Spectral gamma logs are run in newly drilled RCRA groundwater wells prior to well completion. In many cases, neutron moisture logs are also run. These logs provide a record of vadose zone conditions at the well location and help stratigraphic interpretation. During FY 2004, 14 groundwater wells were logged.

3.1.5 Characterization of the BC Cribs and Trenches

J. W. Lindberg

Characterization of the BC cribs and trenches began in FY 2004 to support the 200-TW-1 Scavenged Waste Operable Unit feasibility study. The purpose of the characterization is to find the concentration and extent of subsurface contamination in the area. The location of the BC cribs is shown on Figure 2.10-1 in Section 2.10.

Field activities included drilling 14 shallow boreholes to find the most contaminated areas, drilling 3 deeper boreholes to characterize the contamination at depth, and surface geophysical surveys to identify existing infrastructure from legacy disposal activities and delineate the edges of a radionuclide and heavy metal contamination plume in the vadose zone. Preliminary results are summarized in this section. A more detailed discussion of the characterization activities will be included in the FY 2005 groundwater report after data become available.

Results of soil sampling and analysis in the shallow boreholes indicated that the surface contamination was greatest at two trenches: 216-B- 26 and 216-B-58. The three deeper soil borings focused on these two trenches. At trench 216-B-26, one borehole was drilled to the water table, soil samples were collected while drilling, and a water sample was collected from the aquifer. At trench 216-B-58, two 30.5-meter boreholes were drilled and soil samples were collected.

Preliminary results of soil sampling at the 216-B-26 trench indicated that there was significant near-surface contamination that included cesium-137 (529,000 pCi/g), strontium-90 (974,000 pCi/g), and uranium (56.9 mg/kg) contamination between 3.7 and 4.6 meters depth. The bottom of the trench is at ~3 meters depth. The maximum technetium-99 (92 pCi/g) and nitrate (4,090 mg/kg) concentrations occurred at ~30.5 meters depth. Soil samples in the two 30.5-meter boreholes, at the 216-B-58 trench, showed little contamination. The only significant contamination in the groundwater sample was filtered manganese with a concentration of 208 μg/L (drinking water standard 50 μg/L). High concentrations of manganese are common in recently drilled wells suggesting that the elevated manganese in the groundwater may not be related to BC cribs waste disposal.

The high resolution resistivity survey successfully identified subsurface contamination at the BC cribs and trenches.

The surface geophysical investigations (PNNL-14948) included magnetic gradiometry, electromagnetic induction, and high resolution resistivity. The magnetic and electromagnetic surveys were to provide rapid reconnaissance coverage to detect the presence of shallow, electrically-conductive material (liquid and metallic) and ferrous metallic material associated with historic disposal activities. These features were a concern because they could influence the subsequent high resolution resistivity survey.

The electromagnetic surveys found that only some of the trenches gave shallow electromagnetic responses and several showed unusual responses. All of the cribs responded to the electromagnetic surveys. Several pipelines and infrastructural features were detected.

The high resolution resistivity survey successfully identified subsurface contamination because the contaminant plume has electrical properties that were significantly different from the background Hanford formation. The plumes electrical signature was found to spread laterally beyond the edges of the trenches and cribs and vertically down to a hydraulically resistive layer at a depth of 42 meters below ground surface.

Table 3.1-1. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-A-29 Ditch[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Acetone	13	Test pit AD-2	2.3
Americium-241	145	B8826	1.2
Ammonia	41.6	Test pit AD-1	1.2 to 1.5
Bis(2-ethylhexyl)phthalate	470	Borehole B8826	2.7
Chloride	226	Test pit AD-1	1.2 to 1.5
Cadmium	28	Test pit AD-1	1.2 to 1.5
Calcium	24,300	Test pit AD-3	1.8 to 2.1
Cesium-137	98	Test pit AD-1	1.2 to 1.5
Chromium	36.8	Test pit AD-1	1.2 to 1.5
Copper	172	Test pit AD-1	1.2 to 1.5
Lead	390	Test pit AD-1	1.2 to 1.5
Mercury	5.2	Test pit AD-1	1.2 to 1.5
Nickel	27.6	Test pit AD-1	1.2 to 1.5
Nitrate (as N)	209	Test pit AD-1	1.2 to 1.5
Potassium	2,230	Test pit AD-2	1.5 to 1.8
Plutonium-238	15.7	Borehole B8826	1.2 to 1.8
Plutonium-239/240	667	Borehole B8826	1.2 to 1.8
Silver	42	Test pit AD-1	1.2 to 1.5
Sulfate	2,970	Test pit AD-1	1.2 to 1.5
Tritium	7.05	Borehole B8826	79.2 to 79.8
Total petroleum hydrocarbons, kerosene range	440,000	Borehole B8826	1.2
Total uranium	5.28	Test pit AD-2	2.2 to 2.6
Vanadium	104	Test pit AD-2	1.5 to 1.8
Zinc	224	Test pit AD-1	1.2 to 1.5

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-2. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-B-63 Trench[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Acetone	66	Test pit BT-2	1.5
Benzene	8	Test pit BT-2	1.5
Cadmium	2.42	Borehole B8827	5.3 to 5.8
Cesium-137	3.56	Test pit BT-1	2.9 to 3.2
Chromium	21.9	Borehole B8827	3.8 to 4.4
Copper	30.6	Test pit BT-1	3.7 to 4.0
Methylene chloride	16	Test pit BT-1	5.2
Nickel	21.0	Borehole B8827	5.9 to 6.6
Nitrate (as N)	188	Test pit BT-2	1.5 to 1.8
Phosphate	6.4	Test pit BT-1	2.1 to 2.4
Strontium-90	24	Test pit BT-2	1.8 to 2.1
Toluene	5	Test pit BT-2A	7.3
Vanadium	86.6	Test pit BT-1	2.3 to 2.6
Xylene	8	Borehole 299-E33-333 (sampled in 1998)	45.7

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-3. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-S-10 Pond[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Acetone	26	Test pit SP-3	2.6
Barium	180	Test pit SP-1	6.1 to 6.4
2-Butanone	12	Borehole B8817	30.3
Carbon-14	12.2	Test pit SP-2	2.0 to 2.3
Chromium	26.2	Borehole B8817	60.1 to 60.7
Lead	10.3	Borehole B8817	15.3 to 15.9
Mercury	0.43	Test pit SP-2	3.5 to 3.8
Methylene chloride	23	Test pit SP-3	4.9
Nickel	25	Borehole B8817	60.1 to 60.7
Nickel-63	2.46	Borehole B8817	15.2 to 15.8
Nitrate (as N)	30	Test pit SP-3	4.9 to 5.2
Phosphate	3.8	Test pit SP-2	3.5 to 3.8
Plutonium-239/240	2.33	Test pit SP-2	3.5 to 3.8
Silver	8.3	Test pit SP-2	2.7 to 3.1
Vanadium	87.5	Borehole B8817	45.8 to 46.4
Zinc	201	Borehole B8817	60.1 to 60.7

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-4. Maximum Concentrations for Radionuclides and Non-Radionuclides Exceeding Background in Samples from the 216-S-10 Ditch[a]

Constituent	Concentration[b]	Location	Depth Below Ground Surface (m)
Bis(2-ethylhexyl)phthalate	380	Test pit SD-1	2.6
Cesium-137	9.13	Test pit SD-2	0 to 0.5
Chromium	815	Test pit SD-2	0 to 0.5
Lead	30	Test pit SD-2	0 to 0.5
Mercury	4.3	Test pit SD-2	0 to 0.5
Methylene chloride	17.72	Borehole B8828	6.1
Nickel	21	Borehole B8828	45.8 to 46.4
Nickel-63	38.4	Borehole B8828	7.6 to 8.2
Nitrate (as N)	18	Borehole B8828	0 to 0.5
Phenanthrene	930	Test pit SD-2	0.4
Phosphate	2.4	Borehole B8828	61.0 to 61.6
Plutonium-239/240	3.24	Test pit SD-2	0 to 0.5
Silver	30	Test pit SD-2	0 to 0.5
Total petroleum hydrocarbons, kerosene range	19,000	Borehole B8828	45.7
Vanadium	131	Borehole B8828	61.0 to 61.6
Zinc	506	Test pit SD-2	0 to 0.5

(a) Background values were obtained from DOE/RL-92-24, DOE/RL-96-12, and Ecology (1994b).
(b) Concentrations are mg/kg for metals and anions, pCi/g for radionuclides, and µg/kg for organics.

Table 3.1-5. Maximum Concentrations and Depths of Maximum Concentrations for Selected Constituents in Borehole C3245 at the 216-A-19 Trench[a]

Constituent	Maximum Concentration[b]	Depth of Maximum Concentration (m)
Manganese	538	5.3
Nickel-63	17.6	4.4
Nitrate	9,860	8.3
Strontium-90	20.0	5.3
Thorium-234	56.8	4.4
Uranium-233/234	6.0	4.4
Uranium-238	51	4.4
Uranium, total	130	6.9

(a) All data from DOE/RL-2004-25.
(b) Concentrations are mg/kg for non-radionuclides and pCi/g for radionuclides.

Table 3.1-6. Maximum Concentrations and Depths of Maximum Concentrations for Selected Constituents in Borehole C3247 at the 216-A-10 Crib[(a)]

Constituent	Maximum Concentration (pCi/g)	Depth of Maximum Concentration (m)
Americium-241	1,320	15.8
Carbon-14	7.5	19.0
Cesium-137	2,950	15.8
Iodine-129	38.8	19.0
Plutonium-238	316	15.8
Plutonium-239/240	7,110	15.8
Potassium-40	27.2	15.8
Strontium-90	44.7	38.9
Tritium	835	96.6

(a) All data from DOE/RL-2004-25.

Table 3.1-7. Maximum Concentrations of Selected Radionuclides and Non-Radionuclides in Samples from the 216-A-36B Crib[(a)]

Constituent	Maximum Concentration[(b)]	Depth of Maximum Concentration (m)
Americium-241	40,000	7.6
Ammonium (as N)	1550	7.3
Carbon-14	116	7.6
Cesium-137	2,650,000	7.6
Cobalt-60	623	7.6
Europium-154	1,800	7.6
Nickel	58,000	7.6
Nickel-63	181,000	7.6
Nitrate (as N)	289,000	16.3
Nitrite (as N)	18,800	7.6
Plutonium-239/240	98,000	7.6
Total radioactive strontium	92,000	8.4
Technetium-99	41.9	7.6
Thorium-230	11.4	9.1
Thorium-232	4.8	7.6
Tritium	76	87.6
Uranium (total)	36,800	9.1
Uranium-233/234	81.2	7.6
Uranium-235	3.3	7.6
Uranium-236	4.5	7.6
Uranium-238	70.9	7.6

(a) All data from DOE/RL-2004-25.
(b) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

Table 3.1-8. Concentrations for Selected Constituents in Samples from the 216-A-37-1 Crib

Constituent	Maximum Concentration[(a)]	Depth of Maximum Concentrations (m)
Aluminum	15,000	22
Manganese	652	15.2
Nickel-63	14.4	11.4
Nitrate (as N)	385	3.8
Strontium-90	1.7	3.8
Thallium	1.54	29.5
Tritium	267	14.5

(a) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

Table 3.1-9. Concentrations for Selected Constituents in Samples from the 216-B-12 Crib

Constituent	Maximum Concentration[(a)]	Depth of Maximum Concentrations (m)
Ammonium (as N)	404	28.6
Boron	1.3	14.5
Chromium (total)	30.4	91.5
Cesium-137	61,000	10.8
Europium-155	34.9	10.8
Mercury	1.3	10.8
Nitrate (as N)	165	10.8
Potassium-40	15.8	60.2
Silver	2.4	15.2
Strontium-90	12,700	10.8
Thorium	5.4	28.6
Thorium-228	7.54	10.8
Tributyl phosphate	2,000	12.2
Tritium	8.28	4.4
Uranium	42	60.2
Uranium-233/234	4.9	12.2
Uranium-238	5.10	12.2

(a) Concentrations are pCi/g for radionuclides and mg/kg for non-radionuclides.

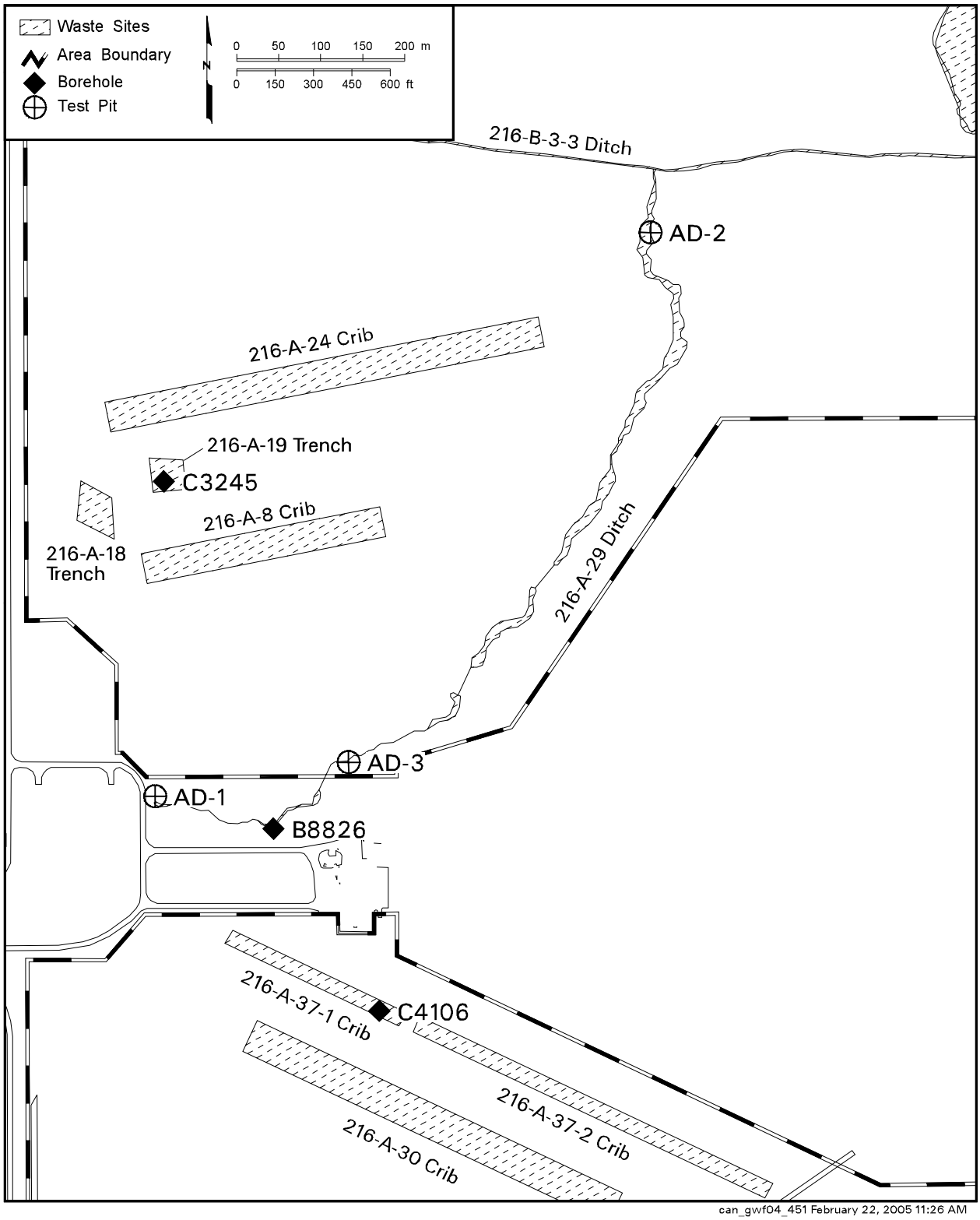

Figure 3.1-1. Borehole and Test Pit Locations at the 216-A-29 Ditch

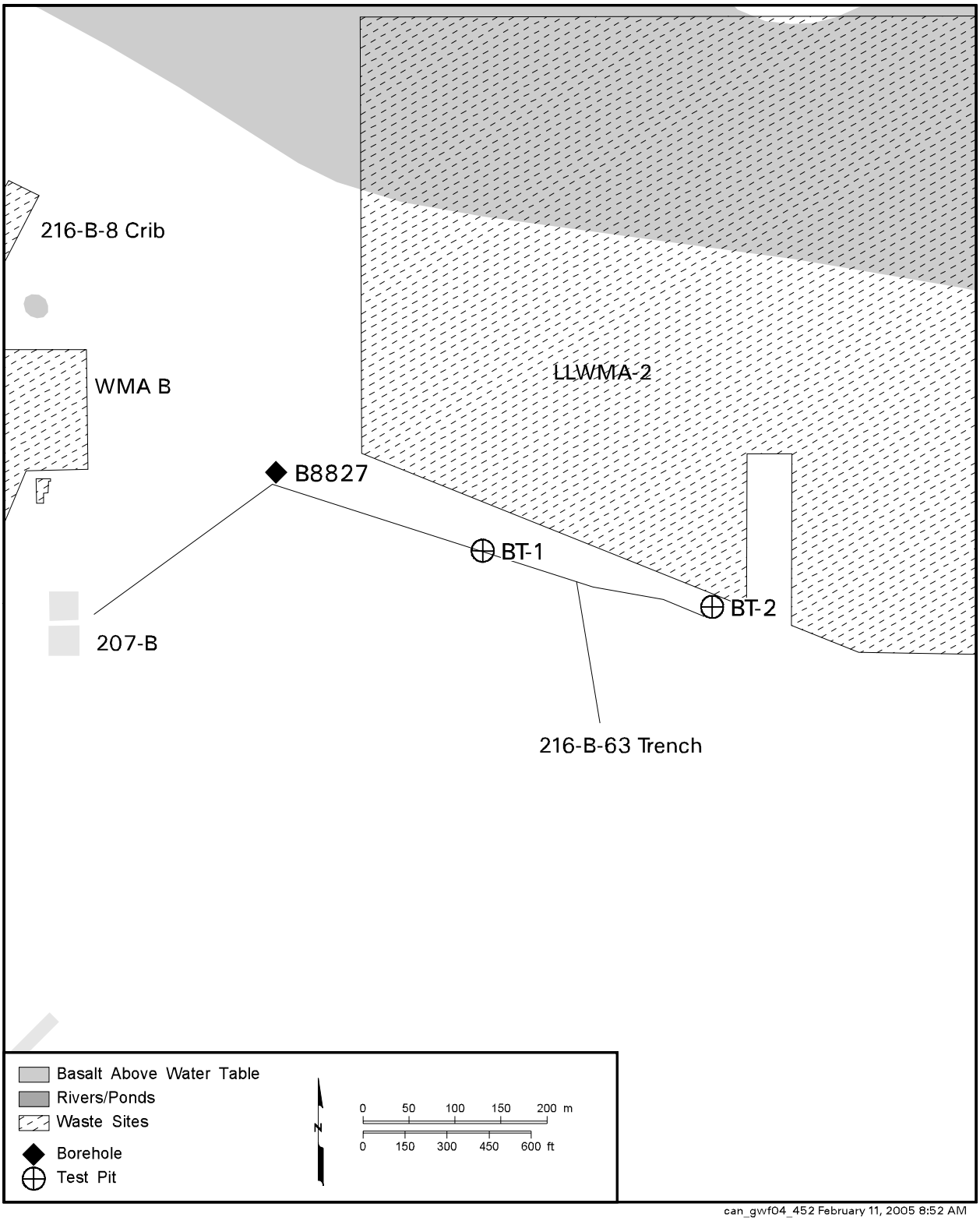

Figure 3.1-2. Borehole and Test Pit Locations at the 216-B-63 Trench

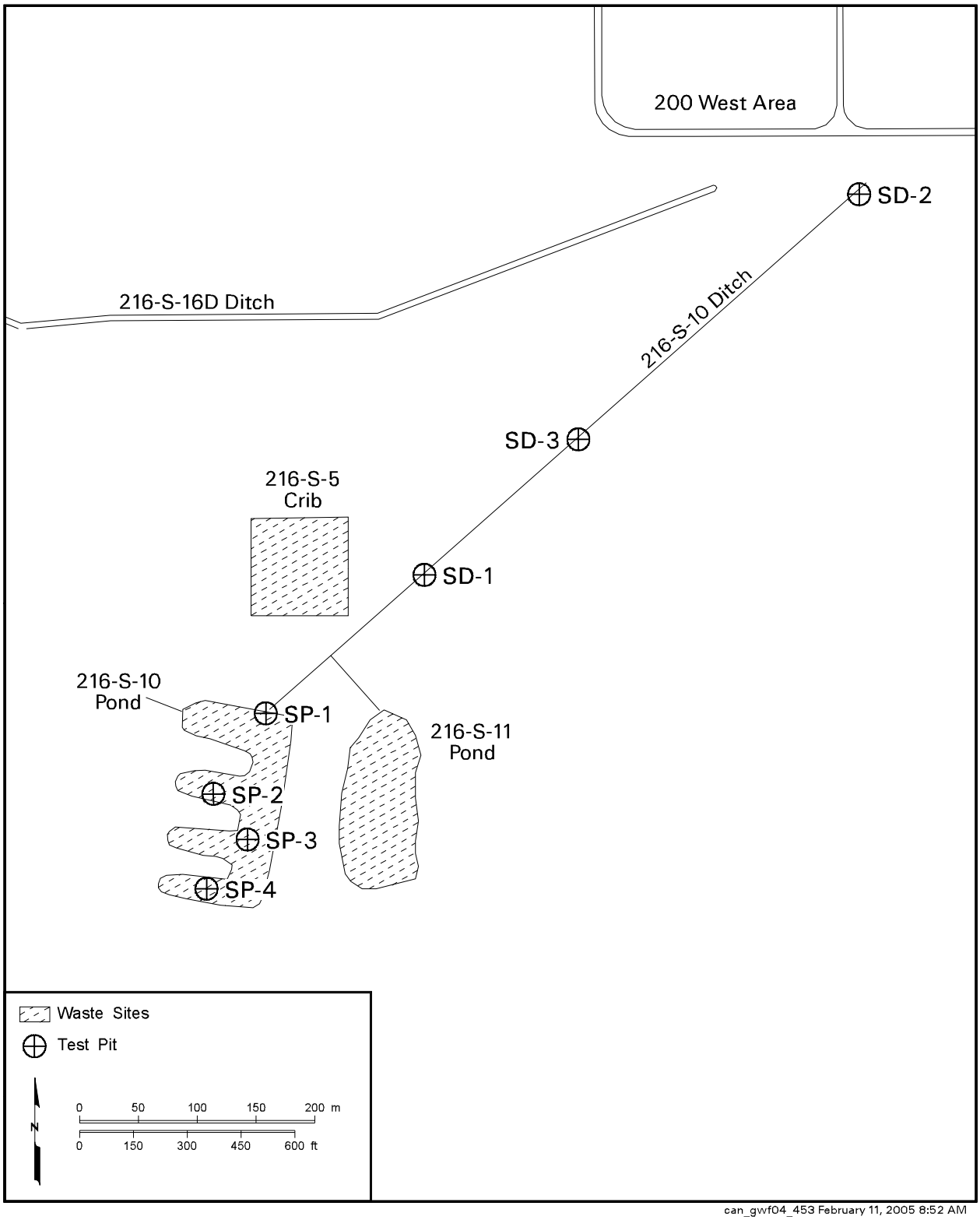

Figure 3.1-3. Borehole and Test Pit Locations at the 216-S-10 Pond and 216-S-10 Ditch

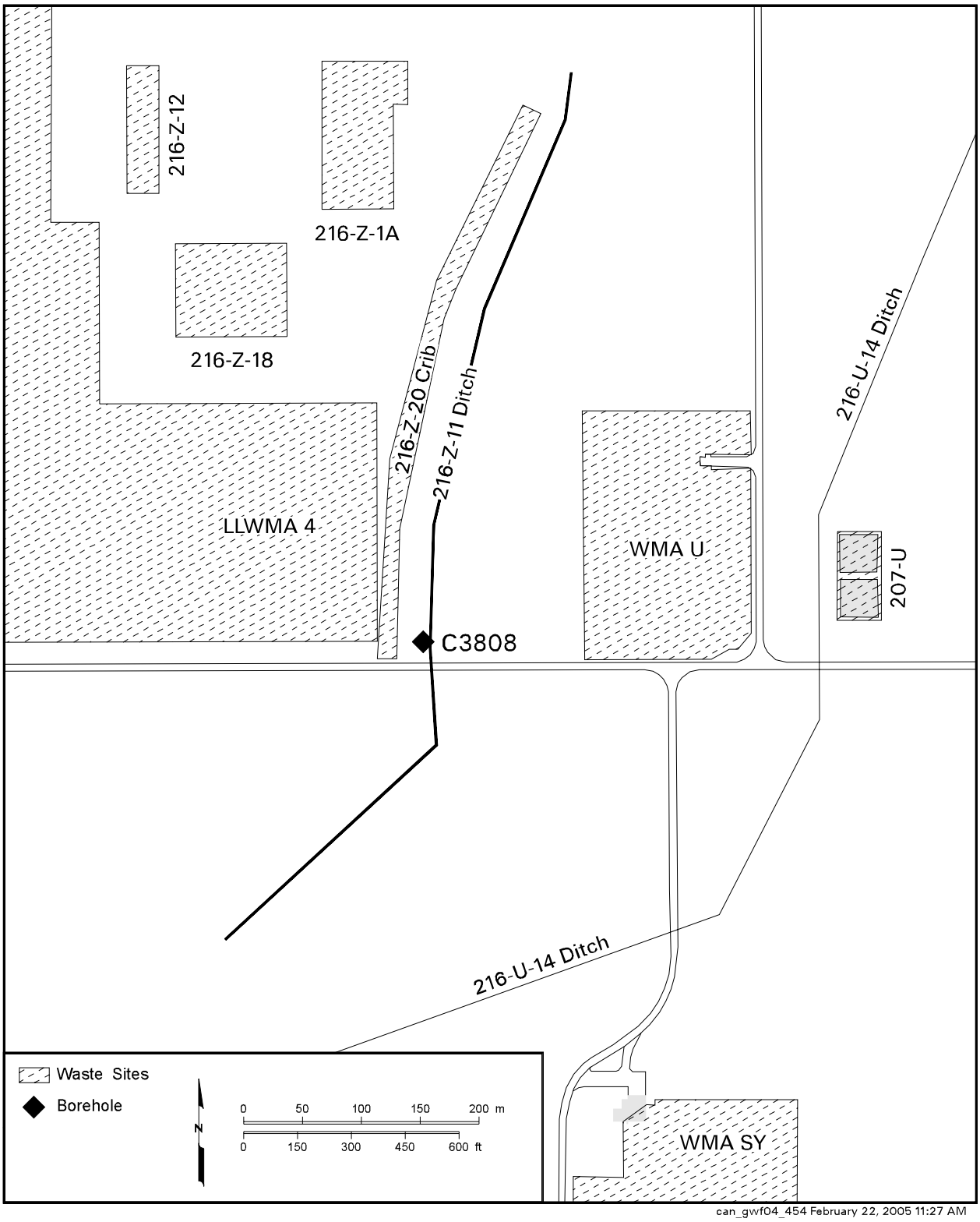

Figure 3.1-4. Location of Borehole C3808 at the 216-Z-11 Ditch

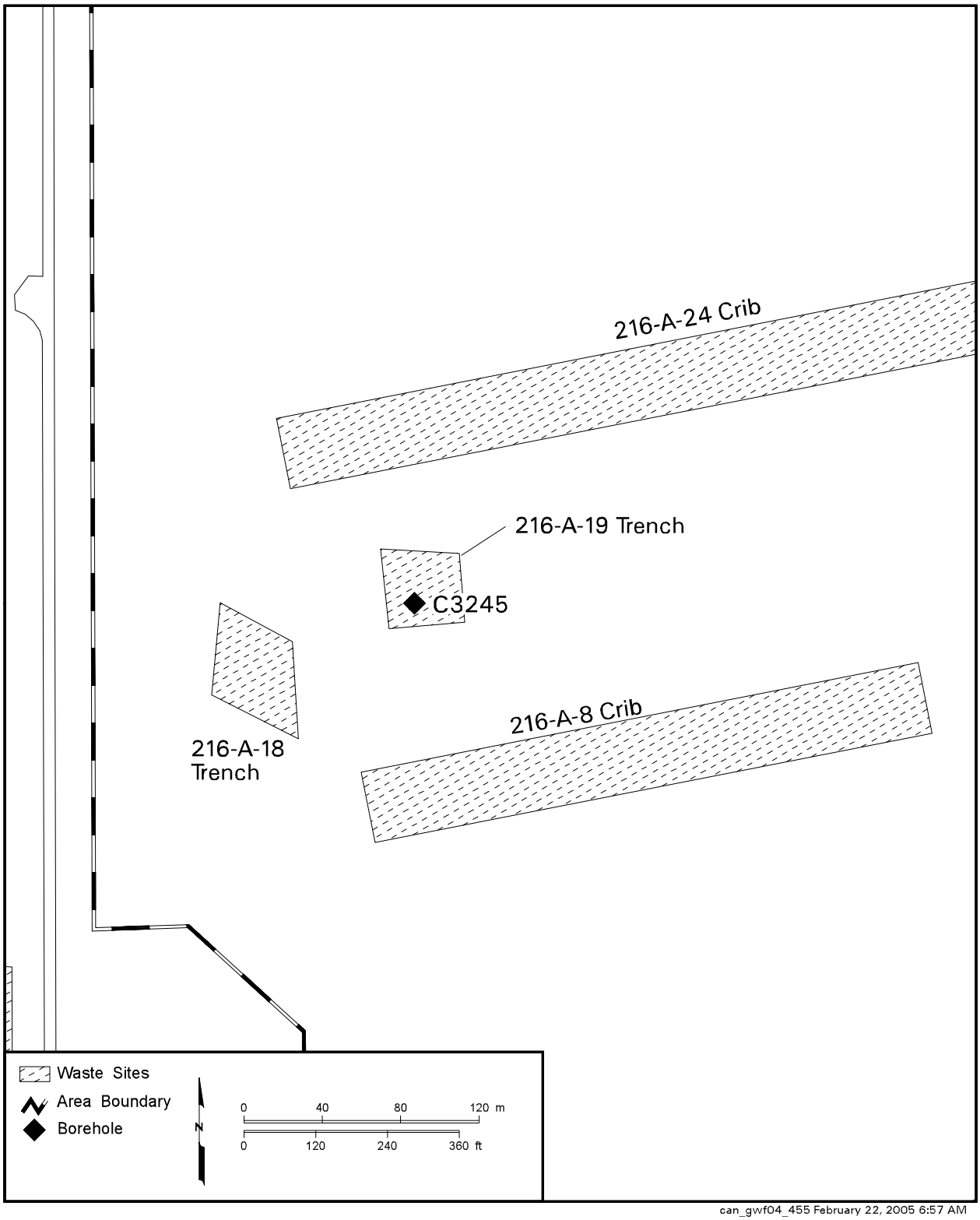

Figure 3.1-5. Location Map for Borehole C3245 at the 216-A-19 Trench

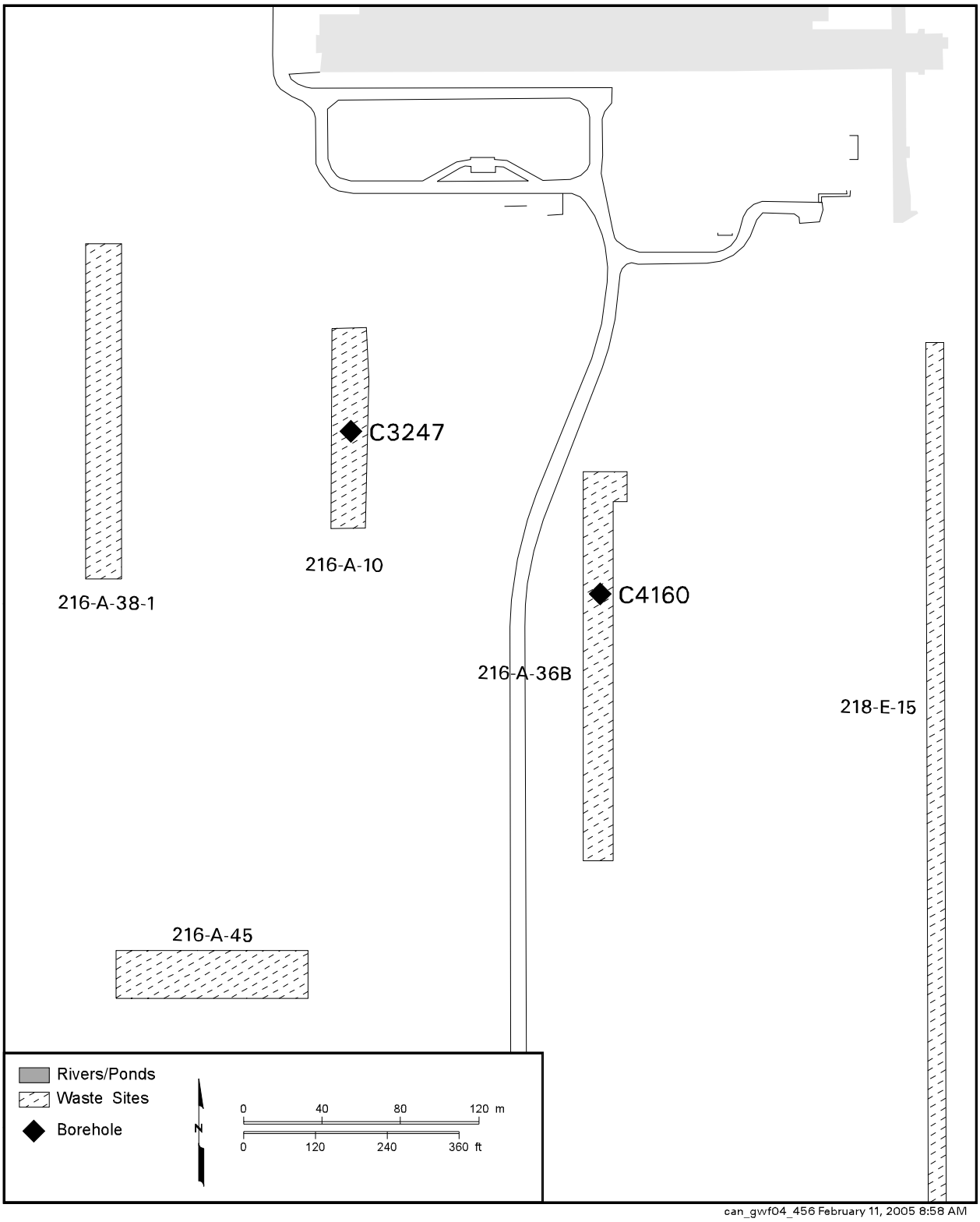

Figure 3.1-6. Borehole Location Map for the 216-A-10 and 216-A-36B Cribs

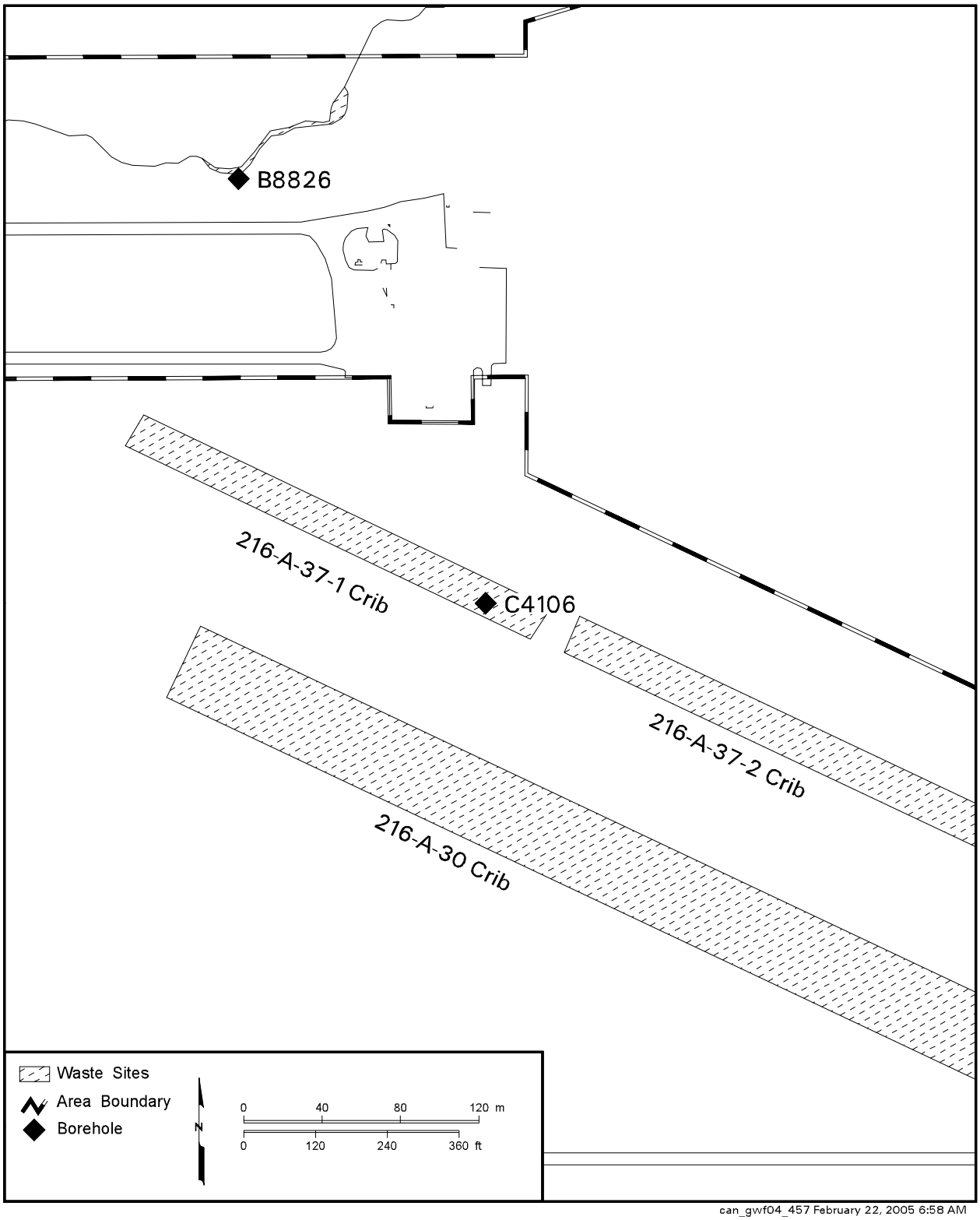

Figure 3.1-7. Location Map for Borehole C4106 at the 216-A-37-1 Crib

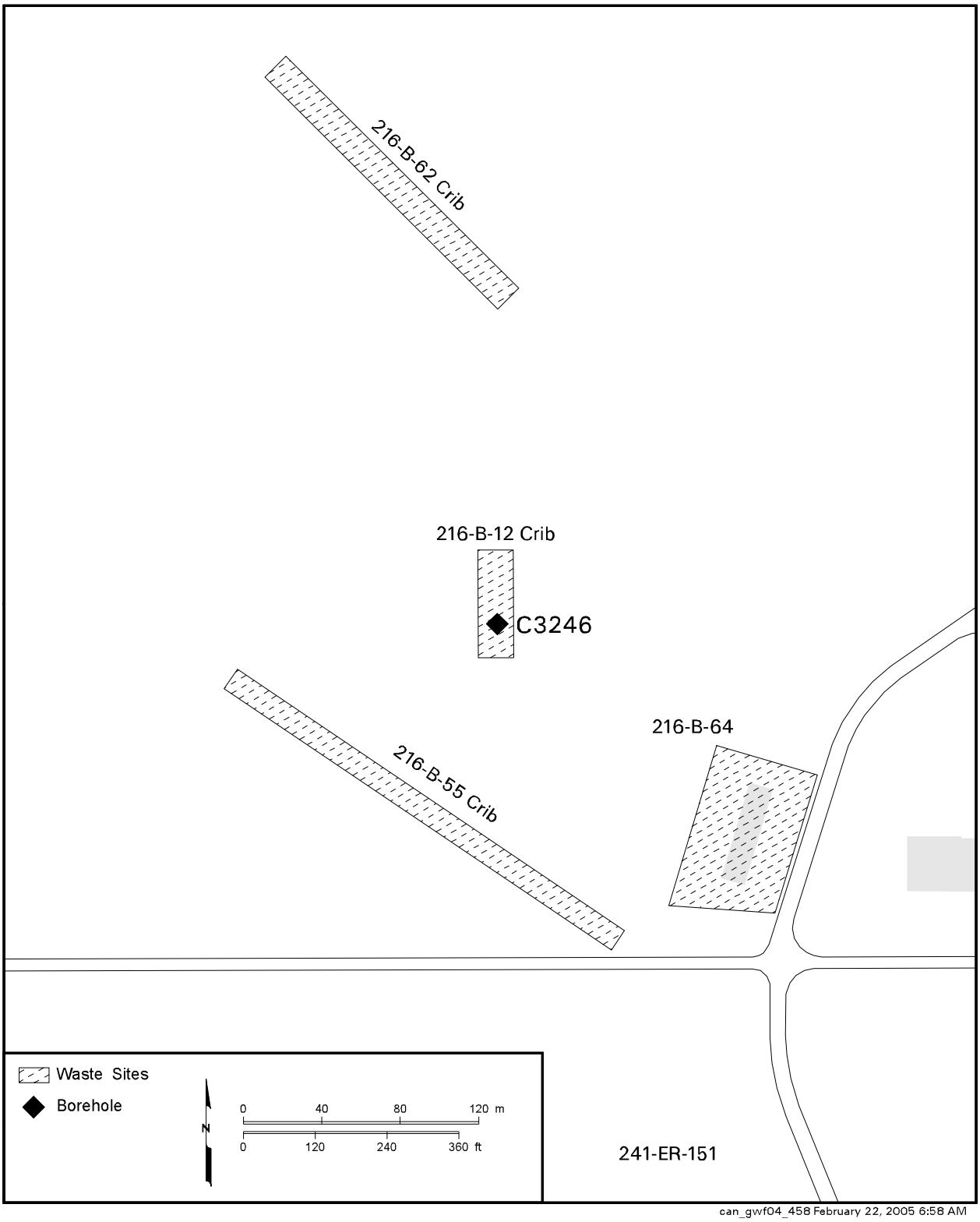

Figure 3.1-8. Location Map for Borehole C3248 at the 216-B-12 Crib