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. Sidewall 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_ds are shown in Table 3.2-5.

The K_ds 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_ds 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 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.

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.

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-HAN133. 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 or 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 m^3/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 m^3/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-Pliestocene 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 geostructural 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_ds, 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]	pH	1:1 Water Extracts: Specific Conductance (µS/cm)	Nitrate (µg/g soil)	Sodium (µg/g soil)	Technetium-99 (pCi/g soil)	Cesium-137 (pCi/g soil)	Chromium (µg/g soil)	Selenium (µg/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	6.3	1.8E+02	2.9E-01
38.8	7.9	16,550	12,813	1,889	334	6.3	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) Radiological 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.

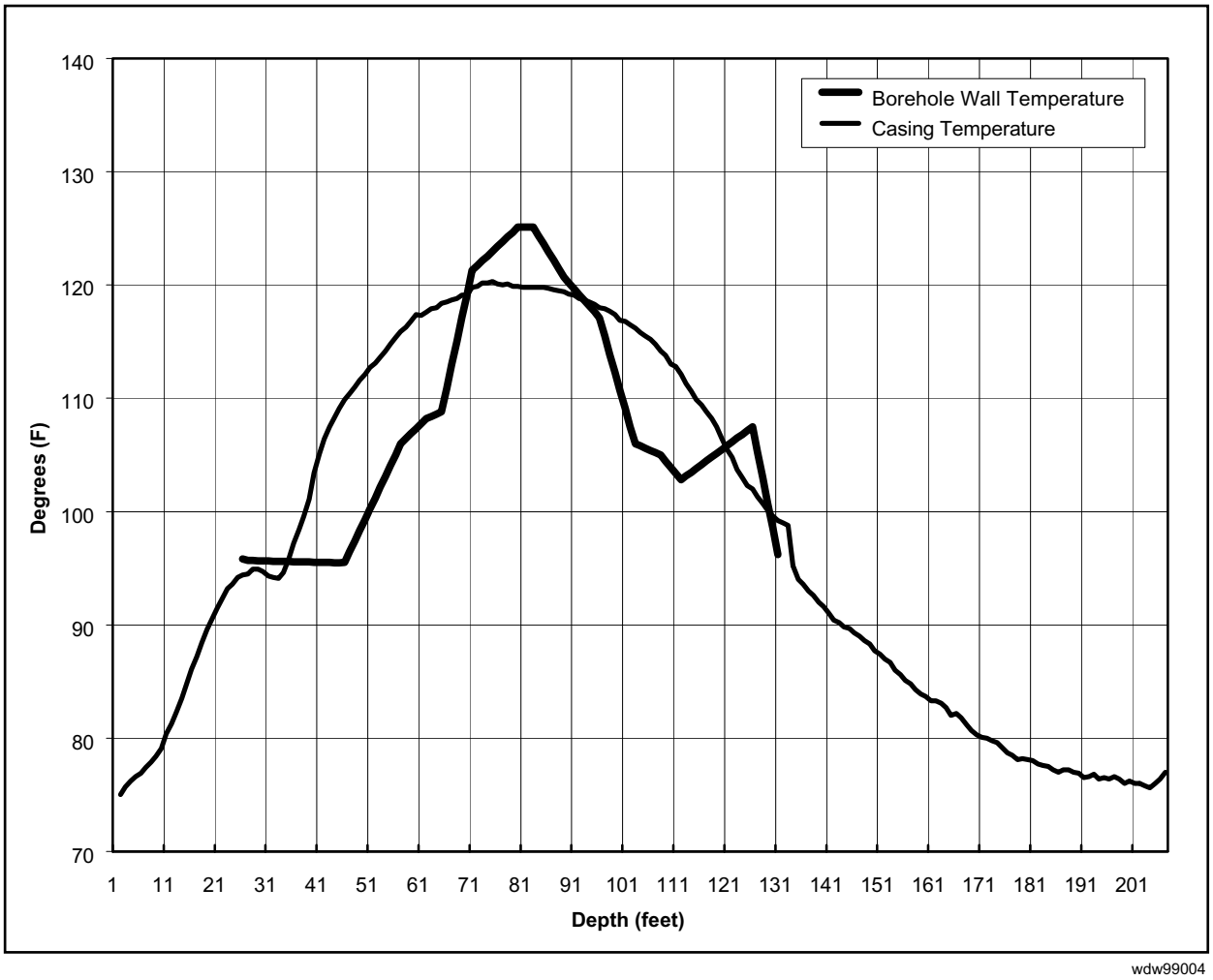

Figure 3.2-1. Temperature Distribution in Borehole 41-09-39

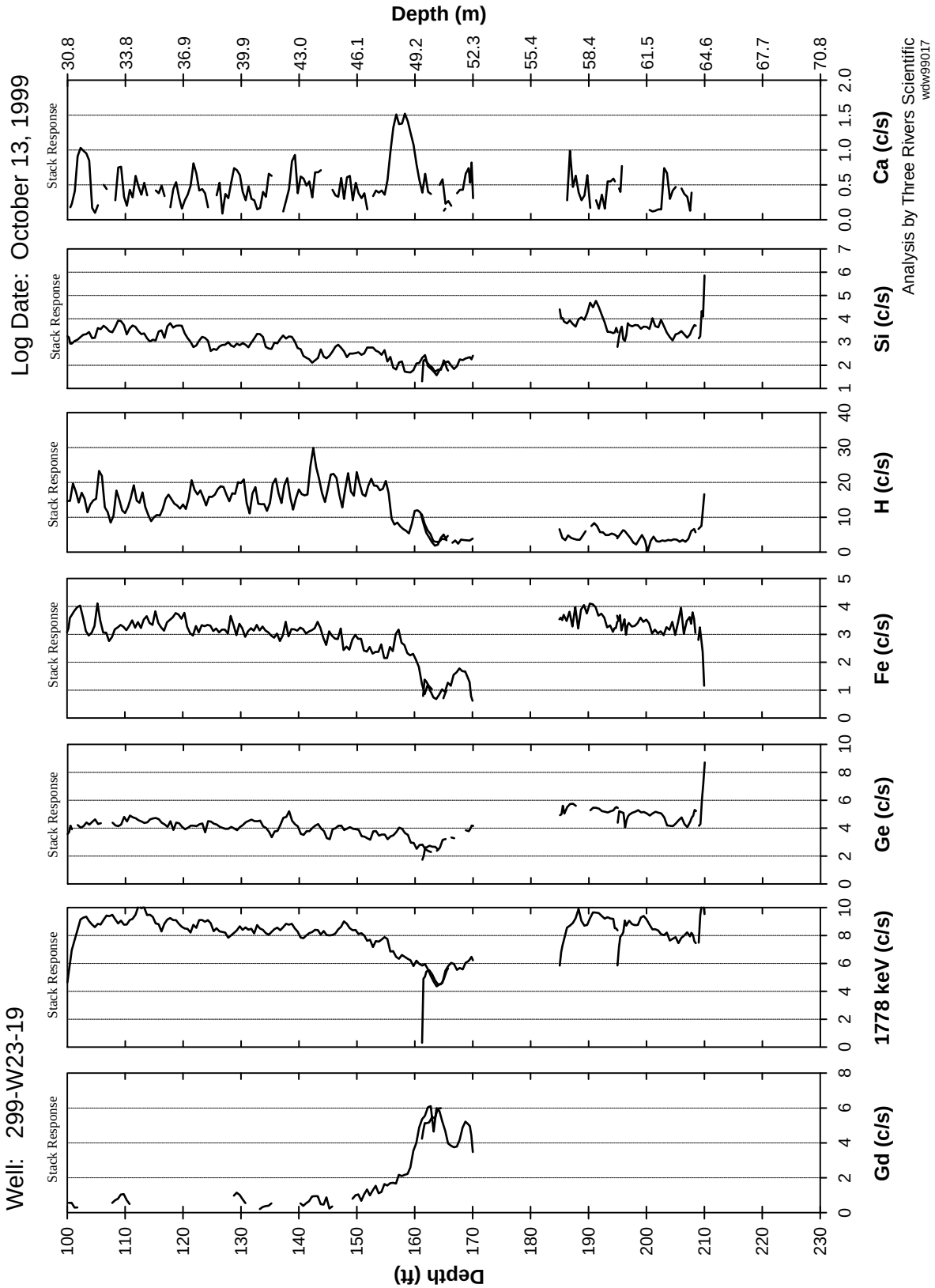

Figure 3.2-2. Neutron-Gamma Capture Spectroscopy Log from the New Borehole at Single-Shell Tank SX-115

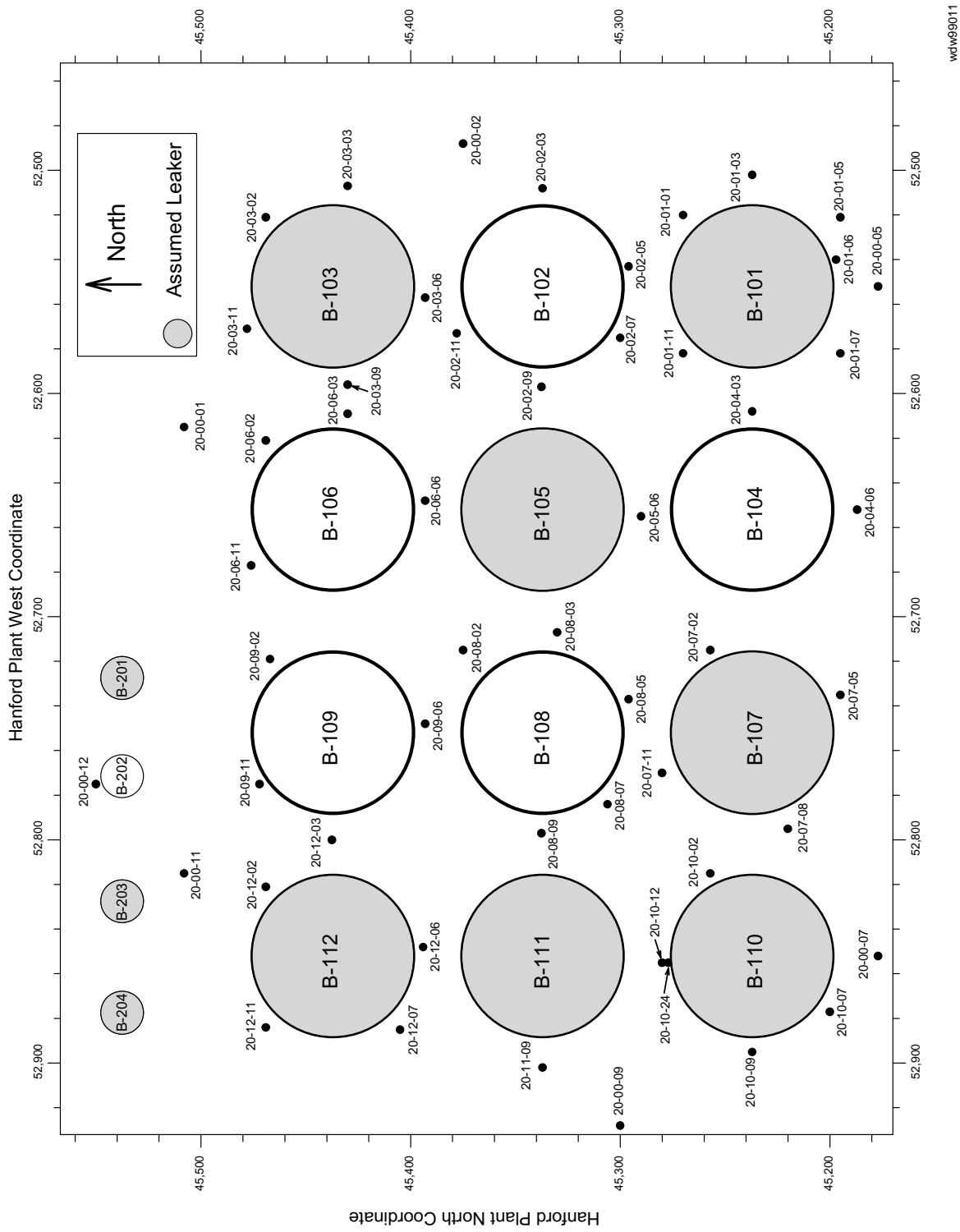

Figure 3.2-3. Map of B Tank Farm with Layout of Tanks and Locations of Monitoring Boreholes. Tanks indicated by shading are assumed to have leaked.

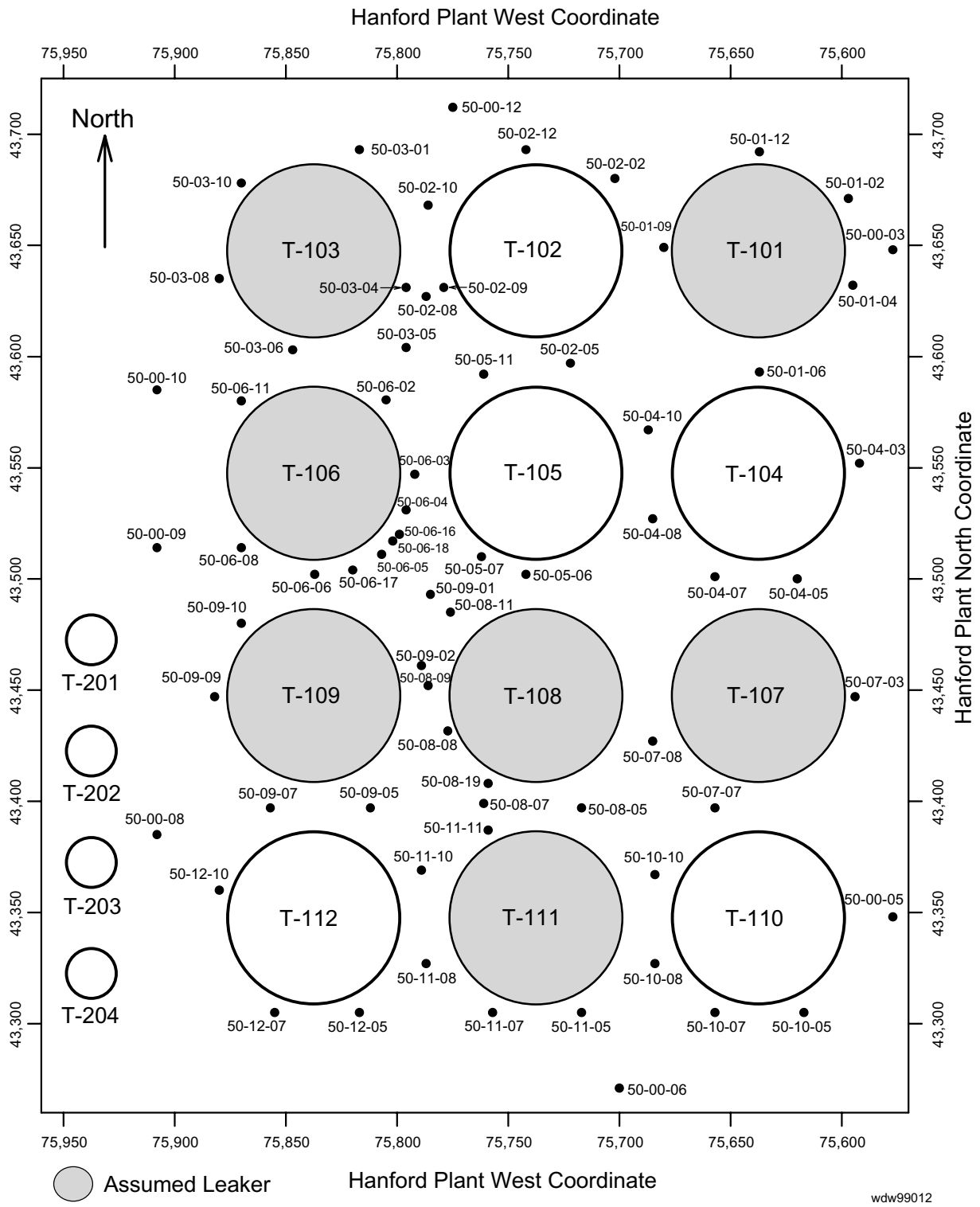

Figure 3.2-4. Map of T Tank Farm with Layout of Tanks and Locations of Monitoring Boreholes. Tanks indicated by shading are assumed to have leaked.

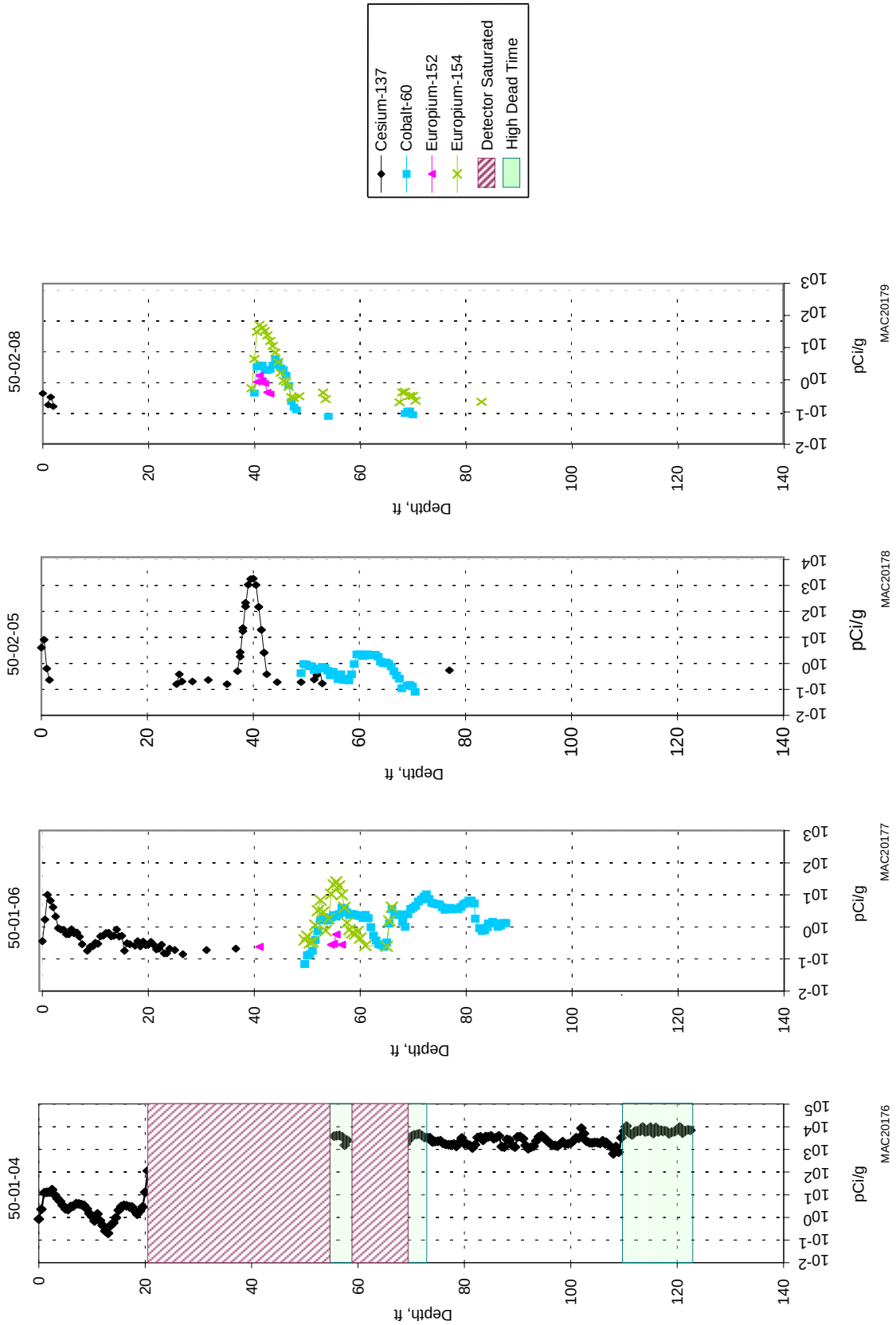

Figure 3.2-5. Selected Spectral Gamma-Ray Logs of Radionuclides Around Boreholes in T Tank Farm Showing Concentrations of Contaminants versus Depth (after GJO-99-101-TAR, GJO-HAN-27)

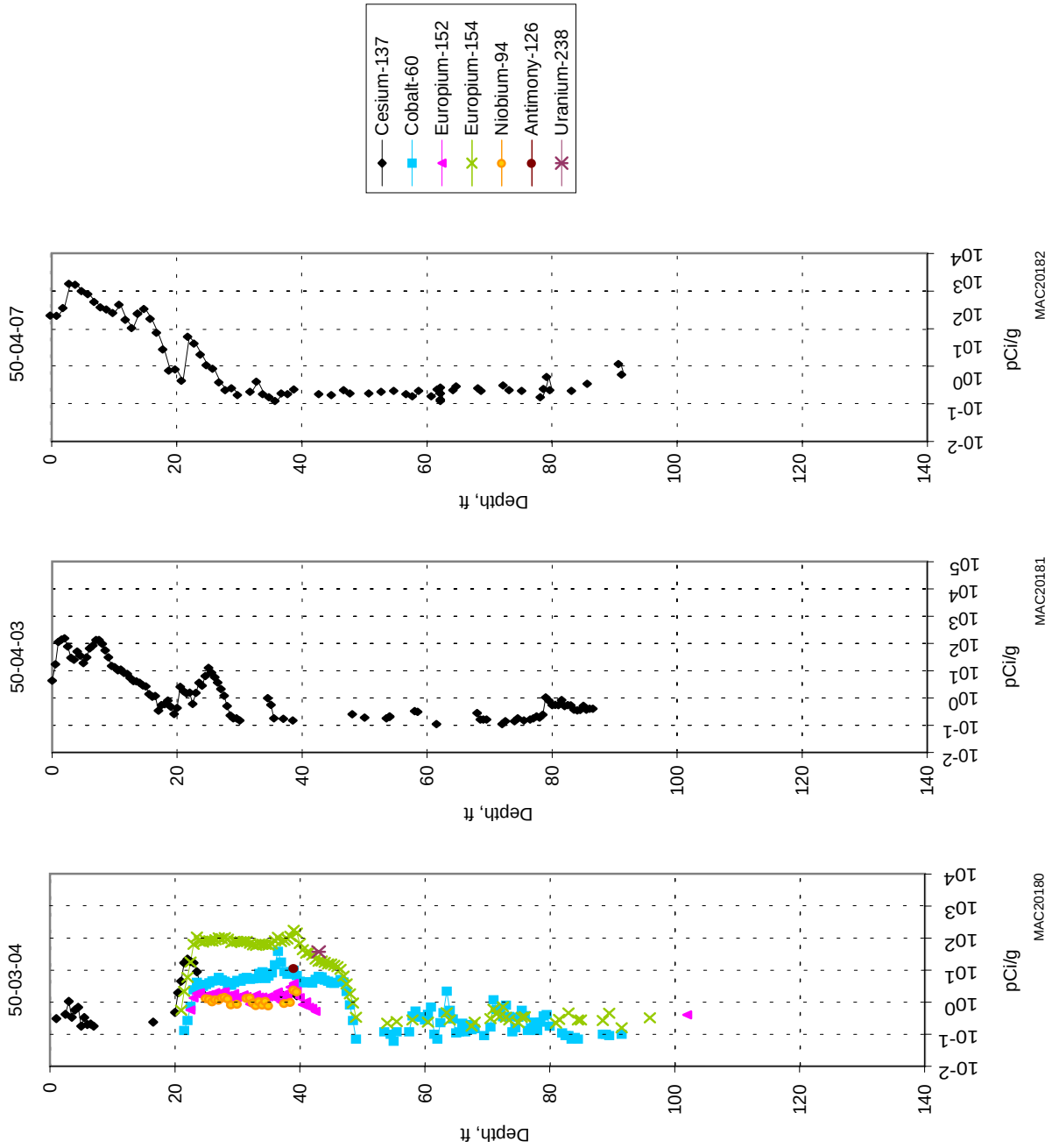

Figure 3.2-5. (contd)

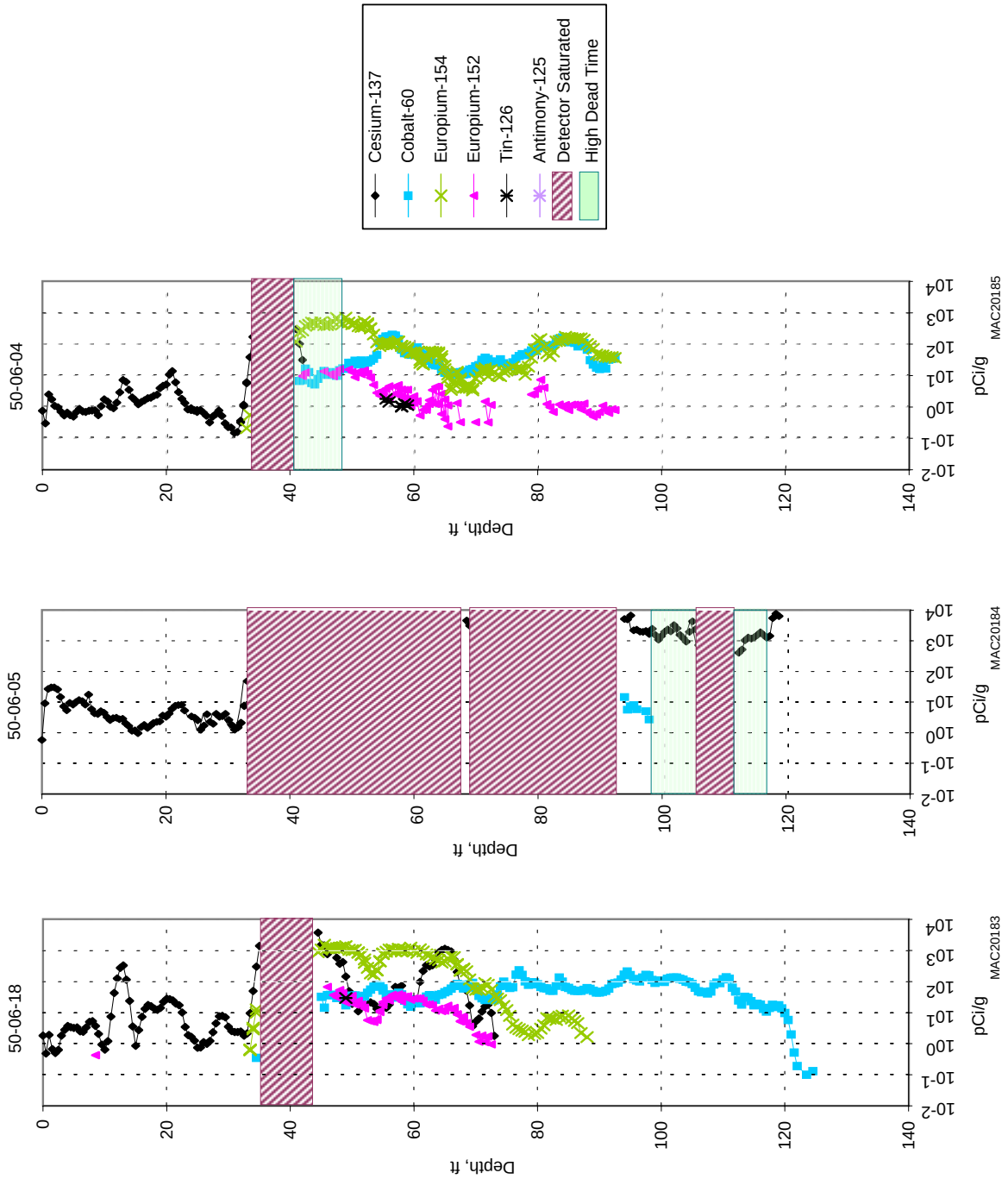

Figure 3.2-6. Selected Spectral Gamma-Ray Logs of Radionuclides Around Boreholes Near Tank T-106 in T Tank Farm Showing Concentrations of Contaminants versus Depth (after GJO-99-101-TAR, GJO-HAN-27)

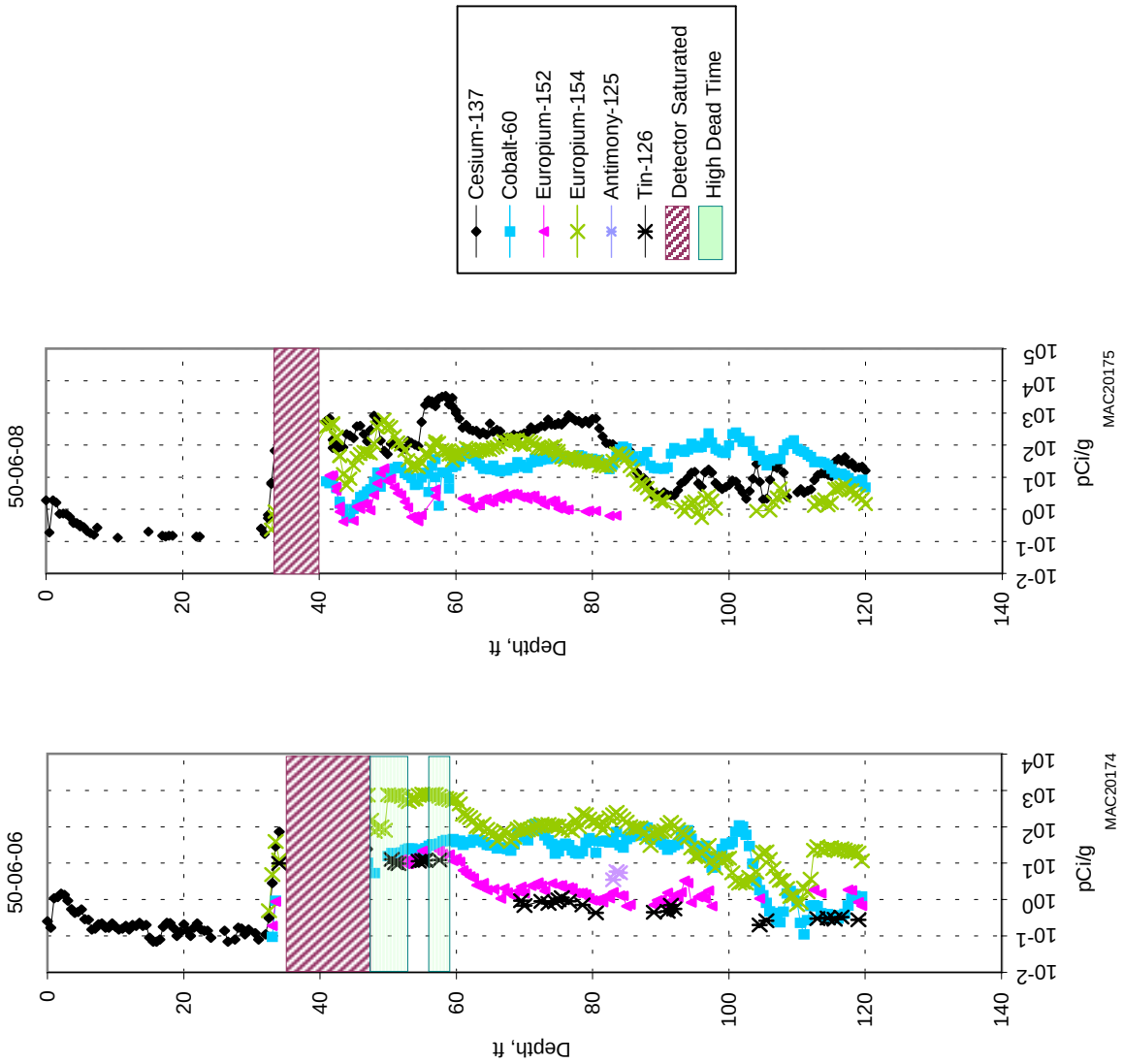

Figure 3.2-6. (contd)

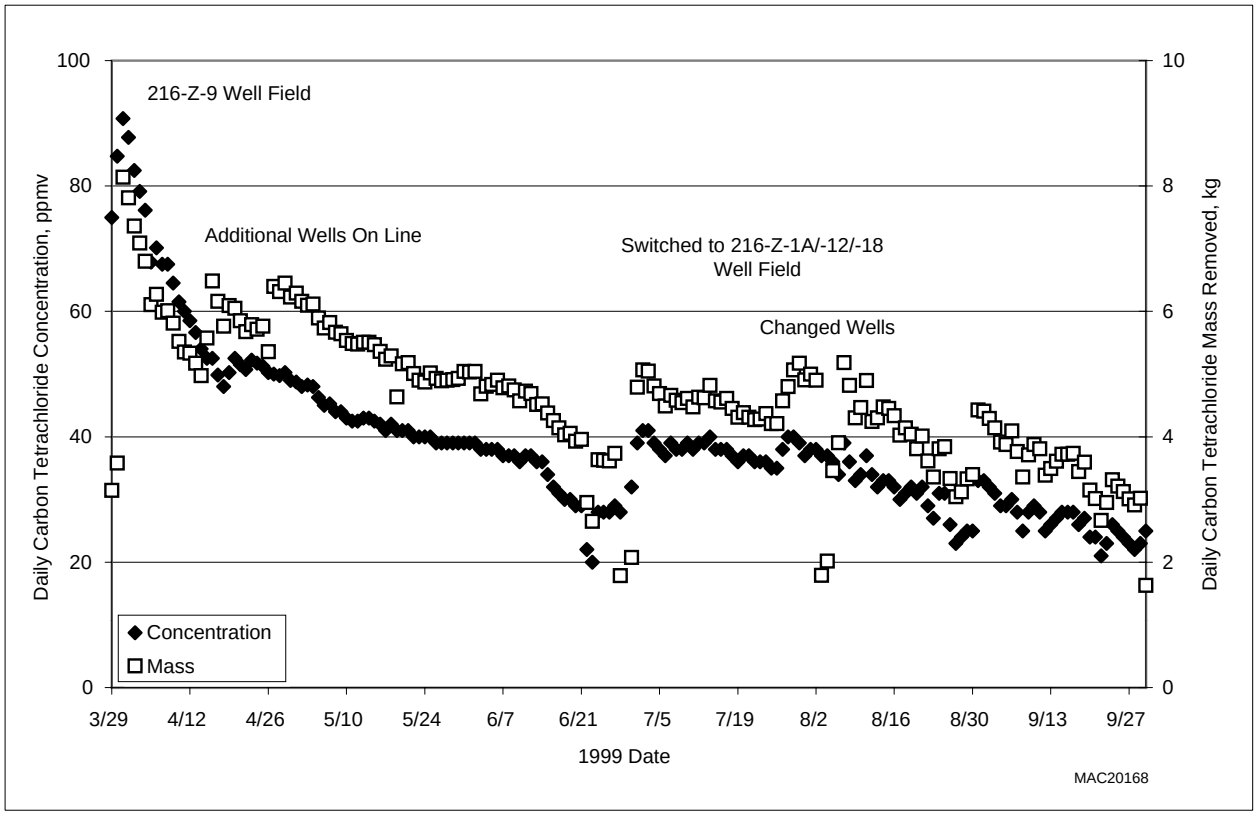

Figure 3.2-7. Time Series Concentrations of Carbon Tetrachloride in Soil Vapor Extracted from the 216-Z-9 Well Field and the 216-Z-1A/-12/-18 Well Fields

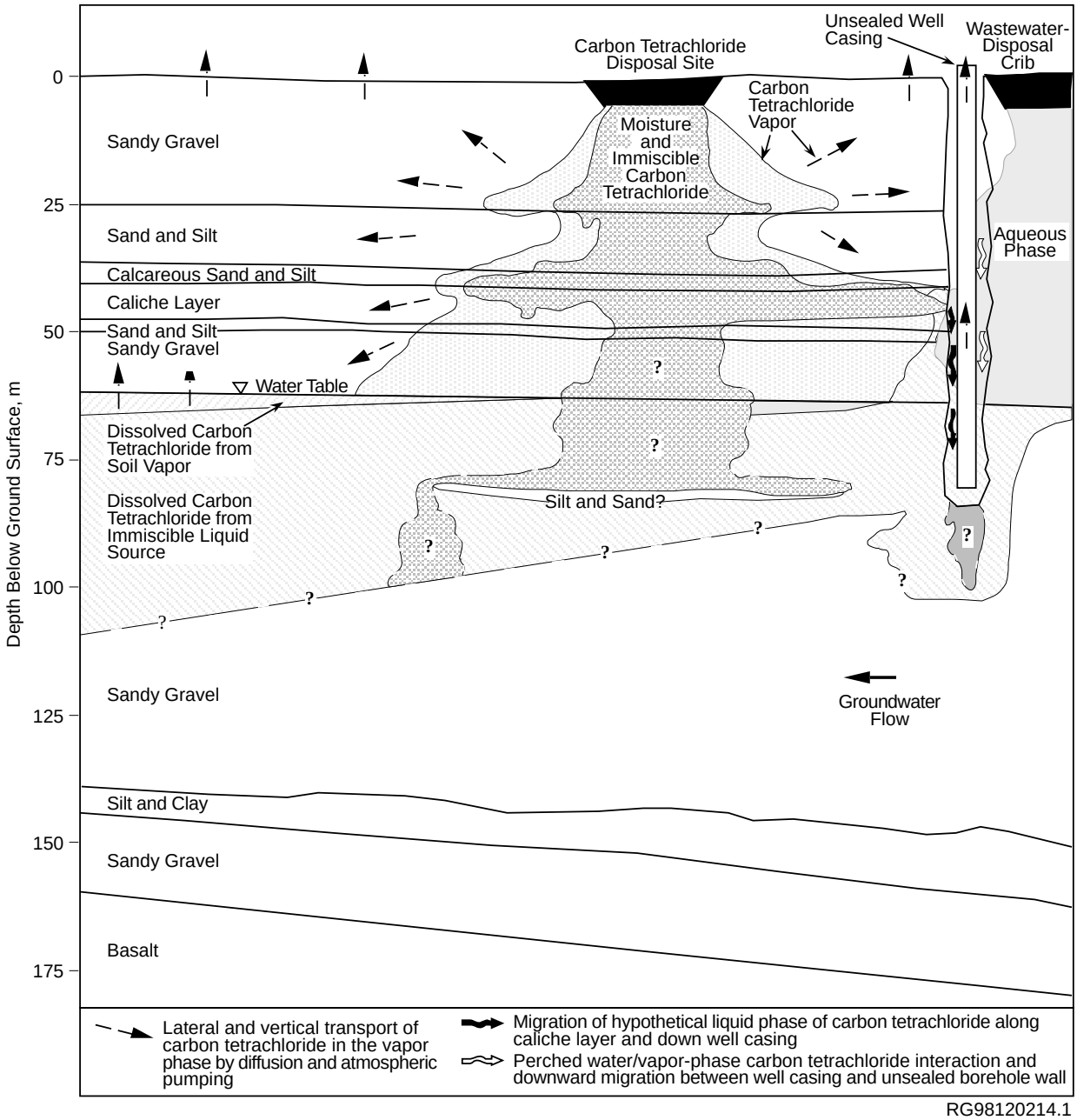

Figure 3.2-8. Conceptual Model of Carbon Tetrachloride and Wastewater Migration Beneath 216-Z-9 Trench

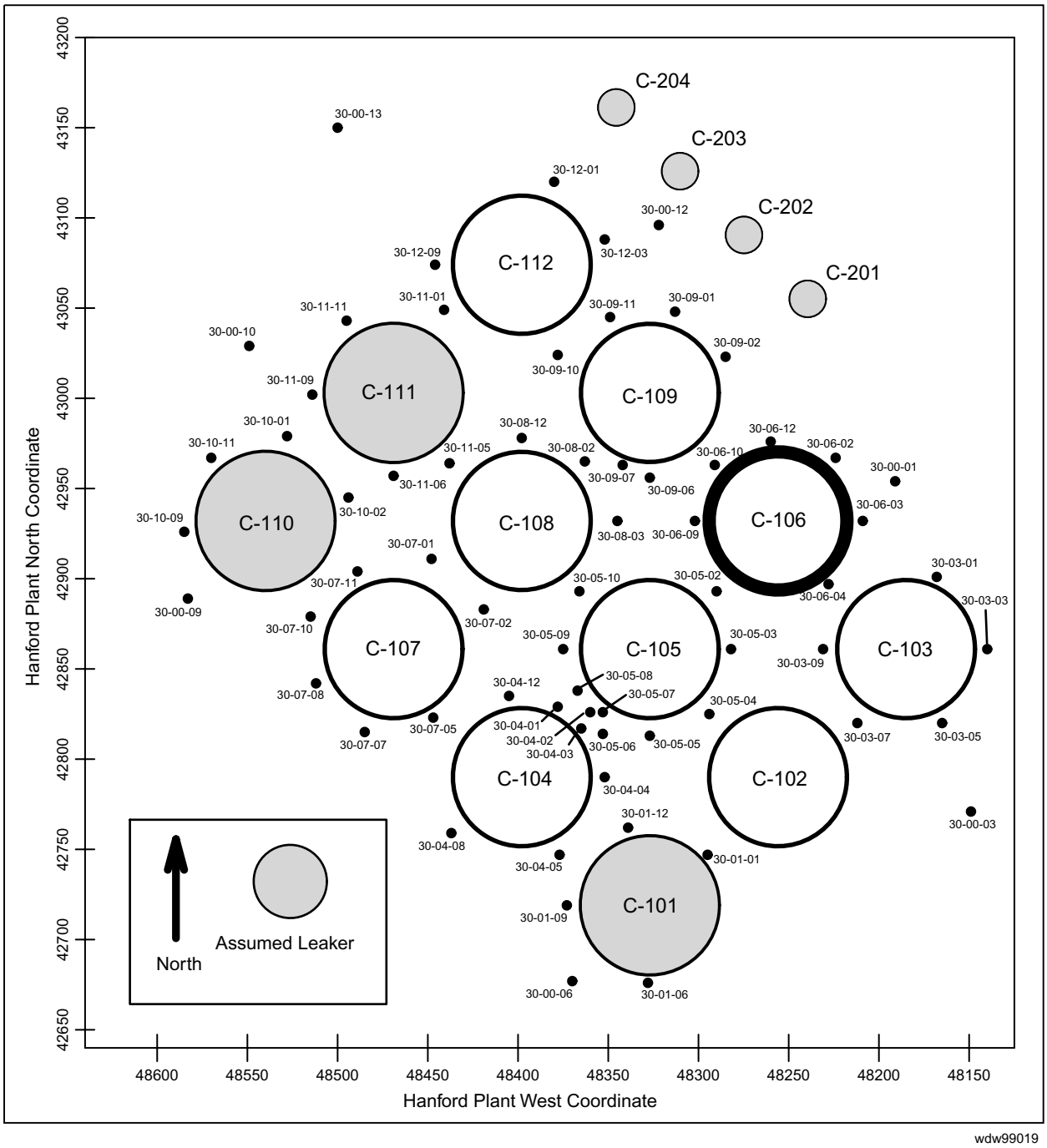

Figure 3.2-9. Location Map for Boreholes Logged at Single-Shell Tank C-106 (adapted from GJ-HAN-84)

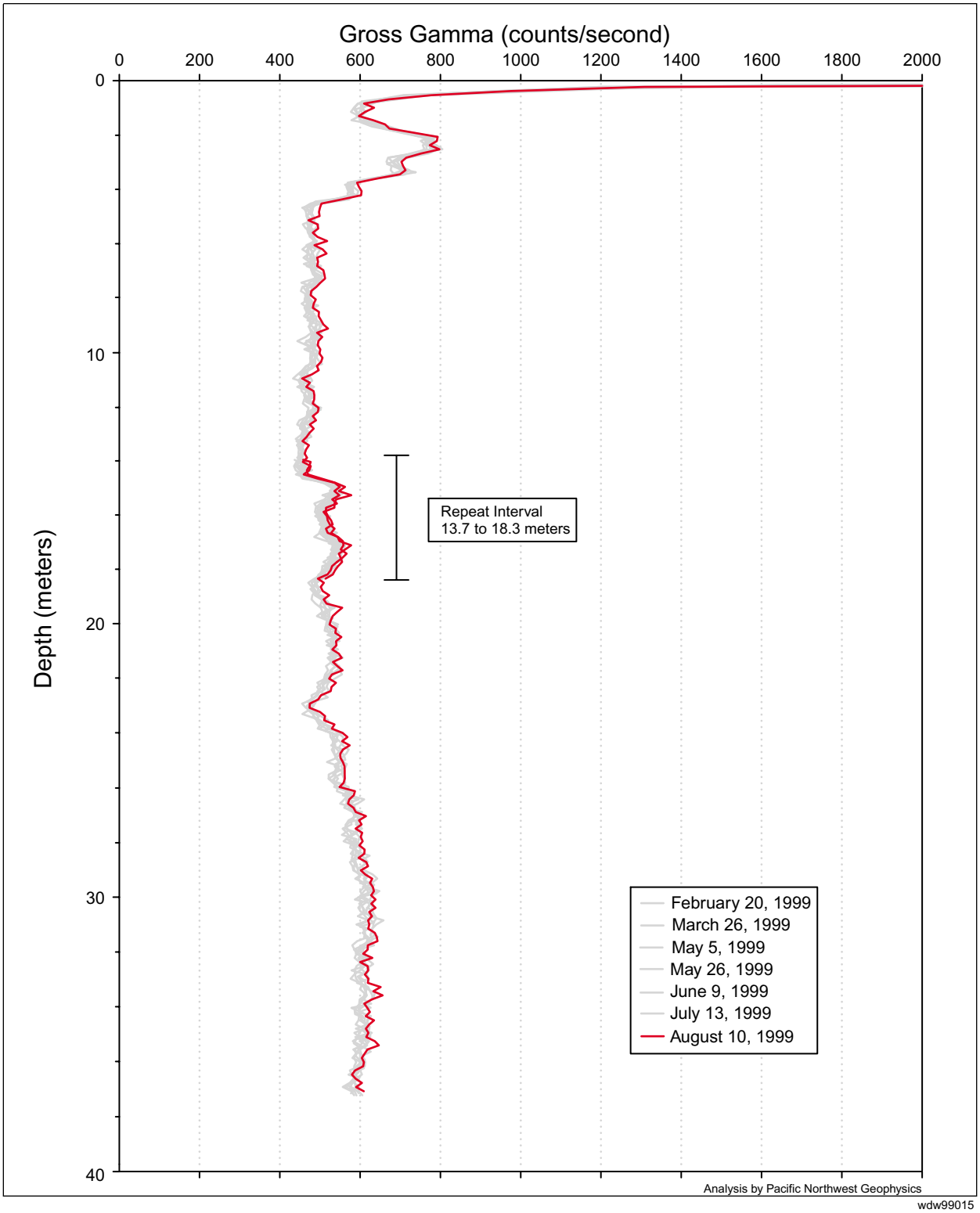

Figure 3.2-10. Time Series Gross Gamma-Ray Logs from Borehole 30-06-02

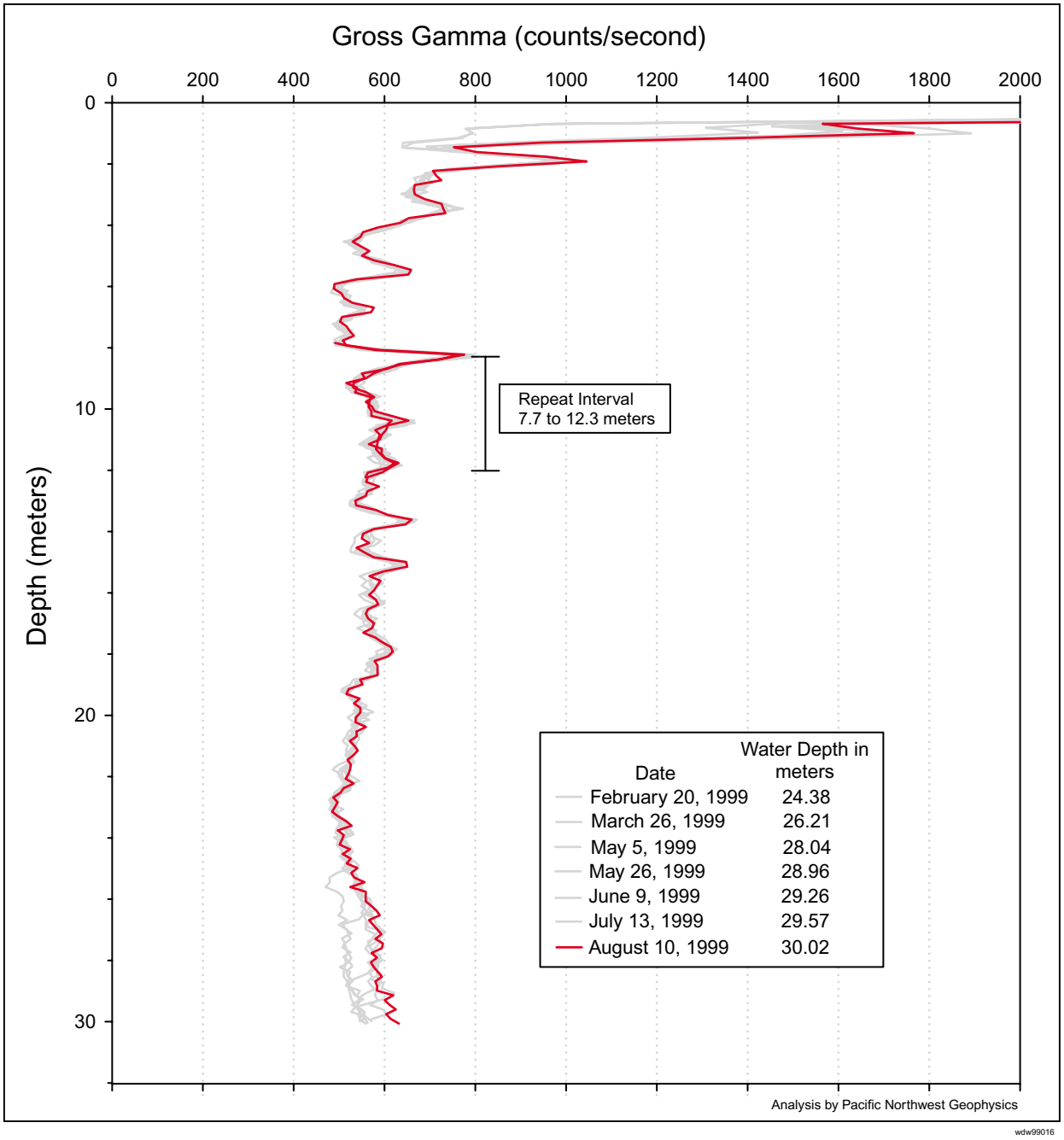

Figure 3.2-11. Time Series Gross Gamma-Ray Logs from Borehole 30-06-03

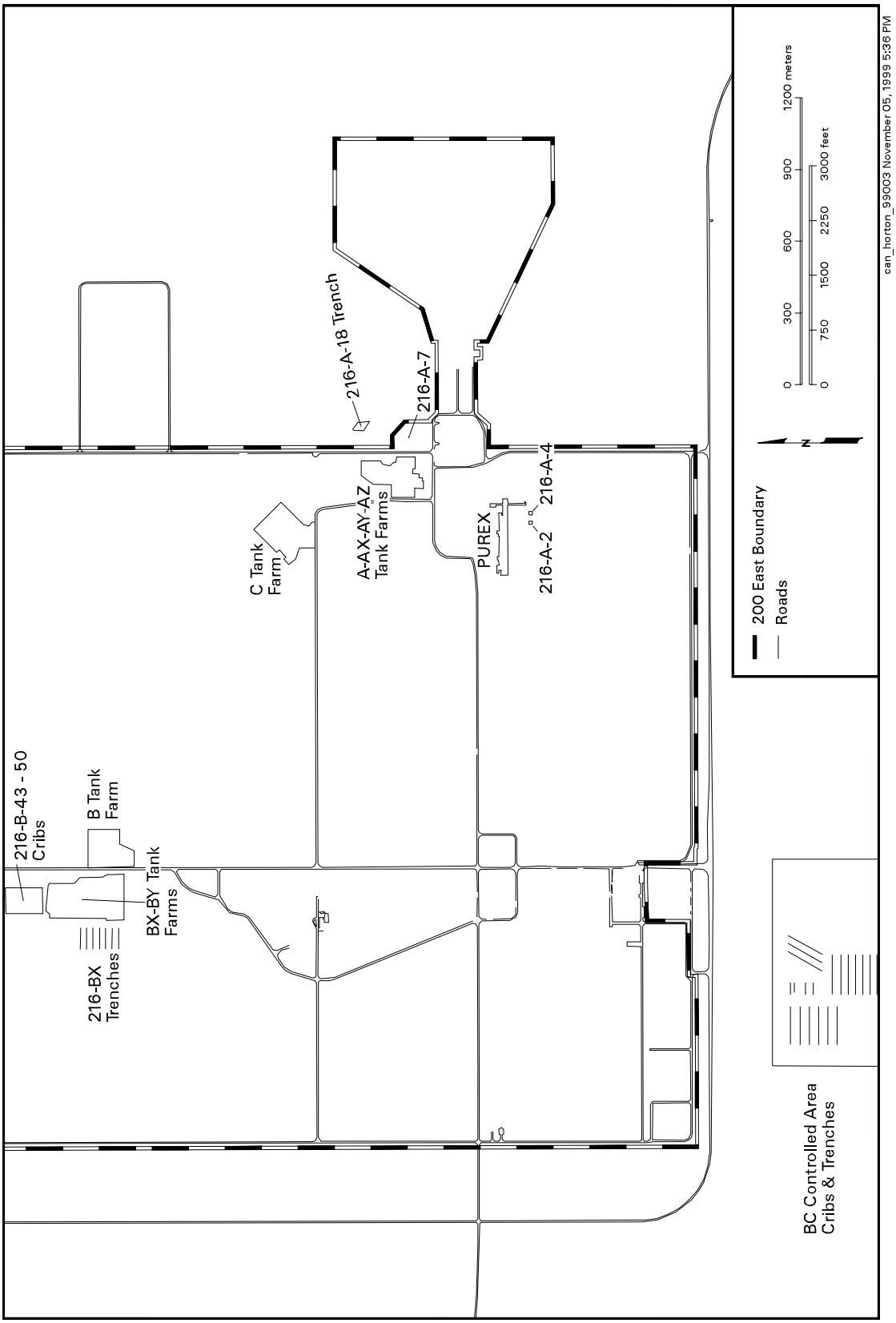

Figure 3.2-12. Map of the 200 East Area Showing Locations of Facilities Monitored, Fiscal Year 1999

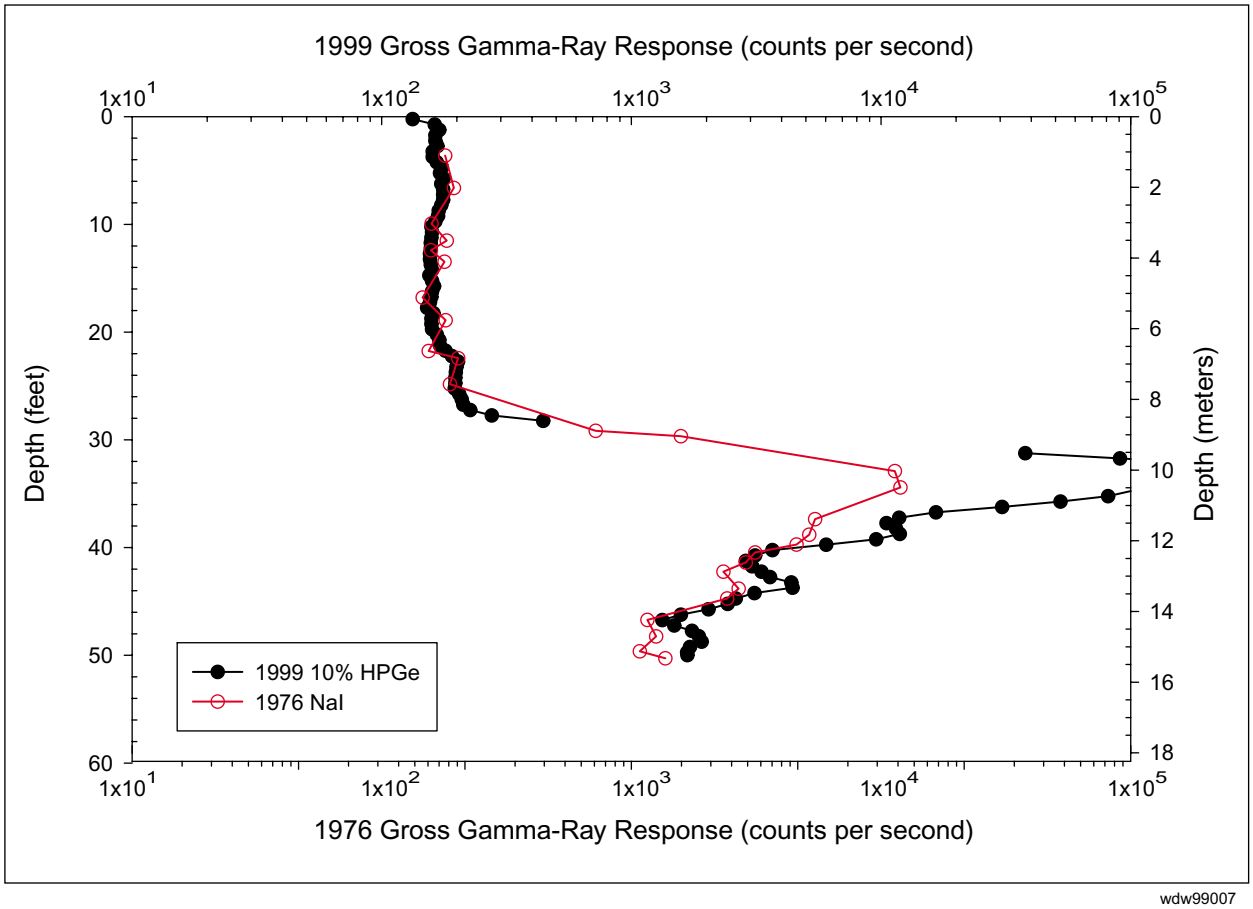

Figure 3.2-13. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E24-53 at the 216-A-2 Crib

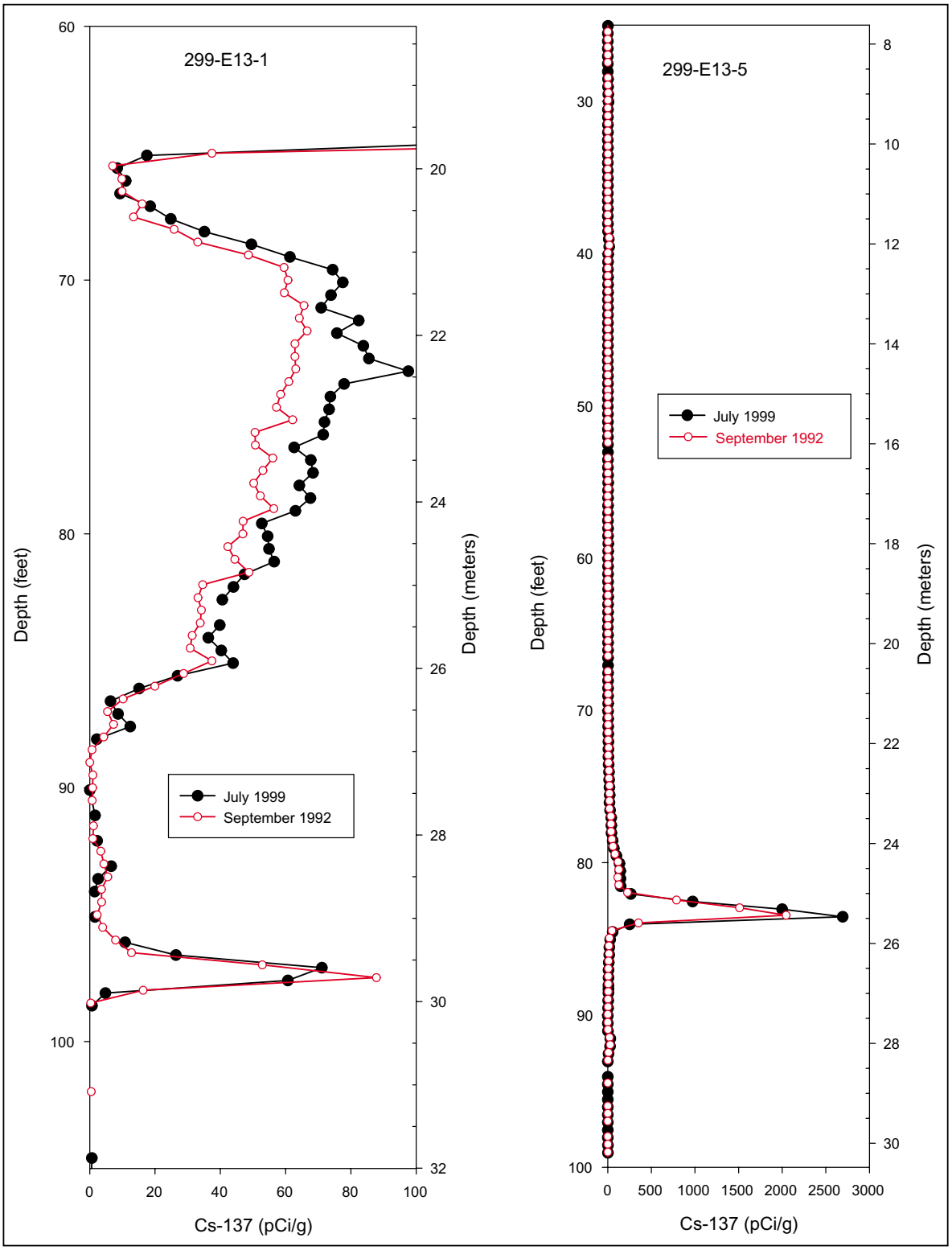

Figure 3.2-14. Comparison of 1999 and 1992 Spectral Gamma-Ray Logs for Cesium-137 from Well 299-E13-1 at the 216-B-14 Crib and Well 299-E13-5 at the 216-B-18 Crib

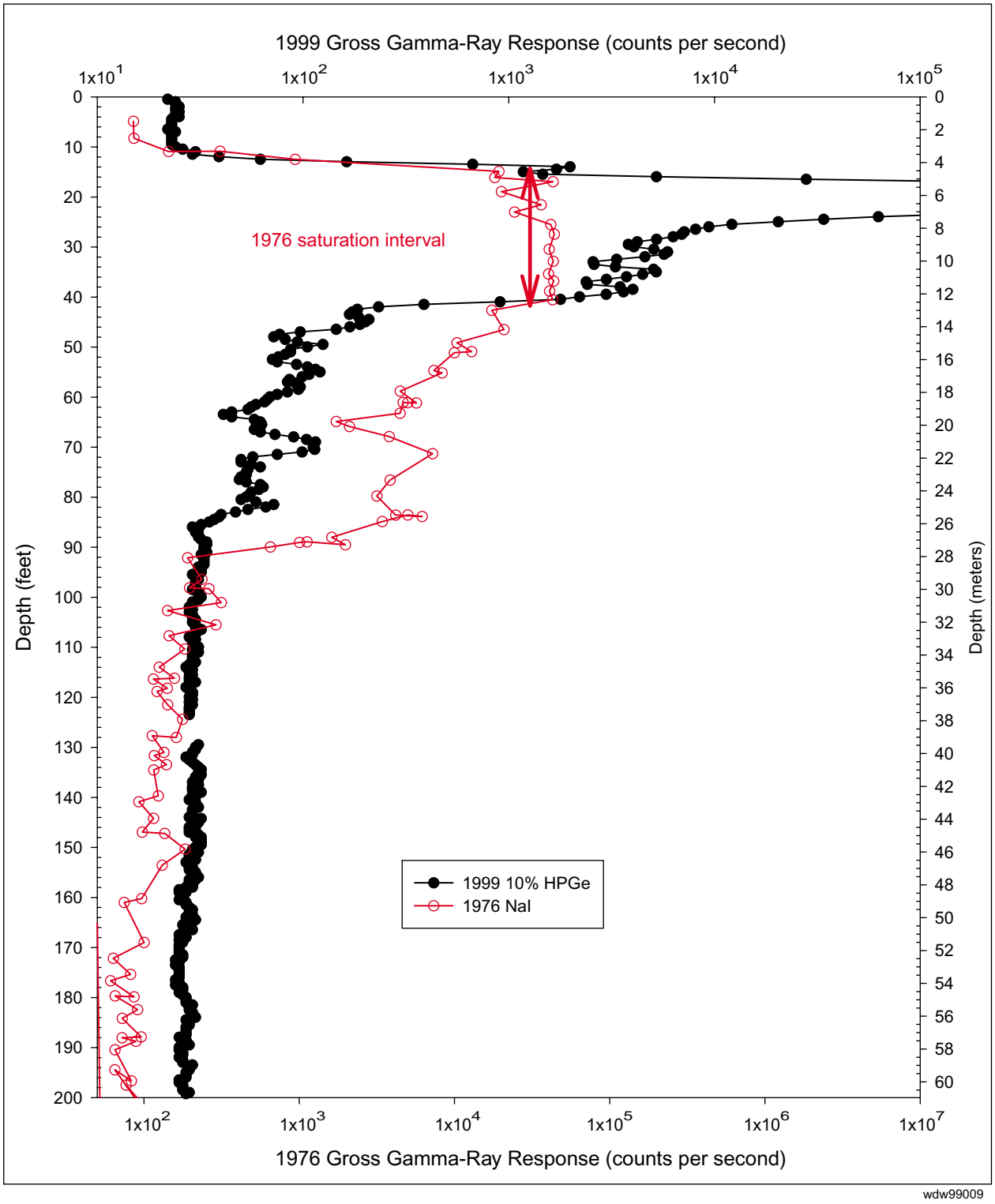

Figure 3.2-15. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E13-2 at the 216-B-15 Crib

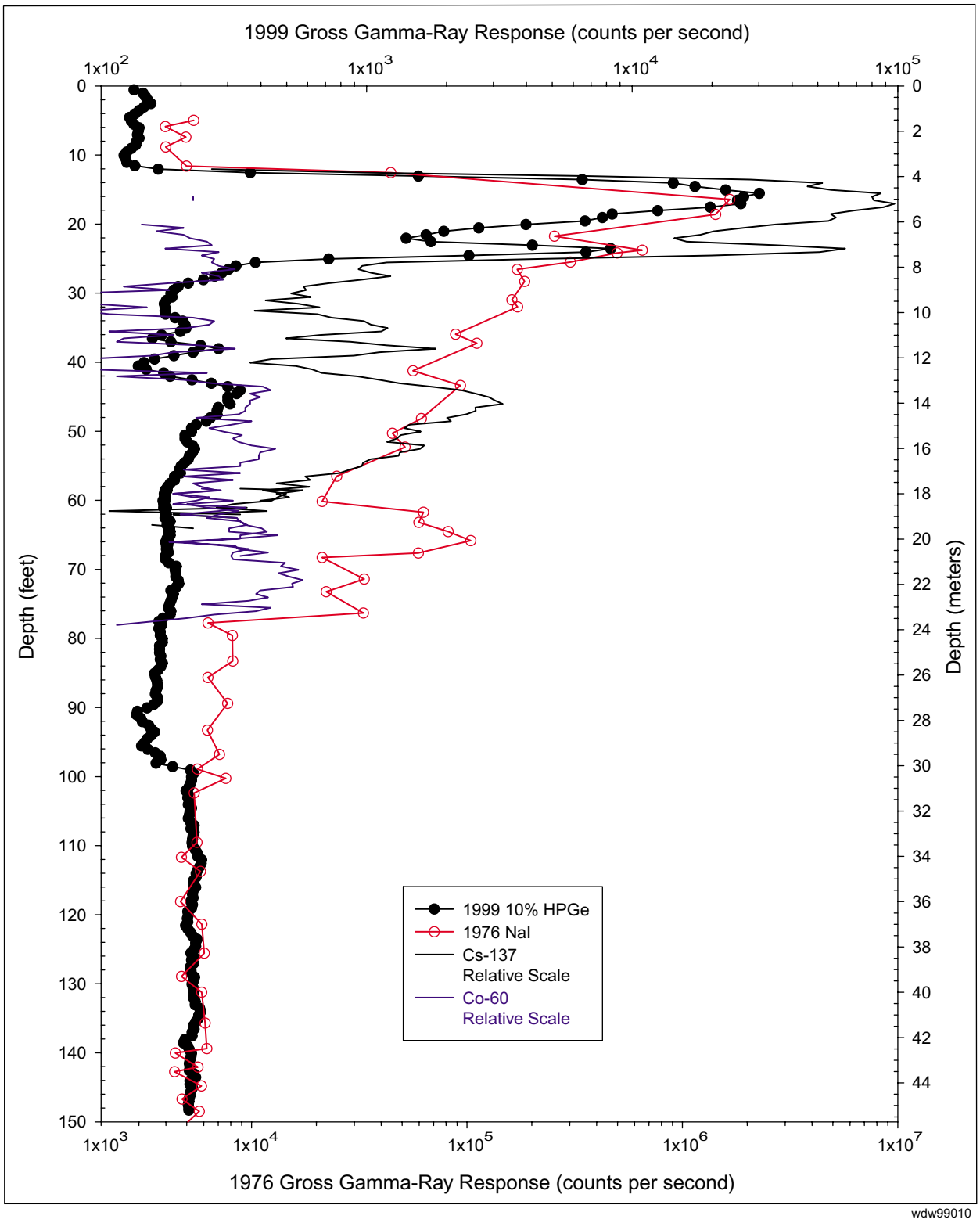

Figure 3.2-16. Comparison of 1999 and 1976 Gross Gamma-Ray Logs from Borehole 299-E13-4 at the 216-B-17 Crib

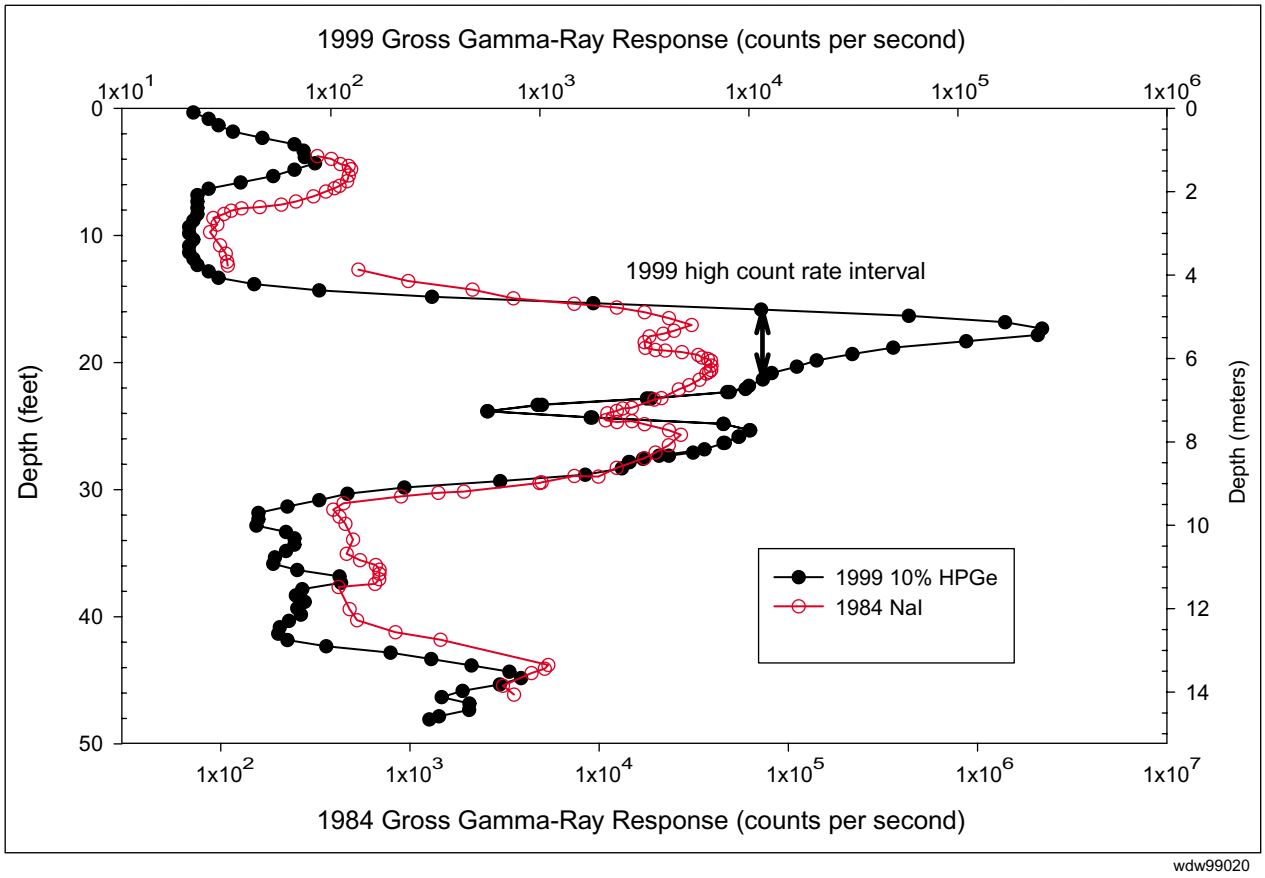

Figure 3.2-17. Comparison of 1999 and 1984 Gross Gamma-Ray Logs from Borehole 299-E13-289 at the 216-B-38 Crib

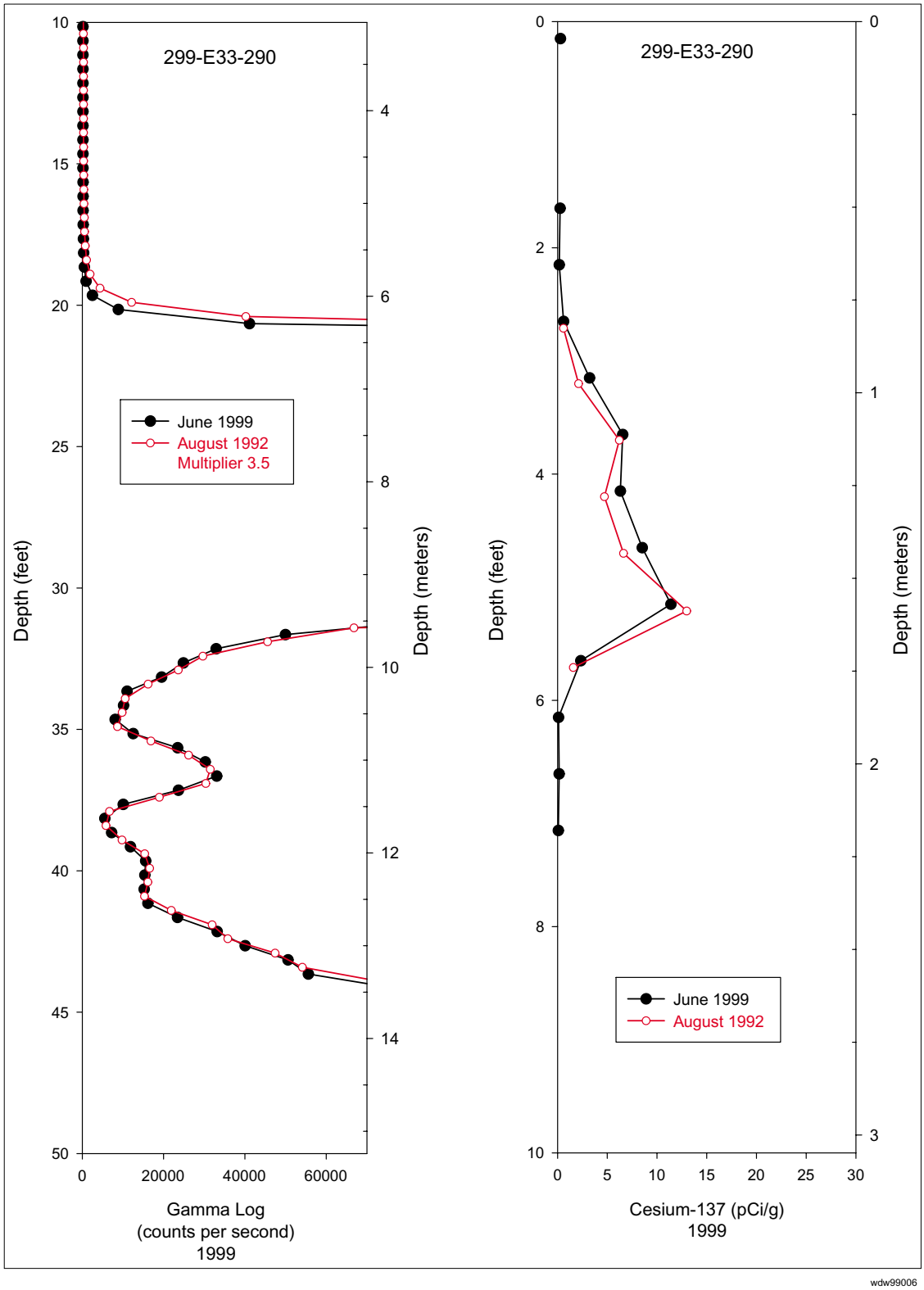

Figure 3.2-18. Comparison of 1999 and 1992 Gross Gamma-Ray Logs and Spectral Gamma-Ray Logs for Cesium-137 from Borehole 299-E33-290 at the 216-B-38 Trench