GJ–HAN–86
Tank C–102

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C–102

September 1997

U.S. Department of Energy

GRAND JUNCTION OFFICE

Work Performed Under DOE Contract No. DE–AC13–96GJ87335 for the U.S. Department of Energy

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Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office
Grand Junction, Colorado

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1.0 Introduction

1.1 Background

The U.S. Department of Energy (DOE) Richland Operations Office tasked the DOE Grand Junction Office (GJO) with characterizing and establishing a baseline of man-made radionuclide concentrations in the vadose zone surrounding the single-shell tanks (SSTs) at the Hanford Site. These tasks are being accomplished using spectral gamma-ray borehole geophysical logging measurements made in the boreholes surrounding the tanks. The primary objective of this project is to provide data on the tanks for use by DOE organizations. These data may also be used to develop an SST Closure Plan in compliance with the Resource Conservation and Recovery Act and to prepare an Environmental Impact Statement for the Tank Waste Remediation Systems program.

1.2 Scope of Project

The scope of this project is to locate and identify the gamma-ray-emitting radionuclides and determine their concentrations in the vadose zone sediment by logging the monitoring boreholes around the SSTs with a Spectral Gamma Logging System (SGLS). Additional details regarding the scope and general approach to this characterization program are included in the project management plan (DOE 1995c) and baseline monitoring plan (DOE 1995d). This project may help to identify possible sources of any subsurface contamination encountered during the logging and to determine the implications of the contamination for Tank Farm operations. The acquired data will establish a contamination baseline that can be used for future data comparisons, for tank-leak verifications, and to help develop contaminant flow-and-transport models.

1.3 Purpose of Tank Summary Data Report

A Tank Summary Data Report (TSDR) will be prepared for each SST to document the results of the spectral gamma-ray logging in the boreholes around the tank. Each TSDR provides a brief review and a summary of existing information about a specific tank and an assessment of the implications of the spectral gamma-ray log information, including recommendations on future data needs or immediate corrective action, where appropriate. Appendix A of each TSDR presents logs of radionuclide concentrations versus depth for all boreholes around that specific tank. A comprehensive Tank Farm Report will be prepared for each tank farm after completion of characterization logging of all boreholes in the subject farm.

2.0 Spectral Gamma-Ray Log Measurements

2.1 Data Acquisition and Processing

The concentrations of individual gamma-ray-emitting radionuclides in the sediments surrounding a borehole can be calculated from the activities in the gamma-ray energy spectra measured in the borehole using calibrated instrumentation. Spectral gamma-ray logging is the process of collecting gamma-ray spectra at sequential depths in a borehole. Figure 1 shows a gamma-ray spectrum with peaks at energies, from 0 to 2,700 kilo-electron-volts (keV), that are characteristic of specific radionuclides. The spectrum includes peaks from naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th (KUT) and from man-made contaminants (e.g., ^{137}Cs and ^{60}Co). Gamma-ray source concentrations are cited in terms of picocuries per gram (pCi/g), even though this unit technically describes decay rate per unit mass of sample rather than concentration. The use of decay rate per unit mass is widespread in environmental work, where health and safety issues relate to the radioactivity, not the chemical concentration.

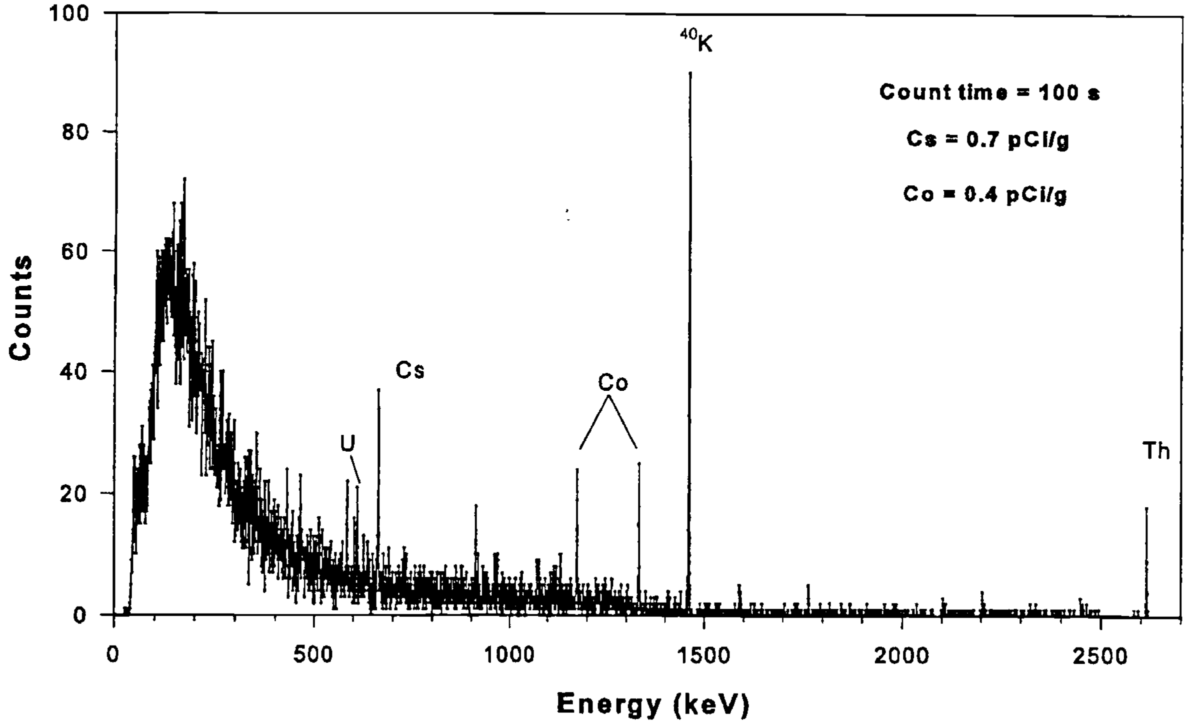

Figure 1. Gamma-Ray Spectrum

Data are acquired in boreholes near the tanks according to methods described in the logging procedures (DOE 1995b). Typical counting times at each measurement position are about 100 seconds (s), with a spectrum being collected every 0.5 foot (ft) along the length of the borehole.

Long data acquisition times can reduce the uncertainties in the calculated concentrations presented on the logs. However, economic and time constraints limit the amount of time available for data collection. The statistical uncertainty for gamma rays emitted from low-activity radionuclides such as ^{238}U and ^{232}Th can be high for this counting time, and the logs for these radionuclides will show high levels of statistical uncertainty, as evidenced on the logs by scatter in the plotted data and wide confidence intervals.

The minimum detection level (MDL) of a radionuclide represents the lowest concentration at which the positive identification of a gamma-ray peak for that radionuclide is statistically defensible. The spectrum analysis program calculates the MDL for a particular peak on the basis of a statistical analysis of the spectral background level in the vicinity of the peak. The same equations that translate peak intensities into decay rates per unit-sample mass also translate the MDLs from counts per second (cps) to picocuries per gram. A description of the MDL calculation is included in the data analysis manual (DOE 1996b).

The gamma-ray spectra measured in a borehole are processed using a variety of software programs to obtain the concentrations of individual gamma-ray-emitting radionuclides. All the algorithms used in the concentration calculations and their application is discussed in the data analysis manual (DOE 1996b). These calculated data, which are usually presented as vertical profiles, are used to make an interpretation of vadose zone contamination associated with each borehole. When data from all the boreholes associated with a specific tank have been processed and interpreted, a correlation interpretation is made of the vadose zone contamination surrounding each tank.

The initial SGLS calibration report (DOE 1995a) contains the results obtained from operating the logging tools in calibration models. The calibration report presents the mathematical functions used to convert the measured peak area count rates to radioelement concentration in picocuries per gram. The SGLS is routinely recalibrated (DOE 1996a) to ensure the accuracy of the calculated radionuclide concentrations. The calculated radionuclide concentrations derived with these conversion factors may be as much as 14 percent higher than the actual in situ concentrations because the concentrations of the calibration models are expressed in terms of gamma-ray activity per unit-sample mass of *dry* bulk material. However, the measurements made in the calibration models were in a water-saturated environment. The conversion factors in the calibration report (DOE 1995a) are strictly applicable only when the logged formation has the same water content as the calibration-model test zones. The vadose zone contains pore-space water in various percentages of saturation from near 0 percent to near 100 percent, and the boreholes are logged dry. Corrections for pore-space water cannot presently be applied to the vadose zone measurements because the in situ water content is not being measured.

The calibration data from which conversion factors were derived were recorded with a logging tool in a borehole drilled through a uniform homogeneous isotropic gamma-ray-source material. If the gamma-ray sources in the borehole being logged are not uniformly distributed in the sediments, the conversion factor produces apparent concentrations. The concentrations calculated for the top and bottom of a borehole are also apparent concentrations, because the source-to-detector geometries at these locations differ from the source-to-detector geometries during calibration.

When gamma-ray spectra are measured in cased boreholes, a casing correction must be applied to the peak count rates to compensate for gamma-ray attenuation by the casing. This correction function is described in the calibration report (DOE 1995a), and the data analysis manual (DOE 1996b) describes the application of the correction function in the data processing.

2.2 Log Data and Plots

The results of the processing and analysis of the log data presented in Appendix A, "Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-102," are grouped into a set of data for each borehole. Each set includes a Log Data Report and log plots showing radionuclide concentration versus depth.

Log plots are presented that show the spatial distribution of the detected man-made radionuclides. Plots of the natural gamma-ray-emitting radionuclides, at the same vertical scale as the man-made contamination plots, allows for interpretation of geologic information and the correlation of these data with the man-made contamination. Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability.

The log plots show the concentrations of the individual radionuclides or the total gamma count rate in counts per second in each borehole. Where appropriate, log plots show the statistical uncertainties in the calculated concentrations at the 95-percent confidence level (±2 standard deviations).

A combination plot for each borehole shows the individual natural and man-made radionuclide concentrations, the total gamma log, and the Tank Farms gross gamma log. The total gamma log is a plot of the total number of gamma rays detected during each spectrum measurement. The combination plot provides information on the relative contributions of individual radionuclides to the total gamma-ray count. The total gamma log also provides a means for comparing the spectral data with the historical Tank Farms gross gamma log data.

The Tank Farms gross gamma log data were collected with a nonspectral logging system previously used by DOE contractors for leak-detection monitoring at the Hanford Tank Farms. This system does not identify specific radionuclides, but its logs provide an important historical record for the individual boreholes and offer a basis for temporal comparison. The gross gamma logs shown on the plots in Appendix A are the latest data available.

Rerun sections in selected boreholes are used to check the logging system for data acquisition repeatability. Radionuclide concentrations shown on these plots are calculated independently from the separate gamma-ray spectra provided by the original and repeated logging runs.

The Log Data Report provides borehole construction information, casing information, logging system identification, and data acquisition parameters used for each log run. A log run is a set of spatially sequential spectra that are recorded in the borehole with the same data acquisition parameters. A single borehole may have several log runs, often occurring on different days because of the length of time required to log the deeper boreholes. The Log Data Report also contains analysis information, including analysis notes and log plot notes.

3.0 Review of Tank History

3.1 C Tank Farm

3.1.1 Construction History

The C Tank Farm is located in the east portion of the 200 East Area, north of 7th Avenue and west of Canton Avenue. This farm was constructed during 1943 and 1944 to store high-level radioactive waste generated by chemical processing of irradiated uranium fuel from C Plant. The tank farm consists of four Type I and twelve Type II single-shell storage tanks. Vadose zone boreholes are located around the tanks for purposes of leak detection. Figure 2 shows the relative positions of the storage tanks and the vadose zone monitoring boreholes around them.

All 16 tanks in the C Tank Farm were constructed to the first-generation tank design and were designed for non-boiling waste with a temperature of less than 220 °F. The twelve Type II tanks are 75 ft in diameter and have capacities of 530,000 gallon (gal) each. The four Type I tanks are 20 ft in diameter and have capacities of 55,000 gal each. Other than diameter, the Types I and II tanks are of the same basic design (Brevick et al. 1994a and 1994b).

The Type II tanks are domed and steel-lined, with a maximum operating depth (cascade overflow level) of approximately 17 ft above the center of the dished tank base; the tank base is 1 ft lower at its center than at its edges. The storage portion of each tank is lined with a 0.25-in.-thick carbon-steel liner. The steel liners on the tank sides extend to 19 ft above the dished bottoms of the tank bases. The interiors of the concrete dome tops are not steel lined, but were treated with a magnesium zincfluosilicate wash. The tanks are entirely below the ground surface and are covered with approximately 7.25 ft of backfill material (Brevick et al. 1994a and 1994b).

The twelve type II tanks are connected in four three-tank cascade series. These cascade series consist of tanks C-101, -102, and -103, C-104, -105, and -106, C-107, -108, and -109, and C-110, -111, and -112. The tanks in the cascade series are arranged with each successive tank sited at an elevation 1 ft lower than the previous tank, creating a gradient allowing fluids to flow from one tank to another as they were filled. The four Type I tanks are connected with tie lines. The tie lines allow the tanks to overflow to other tanks in the series and equalize tank volumes (Brevick et al. 1994a and 1994b).

For primary internal leak detection, tanks C-103, -106, and -107 are each equipped with an ENRAF level detector and tank C-110 is equipped with a manual tape. Tanks C-101, -102, -104,

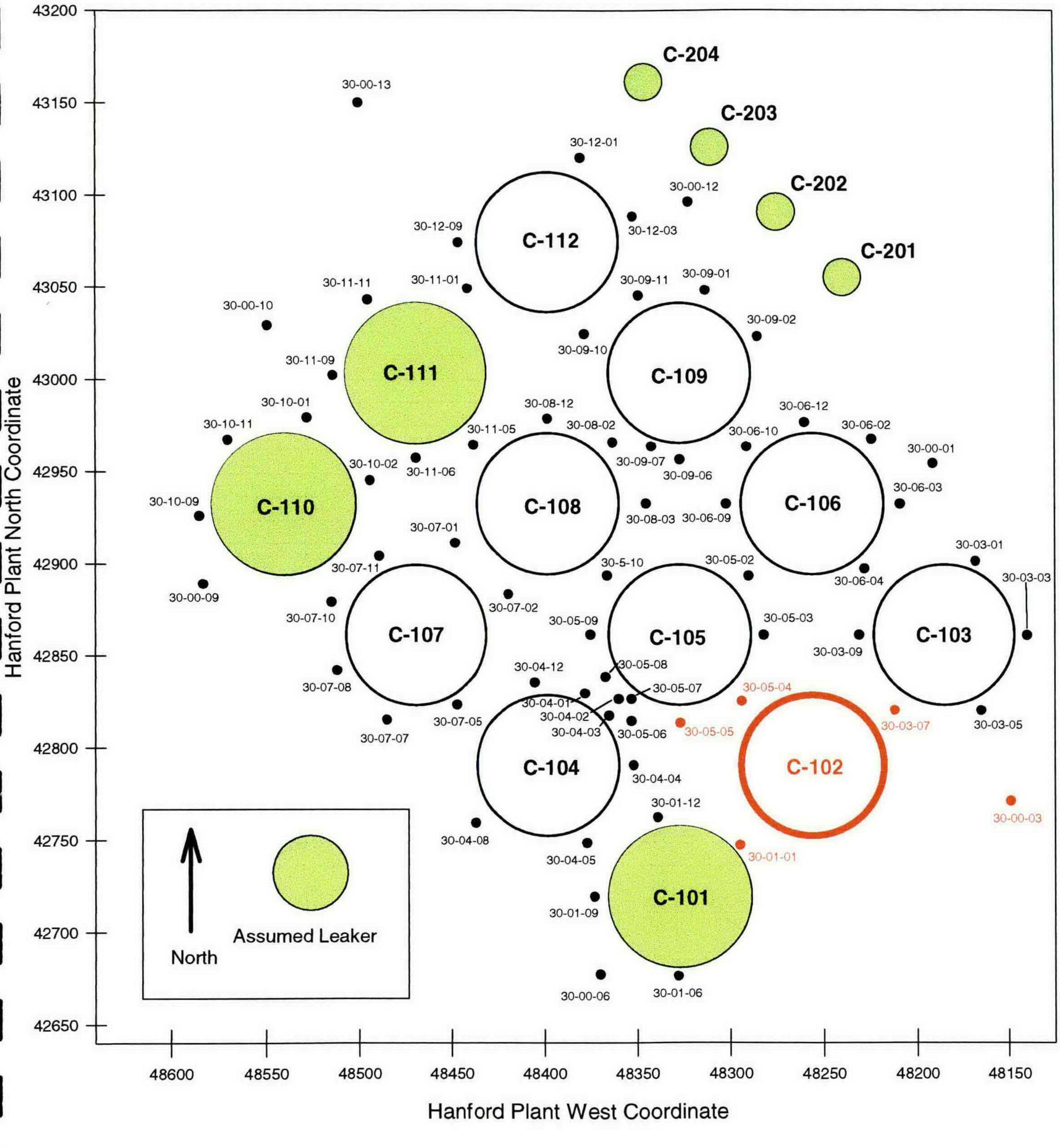

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

-105, -108, -109, -111, -112, -201, -202, -203, and -204 are not equipped with primary leak-detection sources (Hanlon 1997).

3.1.2 Geologic and Hydrologic Setting

Excavation for the construction of the C Tank Farm occurred in glaciofluvial sediments of the Hanford formation. These sediments consist primarily of cobbles, pebbles, and coarse to medium sands with some silts. The excavated sediments were used as backfill around the completed tanks (Price and Fecht 1976).

Beneath the backfill material are the undisturbed sediments of the Hanford formation. The Hanford formation sediments consist of pebble to boulder gravel, fine- to coarse-grained sand, and silt. Three distinct facies were recognized by Lindsey (1992): gravel-dominated, sand-dominated, and silt-dominated (ordered from top to bottom of the formation). Baker et al. (1991) named these facies the coarse-grained deposits (generally referred to as the Pasco Gravels), the plane-laminated sand facies, and the rhythmite facies (commonly referred to as the Touchet Beds), respectively. The Hanford formation sediments extend to a depth of about 225 ft in the vicinity of the C Tank Farm (Lindsey 1993).

The distribution and similarities in lithologic succession of the facies types described above indicate the Hanford formation can be divided into three stratigraphic sequences across the 200 East Area. These sequences are designated: 1) upper gravel, 2) sandy, and 3) lower gravel. The sequences are composed mostly of the gravel-dominated and sand-dominated facies. The silt-dominated facies are relatively rare except in the southern part of the 200 East Area. Because of the variability of Hanford deposits, contacts between the sequences can be difficult to identify (DOE 1993).

In the vicinity of the C Tank Farm, the upper gravel sequence is dominated by deposits typical of the gravel-dominated facies of the Hanford formation. Lesser occurrences of the sand-dominated facies are encountered locally (DOE 1993). The upper gravel sequence consists of well-stratified gravels with lenticular sand and silt interbeds and extends to a depth of approximately 61 to 73 ft (23 to 35 ft below the base of the tank farm excavation). Strata within this interval generally dip to the east-southeast and thin to the south (Lindsey 1993). However, strata near the transition from the gravel-dominated to the sand-dominated facies locally dip to the north and east (Price and Fecht 1976).

The sandy sequence generally consists of deposits typical of the sand-dominated facies of the Hanford formation (DOE 1993). The sandy sequence is characterized by well-stratified coarse- to medium-grained sand with minor pebble and lenticular silt interbeds less than 1 ft thick. Localized silty intervals greater than 1 ft thick may be present and could potentially host perched water horizons that would probably not be laterally extensive because of pinchouts and clastic dikes. The sandy sequence extends to a depth of approximately 198 ft (Lindsey 1993).

The lower gravel sequence of the Hanford formation is dominated by deposits typical of the gravel-dominated facies. Local intercalated intervals of the sand-dominated facies are also found

(DOE 1993). This unit is composed of interbedded sands and gravels with few silt interbeds. Perched water is considered unlikely in this unit. The lower gravel sequence is about 27 ft thick and extends to a depth of approximately 225 ft (Lindsey 1993).

The Ringold Formation directly underlies the Hanford formation in the vicinity of the C Tank Farm. The Ringold Formation is approximately 70 ft thick and extends to a depth of 295 ft. A thin, discontinuous silt-rich layer that dips to the south and pinches out to the north and west is present in the southern portion of the tank farm. Perched water may occur at the top of this unit. A variably cemented pebble to cobble gravel with a sand matrix occurs stratigraphically below the silt-rich layer. This gravel may contain mud interbeds that could cause perched water to form if the mud is cemented or well enough developed (Lindsey 1993).

In the vicinity of the C Tank Farm, the uppermost aquifer occurs within the Ringold Lower Mud Unit at a depth of approximately 245 ft (Lindsey 1993; PNNL 1997). This uppermost aquifer is generally referred to as the unconfined aquifer, but includes locally confined to semi-confined areas DOE 1993).

The Ringold Formation is underlain by the Columbia River Basalt Group, which includes approximately 50 basalt flows. Sandwiched between the various basalt flows are sedimentary interbeds, collectively called the Ellensberg Formation. The Ellensberg Formation consists of mud, sand, and gravel deposited between volcanic eruptions. These sediments and porous flow tops and bottoms form confined aquifers that extend across the Pasco Basin (PNNL 1997).

At the Hanford Site, recharge of the unconfined aquifer by precipitation is highly variable depending on climate, vegetation, and soil texture. Recharge from precipitation is highest in coarse-textured soils with little or no vegetation (PNNL 1997). Fayer and Walters (1995) estimate that recharge to the unconfined aquifer in the area of the C Tank Farm is approximately 2 to 4 in. per year.

For more detailed information about the geology and hydrogeology below the C Tank Farm, the reader is referred to the following documents: Price and Fecht (1976), Caggiano and Goodwin (1991), Lindsey (1993), Lindsey (1995), and PNNL (1997).

3.1.3 Tank Contents

The C Tank Farm received a variety of waste types beginning in 1945. Initially, tanks C-101, -102, -103, -104, -105, and -106 received metal waste, and tanks C-107, -108, -109, -110, -111, and -112 received byproduct cake solution and waste solution from the first decontamination waste cycle (referred to collectively as first-cycle waste). Tanks C-201, -202, -203, and -204 were used to settle waste to allow the supernatant liquid to be sent to a crib (Brevick et al. 1994b). Over their operating life, the C Tank Farm tanks also received B-Plant decontamination waste, U Plant waste, cladding wastes, PUREX Plant fission product waste, waste water, and other waste types (Agnew 1997). A large amount of strontium from the PUREX Plant fission product waste remains in tank C-106 and has caused a high heat load in the tank (Brevick et al. 1994b).

The tanks in the C Tank Farm currently contain an estimated 1,976,000 gal of mixed wastes (Hanlon 1997) consisting primarily of various cladding wastes, tributyl phosphate and uranium recovery wastes, and sludge produced by in-tank scavenging (Agnew 1997). Detailed descriptions of the waste streams are presented in Anderson (1990) and Agnew (1995 and 1997). On the basis of information presented in Agnew (1997), some of the principal radionuclides in the tank wastes include ^{90}Sr, ^{137}Cs, ^{144}Ce, ^{151}Sm, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{63}Ni, ^{137m}Ba, ^{155}Eu, and ^{154}Eu.

The wastes currently contained in the C Tank Farm tanks are in the form of sludge, supernatant liquid, and interstitial liquid. Sludge is composed of a solid precipitate (hydrous metal oxides) that results from the neutralization of acid waste. The wastes were neutralized before being transferred to the tanks. Sludge forms the "solids" component of the tank waste. Liquids are present as supernatant and interstitial liquids. Supernatant liquid floats on the surface of the solid waste and interstitial liquid fills the interstitial voids within the solid waste. Interstitial liquid may be drainable if it is not held in the interstitial voids by capillary forces.

3.1.4 Tank Farm Status

All the tanks in the C Tank Farm were removed from service during the late 1970s and early 1980s (Brevick et al. 1994a). Nine tanks in the C Tank Farm are categorized as sound (C-102, -103, -104, -105, -106, -107, -108, -109, and -112), and seven are categorized as assumed leakers (C-101, -110, -111, -201, -202, -203, and -204) (Hanlon 1997). The tanks in the C Tank Farm that have been designated as "assumed leakers" are identified on Figure 2.

All the tanks in the C Tank Farm, except tanks C-103 and C-106, have been interim stabilized, and all the tanks, except tanks C-103, -105, and -106, have intrusion prevention completed. Tanks C-103, -105, and -106 have been partial interim isolated (Hanlon 1997).

Currently, tanks C-102 and C-103 are on the Organics Watch List and tank C-106 is on the High-Heat Load Watch List (Hanlon 1997). SSTs are added to a watch list because the waste in the tanks may be in a potentially unsafe condition and the handling of the waste material requires corrective action or special monitoring to reduce or eliminate the hazard. Resolution of the safety issues has been codified under Public Law 101-510 (generally known as the Wyden Amendment).

3.2 Tank C-102

Tank C-102 was constructed during 1943 and 1944 (Welty 1988) as the second tank in a three-tank cascade series. This tank received cascade waste from tank C-101 from 1946 until 1953. The overflow outlet from tank C-101 to tank C-102 became partially plugged during the second quarter of 1954 (Brevick et al. 1994b).

This tank began receiving metal waste in May 1946 and stored metal waste until the second quarter of 1953. Tank C-102 cascaded waste to tank C-103 from 1946 until 1953. In 1953, the metal waste in the tank was sluiced to a sludge heel in an effort to recover uranium. The tank received uranium recovery waste from the third quarter of 1953 until the fourth quarter of 1954. During the second quarter of 1957, the tank was scavenged (Brevick et al. 1994b).

During the third quarter of 1960, tank C-102 received waste water, and from the third quarter of 1960 until the fourth quarter of 1969, the tank received PUREX cladding waste (Brevick et al. 1994b). The tank received high-level waste from the 1966 Thorium Campaign during the second quarter of 1966 (Anderson 1990) and PUREX organic wash waste from the second quarter of 1968 until the first quarter of 1969 (Brevick et al. 1994b).

A salt-well pump was installed in tank C-102 in November 1975; salt-well pumping was completed in June 1978 (Welty 1988). The tank was declared inactive in 1977 and was partially isolated in December 1982. In November 1991, the tank was salt-well pumped again (Brevick et al. 1994b).

The present inventory of tank C-102 includes 316,000 gal of sludge with 30,000 gal of drainable liquid. The waste in tank C-102 is classified as dilute-complexed waste (Hanlon 1997). The waste level is approximately 150 in. above the dished bottom of the tank base and has remained constant since a level decrease caused by salt-well pumping that occurred in November 1991 (Brevick et al. 1994b).

Hanlon (1997) does not identify a primary method of leak detection for tank C-102. Welty (1988) notes that the eight vadose zone monitoring wells planned for tank C-102 were instead installed around tanks C-104 and C-105 for a leak investigation. Welty (1988) also states that "[t]ank 102-C has no means of leak detection available as the tank has no dry wells and, because the tank contains solids, liquid-level measurements are no longer meaningful for leak-detection purposes."

As noted in Section 3.1.4, tank C-102 is on the Organic Salts Watch List (Hanlon 1997).

4.0 Boreholes in the Vicinity of Tank C-102

Five vadose zone monitoring boreholes are located near tank C-102. All the boreholes are associated with tanks other than tank C-102; the closest borehole is located about 12 ft from tank C-102. The five boreholes around tank C-102 are 30-03-07, 30-00-03, 30-01-01, 30-05-05, and 30-05-04. Figure 2 shows the locations of these boreholes in red.

All the boreholes, except borehole 30-00-03, were completed with 6-in. steel casings. The surface exposures of most the borehole casings are flush with small-diameter concrete pads, making accurate measurements of the borehole casing wall thicknesses difficult. Because the calculations of radionuclide concentrations incorporate a correction factor based on casing thickness, correction factors appropriate to the casing thicknesses must be determined and applied in the development of the log data. The casing thickness for the 6-in. boreholes is assumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in., carbon-steel casing, which was the typical casing used in tank farm borehole construction in the 1970s.

Borehole 30-00-03 was completed with 8-in. and 12-in. casings to a depth of approximately 54 ft, and with 8-in. casing below approximately 54 ft. A correction factor for the 8-in. casing was applied to data acquired over the entire borehole because an appropriate correction factor is not available to account for the attenuation caused by the double casing and any grout, soil, or open space between the two casings above approximately 54 ft. A correction factor for 0.330-in. casing was applied because it most closely matches the actual casing thickness of 0.322 in. The use of this correction factor will cause the calculated concentrations for radionuclides above 54 ft to be underestimated and below 54 ft to be slightly overestimated. Concentration values for the interval above approximately 54 ft are highly inaccurate and should only be used as qualitative indicators of contaminant presence, lithology changes, and casing locations.

Spectral gamma-ray data were acquired for each borehole. The spectral gamma-ray data were collected in the move/stop/acquire logging mode with a 100-s acquisition time at 0.5-ft depth intervals. All boreholes were logged dry.

The pre- and post-survey field verification spectra were used to create the peak resolution and channel-to-energy parameters used in processing the spectra acquired during logging operations.

Westinghouse Hanford Company (WHC) performed spectral gamma logging of boreholes surrounding tanks C-103, -105, and -106 in 1993 and 1994 using the Radionuclide Logging System (RLS). The results of the RLS logging for boreholes 30-03-07, 30-05-05, and 30-05-04 are discussed in this report. The RLS used a lower efficiency detector and shorter data acquisition time than the SGLS; therefore, the RLS data exhibit a higher degree of uncertainty than the SGLS data. In addition, the RLS data include low contaminant concentrations at depths where the SGLS data do not indicate the presence of contamination because the reported MDL for the RLS was lower than the MDL for the SGLS. Also, the RLS was unable to log the bottom 6 ft of the boreholes because the logging tool housing extended 6 ft below the logging tool's detector. However, the RLS provided quantitative spectral gamma-ray data of sufficient quality to compare to the SGLS data. Individual plots comparing the measured concentrations of man-made radionuclides from 1994 to 1997 are included in Appendix A for each borehole logged by both systems.

The following sections present results of the spectral gamma-ray log data collected from these boreholes. Appendix A contains the plots of the log data. The most recent historical gross gamma data are presented on the combination plots in Appendix A. These data, historical gross gamma logs from 1975 to 1994, RLS logging data, and results from other investigations were used in the preparation of this report.

4.1 Borehole 30-03-07

Borehole 30-03-07 is located approximately 7 ft from the southwest side of tank C-103 and was given the Hanford Site designation 299-E27-77. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. The driller's log does not indicate that the borehole was grouted or perforated. Total logging depth achieved by the SGLS was 96.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected continuously from the ground surface to a depth of 40 ft, almost continuously from 42.5 to 62.5 ft, and intermittently from 93 ft to the bottom of the borehole. The maximum concentration was 82.5 pCi/g at a depth of 9.5 ft.

The KUT log plots show an increase in concentration at a depth of 40 ft. This concentration increase probably represents a change from backfill material above this depth to undisturbed Hanford formation sediments below this depth.

At a depth of 42 ft, the ^{40}K concentrations increase from a background of about 16.5 to 19 pCi/g, and then return to background at about 43.5 ft. This ^{40}K concentration peak may be caused by a silt- or clay-rich interval at this depth.

The KUT concentrations increase below a depth of about 54 ft. This concentration increase probably represents a change from the gravel- to the sand-dominated facies.

A ^{40}K concentration increase was detected from 80.5 ft to the bottom of the logged interval. This concentration increase is probably from an increase in the silt content of the sediments.

It was not possible to identify the 609-keV peaks in many of the spectra between the ground surface and about 11 ft. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The ^{137}Cs concentrations from about 44 to 56 ft are clearly reflected on the total gamma-ray plot.

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1994 to the current SGLS data. The plot demonstrates excellent repeatability in the regions of the borehole where ^{137}Cs concentrations are greater than about 1 pCi/g. The repeatability is not as good where ^{137}Cs concentrations are less than 1 pCi/g. The lack of repeatability at the lower concentrations is probably caused by a higher error level of the 1994 data at low count rates.

A comparison between the 1997 and 1994 data indicates that the ^{137}Cs contamination in this interval has migrated since 1994. In this time period, the ^{137}Cs contamination at about 9 ft has increased from about 14.3 to about 82.5 pCi/g. This is probably from continued movement of contamination that appears, based on a review of the historical gross gamma logs, to have been spilled between January and May 1980.

Historical gross gamma logs from January 1975 through November 1994 were reviewed and a plot of representative historical logs for this borehole is included in Appendix A. A zone of anomalous gamma ray activity is present from about 40 to 52 ft in the earliest gross gamma log available (January 1975). Welty (1988) notes that anomalously high gamma-ray activity was present in this interval by September 1974. Anomalous gamma-ray activity was still present in this interval in the latest gross gamma-ray logs (November 1994).

In addition, as in borehole 30-03-07, gamma-ray activity in the upper 9 ft of the borehole significantly increased between January and May 1980, probably indicating that a surface spill occurred during that time interval. Historical gross gamma logs from January through April 1980 were not available.

The ^{137}Cs contamination in the upper 10 ft of the borehole is probably the result of a surface spill that migrated into the backfill material around the borehole or down the inside or outside of the borehole casing. Anomalously high gamma-ray activity was not present in this interval before May 1980. Historical gross gamma logs for January through April 1980 were not available.

The ^{137}Cs contamination from about 10 to 40 ft is probably the result of pipeline leaks or surface spills that migrated into the backfill material around the tank.

The ^{137}Cs contamination from 42.5 to 62.5 ft is probably the result of a tank or pipeline leak that migrated into the Hanford formation sediments beneath the tank farm excavation. The origin of this contamination could be any number of tanks and associated pipelines in the C Tank Farm, including tank C-103. A zone of anomalously high gamma activity is present in this interval in the earliest historical gross gamma logs.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole.

4.2 Borehole 30-00-03

Borehole 30-00-03 is located approximately 55 ft from the southeast side of tank C-103 and was given the Hanford Site designation 299-E27-54. This borehole was drilled in December 1944 and January 1945 and was completed to a depth of 155 ft with 8-in. casing. The driller's log indicates that a string of 12-in.-diameter casing was installed to a depth of 54 ft. The driller's log also indicates the borehole was perforated from 54 to 154 ft with five cuts per foot and the bottom of the 8-in. casing was grouted.

Total logging depth achieved by the SGLS was 118.0 ft. The depth of the borehole, measured with an electrical tape before borehole logging, is about 119 ft, rather than 155 ft as reported on the driller's log. In addition, the earliest historical gross gamma logs available (1975) show a total depth of about 121 ft at that time. The reason the borehole is more shallow than reported in the driller's log is not known, but it may be partially due to the build-up of sediment at the bottom of the borehole from 1944 to 1975.

The zero reference for logging is the top of the 8-in. casing. The borehole is located on a hillside, and the top of the 8-in. casing is approximately 2.5 ft above the ground surface. The logged interval begins at a depth of 2.5 ft; no spectra were collected above 2.5 ft.

A 0.330-in. casing correction factor was used for the 8-in. casing because a casing correction factor for 0.322 in. is not available. Use of the correction factor for 0.330-in. casing will cause the calculated radionuclide concentrations to be slightly overestimated for the interval below about 56 ft. Data from above 56 ft are only usable for qualitative interpretations because of the double casing.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs concentrations were detected intermittently from about 2.5 to 16.5 ft and almost continuously from 55.5 ft to the bottom of the logged interval. The maximum ^{137}Cs concentration for this borehole could not be measured because of the double casing.

An increase in KUT concentrations was detected below 56 ft. This concentration increase probably represents the change from the double-cased portion of the borehole to the perforated single casing and indicates that the 12-in. casing extends to about 56 ft, rather than 54 ft as indicated in the driller's log. This may be due to an approximately 2-ft section of 8-in.-diameter casing being added to the top of the borehole sometime after the borehole was completed. The decrease in ^{40}K and ^{238}U concentrations and the total count plot from 54.5 to 55.5 ft may indicate the presence of a casing shoe in this interval.

The ^{40}K and ^{232}Th concentrations decrease slightly from 70 to 90 ft. The ^{40}K concentrations gradually increase from 85 to 106 ft, which is probably caused by a gradual increase in silt or clay content in this depth interval. The ^{232}Th concentrations increase below about 99 ft and decrease below 111 ft.

Historical gross gamma logs from January 1975 through October 1993 were reviewed. No zones of anomalous gamma-ray activity were identified in logs for this time interval.

The near-surface ^{137}Cs contamination may be the result of a surface spill that migrated into the backfill material around the borehole or down the inside or outside of the borehole casing.

The origin of the ^{137}Cs contamination detected below 56 ft is uncertain. Without information from higher in the borehole, it is not possible to determine whether this contamination moved downward or migrated laterally to this location. Downward contamination migration could be enhanced by the perforations below 54 ft, but the mechanism that promotes this activity is unknown.

It is also possible that the calculated radionuclide concentrations below 54 ft are further overstated because of the casing perforations. The radionuclide concentrations are calculated on the basis of the steel casing thickness, which acts as shielding to gamma rays. The perforations remove portions of this shielding.

4.3 Borehole 30-01-01

Borehole 30-01-01 is located approximately 2 ft from the southwest side of tank C-101 and was given the Hanford Site designation 299-E27-60. This borehole was drilled in March 1970 and completed to a depth of 100 ft with 6-in. casing. The driller's log does not indicate that the casing was perforated or the borehole grouted. Total logging depth achieved by the SGLS was 98.0 ft.

The man-made radionuclides detected in this borehole were ^{137}Cs and ^{60}Co. ^{137}Cs contamination was detected continuously from the ground surface to 13 ft, almost continuously from 20.5 to 32 ft, and at the bottom of the logged interval from 97.5 to 98 ft. ^{137}Cs contamination was also detected at depths of 18, 41.5, and 43 ft. The maximum measured ^{137}Cs concentration was about 2 pCi/g at 29.5 ft. A higher concentration (28.5 pCi/g) was detected at the ground surface; however, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used in the calibration.

^{60}Co contamination was detected almost continuously from 37 to 41 ft. The maximum ^{60}Co concentration of 0.16 pCi/g was measured at 38 and 38.5 ft.

The KUT concentration plot shows an apparent decrease in ^{238}U concentrations below about 6 ft. This concentration decrease coincides with an overlap of two logging runs on two different days. The apparent change in ^{238}U concentrations is probably the result of radon venting up the borehole between log runs. The variability in the ^{238}U background is not related to changes in the efficiency of the logging system, but more likely to the weather conditions during a particular run. The 609-keV spectral peak used to calculate the ^{238}U concentration is actually emitted by ^{214}Bi, and the calculated ^{238}U concentration is only accurate if the ^{214}Bi and ^{238}U are in secular equilibrium. Because radon gas is an intermediate member of the ^{238}U decay chain, the equilibrium condition will be disturbed by changes in the weather conditions in the vicinity of the borehole. Wind, or the absence of it, affects the rate of radon venting from the borehole. The variations in the calculated ^{238}U background do not affect the determination of man-made gamma-ray-emitting nuclides from the SGLS data set.

^{40}K concentrations are slightly decreased from 32 to 37.5 ft. This concentration decrease coincides with an overlap of logging runs from two different days. This difference in measurement may be caused by drift in the logging system rather than changes in the backfill material. It should be noted that the ^{40}K measurements within the overlapping interval (31 to 32 ft) repeat within two standard deviations (95-percent confidence level), indicating the measurements are essentially equivalent within the stated accuracy for the system.

The ^{40}K concentrations increase from 38 to 40 ft. This concentration increase is caused by a change from backfill material to the undisturbed sediments of the Hanford formation at about this depth.

^{40}K concentrations decrease from about 14 to 12.5 pCi/g below 53.5 ft. ^{40}K concentrations are slightly decreased and variable from 53.5 to 69.5 ft. These decreased concentrations are probably caused by a decrease in the fraction of fine-grained sediments in this interval.

^{40}K concentrations increase gradually from 69.5 ft to the bottom of the logged interval, with ^{40}K concentrations relatively variable below about 72 ft. This gradual concentration increase probably represents a gradual increase in the fine-grained fraction of the sediments in this interval.

The SGLS total gamma-ray plot reflects the influence of the natural and man-made radionuclides. The ^{137}Cs concentrations from the ground surface to 13 ft and about 25 to 30 ft and the ^{60}Co concentrations from 37 to 41 ft are clearly reflected on the total gamma-ray plot.

Gross gamma logs from January 1975 through June 1994 were reviewed and a plot of representative gross gamma logs is included in Appendix A. Anomalous gamma-ray activity is present from about 35 to 52 ft in the earliest gross gamma logs available, indicating the contamination was present by January 1975 or earlier. In addition, Welty (1988) indicates that a zone of anomalous gamma-ray activity was present at 39 ft in July 1972.

The historical gamma logs indicate that the gamma-ray activity from about 35 to 52 ft decreased rapidly between 1975 and 1979. This could indicate that a short-lived radionuclide, such as ^{125}Sb, was responsible for some of the activity and then decayed away over this time interval. However, the historical gross gamma logs are not of sufficient quality to make such a determination.

The ^{137}Cs contamination from the ground surface to about 13 ft may be the result of a surface spill. Contamination probably migrated down into the backfill material or down the outside of the borehole casing to this depth. The ^{137}Cs contamination from 20.5 to 32 ft may be from a pipeline leak.

The ^{60}Co contamination from 37 to 41 ft is probably the result of a tank leak from which contamination collected at the base of the tank farm excavation at approximately this depth. The driller's log notes elevated gross gamma activity at this depth during borehole construction in March 1970. Count rates of 10,000 counts per minute (cpm) were recorded with an unknown radiation survey instrument for samples taken from depths of 38, 40, 41, 42, 43, and 44 ft. Count rates of 5,000 cpm were recorded for a sample from 39 ft, and 800 cpm were recorded for a sample from 45 ft.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that were blown down into the borehole.

4.4 Borehole 30-05-05

Borehole 30-05-05 is located approximately 34 ft from the west-northwest side of tank C-102. It was given the Hanford Site designation 299-E27-82. This borehole was drilled in June 1974 to a depth of 100 ft using 6-in. casing. The driller's log does not indicate that the casing was perforated or that the borehole was grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 98.5 ft.

The man-made radionuclides ^{137}Cs and ^{60}Co were detected in this borehole. Extensive ^{137}Cs contamination was measured continuously from the ground surface to a depth of 84.5 ft. Regions of relatively higher ^{137}Cs concentrations were detected from the ground surface to 18 ft and 44 to 66 ft. The ^{137}Cs concentrations ranged from 30 to 70 pCi/g between 60 and 66 ft. Measurable ^{137}Cs contamination was also detected at 97 ft and at the bottom of the logged interval (98 to 98.5 ft). The maximum measured ^{137}Cs concentration was about 67.9 pCi/g at 63.5 ft. A higher concentration (161 pCi/g) was detected at the ground surface; however, the ^{137}Cs concentration calculated at the ground surface is an apparent concentration because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

The presence of ^{60}Co was detected continuously from 69.5 to 74.5 ft and also at depths of 79, 79.5, and 97 ft. The maximum ^{60}Co concentration of 1 pCi/g was detected at 70.5 ft.

The significant increase in the ^{40}K concentration values between 35.5 and 43 ft may represent a change in lithology from backfill material to the undisturbed Hanford formation. However, the lithology reported on the drilling log is not detailed enough to support or contradict this interpretation.

The ^{40}K concentrations become slightly variable and gradually decrease between 43 and 65 ft, increase sharply from 65 to 67.5 ft, and then generally remain elevated to the bottom of the logged interval. The drilling log reports a change in lithology from slightly gravelly, very coarse sand to slightly silty, medium to fine sand at a depth of 65 ft. The lithologic information reported in the driller's log generally supports the interpretation that the slight variation and decrease in the ^{40}K concentrations between 43 and 65 ft may represent the basal region of the gravel-dominated facies of the Hanford formation. The increase in the ^{40}K concentrations at about 65 ft may represent the contact with the sand-dominated facies of the Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 11 ft, along several short intervals between 14 and 50 ft, and from 53 to 69 ft. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the presence of the man-made radionuclides in the borehole. The numerous peaks in the SGLS total count rate between the ground surface and 85 ft correspond closely to the peaks shown on both the ^{137}Cs and ^{60}Co concentration plots.

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1993 to spectral gamma data collected with the SGLS in 1997. Although the plot shows good correlation of the 1993 and 1997 ^{137}Cs concentration profiles along the length of the logged interval, the ^{137}Cs concentrations measured in 1997 were generally 15 to 30 percent less than those measured in 1994. This may be attributable to the difference in the environmental corrections used for the two data sets. The RLS and SGLS data show a continuous zone of ^{60}Co contamination between 70 and 75 ft. Between 1993 and 1997, the ^{60}Co concentrations have decreased within this zone, illustrating the apparent radioactive decay of the ^{60}Co. The data also suggest that no downward migration of the ^{60}Co contamination has occurred since 1993.

An additional data plot included in Appendix A provides a more detailed comparison of the ^{137}Cs, ^{60}Co, and ^{40}K concentrations detected by the RLS and SGLS between 50 and 80 ft. The ^{60}Co and ^{40}K radionuclide concentrations were plotted on a linear scale to provide a more quantitative comparison of these data. The plot shows good correlation of the ^{137}Cs concentration profiles, suggesting that the ^{137}Cs contamination has remained fixed in the vadose zone since 1993. The plot shows good correlation of the ^{60}Co contamination detected between 70 and 75 ft and illustrates the radioactive decay of the ^{60}Co between 1993 and 1997. It was calculated that 55 percent of the ^{60}Co contamination has decayed away during the past 4 years by averaging the relative decrease in the ^{60}Co concentrations since 1993. However, the calculated decay rate is too high to be consistent with the 5.27-year half-life of the ^{60}Co radioisotope. The ^{60}Co concentrations measured in 1997 were lower than expected, which may indicate that some redistribution of the highly mobile nuclide occurred during the past 4 years. The plot shows poor correlation of the ^{40}K data along several zones of the logged interval. The 1997 ^{40}K data exhibit much less variation and appear to be generally more consistent than the 1993 ^{40}K data.

The historical gross gamma log data from 1975 to 1996 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The gross gamma-ray plot reflects the ^{137}Cs contamination profile shown on the SGLS plot; the earliest gross gamma log available (January 1975) shows the same basic activity profile. Welty (1988) indicates that a zone of anomalous gamma-ray activity was present at 64 ft in the earliest data available for this borehole (July 1974), indicating that the contamination was deposited by mid-1974.

The significant increase in the ^{40}K concentration values shown on the KUT plot between 35.5 and 43 ft probably indicates the base of the tank farm excavation. This concentration increase corresponds with the lowermost extent of the zone of shallow ^{137}Cs contamination detected by the SGLS. This contamination probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The zone of slightly increased ^{137}Cs contamination between 7 and 13 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the borehole. The thin layer of relatively higher ^{137}Cs contamination detected at about 37 ft may indicate some accumulation of ^{137}Cs contamination near the base of the tank farm excavation.

The elevated ^{137}Cs contamination detected between 42 and 66 ft may be from a tank or pipeline leak. The source of the tank leak could be tank C-105 or another nearby tank. The pipeline leak that occurred between tanks C-104 and C-105 could also be a source of this contamination. The ^{137}Cs contamination occurs in the zone of relatively low ^{40}K concentrations that the driller's log noted as containing a high percentage of coarse sand. The interval of highest ^{137}Cs concentrations (60 to 65 ft) correlates with an interval noted in the driller's log as containing "pea-gravel." It is possible that this low ^{40}K zone acted as a preferential pathway for contaminants to migrate to this location.

The ^{137}Cs contamination below about 66 ft is probably from the same tank or pipeline leak that was the source of the contamination between 42 and 66 ft. The driller's log reports a transition to finer grained material at a depth of 65 ft, which correlates with a change from low to relatively high ^{40}K concentrations. This high ^{40}K concentration zone seems to be caused by finer grained sediments, and probably forms the base of the highest concentrations of ^{137}Cs contamination.

The ^{60}Co contamination from 69.5 to 79.5 ft may be from the same source as the ^{137}Cs contamination detected in this interval, or it may be from another source. The ^{60}Co contamination in this depth interval correlates with ^{60}Co contamination detected in other nearby boreholes. These correlating zones of ^{60}Co in other boreholes are often not associated with ^{137}Cs contamination.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole.

4.5 Borehole 30-05-04

Borehole 30-05-04 is located approximately 12 ft from the northwest side of tank C-102. It was given the Hanford Site designation 299-E27-69. This borehole was drilled in December 1972 to a depth of 120 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 118.0 ft.

The man-made radionuclides ^{137}Cs and ^{60}Co were detected in this borehole. Mostly continuous ^{137}Cs contamination was measured from the ground surface to the bottom of the logged interval. A near-surface zone of elevated ^{137}Cs contamination (25 to 45 pCi/g) extends to a depth of 2 ft. The ^{137}Cs contamination decreases to less than 5 pCi/g below this zone, continues to gradually decrease to a depth of 103 ft, then progressively increases to the bottom of the logged interval. The region between 38 and 58 ft contains slightly elevated ^{137}Cs concentrations (1 to 2 pCi/g) relative to the regions above and below. The maximum measured ^{137}Cs concentration was about 44.7 pCi/g at 1 ft. A higher concentration (68 pCi/g) was detected at the ground surface; however, the ^{137}Cs concentration calculated at the ground surface is an apparent concentration because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry during calibration.

A thin zone of ^{60}Co contamination was measured continuously from 81.5 to 84 ft. Many isolated occurrences of ^{60}Co contamination were also detected between 85 and 105.5 ft. The maximum measured ^{60}Co concentration was 0.2 pCi/g at 82.5 ft.

The increase in the ^{40}K concentration values at 41 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The driller's log reports a change in lithology from packed gravel, rust, and sand to very coarse sand at about this depth.

^{40}K concentrations increase at about 72 ft and remain elevated to the bottom of the logged interval. The driller's log reports a change in lithology from coarse sand and pea gravel to medium sand at a depth of about 70 ft. The increase in ^{40}K concentrations at about 72 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

Between the ground surface and 2 ft, it was not possible to identify any of the 609-keV peaks used to derive the ^{238}U concentrations. This occurred because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentrations.

The SGLS total gamma-ray plot reflects the presence of the man-made radionuclides where they occur and the changes in the naturally occurring radionuclides elsewhere. The sharp increase in the SGLS total count rate at the bottom of the logged interval corresponds closely to the peak shown on the ^{137}Cs concentration plot. The gradual increase in the total count rate between 70 and 80 ft corresponds with increases in the ^{40}K concentration values within this depth range.

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1993 to spectral gamma data collected with the SGLS in 1997. The plot shows acceptable repeatability of the ^{137}Cs data along the length of the logged interval. The data repeat less closely along the regions of relatively lower ^{137}Cs concentrations. The RLS and SGLS data show intermittent, low concentrations of ^{60}Co contamination between 75 and 113 ft. Along most of this interval, there is generally poor correlation between the 1993 and 1997 ^{60}Co data.

The historical gross gamma log data from 1975 to 1996 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The plot illustrates only the lower portion of the near-surface peak that is shown on the SGLS plot because data were apparently not collected at depths of 1 and 2 ft. This peak is clearly evident on the earliest gross gamma log available (January 1975), which indicates that the near-surface ^{137}Cs contamination was present by that date.

Summaries of the historical gross gamma log data from 1974 to 1987 are presented in Welty (1988). A single anomalous reading of 700 cps was recorded near the bottom of the borehole (approximately 119 ft) in April 1974. This anomaly corresponds to the ^{137}Cs peak shown at the bottom of the logged interval on the SGLS plot. Although this anomaly was not subsequently recorded in Welty (1988), a review of the available gross gamma log data indicates that this activity persisted over time. The most recent historical gross gamma data presented on the combination plot do not show this anomalous activity because data were apparently not collected in the bottom 2 ft of the borehole.

The ^{137}Cs contamination from the ground surface to 16 ft probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The zone of relatively increased ^{137}Cs concentrations between 5 and 16 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the borehole.

Much of the ^{137}Cs contamination detected below about 16 ft may have been carried down during borehole drilling activities. This contamination could also be distributed in the formation near the borehole or may have migrated down the outside of the borehole casing.

The ^{60}Co contamination between 81.5 and 105.5 ft may be from the same source as the ^{137}Cs contamination detected in this interval, or the contamination may be from another source. The ^{60}Co concentrations in this depth interval correlate with ^{60}Co contamination detected in other nearby boreholes. These correlating zones of ^{60}Co in other boreholes are often not associated with ^{137}Cs contamination.

The zone of increasing ^{137}Cs contamination at the bottom of the borehole is probably contamination that accumulated around the base of the borehole casing. This contamination could also be in the formation near this borehole.

5.0 Discussion of Results

A plot of the man-made radionuclide concentration profiles for the five boreholes near tank C-102 is presented in Figure 3. The plot shows widespread ^{137}Cs contamination and less extensive ^{60}Co contamination.

The SGLS detected ^{137}Cs contamination in the upper 10 ft of the vadose zone around all five boreholes. This contamination is most likely from surface spills that migrated into the backfill material around the boreholes.

Relatively high ^{137}Cs concentrations were detected between about 42 and 55 ft in boreholes 30-03-07 and 30-05-05. This ^{137}Cs contamination is probably the result of contamination from a pipeline or tank leak that migrated into the Hanford formation sediments below the base of the tank farm excavation. The source of this contamination could be any of the nearby tanks and their associated piping.

The ^{137}Cs contamination in borehole 30-05-05 is more extensive than in borehole 30-03-07, with an interval of high ^{137}Cs concentrations below about 55 ft near borehole 30-05-05. This zone of high ^{137}Cs concentrations in borehole 30-05-05 is associated with a zone of low ^{40}K concentrations that is not present around borehole 30-03-07.

Nearly continuous ^{137}Cs contamination was detected throughout the length of borehole 30-05-04. The SGLS did not detect any zones of relatively high ^{137}Cs contamination in the upper 40 ft that might indicate a tank leak occurred near this borehole. The source of this contamination may be a pipeline or tank leak from which contaminants migrated into the backfill material and into the Hanford formation sediments below the base of the tank farm excavation. It is also possible that contamination intercepted this borehole and then migrated down the outside of the borehole

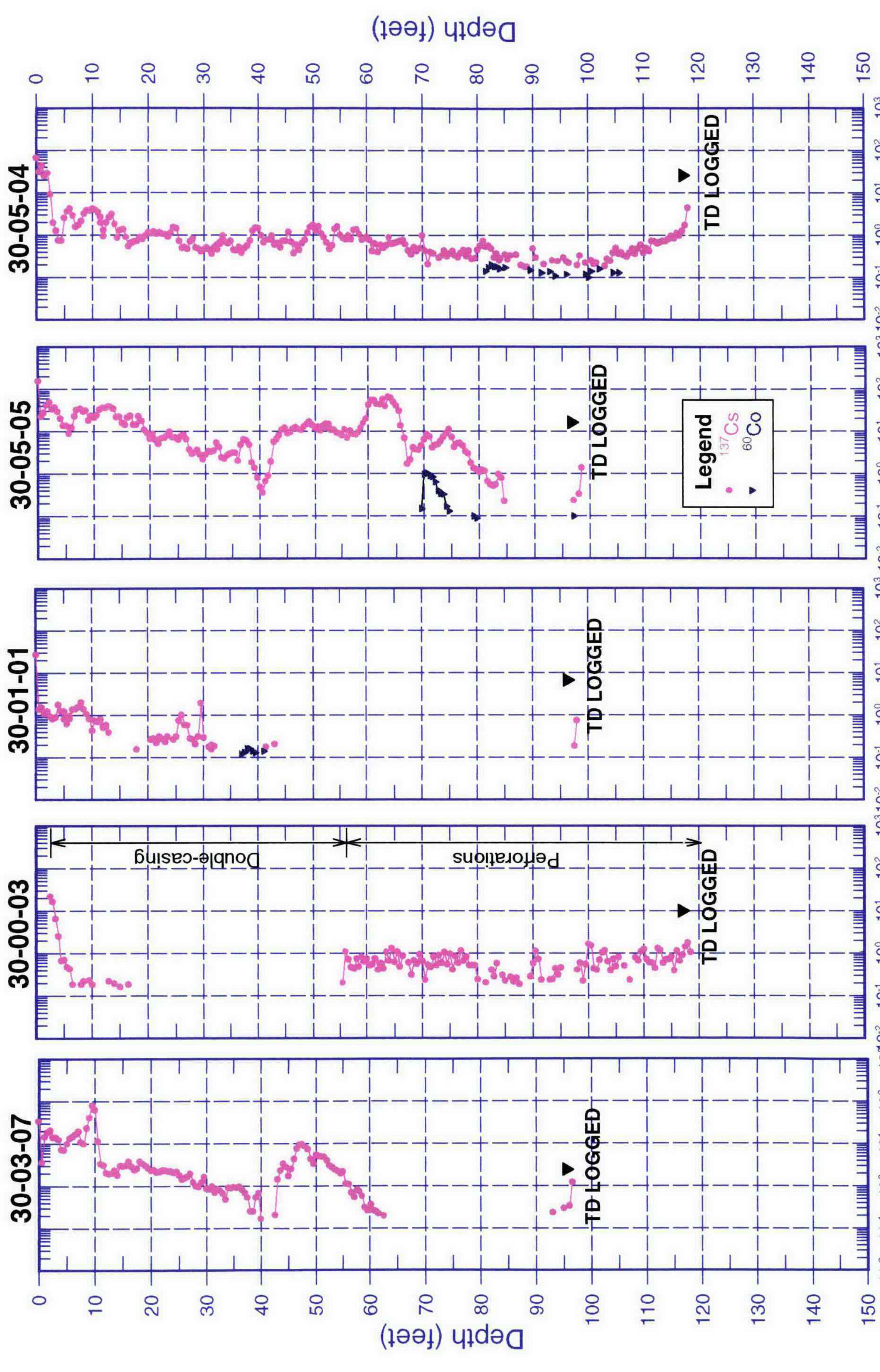

Figure 3. Correlation Plot of ^{137}Cs and ^{60}Co Concentrations in Boreholes Surrounding Tank C-102

casing. The source of this contamination could be any of the nearby tanks and their associated piping.

The ^{60}Co contamination detected in boreholes 30-01-01, 30-05-05, and 30-05-04 probably resulted from a pipeline or tank leak. The leak source could be any of the tanks in the vicinity of tank C-102 or their associated pipelines. The documented cascade-line leak between tanks C-104 and C-105 (Welty 1988) is one possible source of this contamination. ^{60}Co contamination probably collected at the base of the tank farm excavation in the vicinity of borehole 30-01-01 and was detected at about 38.5 ft. The ^{60}Co contamination detected in boreholes 30-05-05 and 30-05-04 is from ^{60}Co contamination that has migrated into the Hanford formation sediments below the base of the tank farm excavation.

The SGLS detected ^{137}Cs contamination from 55 ft to the bottom of the logged interval in borehole 30-00-03. Downward migration of contamination in this borehole could have been enhanced by the perforations from 54 ft to the bottom of the borehole. It is also possible that the calculated radionuclide concentrations in this depth interval are overstated because of the casing perforations. The radionuclide concentrations are calculated on the basis of the thickness of the steel casing, which acts as shielding to gamma rays, and the perforations remove portions of this shielding.

6.0 Conclusions

The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-102 was completed to the extent possible using boreholes associated with nearby tanks. However, the vadose zone in the immediate vicinity of tank C-102 could not be characterized because of a lack of adequately placed monitoring boreholes. Data obtained with the SGLS from boreholes associated with nearby tanks and geologic and historical information indicate that the source of the ^{137}Cs contamination detected around this tank is from a combination of surface spills and pipeline and tank leaks. Any of the tanks near tank C-102 or their associated piping could be the source of this contamination.

The ^{60}Co contamination appears to have originated from a tank other than tank C-102, although the available data are insufficient to rule out tank C-102 as a source of this contamination. The ^{60}Co contamination seems to be related to similar contamination detected in boreholes throughout this section of the C Tank Farm. The source of this contamination will be better defined as the C Tank Farm Report (to be published) is developed.

7.0 Recommendations

Approximately 316,000 gal of sludge including 30,000 gal of drainable liquid remains in tank C-102 (Hanlon 1997). It is recommended that several appropriately placed vadose zone monitoring boreholes be installed around this tank. Absent any liquid-level measuring instrumentation in tank C-102 (Hanlon 1997); monitoring of vadose zone boreholes provides the only means of leak detection for tank C-102. Monitoring could then be performed to identify potential past or future leakage from the tank and to identify the movement of contaminants in the vadose zone.

It is further recommended that borehole 30-00-03 be replaced with a new, single-cased, nonperforated borehole. The perforations in borehole 30-00-03 are not needed and may enhance downward migration of contamination; the double casing makes the borehole practically unusable for vadose zone monitoring. A new monitoring borehole should be constructed in this general area to monitor possible contaminant migration.

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-102

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-03-07

Borehole Information

Farm :	C	**Tank :**	C-103	**Site Number :**	299-E27-77
N-Coord :	42,820	**W-Coord :**	48,212	**TOC Elevation :**	645.64
Water Level, ft :	None	**Date Drilled :**	9/30/74		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:
This borehole was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System :	1	**Detector Type :**	HPGe	**Detector Efficiency :**	35.0 %
Calibration Date :	10/96	**Calibration Reference :**	GJO-HAN-13	**Logging Procedure :**	P-GJPO-1783

Log Run Information

Log Run Number :	1	**Log Run Date :**	4/11/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	96.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	23.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	4/14/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	24.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Event A

Borehole 30-03-07

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : P-GJPO-1787 Analysis Date : 5/6/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. There was some gain drift and it was necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured continuously from the ground surface to 40 ft, almost continuously from 42.5 to 62.5 ft, and intermittently from 93 ft to the bottom of the borehole.

The KUT concentrations increase at 40 ft. A distinctive peak is shown on the K-40 concentration plot at 42 ft.

The KUT concentrations increase below a depth of about 54 ft. The K-40 concentrations increase again from 80.5 ft to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-102 and C-103.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

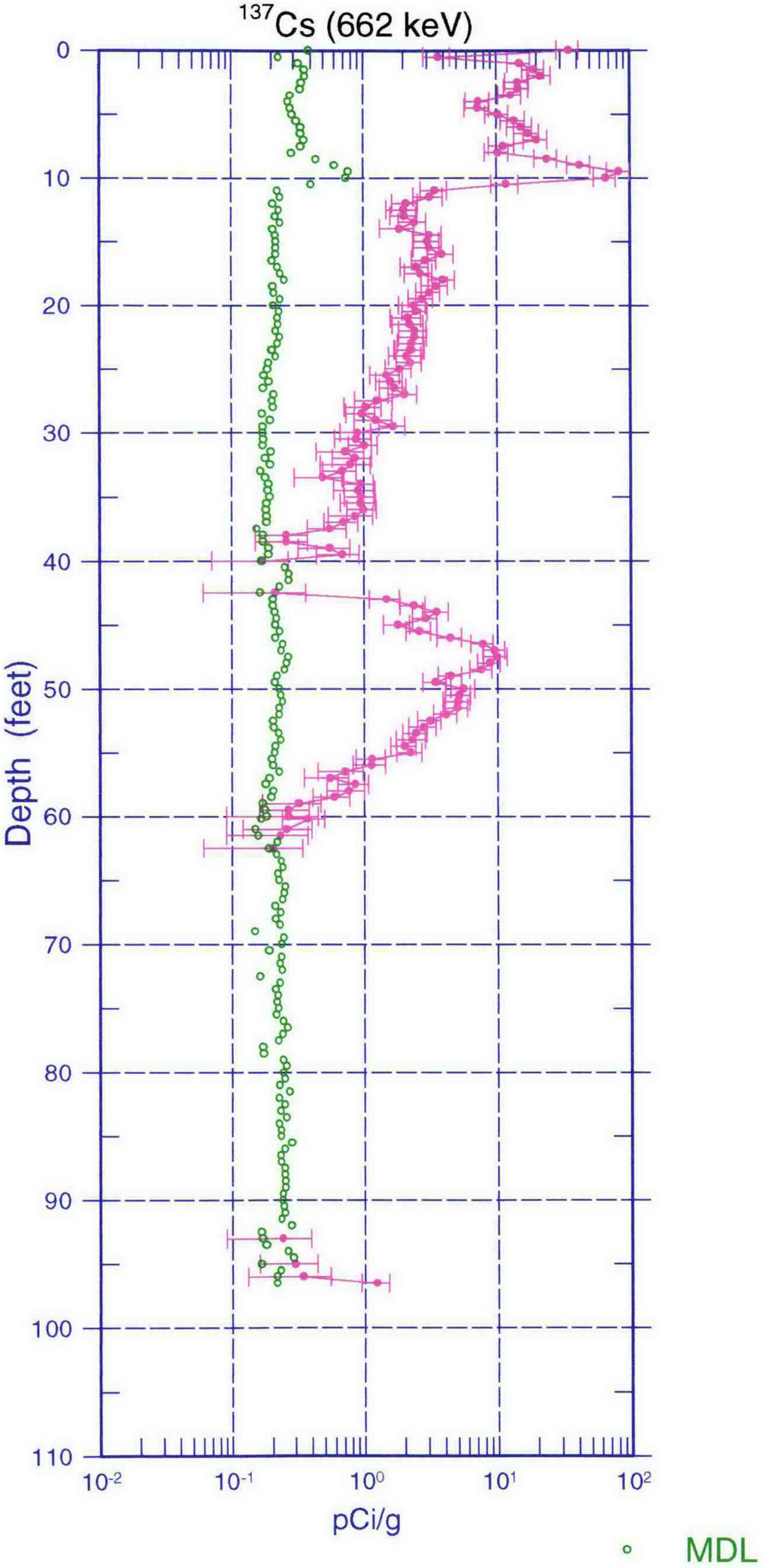
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

A comparison plot is also provided showing the Cs-137 and Co-60 concentrations determined from the SGLS and those determined from the Radionuclide Logging System (RLS) in 1994.

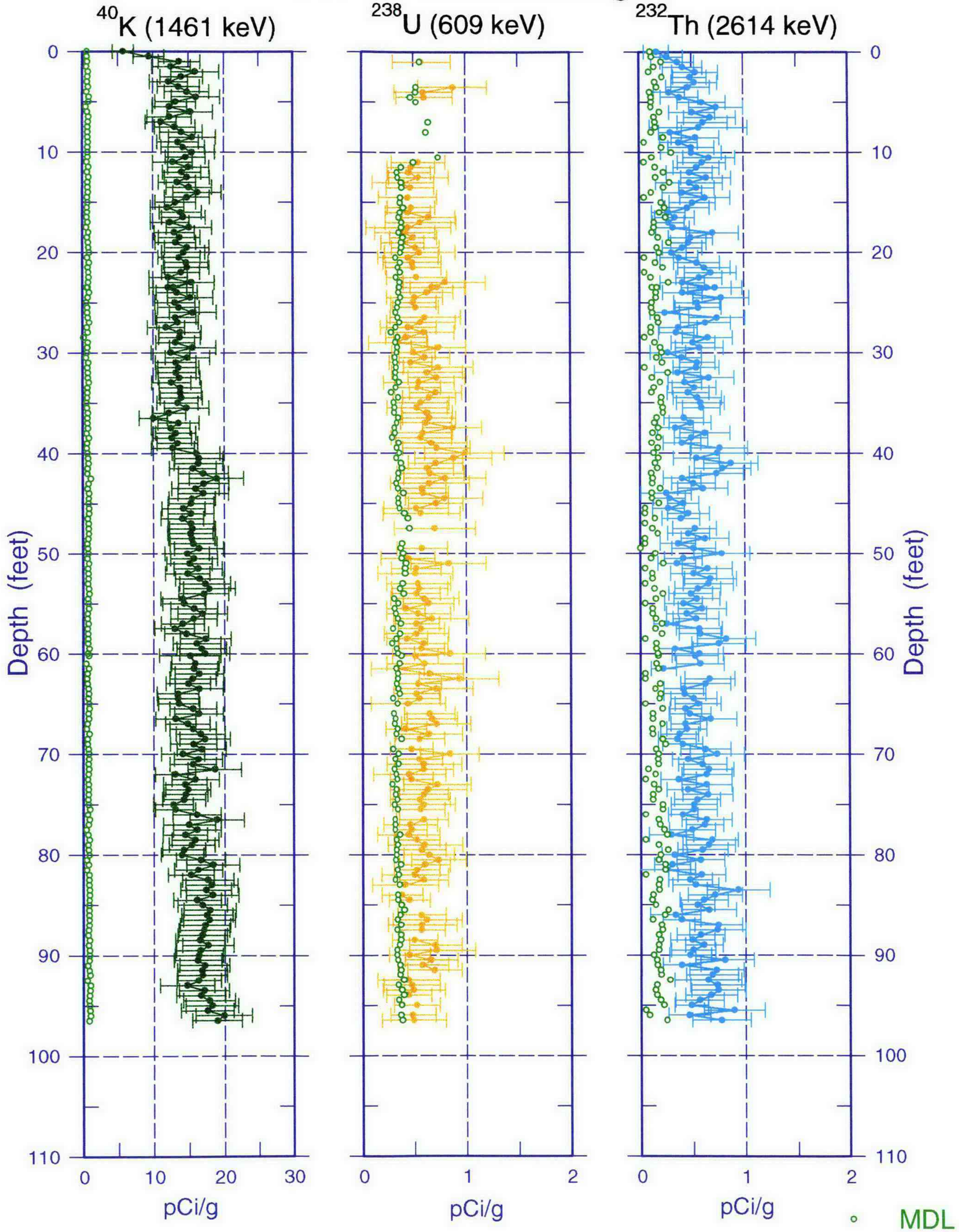
A plot of representative historical gross gamma-ray logs from 1975 to 1982 is included. The headings of the plots identify the date on which the data in the plots were gathered.

30-03-07

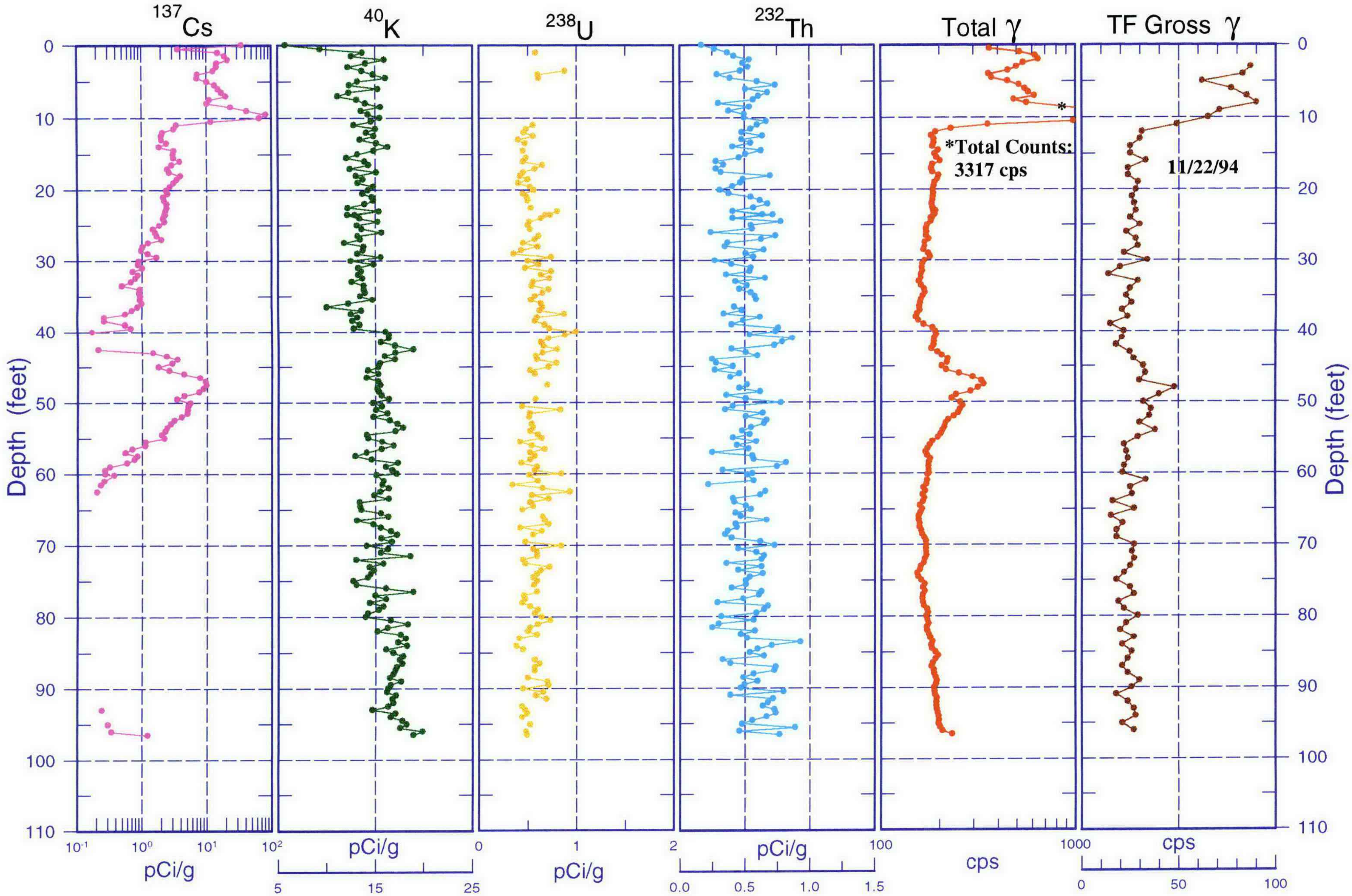
Man-Made Radionuclide Concentrations



30-03-07
Natural Gamma Logs



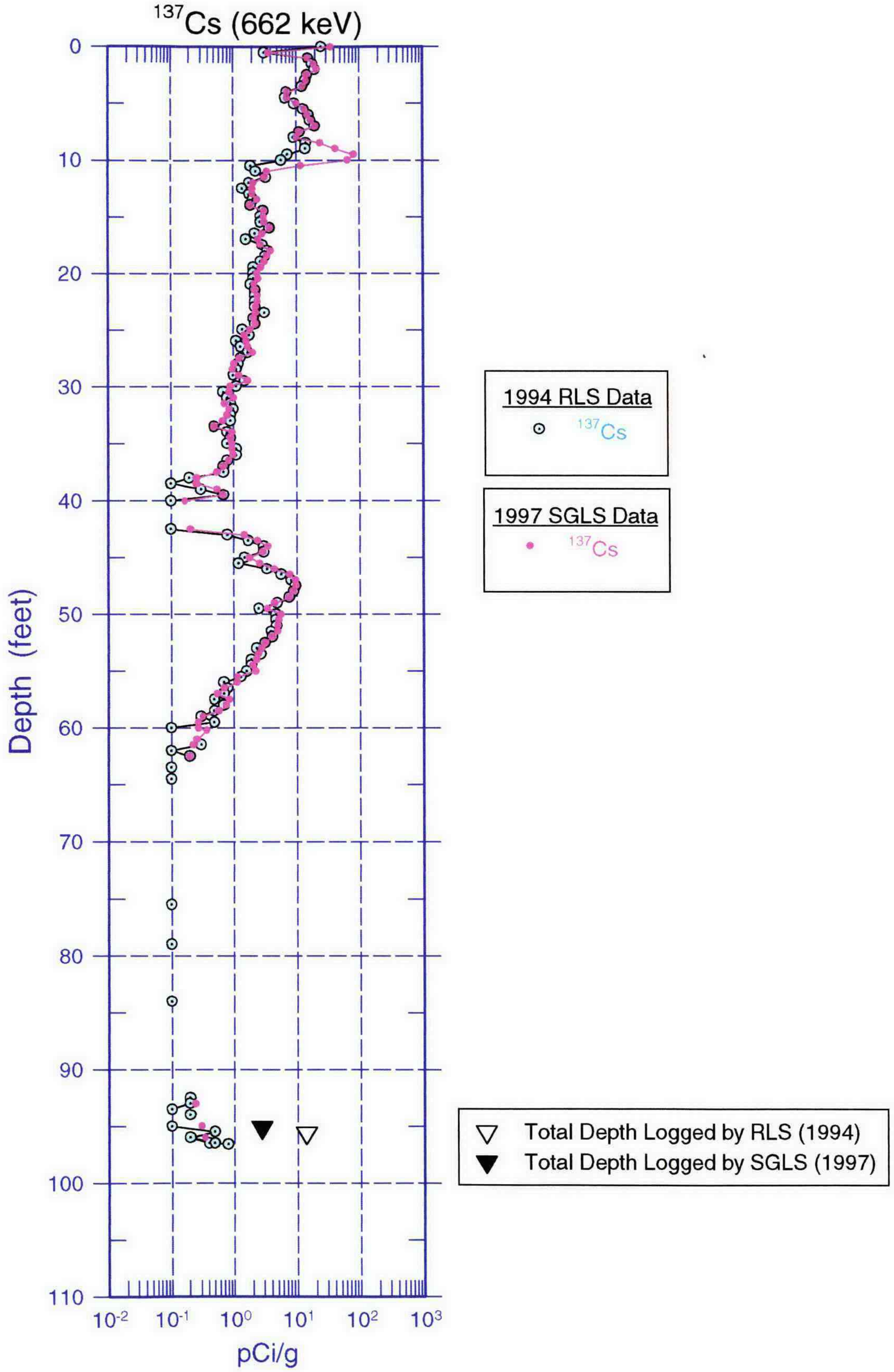
30-03-07 Combination Plot



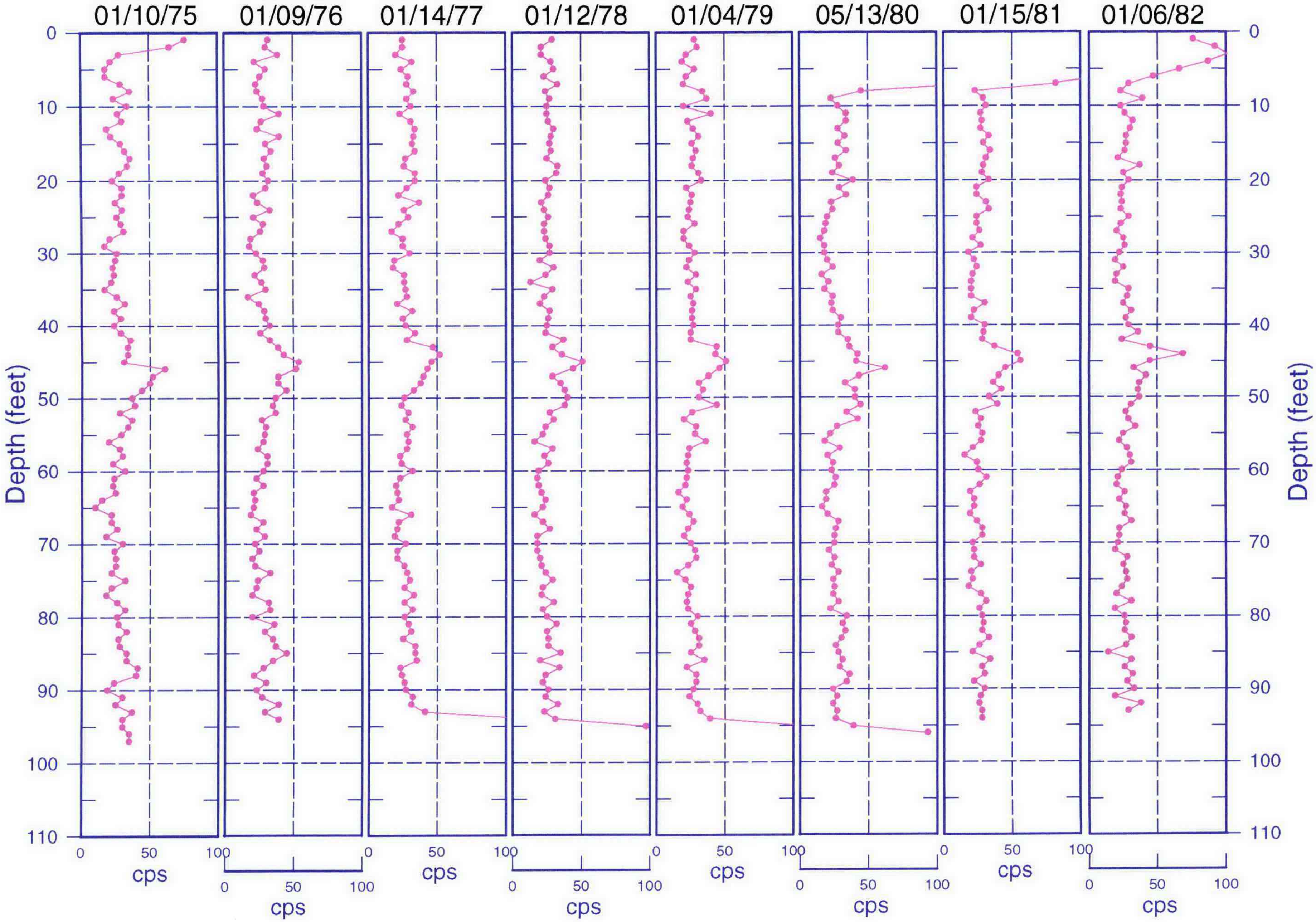
30-03-07

Man-Made Radionuclide Concentrations

1994/1997 Spectral Gamma Data Comparison



Historical Gross Gamma Logs for Borehole 30-03-07



Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-00-03

Borehole Information

Farm :	C	**Tank :**	C	**Site Number :**	299-E27-54
N-Coord :	42,771	**W-Coord :**	48,149	**TOC Elevation :**	651.57
Water Level, ft :	None	**Date Drilled :**	1/31/45		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.500	ID, in. :	12
Top Depth, ft. :	0	Bottom Depth, ft. :	54		
Type :	Steel-welded	Thickness, in. :	0.313	ID, in. :	8
Top Depth, ft. :	0	Bottom Depth, ft. :	155		

Cement Bottom, ft. : 155 **Cement Top, ft. :** 154

Borehole Notes:

This borehole was drilled in December 1944 and January 1945 and was completed to a depth of 155 ft with 8-in. casing. The 8-in. casing extends from the top of the borehole (approximately 2.5 ft above ground surface) to a depth of 154 ft. A string of 12-in. surface casing is also present from about 2 ft below the top of the borehole and extends (according to the driller's log) to a depth of 54 ft. The space between the outer 12-in. and inner 8-in. casing may be grouted, although the driller's log contains no mention of grout in this interval. The driller's log does indicate that the borehole was perforated between 54 and 154 ft with five perforations per foot, and that the bottom 8 in. of the borehole was grouted with half a bag of cement.

The zero reference for the SGLS logs is the top of the 8-in. casing. This borehole is located on the side of a hill with the top of the 8-in. casing approximately 2.5 ft above the slope of the hill. The top 2.5 ft of the borehole was not logged. The top of the 12-in. casing is approximately 0.5 ft above the slope of the hill. The current depth of the borehole, as verified with an electrical tape, is 118.8 ft. There is no information given as to when or how the bottom portion of the borehole was filled.

Equipment Information

Logging System :	1	**Detector Type :**	HPGe	**Detector Efficiency :**	35.0 %
Calibration Date :	10/96	**Calibration Reference :**	GJO-HAN-13	**Logging Procedure :**	P-GJPO-1783

Log Run Information

Log Run Number :	1	**Log Run Date :**	4/15/97	**Logging Engineer:**	Alan Pearson
Start Depth, ft.:	2.5	**Counting Time, sec.:**	100	**L/R :** L	**Shield :** N
Finish Depth, ft. :	15.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a

Borehole # 30-00-03

Log Event A

Log Run Number : 2	**Log Run Date :** 4/16/97	**Logging Engineer:** Alan Pearson			
Start Depth, ft.: 118.5	**Counting Time, sec.:** 100	**L/R :** L	**Shield :** N		
Finish Depth, ft. : 33.0	**MSA Interval, ft. :** .5	**Log Speed, ft/min.:** n/a			

Log Run Number : 3	**Log Run Date :** 4/17/97	**Logging Engineer:** Alan Pearson			
Start Depth, ft.: 34.0	**Counting Time, sec.:** 100	**L/R :** L	**Shield :** N		
Finish Depth, ft. : 14.0	**MSA Interval, ft. :** .5	**Log Speed, ft/min.:** n/a			

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : P-GJPO-1787 Analysis Date : 5/15/97

Analysis Notes :

This borehole was logged in three log runs using a centralizer. Spectra were not collected in the top 2.5 ft of the borehole. The pre- and post-survey field verification spectra met the acceptance criteria established for peak shape and system efficiency. The energy and peak-shape calibration from the field verification spectra that best matched the data were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the three log runs. There was some gain drift and it was necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

This borehole is double-cased between depths of 0.5 and 54 ft. An appropriate casing correction factor for the double-cased portion of the borehole could not be applied because of the attenuation caused by the double-steel casings in this interval and the potential for grout between the two casings.

A casing correction factor for a 0.330-in.-thick casing was applied during the analysis of borehole data. This correction factor most closely matches the actual thickness of the 8-in. casing. Use of this casing correction factor will cause the radionuclide concentrations to be overestimated below the double-cased portion of the borehole, and significantly underestimated in the double-cased portion of the borehole.

Cs-137 was the only man-made radionuclide detected in this borehole. Cs-137 contamination was detected intermittently from 2.5 to 16.5 ft and almost continuously from 55.5 to 118 ft. The maximum measured Cs-137 concentration was approximately 1.8 pCi/g at a depth of 118 ft. Apparently higher concentrations were detected in the double-cased portion of the borehole; however, an actual concentration cannot be calculated for the reasons described previously.

The logs of the naturally occurring radionuclides show an increase in K-40 and Th-232 concentrations at about 56 ft. The logs show a slight decrease in K-40 and Th-232 concentrations between depths of about 70 and 90 ft. K-40 concentrations gradually increase from 85 to about 106 ft. Th-232 concentrations increase below a depth of about 99 ft and decrease again below a depth of about 111 ft.

Details concerning the interpretation of data for this borehole are presented in the Tank Summary Data Reports for tanks C-102 and C-103.

Log Event A

Borehole 30-00-03

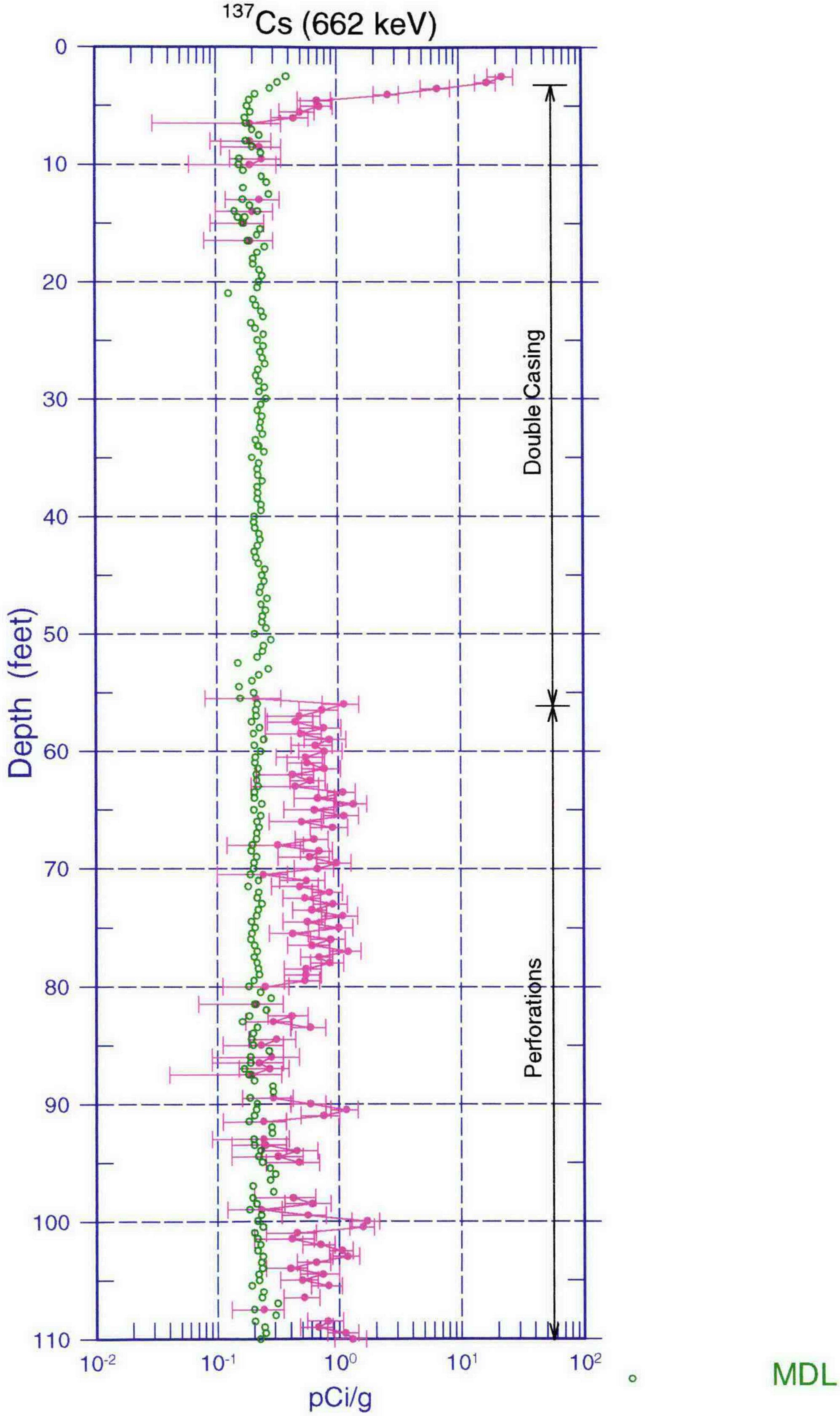
Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

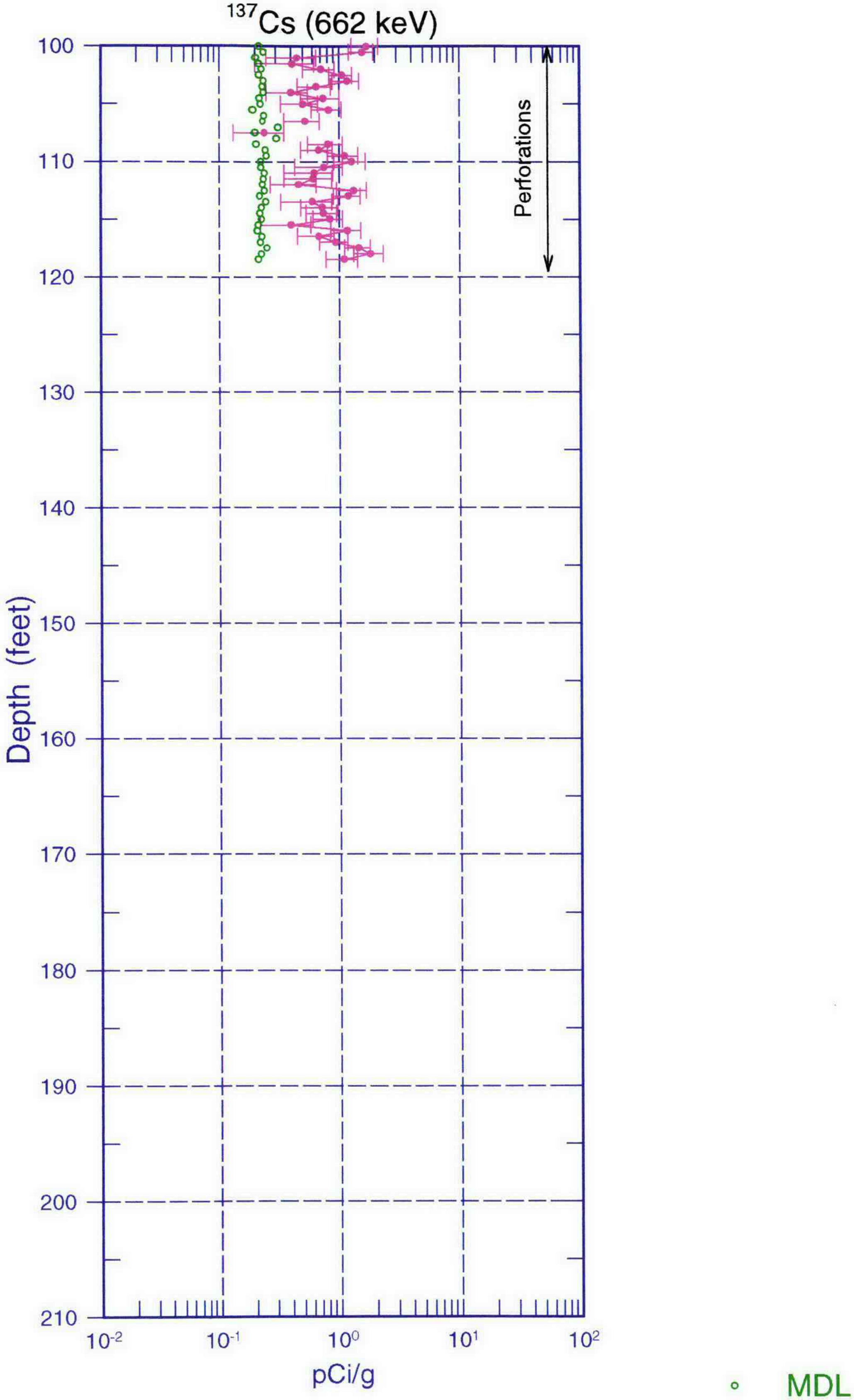
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

30-00-03

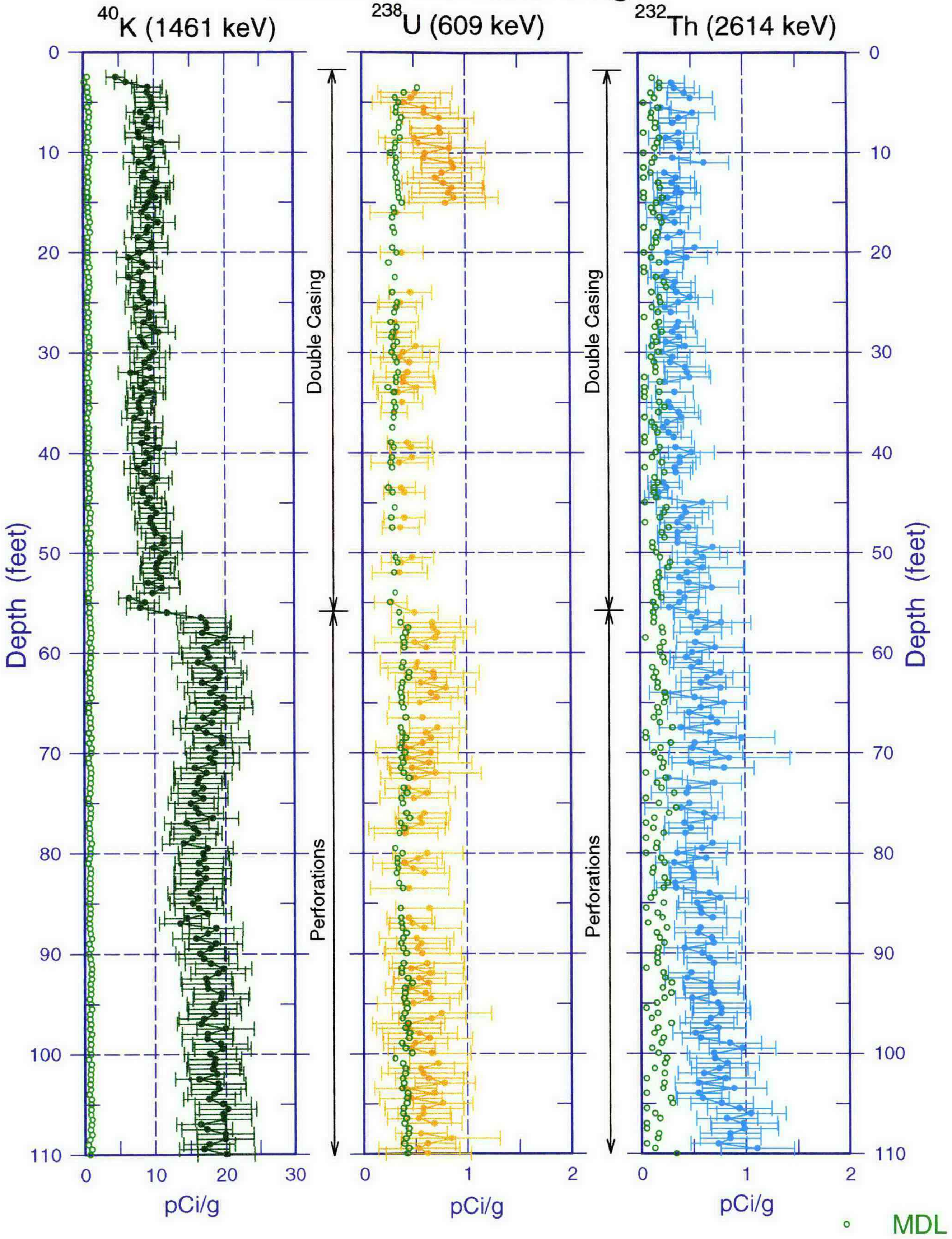
Man-Made Radionuclide Concentrations



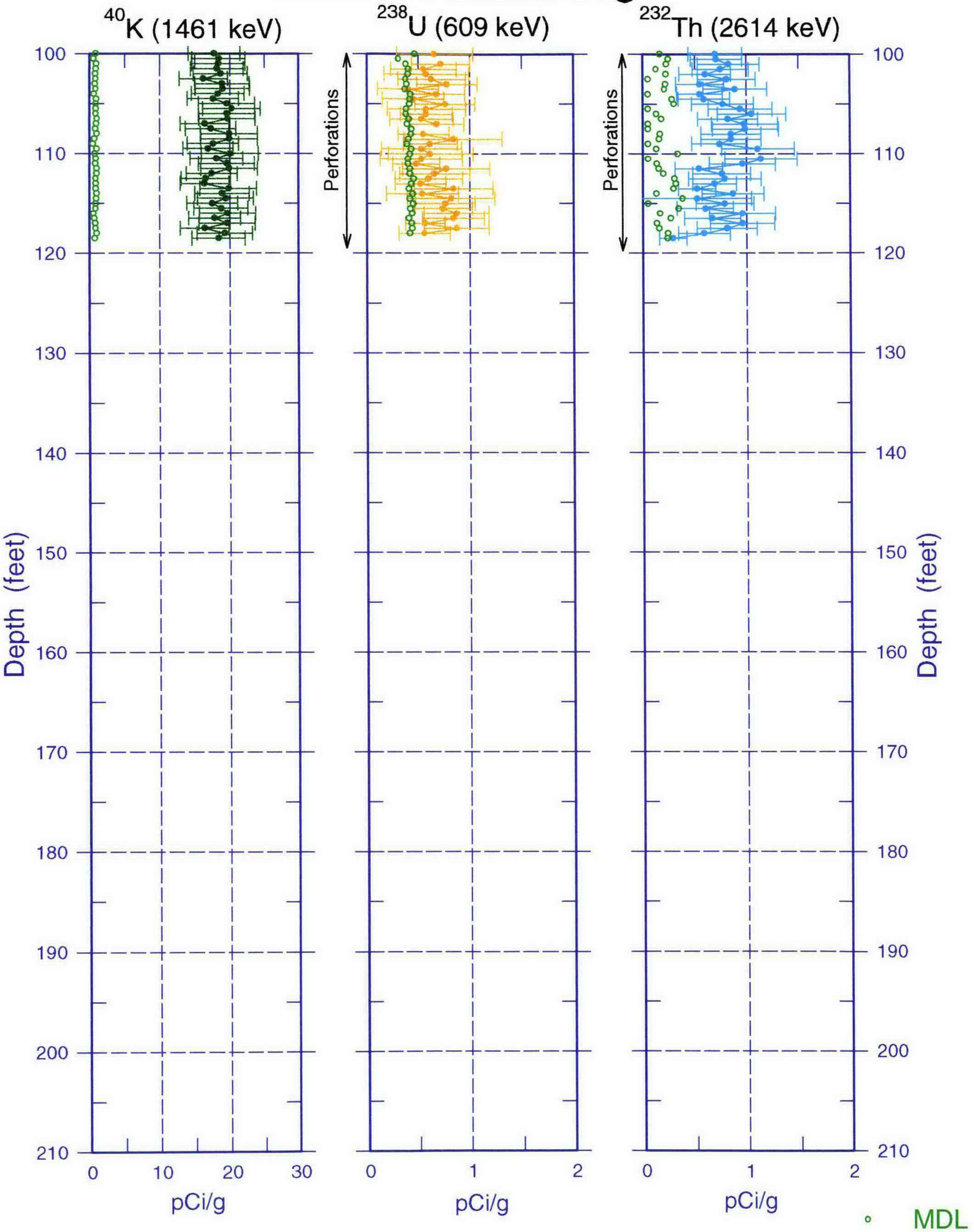
30-00-03
Man-Made Radionuclide Concentrations



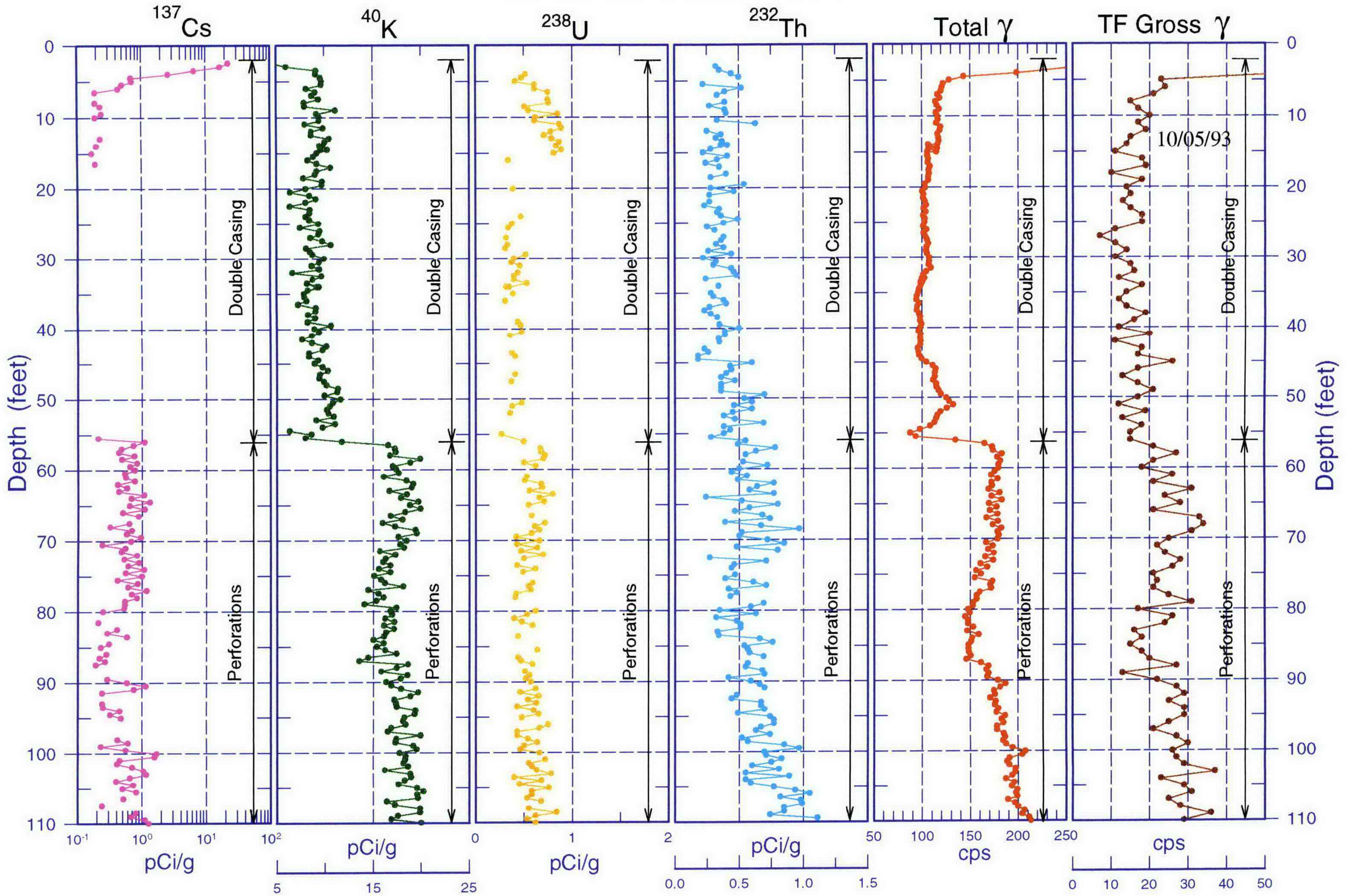
30-00-03
Natural Gamma Logs



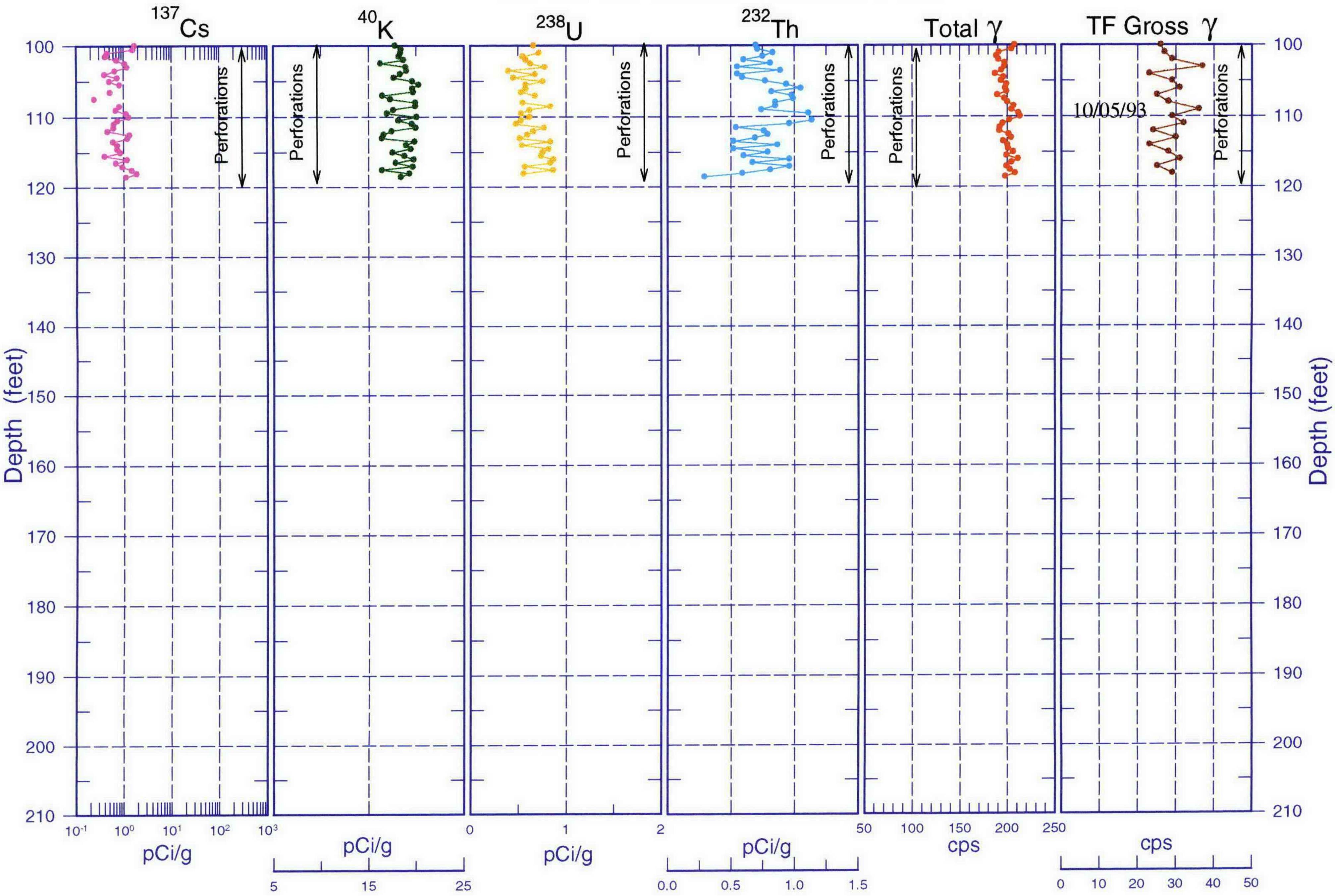
30-00-03
Natural Gamma Logs



30-00-03 Combination Plot



30-00-03 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-01-01

Borehole Information

Farm :	C	**Tank :**	C-101	**Site Number :**	299-E27-60
N-Coord :	42,747	**W-Coord :**	48,295	**TOC Elevation :**	646.33
Water Level, ft :	None	**Date Drilled :**	3/31/70		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:

This borehole was drilled in March 1970 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or the borehole grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is even with the tank farm ground surface.

Equipment Information

Logging System :	2	**Detector Type :**	HPGe	**Detector Efficiency :**	35.0 %
Calibration Date :	10/96	**Calibration Reference :**	GJO-HAN-13	**Logging Procedure :**	P-GJPO-1783

Log Run Information

Log Run Number :	1	**Log Run Date :**	3/26/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	6.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	3/27/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	5.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	13.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	3/27/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	98.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	31.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-01-01

Log Run Number :	4	**Log Run Date :**	3/28/97	**Logging Engineer:**	Bob Spatz
Start Depth, ft.:	32.0	**Counting Time, sec.:**	100	**L/R :** L	**Shield :** N
Finish Depth, ft. :	12.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a

Analysis Information

Analyst :	D.L. Parker		
Data Processing Reference :	P-GJPO-1787	Analysis Date :	6/27/97

Analysis Notes :

This borehole was logged by the SGLS in four log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation. No fine gain adjustments were necessary during these log runs.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides Cs-137 and Co-60 were detected in this borehole. Cs-137 contamination was measured continuously from the ground surface to 13 ft, at 18 ft, almost continuously from 20.5 to 32 ft, at 41.5 ft, at 43 ft, and the bottom of the logged interval (97.5 and 98 ft). Co-60 contamination was detected almost continuously from 37 to 41 ft.

The U-238 concentrations decrease below 6 ft. The K-40 concentrations decrease slightly from 32 to 37.5 ft, increase from 38 to 39 ft, and decrease to a background concentration of about 14 pCi/g from 39.5 to 53 ft. K-40 concentrations are slightly decreased and variable from 53.5 to about 69.5 ft, increase gradually from 69.5 to 72 ft, and become variable below about 72 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-101 and C-102.

Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

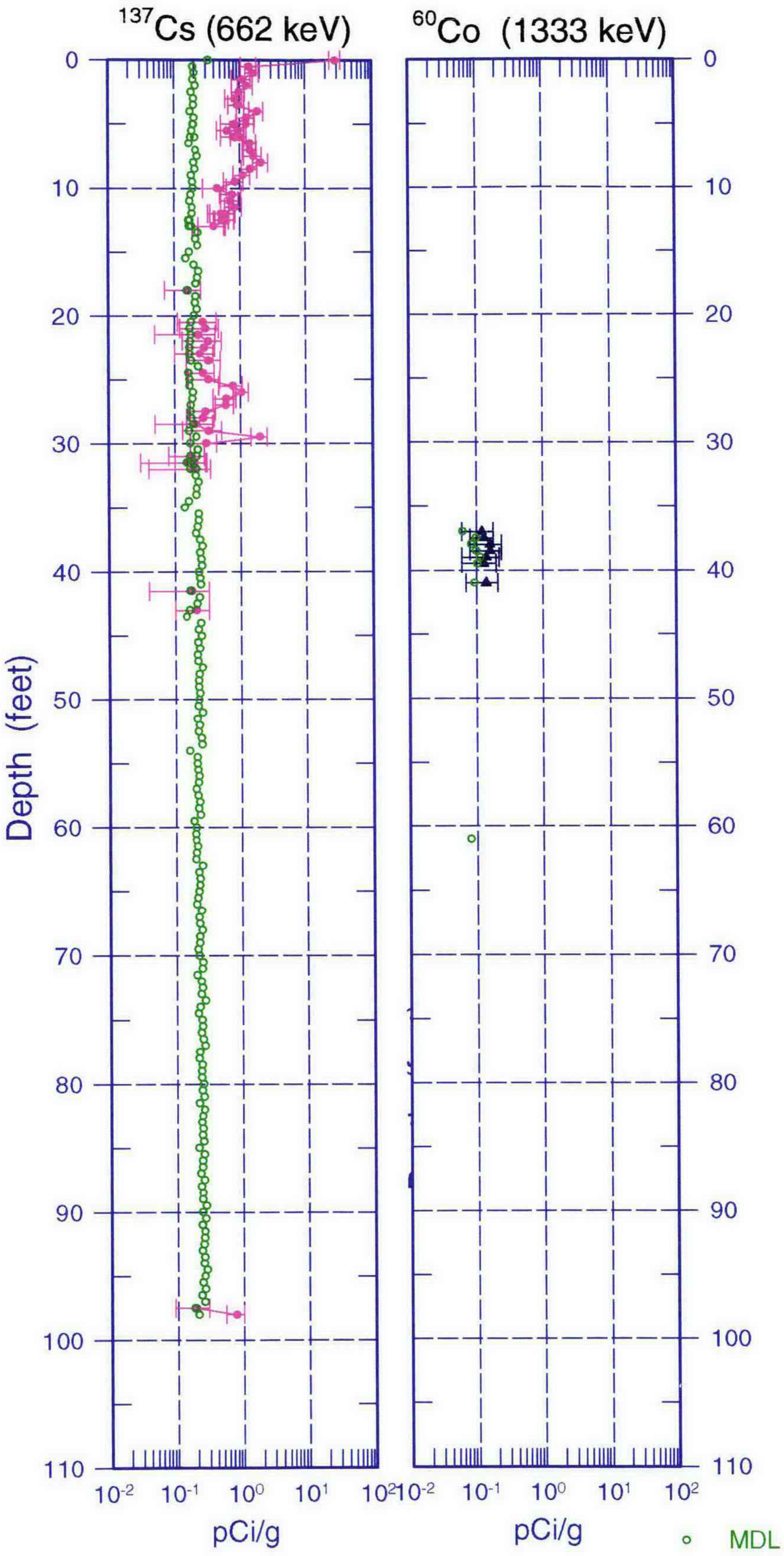
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

Borehole 30-01-01

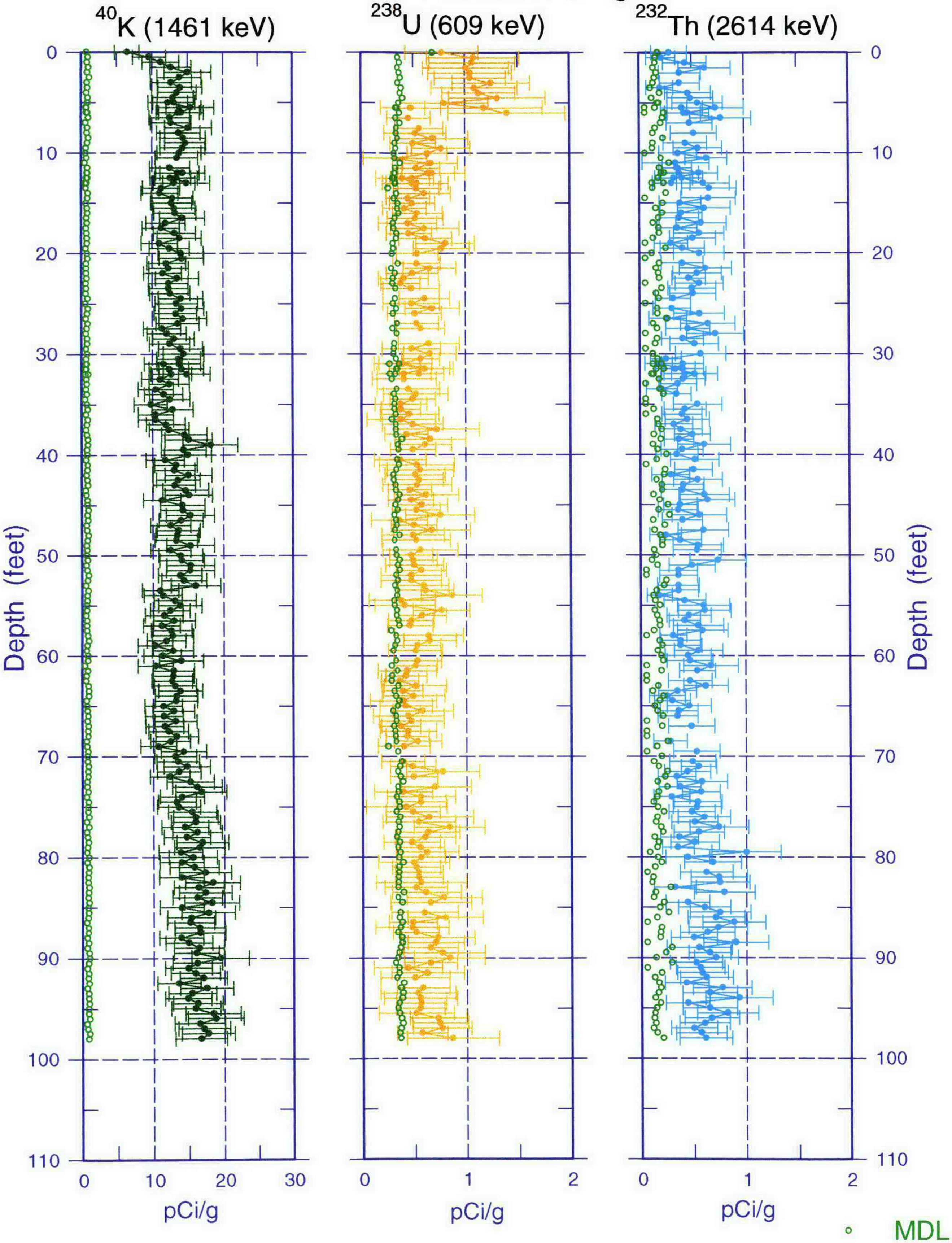
Log Event A

A plot of representative historical gross gamma-ray logs from 1975 to 1992 is included. The headings of the plots identify the date on which the data in the plots were gathered.

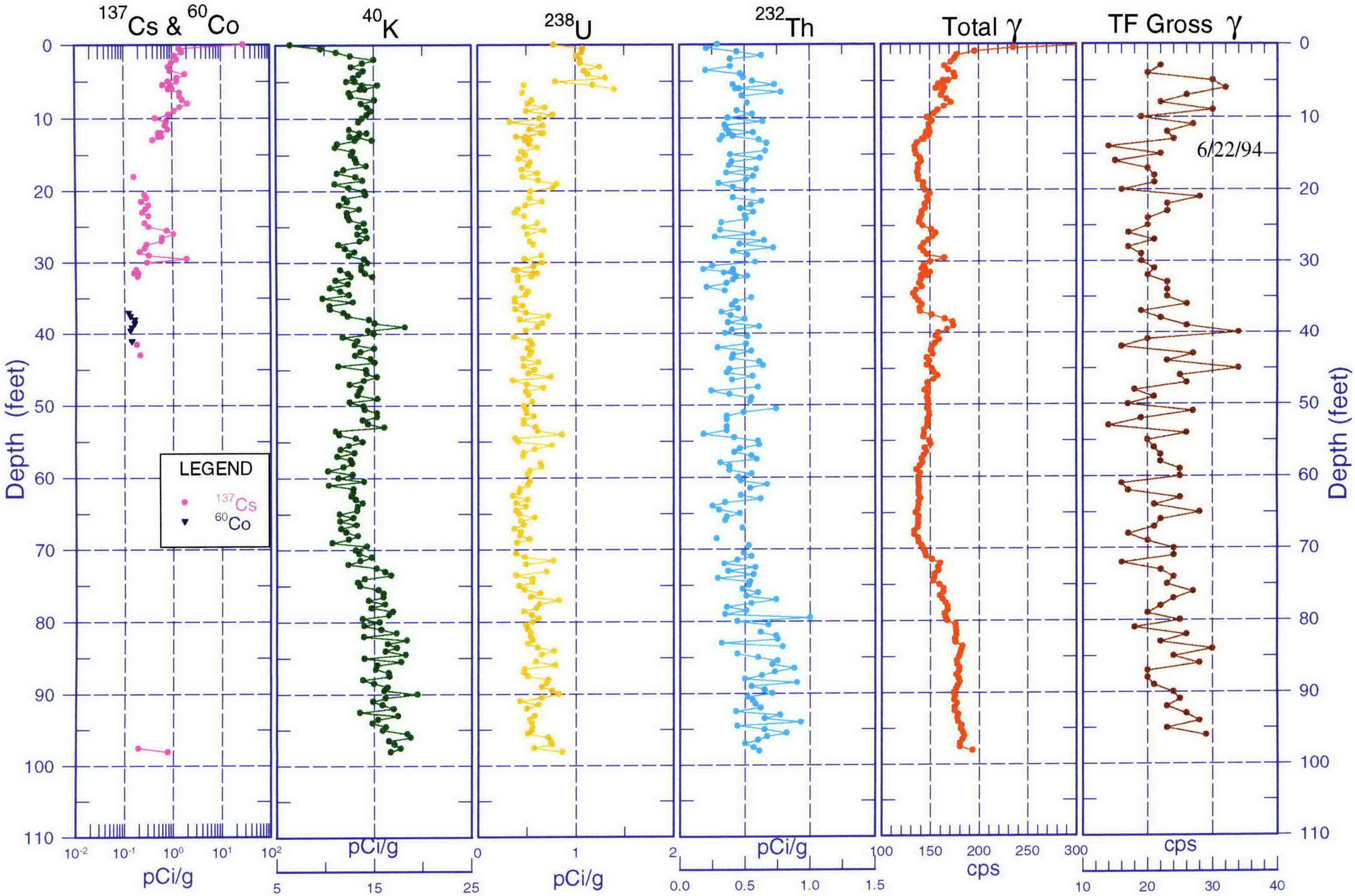
30-01-01
Man-Made Radionuclide Concentrations



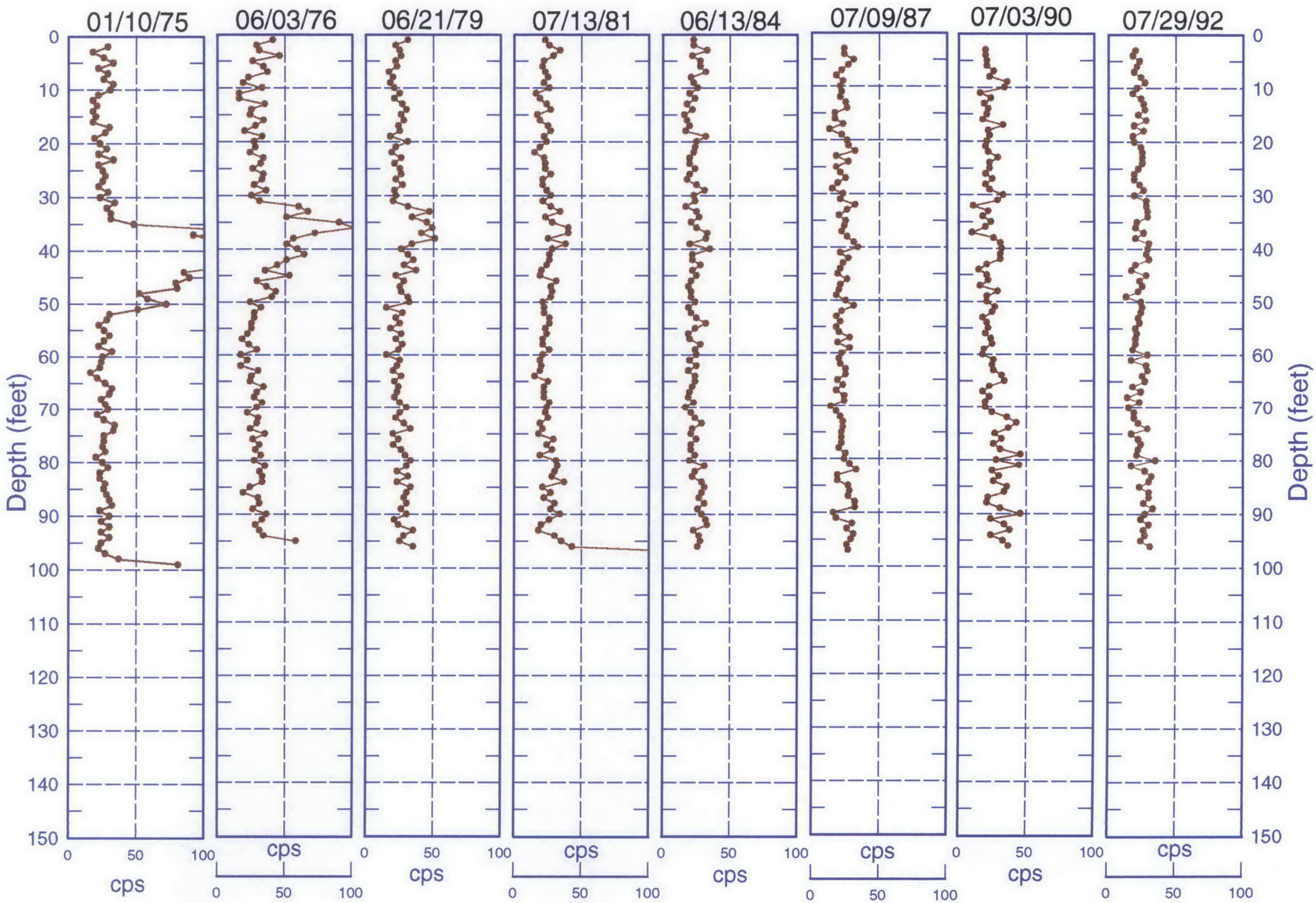
30-01-01
Natural Gamma Logs



30-01-01 Combination Plot



Historical Gross Gamma Logs for Borehole 30-01-01



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-05-05

Borehole Information

Farm :	C	Tank :	C-105	Site Number :	299-E27-82
N-Coord :	42,813	W-Coord :	48,327	TOC Elevation :	646.21
Water Level, ft :	None	Date Drilled :	6/30/74		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	100		

Borehole Notes:
This borehole was drilled in June 1974 to a depth of 100 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	1/29/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	98.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	51.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	1/29/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	52.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-05-05

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/2/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides Cs-137 and Co-60 were detected in this borehole. Extensive Cs-137 contamination was measured continuously from the ground surface to a depth of 84.5 ft, at 97 ft, and at the bottom of the logged interval (98 to 98.5 ft). Continuous Co-60 contamination was detected from 69.5 to 74.5 ft, and at 79, 79.5, and 97 ft.

The K-40 concentration values increase significantly from 35.5 to 43 ft, become slightly variable and gradually decrease between 43 and 65 ft, increase sharply from 65 to 67.5 ft, then generally remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-102 and C-105.

Log Plot Notes:

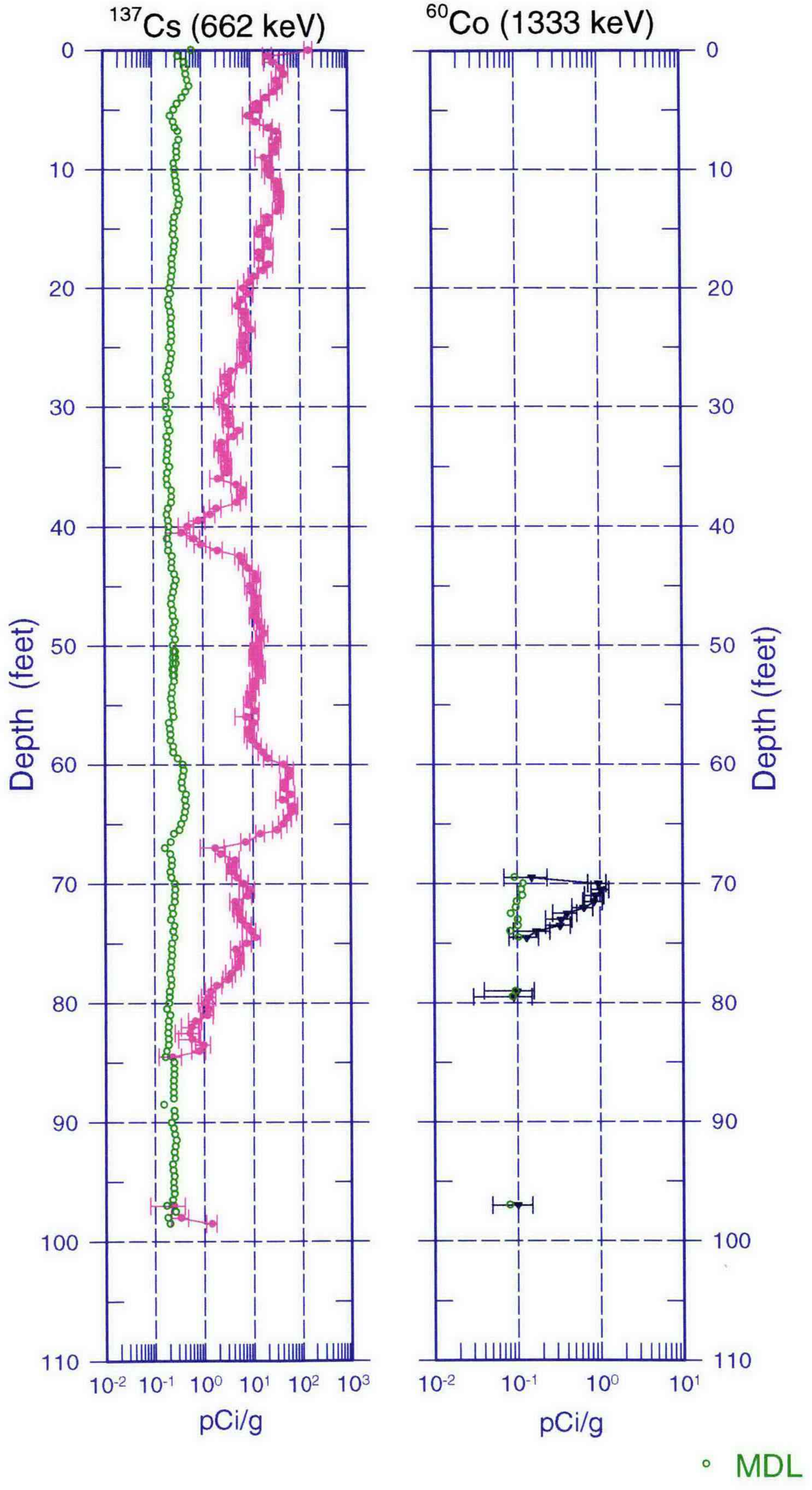
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

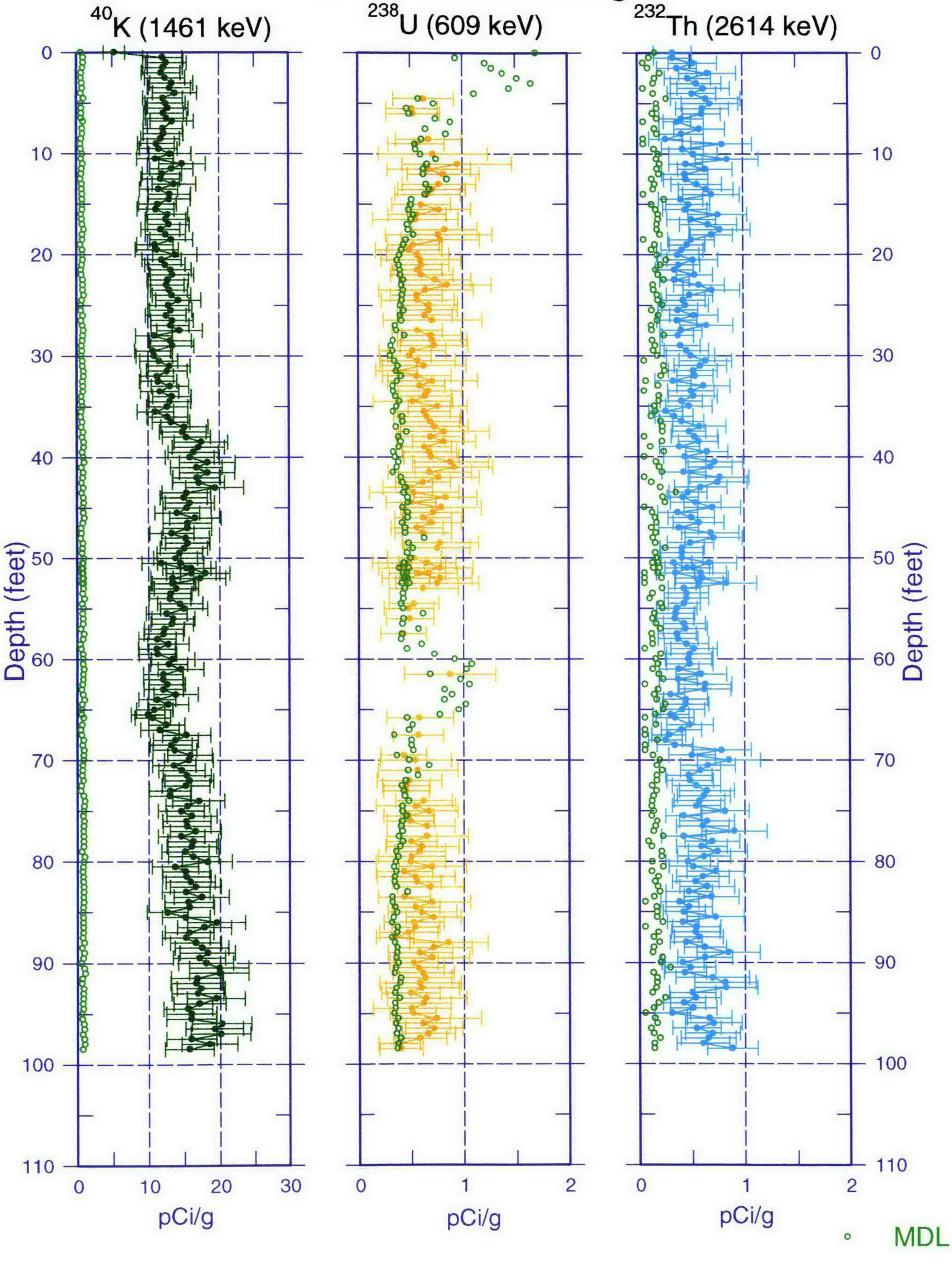
An additional log plot compares spectral gamma data collected with the Radionuclide Logging System (RLS) in 1993 to spectral gamma data collected with the SGLS in 1997. A separate plot was generated from this data that includes the Cs-137, Co-60, and K-40 concentrations detected between 50 and 80 ft plotted on a linear scale to provide a more detailed quantitative comparison of the data. Uncertainty bars and MDLs are not included on either plot.

30-05-05

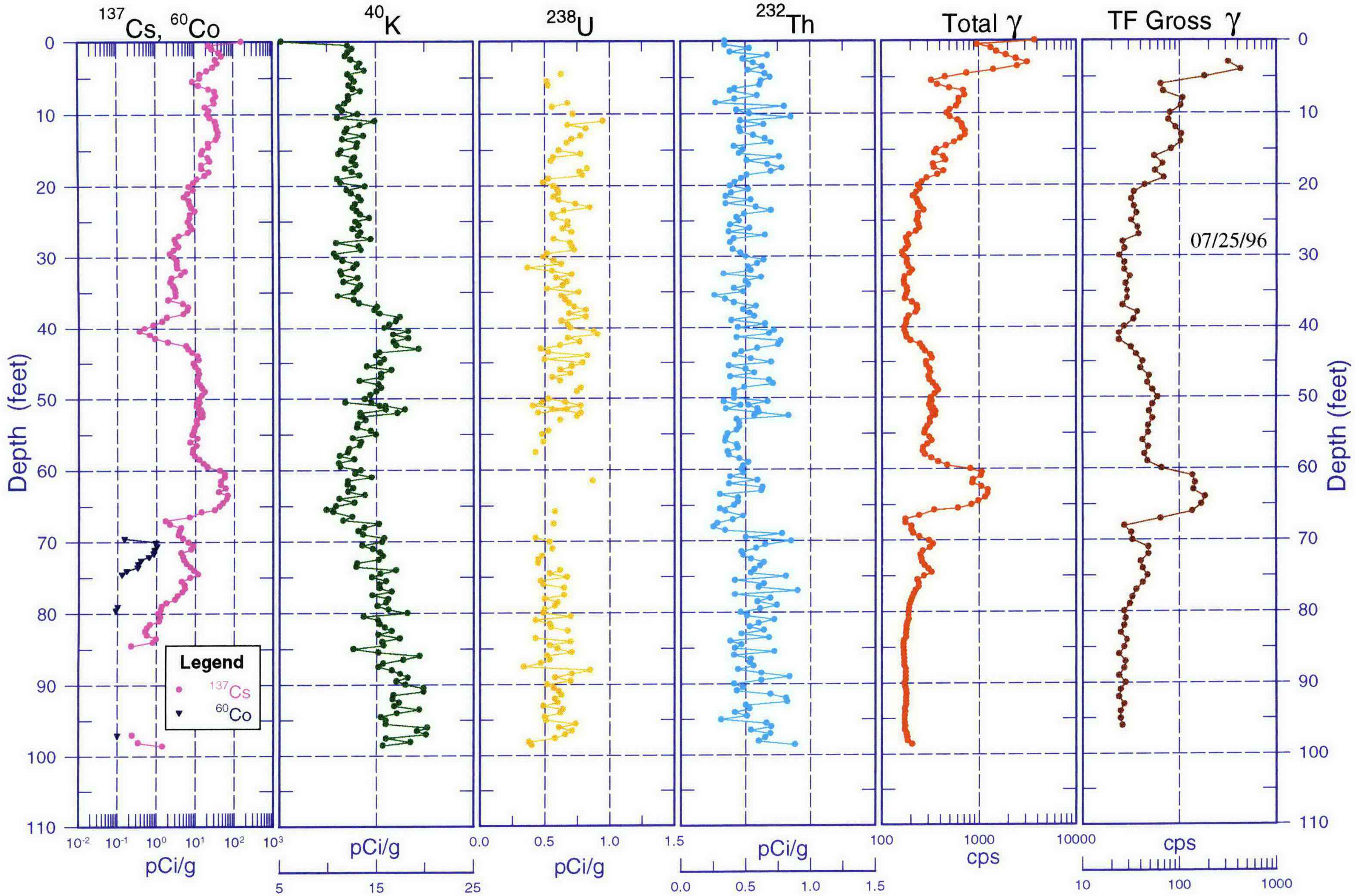
Man-Made Radionuclide Concentrations



30-05-05
Natural Gamma Logs



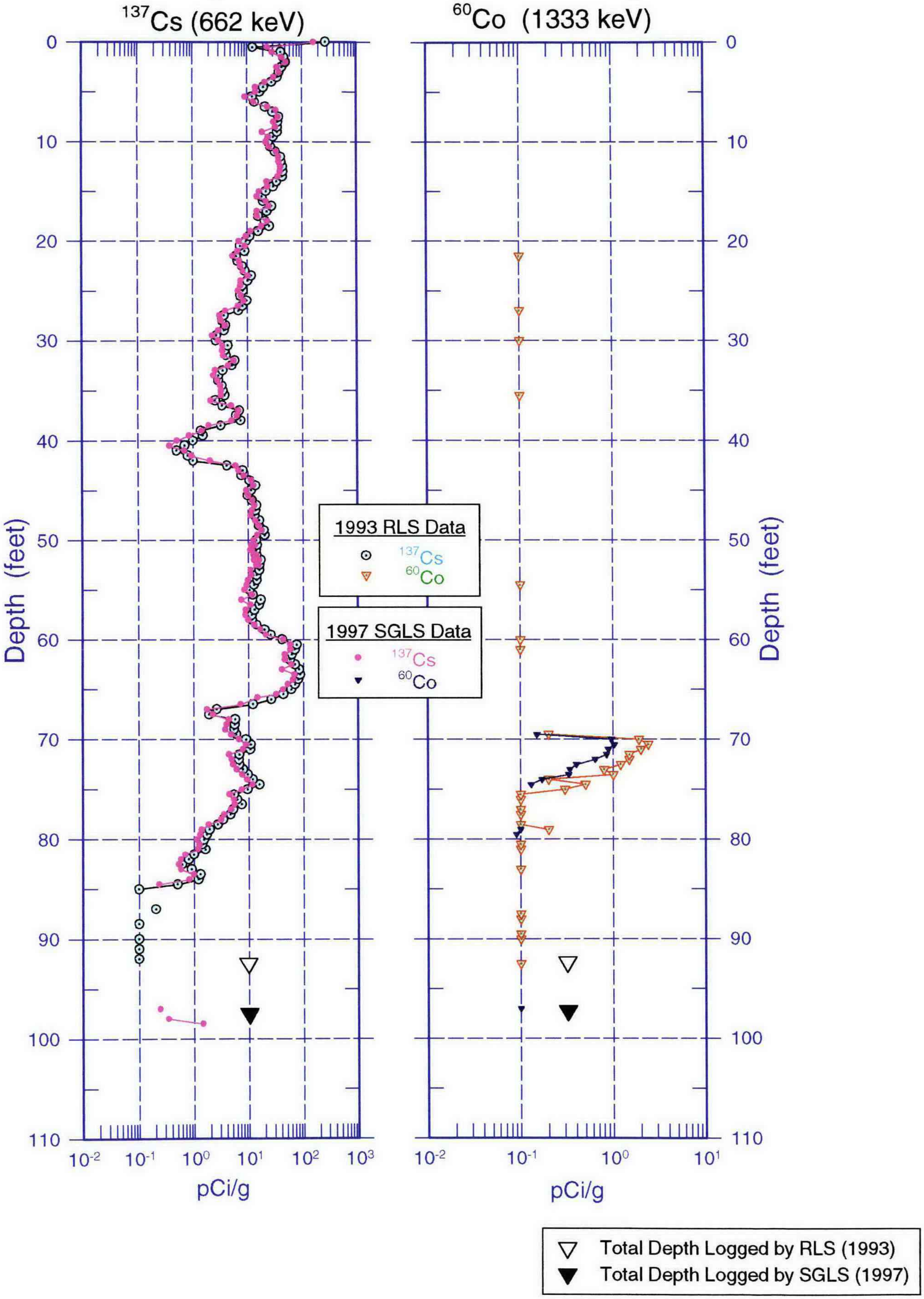
30-05-05 Combination Plot



30-05-05

Man-Made Radionuclide Concentrations

1993/1997 Spectral Gamma Data Comparison



MACTEC ENVIRONMENTAL RESTORATION SERVICES, LLC

Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-05-04

Borehole Information

Farm :	C	Tank :	C-105	Site Number :	299-E27-69
N-Coord :	42,825	W-Coord :	48,294	TOC Elevation :	646.07
Water Level, ft :	None	Date Drilled :	12/31/72		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	120		

Borehole Notes:

This borehole was drilled in December 1972 to a depth of 120 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface.

Equipment Information

Logging System :	2	Detector Type :	HPGe	Detector Efficiency :	35.0 %
Calibration Date :	10/96	Calibration Reference :	GJO-HAN-13	Logging Procedure :	P-GJPO-1783

Log Run Information

Log Run Number :	1	Log Run Date :	1/29/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	12.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Log Run Number :	2	Log Run Date :	1/30/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	11.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	33.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Log Run Number :	3	Log Run Date :	1/30/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	32.5	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	43.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Borehole 30-05-04

Log Event A

Log Run Number :	4	Log Run Date :	1/31/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	118.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	42.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/2/97

Analysis Notes :

This borehole was logged by the SGLS in four log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and the channel-to-energy parameters used in processing the spectra acquired during the logging operation.

Casing correction factors for a 0.280-in.-thick steel casing were applied during analysis.

The man-made radionuclides detected in this borehole were Cs-137 and Co-60. Nearly continuous Cs-137 contamination was measured from the ground surface to the bottom of the logged interval (118 ft). A thin zone of continuous Co-60 contamination was measured from 81.5 to 84 ft. Many isolated occurrences of Co-60 contamination were also detected between 85 and 105.5 ft.

The K-40 concentration values increase at 41 ft, increase again at about 72 ft, then remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-102 and C-105.

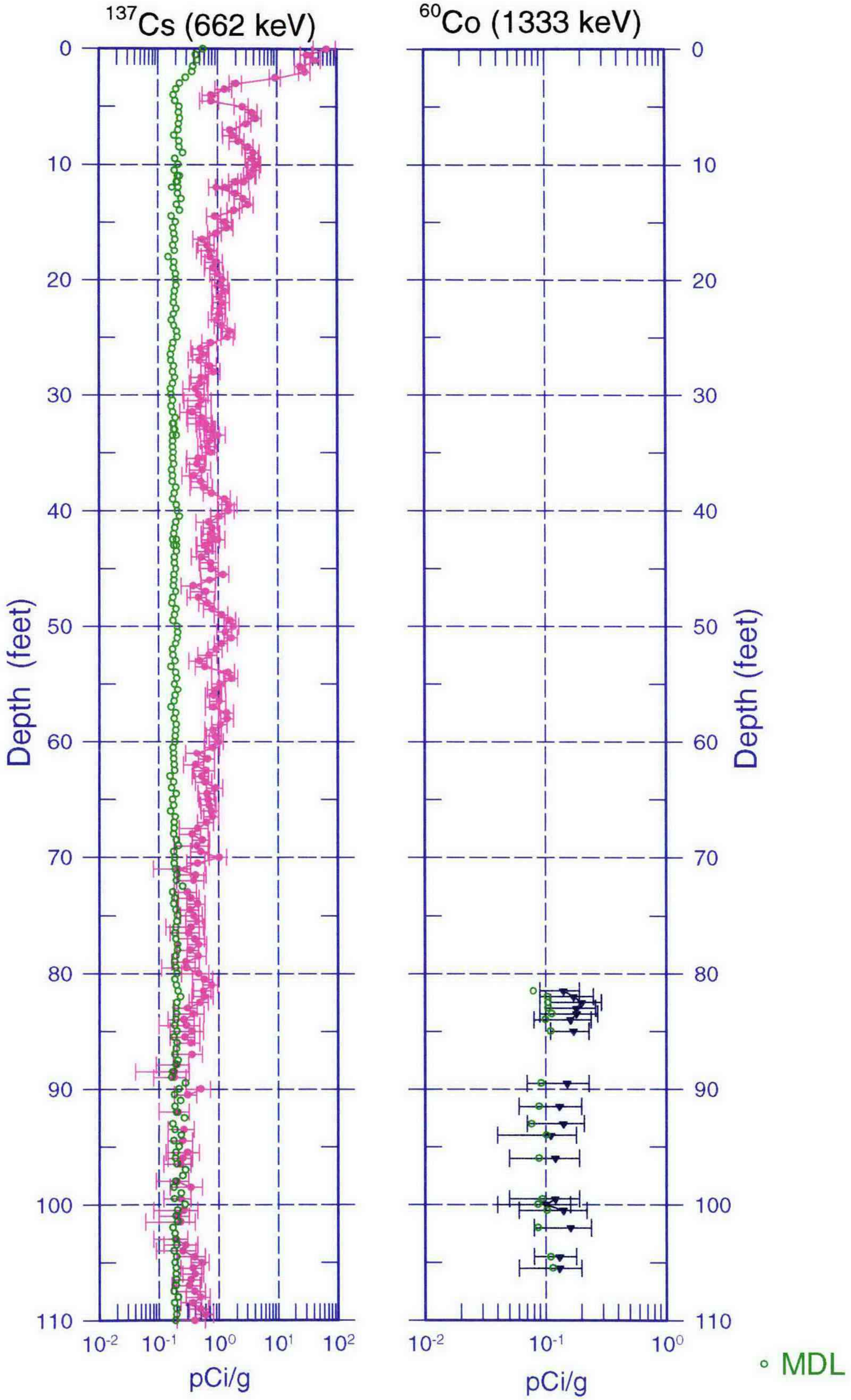
Log Plot Notes:

Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with the SGLS data.

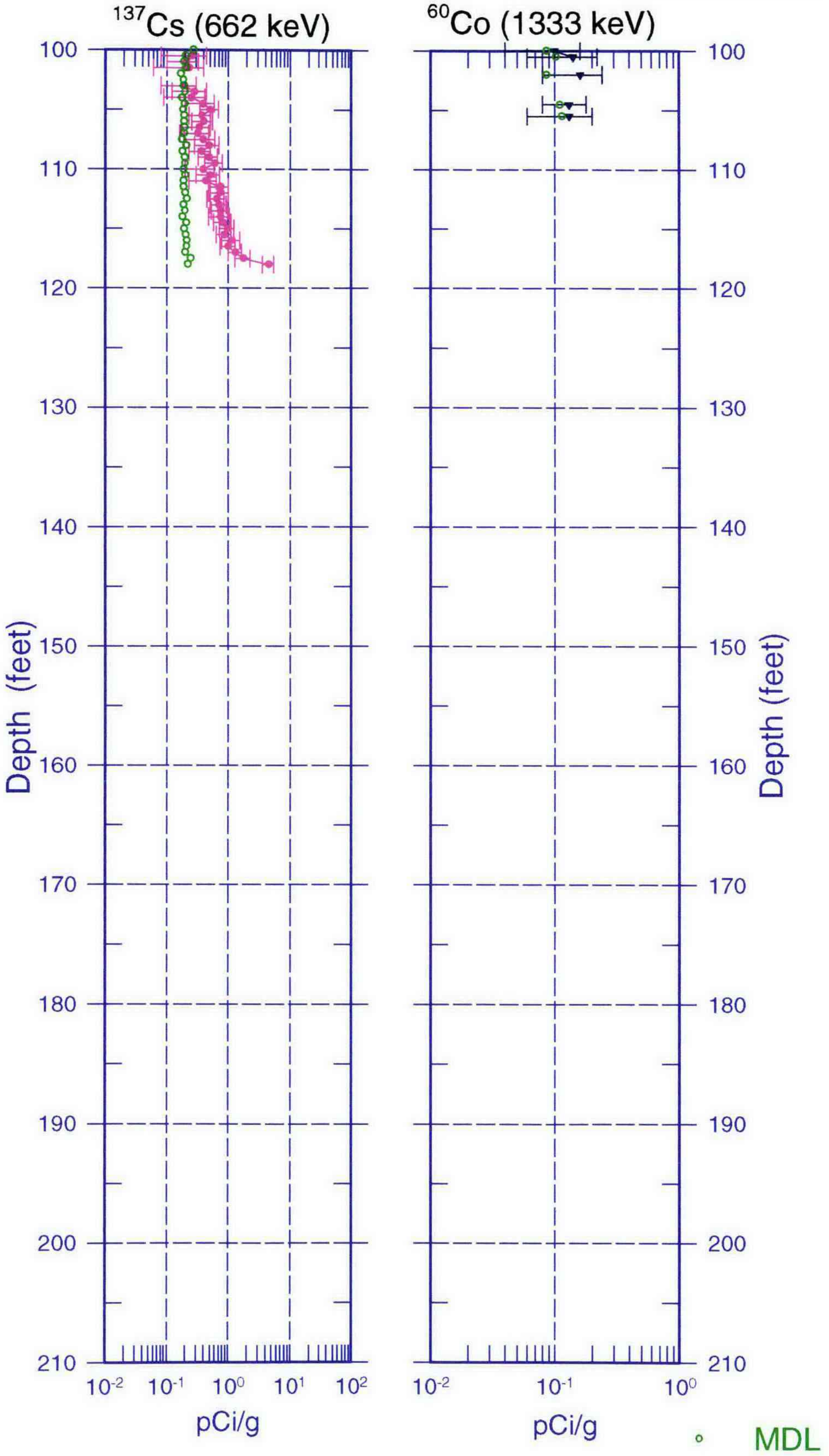
An additional log plot compares spectral gamma data collected with the Radionuclide Logging System (RLS) in 1993 to spectral gamma data collected with the SGLS in 1997. Uncertainty bars and MDLs are not included on these plots.

30-05-04
Man-Made Radionuclide Concentrations

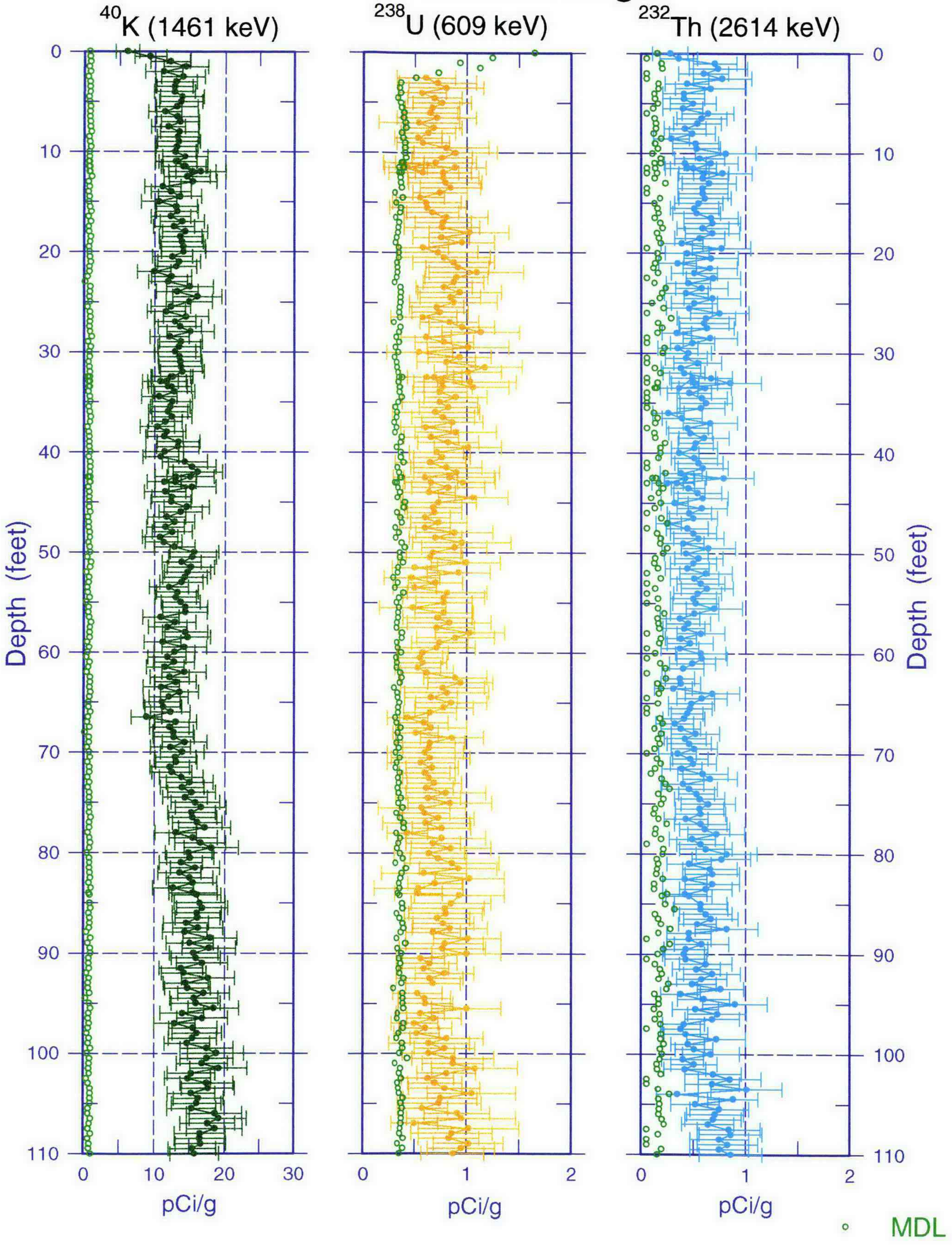


30-05-04

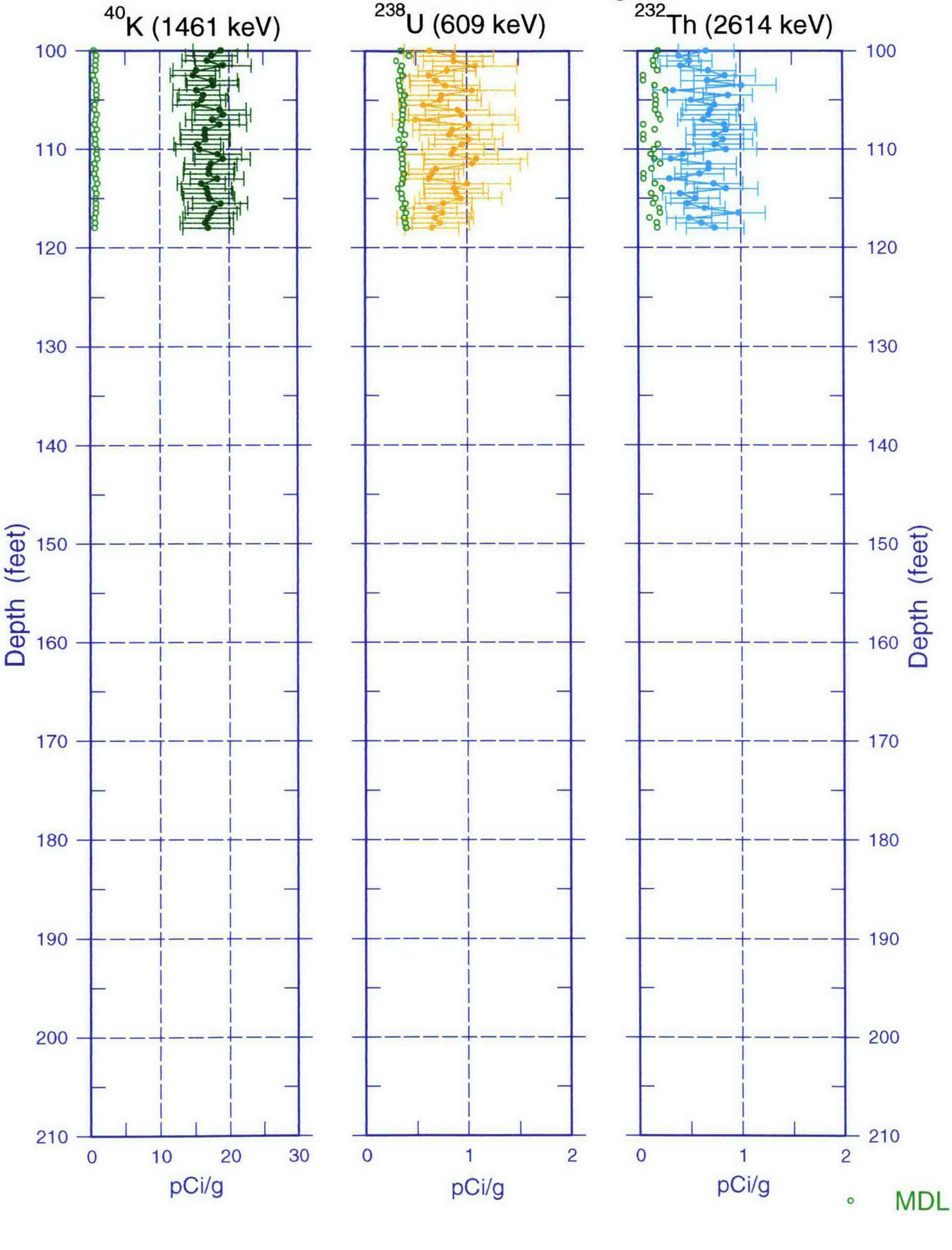
Man-Made Radionuclide Concentrations



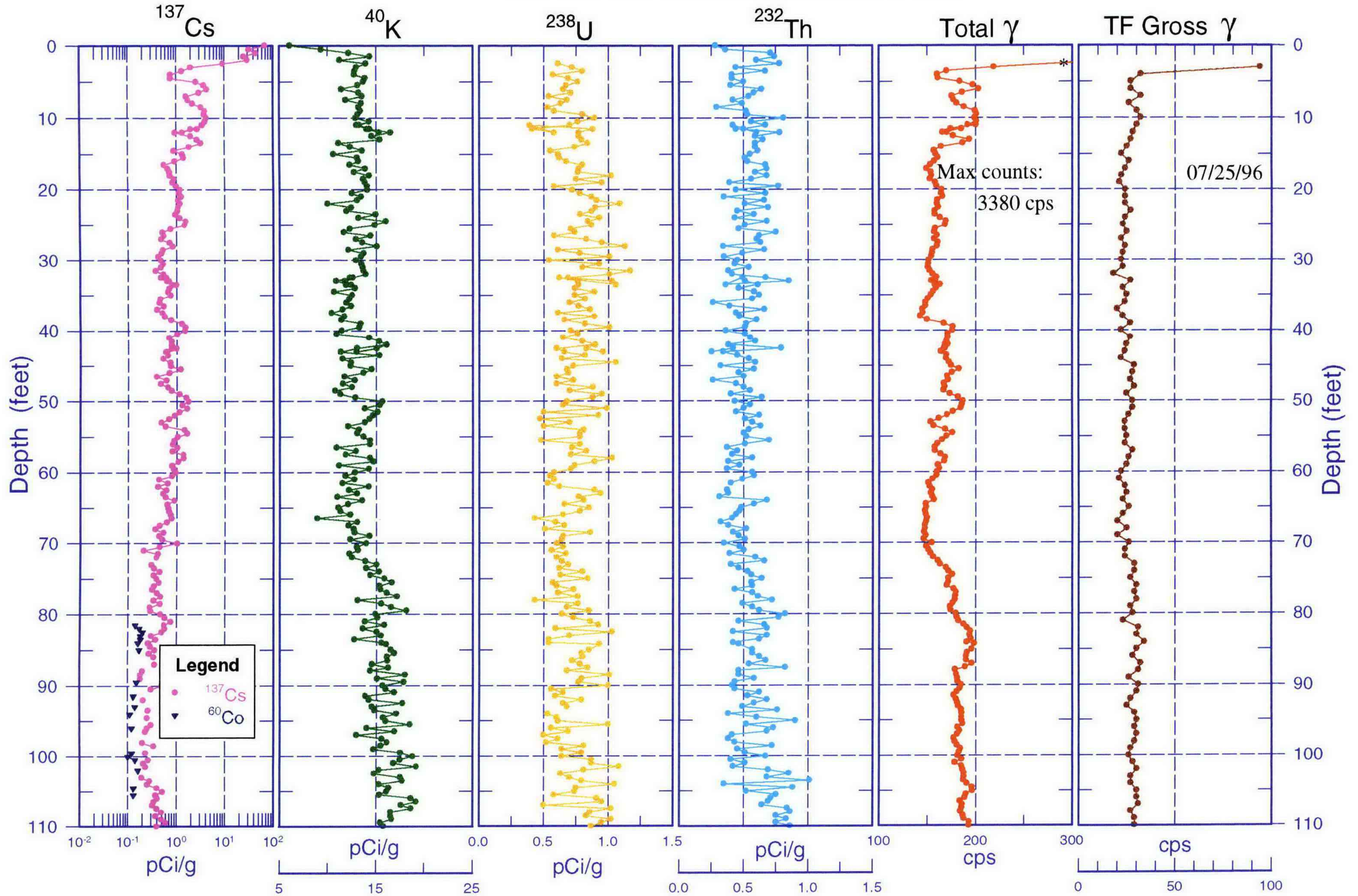
30-05-04
Natural Gamma Logs



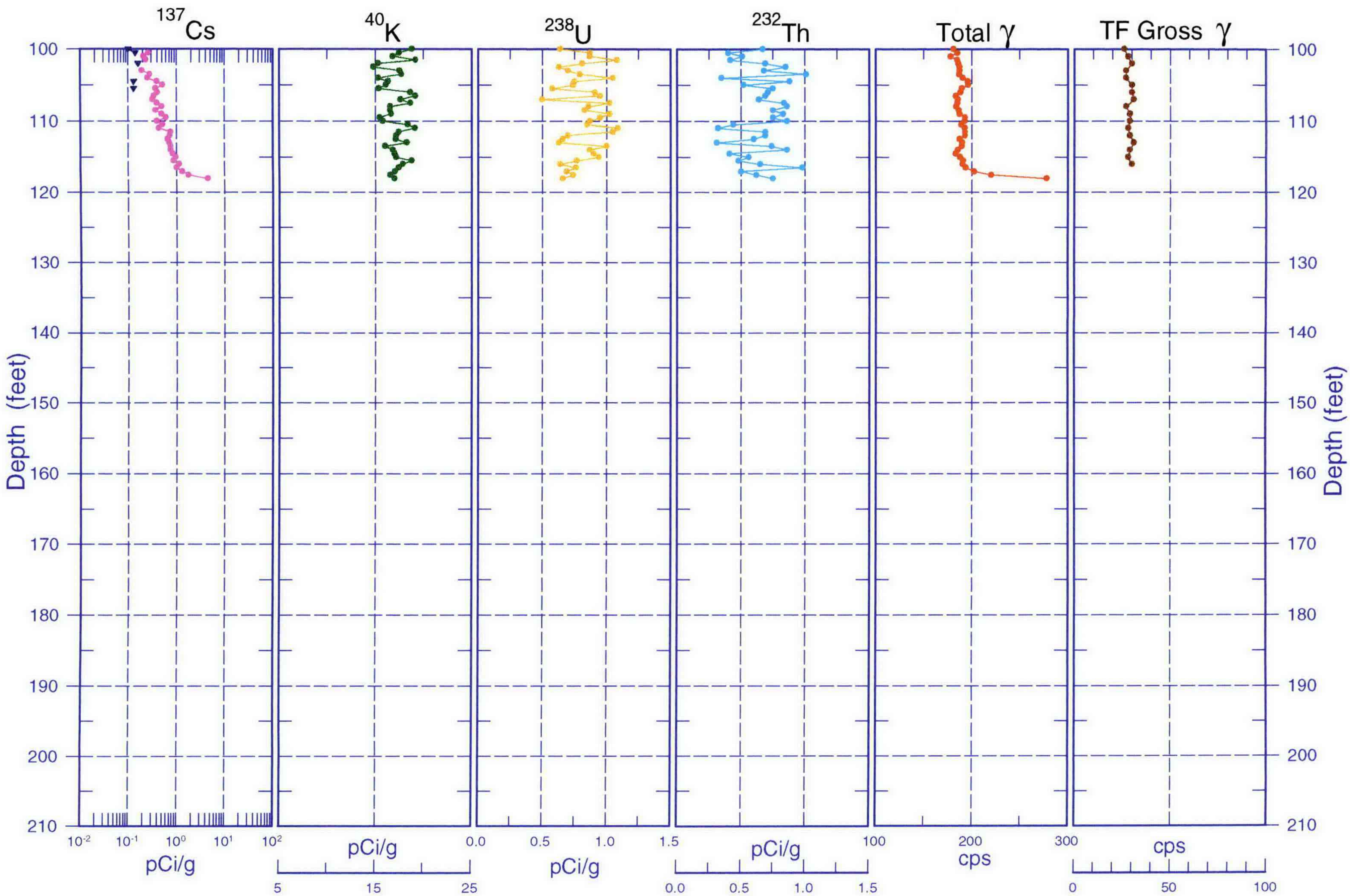
30-05-04
Natural Gamma Logs



30-05-04 Combination Plot

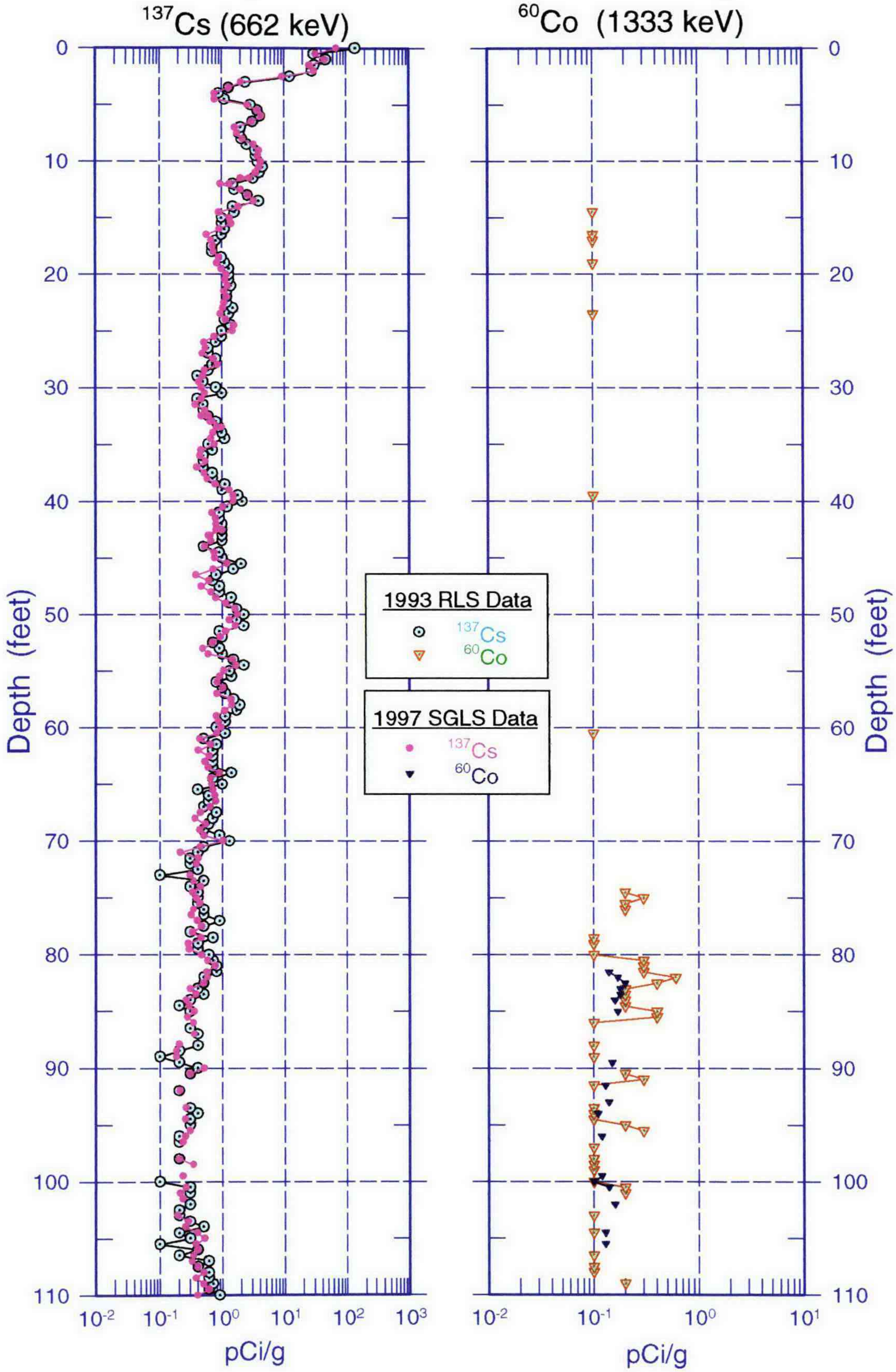


30-05-04 Combination Plot



30-05-04

Man-Made Radionuclide Concentrations
1993/1997 Spectral Gamma Data Comparison



30-05-04

Man-Made Radionuclide Concentrations
1993/1997 Spectral Gamma Data Comparison