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GJ–HAN–82
Tank C–103

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C–103

August 1997

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U.S. Department of Energy

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

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August 1997

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

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

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Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-103

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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.

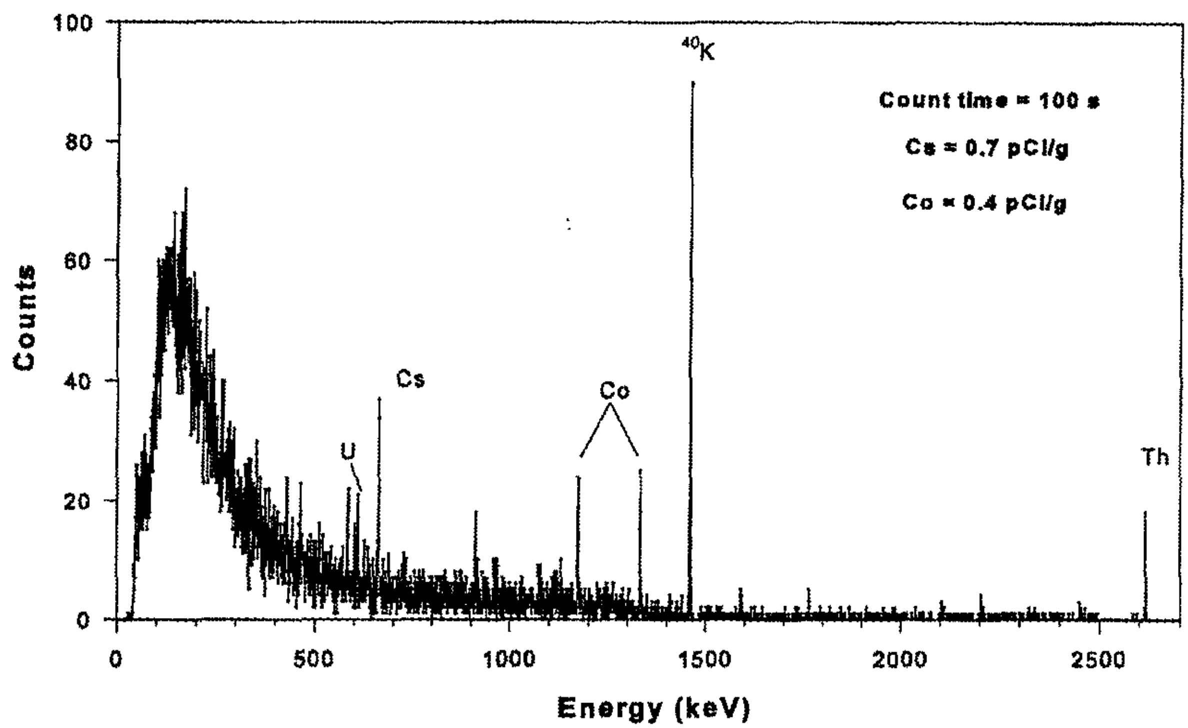

Figure 1. Gamma-Ray Spectrum

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-103," 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, allow 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 tank farm was constructed during 1943 and 1944 to store high-level radioactive waste generated by chemical processing of irradiated uranium fuel from B Plant. 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 tank farm consists of four Type I and twelve Type II single-shell storage tanks. The four Type I tanks are 20 ft in diameter and have capacities of 55,000 gallon (gal) each. The twelve Type II tanks are 75 ft in diameter and have capacities of 530,000 gal each. Other than diameter, the Types I and II tanks are of the same basic design (Brevick et al. 1994a and 1994b).

The 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 zinc-fluosilicate 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,

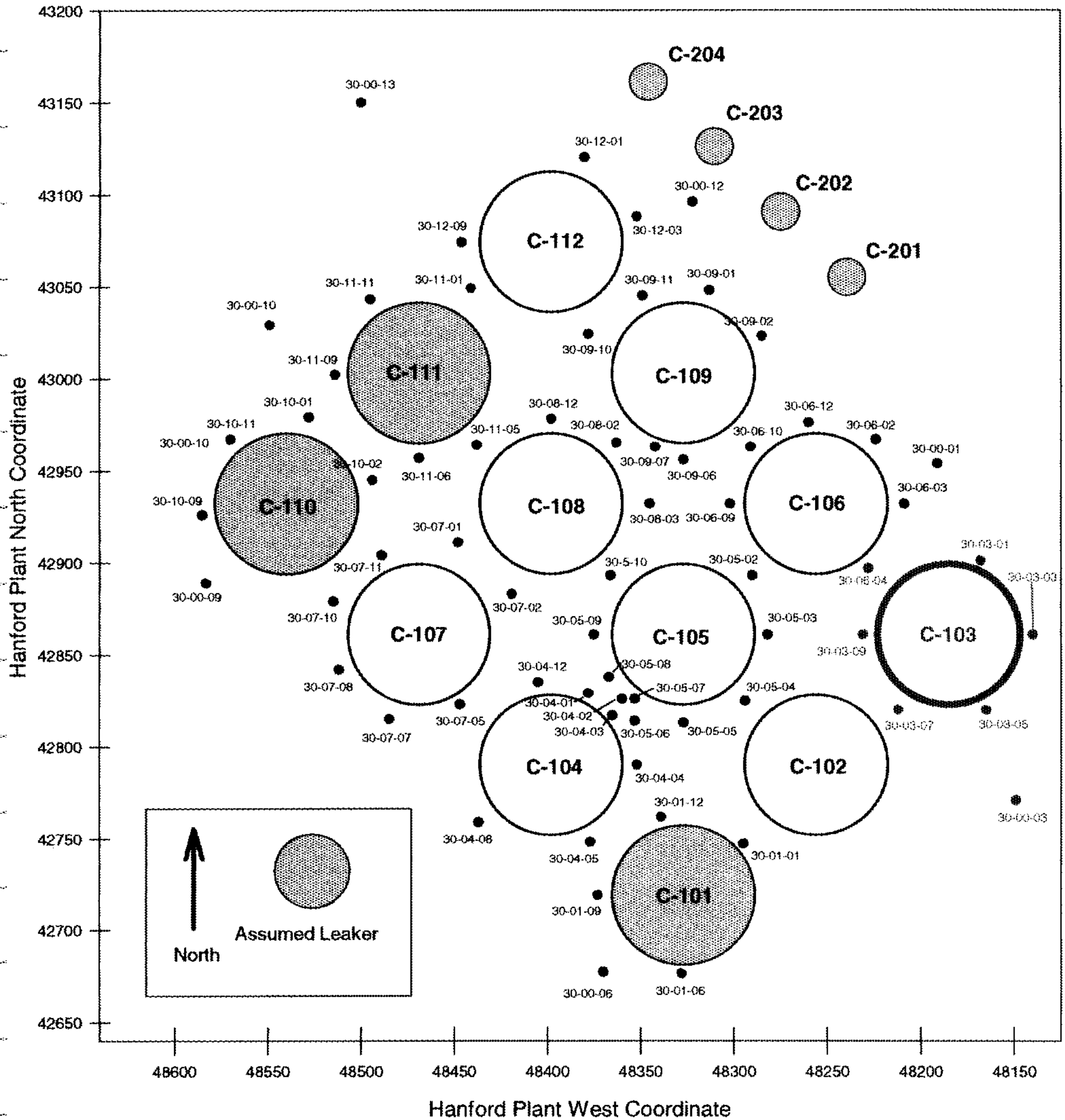

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

-105, -108, -109, -111, -112, -201, -202, -203, and -204 are not equipped with primary leak-detection devices (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). During 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 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. An estimated 1,804,000 gal of sludge remains in the C Tank Farm (Hanlon 1997). 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. An estimated 172,000 gal of supernatant liquid and 174,000 gal of interstitial liquid remain in the C Tank Farm tanks (Hanlon 1997).

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-103

Tank C-103 was constructed during 1943 and 1944 (Welty 1988) and is the last tank in a three-tank cascade series. The tank began receiving metal waste via cascade from tank C-102 in August 1946 (Agnew et al. 1995). The tank received and stored metal waste from August 1946 until the fourth quarter of 1952, and was sluiced for uranium recovery in 1953. The tank received U Plant waste through 1961, PUREX waste from 1963 to 1970, and B Plant evaporator bottoms containing ^{90}Sr until 1977 (Agnew et al. 1995). Tank C-103 was removed from service and declared inactive in 1979 and was partially isolated in December 1982 (Brevick et al. 1994a).

Beginning in 1985, data collected from borehole 30-03-09 (associated with tank C-103) showed an increase in gamma activity at a depth of approximately 80 ft. Anomalously high gamma activity had been present at this depth in 1975, but the activity decreased by 1985. The activity increase resulted in the issuance of an Environmental Protection Deviation Report in May 1987 (Anderson 1987). As part of the investigation into this activity increase, borehole 30-03-09 was relogged using a spectral gamma-ray logging system using an intrinsic germanium detector (Ulbricht 1987). The man-made radionuclide ^{60}Co was identified as the source of the gamma-ray activity at 80 ft on the basis of 1987 spectral gamma-ray data analysis (Ulbricht 1987).

Additional boreholes in the vicinity of tanks C-103, -105, and -106 were logged in 1987 and 1988 with the intrinsic germanium detector. It was concluded that the ^{60}Co contamination might have migrated from an earlier cascade-line leak located between tanks C-104 and C-105 (Ulbricht 1988). However, the mechanism that caused the transport of contamination to borehole 30-03-09 could not be positively identified (Groth 1988). On the basis of the spectral logging data and other information from the investigation, tank C-103 was declared sound (Groth 1988).

A 0.5-in. liquid-level decrease occurred in tank C-103 between December 1984 and October 1988 (Vermeulen 1988). A subsequent investigation concluded that the decrease was caused by evaporation of water from the liquid waste (Burke 1991). The liquid-level measurement was adjusted in October 1990.

Questions about the integrity of tank C-103 were raised during a 1993 investigation into possible leakage from tanks C-105 and C-106. Brodeur (1993) concluded that there was not a firm basis in the documentation supporting Groth (1988) to declare tank C-103 sound, and that tank C-103 should be declared an assumed leaker.

Partially in response to Brodeur (1993), another investigation of the vadose zone contamination around tank C-103 was conducted during 1994 and 1995. As part of this investigation, additional spectral gamma-ray logging was conducted in six boreholes around tank C-103 using the Radionuclide Logging System (RLS). The RLS used a high-purity geranium detector and was the precursor to the current SGLS. The RLS used a lower efficiency detector and a 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 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. This investigation concluded that the ^{137}Cs contamination in the vadose zone around tank C-103 was from a surface spill that occurred before the monitoring boreholes were installed in 1974 and that the ^{60}Co contamination in the vadose zone was probably the result of contaminant migration along a high-moisture zone from a pipeline leak between tanks C-104 and C-105 (Kos 1995).

The present inventory for tank C-103 includes 62,000 gal of sludge and 133,000 gal of supernatant liquid (Hanlon 1997). The waste level is approximately 66 in. above the dished bottom of the tank base. The liquid level has remained constant since the level adjustment in October 1990 (Brevick et al. 1994b). An ENRAF surface-level gauge was installed in August 1994 and is currently the primary method of leak detection. Tank C-103 is currently listed on the Organics Watch List (Hanlon 1997).

4.0 Boreholes in the Vicinity of Tank C-103

Seven vadose zone monitoring boreholes surround tank C-103. These boreholes are 30-03-01, 30-03-03, 30-03-05, 30-00-03, 30-03-07, 30-03-09, and 30-06-04. 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, the casing thickness must be determined and an appropriate correction factor applied in the development of the log data. The casing thickness for these 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 8-in. casing to total depth at 155 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 for the attenuation caused by the double casing and any grout, soil, or open space between the two casings. A correction factor of 0.330 in. was applied because it most closely matches the actual casing thickness of 0.313 in. for 8-in. casing. The use of this correction factor will cause the calculated concentrations for radionuclides above 54 ft to be underestimated and concentrations below 54 ft to be slightly overestimated. Concentration values for the interval above 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 the boreholes, except boreholes 30-03-01 and 30-03-03, were logged dry. Borehole 30-03-01 was filled with water below 123.9 ft and borehole 30-03-03 was filled with water below 18.75 ft.

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

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 30-03-01

Borehole 30-03-01 is located approximately 3 ft from the northeast side of tank C-103 and was given the Hanford Site designation 299-E27-74. This borehole was drilled in June 1974 and completed to a depth of 100 ft with 6-in. casing. In July 1983, the borehole was deepened to 127 ft and completed to 125 ft with 6-in. casing. The driller's log indicates that the casing was plugged with grout from 125 to 127 ft and does not indicate that the casing was perforated. Water was encountered in the borehole below 123.9 ft. Total logging depth achieved by the SGLS was 124.5 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 82 ft, intermittently from 85 to 88 ft, continuously from 100 to 102 ft, and intermittently from 122 ft to the bottom of the borehole. The maximum ^{137}Cs concentration was 330 pCi/g at 1.5 ft. ^{60}Co contamination was detected continuously from 95 to 112.5 ft, intermittently from 113.5 to 120.5 ft, and continuously from 121.5 ft to the bottom of the borehole. The maximum ^{60}Co concentration was 0.9 pCi/g at 101.5 ft.

The ^{40}K concentrations gradually increase from about 42 to 51 ft and increase again very gradually from about 72 to 89 ft. These concentration increases may represent an increase in silt in the Hanford formation sediments. The KUT plots were compared to the stratigraphic sections presented in Price and Fecht (1976) to determine if changes in the KUT concentrations could be correlated to changes in grain size distributions catalogued in that document. No correlations with the contacts presented in Price and Fecht (1976) were identified.

It was not possible to identify many of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and about 31 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 interval between 50 and 70 ft was relogged as an additional quality check and to demonstrate the repeatability of the radionuclide concentration measurements made by the SGLS. A comparison of the measured concentrations of the naturally occurring and man-made radionuclides using the data sets provided by the original and repeated logging runs is included with Appendix A. The measurements generally repeat within two standard deviations (95-percent confidence level), indicating the excellent repeatability of the measured data.

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.

Comparison of the 1994 RLS data to the current SGLS data indicates that ^{60}Co concentrations have decreased slightly since 1994. This concentration decrease is probably from the radioactive decay of the ^{60}Co. The ^{60}Co contamination detected below 120 ft was not detected by the RLS in 1994 because the configuration of the RLS logging tool prevented logging of the bottom portion of the borehole. It is possible that the ^{60}Co contamination detected below 120 ft was not present in 1994, but the available data are not sufficient to make that determination.

A plot of selected historical gross-gamma logs from 1975 to 1992 is provided in Appendix A. Anomalous gamma-ray activity is present in the upper 30 ft of the borehole in the earliest gross gamma log available, indicating that the contamination was present by 1975. In addition, Welty (1988) indicates that a zone of anomalous gamma-ray activity was present at 28 ft in August 1974, the earliest log reviewed for this borehole. It is very likely that the contamination was present before the borehole was drilled two months earlier in June 1974.

When this borehole was deepened in 1983, there was no change in the contamination profile from the ground surface to about 30 ft, indicating that contamination was not dragged down during drilling in this region of the borehole. However, the contamination identified at 50 ft in the early logs appears to have been driven slightly deeper and to have been smeared along the borehole as a result of deepening the borehole.

Historical gross gamma-ray logs indicate that gamma activity below 95 ft decreased rapidly from 1975 to 1979. This decrease could indicate that, in addition to ^{60}Co, a short-lived radionuclide such as ^{125}Sb was responsible for some of the activity and then decayed away. 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 51 ft is probably the result of a combination of surface spills and pipeline leaks. This contamination appears to have migrated down through the backfill material and into the Hanford formation below the tank farm excavation.

The ^{137}Cs contamination from about 51 to 82 ft was probably carried down during deepening of the borehole. It is also possible that some of the contamination in this interval migrated from higher in the formation and is held up in the finer grained sediments of the Hanford formation. Relatively elevated ^{40}K and ^{232}Th concentrations were detected at the top of this interval.

The ^{60}Co contamination below 95 ft is probably the result of a pipeline or tank leak. The origin of this contamination could be any number of the tanks and associated pipelines in the C Tank Farm, including tank C-103. The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole. The contamination could also have been carried down during borehole drilling activities.

4.2 Borehole 30-03-03

Borehole 30-03-03 is located approximately 4 ft from the east side of tank C-103 and was given the Hanford Site designation 299-E27-75. This borehole was drilled in June and July 1974 and completed to a depth of 100 ft with 6-in. casing. The driller's log does not indicate that the borehole was perforated or grouted. The total logging depth achieved by the SGLS was 98.0 ft.

Water was encountered in the borehole at 18.8 ft. Therefore, a water correction factor was applied to the concentrations measured in this borehole from 19 ft to the bottom of the borehole. The water correction applied to the data was that for a 7-in.-diameter borehole. Because the borehole had only a 6-in.-diameter casing, the water correction will result in radionuclide concentration values that are slightly higher than the actual values.

The man-made radionuclides detected in this borehole were ^{137}Cs and ^{60}Co. ^{137}Cs contamination was detected from the ground surface to 41 ft and at 98 ft. The maximum measured ^{137}Cs concentration was 218 pCi/g at a depth of 7 ft. ^{60}Co contamination was detected almost continuously from 85 to 92.5 ft, at 96 ft, and at 97 ft. The maximum ^{60}Co concentration within the borehole was 1.06 pCi/g at a depth of 89.5 ft.

^{40}K and ^{232}Th concentrations increase below a depth of about 19 ft. This concentration increase corresponds to the top of the water in the borehole and indicates that the water correction applied to the data does not exactly correct the data to match dry conditions as discussed above.

It was not possible to assay many of the 609-keV spectral peaks used to derive the ^{238}U concentrations between the ground surface and about 43 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. Below 43 ft the 609-keV spectral peak data are still poor because of the added attenuation of the water in the borehole.

^{40}K and ^{232}Th concentrations increase below a depth of about 43.5 ft. This concentration increase probably represents the bottom of the tank farm excavation or an increase in silt content in the Hanford formation sediments.

^{40}K concentrations gradually increase at about 80 ft. This concentration increase corresponds to an increase in silt content at about this depth (Price and Fecht 1976).

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1994 to the current SGLS data. The shapes of the two plots are nearly identical, but the current ^{137}Cs concentrations are slightly lower than the 1994 concentrations. This discrepancy is greater than the amount of radioactive decay that would be expected, and is caused by differences in either the water or casing correction factors used in the concentration calculations. It is not known if the borehole was water-filled when logged in 1994, or, if so, how the data were corrected for this condition.

A comparison of the 1994 RLS data and the current SGLS data indicates that ^{60}Co concentrations have decreased slightly since 1994. This concentration decrease is probably from the radioactive decay of the ^{60}Co. However, this observed decrease may be partially caused by differences in the water or casing correction factors used in the concentration calculations, which is similar to the effect seen in the ^{137}Cs concentrations discussed previously.

Historical gross gamma-ray logs from January 1975 through November 1994 were reviewed. Zones of anomalous gamma-ray activity that correlate with zones of current contamination are discussed in the following sections.

The ^{137}Cs contamination from the ground surface to 41 ft is probably the result of surface spills and pipeline leaks that migrated into the backfill material around the tank. Anomalous gamma-ray activity is present in this interval in the earliest gross gamma logs, indicating that the contamination was present in 1975 or earlier. On the basis of the SGLS data, the ^{137}Cs contamination appears to be nearly confined to the backfill material with ^{137}Cs concentrations decreasing sharply at about 39 ft (approximate base of the tank farm excavation).

The ^{60}Co contamination from 85 to 97 ft is probably the result of a pipeline or tank leak. The origin of this contamination could be any number of tanks and associated pipelines in the C Tank Farm, including tank C-103. The driller's log notes that samples taken from this interval during drilling were "hot," and a zone of anomalously high activity is present at this depth in the earliest historical gross gamma logs collected in 1975.

The driller's log reports a 2- to 3-in.-thick "silt layer" between 85 and 95 ft and measured activity of 1,500 counts per minute. The activity measurement was apparently made at the "silt layer." On the basis of SGLS data, the ^{60}Co contamination correlates to elevated ^{40}K and ^{232}Th concentrations. This correlation may indicate that the ^{60}Co contamination is in a region of finer grained sediments within the sand-dominated facies of the Hanford formation.

The historical gross gamma logs indicate that gamma activity at about 85 ft decreased rapidly from 1975 to 1979. This decrease could indicate that in addition to ^{60}Co, a short-lived radionuclide, such as ^{125}Sb was responsible for some of the activity and then decayed away. However, the historical gross gamma logs are not of sufficient quality to make such a determination.

4.3 Borehole 30-03-05

Borehole 30-03-05 is located approximately 4 ft from the southeast side of tank C-103 and was given the Hanford Site designation 299-E27-76. This borehole was drilled in July 1974 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 grouted. Total logging depth achieved by the SGLS was 100.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 43 ft, continuously from 54.5 to 76 ft, and intermittently from 97.5 to 100 ft (the bottom of the borehole). The maximum ^{137}Cs concentration was 36.5 pCi/g at 1 ft. A higher concentration (40 pCi/g) was detected at the ground surface; however, this 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.

^{40}K concentrations increase below a depth of about 39 ft (the approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material above this depth to the undisturbed sediments of the Hanford formation below. ^{40}K and ^{238}U concentrations gradually increase from about 39 to 48 ft to a relatively higher background. This increase probably represents a silt increase in the gravel-dominated facies of the Hanford formation. A thin zone of elevated ^{40}K concentration is also present at about 75 ft.

A data plot included in Appendix A compares spectral gamma data collected in 1994 and 1997. The plot shows good correlation in the regions of the borehole where ^{137}Cs concentrations are greater than about 2 pCi/g. The correlation is not as good where ^{137}Cs concentrations are less than 2 pCi/g, probably because of the poorer precision of the 1994 data.

Historical gross gamma logs from January 1975 through November 1994 were reviewed. A plot of selected historical gross gamma logs from 1975 to 1982 is provided in Appendix A.

The ^{137}Cs contamination detected from the ground surface to 43.5 ft is probably the result of surface spills and pipeline leaks that migrated into the backfill material around the tank. Anomalous gamma-ray activity is present in this interval in the earliest gross gamma logs, indicating that the contamination was present in 1975 or earlier. The increased ^{137}Cs concentrations measured from 35.5 to 38.5 ft may be caused by the spreading of contamination at the base of the tank farm excavation to reach the vicinity of this borehole.

The ^{137}Cs contamination from 54.5 to 76 ft is probably the result of a tank 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.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole. The contamination could also have been carried down during borehole drilling activities.

4.4 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 is also present between 2 and 54 ft. Data from above 54 ft are only usable for qualitative interpretations because of the double casing.

The zero reference for logging is the top of the 8-in. casing. The borehole is located in 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. Total logging depth achieved by the SGLS was 118.5 ft. The total current depth of the borehole is 118.8 ft, as verified with an E-tape. The bottom portion of the borehole has apparently been filled.

The borehole was perforated from 54 to 154 ft with five cuts per foot. The driller's log indicates that the bottom of the 8-in. casing was grouted.

A 0.330-in. casing correction factor was used for the 8-in. casing because a casing correction factor for 0.313 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 54 ft.

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 represents the change from the double-cased portion of the borehole to the perforated single casing. This indicates that the 12-in. casing extends to about 55.5 ft, rather than 54 ft as indicated in the driller's log. The decrease in ^{40}K, ^{238}U, 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. ^{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.

4.5 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 and corresponds to an increase in depth (Price and Fecht 1976).

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 46 to 49 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. A plot of representative historical logs for this borehole is included in Appendix A.

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.

4.6 Borehole 30-03-09

Borehole 30-03-09 is located approximately 5 ft from the west side of tank C-103 and was given the Hanford Site designation 299-E27-78. This borehole was drilled in June 1974 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 grouted. Total logging depth achieved by the SGLS was 98.5 ft.

The man-made radionuclides detected in this borehole were ^{137}Cs, ^{60}Co, ^{154}Eu, and ^{152}Eu. ^{137}Cs contamination was detected continuously from the ground surface to a depth of 41.5 ft, continuously from 44.5 to 61.5 ft, and intermittently from 62.5 ft to the bottom of the logged interval. A maximum ^{137}Cs concentration of 37.8 pCi/g was detected at a depth of 7 ft. A higher concentration (87.2 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.

^{60}Co contamination was detected continuously from 78 ft to the bottom of the logged interval. The maximum ^{60}Co concentration was 3.2 pCi/g at a depth of 79 ft.

^{154}Eu and ^{152}Eu were detected only at the ground surface with apparent concentrations of 13.9 and 20.7 pCi/g, respectively. These are only apparent concentrations because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry during calibration.

The KUT log plots show a gradual increase in ^{40}K concentrations from about 41 to 51.5 ft. This concentration increase probably represents an increase in the silt fraction of the Hanford formation.

A higher ^{40}K concentration background is present below 54 ft. ^{40}K concentrations decrease from 70.5 to 75 ft and gradually increase from about 75.5 ft to the bottom of the logged interval.

A peak is shown on the ^{238}U log plot at 42 ft that correlates with a region absent of ^{137}Cs contamination. It is thought that this may represent a low permeability, compacted zone.

The SGLS total gamma-ray plot reflects the influence of man-made and natural radionuclides. The increases in ^{137}Cs concentrations from 2 to 10 ft and 45 to 54 ft and ^{60}Co concentrations from about 79 to 90 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 of the RLS data from 1994 and the SGLS data from 1997 indicates that ^{60}Co concentrations have decreased slightly above 90 ft and may have increased slightly below 90 ft. The decrease in ^{60}Co concentrations above 90 ft is probably caused by the radioactive decay of the ^{60}Co. The apparent increase in ^{60}Co concentrations below 90 ft may be from continued lateral or downward migration of ^{60}Co contamination. However, the magnitude of the increase is not yet statistically significant and further monitoring is warranted. It should be noted that any changes in ^{60}Co concentrations below 95.5 ft could not be identified because the logging tool configuration in 1994 did not allow logging of the bottom portion of the borehole.

As discussed in Section 3.2, a number of studies were conducted in the late 1980's and early 1990's to identify the source of the ^{60}Co contamination at about 80 ft. The studies concluded that the ^{60}Co contamination source was probably a leak in the cascade line between tanks C-104 and C-105 (Ulbricht 1988; Groth 1988; Kos 1995). Several studies concluded that the ^{60}Co contamination had been migrating through the region of borehole 30-03-09 during the past several years (Ulbricht 1987; Ulbricht 1988; Groth 1988).

Historical gross gamma logs from January 1975 through November 1994 were reviewed. A plot of representative historical logs for this borehole is included in Appendix A. On the basis of historical gross gamma logs, it appears that ^{60}Co contamination may be continuing to migrate through the vicinity of this borehole. Gross gamma activity appears to have increased from 1989 to 1990, decreased from 1990 to 1991, and then remained fairly constant from 1991 to 1994. It should be noted that the historical gross gamma logs are not of sufficient quality to provide a firm basis for drawing conclusions concerning changes in contaminant concentrations.

The ^{154}Eu, ^{152}Eu, and ^{137}Cs contamination in the upper 41.5 ft of the borehole is probably the result of a surface spill and possibly pipeline leaks that migrated into the backfill material around the borehole or down the inside or outside of the borehole casing. Anomalous gamma-ray activity appears to have been present in this interval in the earliest gross gamma logs, but the ^{137}Cs concentrations were too low to produce well-defined peaks on the historical gross gamma logs. As in borehole 30-03-07, gamma-ray activity in the upper 9 ft of the borehole increased greatly between January and May 1980, probably indicating that a surface spill occurred in that time interval. Historical gross gamma logs from January through April 1980 were not available.

The ^{137}Cs contamination from 44.5 to 61.5 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/or 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, indicating the contamination was present in 1975 or earlier.

The ^{60}Co contamination from 78 ft to the bottom of the logged interval 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/or associated pipelines in the C Tank Farm, including tank C-103. Anomalously high gross gamma activity is present in this interval in the earliest historical gross gamma logs (from 1975), and Welty (1988) notes elevated gamma activity at about 80 ft in June 1974. The ^{60}Co contamination below 78 ft corresponds to an interval of increased ^{40}K concentrations, as noted previously.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole. The contamination could also have been carried down during borehole drilling activities.

4.7 Borehole 30-06-04

Borehole 30-06-04 is located approximately 15 ft from the northwest side of tank C-103 and was given the Hanford Site designation 299-E27-73. This borehole was drilled in November 1972 and completed to a depth of 130 ft with 6-in. casing. The driller's log does not indicate that the casing was perforated or grouted. Total logging depth achieved by the SGLS was 129.5 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 a depth of 57 ft, almost continuously from 58.5 to 66 ft, and intermittently from 71 ft to the bottom of the logged interval. A maximum concentration of 79 pCi/g was detected at a depth of 7.5 ft. A higher concentration (153.5 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.

^{60}Co contamination was detected continuously from 85 to 90.5 ft and at 93 ft. A maximum ^{60}Co concentration of about 0.3 pCi/g was detected at a depth of 86 ft.

The KUT log plots show a gradual increase in ^{40}K and ^{238}U concentrations from 43 to 49 ft. This concentration increase probably represents a grading of Hanford formation sediments from sand and cobbles immediately below the tank farm excavation to the sand-dominated facies.

An interval of relatively low ^{40}K concentrations was detected from 69 to 79 ft. KUT concentrations increase below a depth of about 79 ft and remain elevated to the bottom of the logged interval.

It was not possible to identify many of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 13 ft and from 21 to 27 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.

A data plot included in Appendix A compares spectral gamma data collected with the RLS in 1993 to the current SGLS data. The shapes of the two plots are nearly identical, indicating that there has been no migration of contaminants. The ^{137}Cs concentrations measured with the SGLS in 1997 are occasionally slightly lower than the concentrations measured with the RLS in 1993. The discrepancy in ^{137}Cs concentrations could be caused by small differences in the environmental corrections applied to the data. In addition, ^{60}Co concentrations have decreased slightly since 1993. This decrease in ^{60}Co concentrations is probably because of the radioactive decay of the ^{60}Co.

Historical gross gamma logs from January 1975 through January 1994 were reviewed and a plot of representative historical logs for this borehole is included in Appendix A.

The ^{137}Cs contamination in the upper 40 ft of the borehole is probably the result of a surface spill and pipeline leaks that migrated into the backfill material around the tank. The increased ^{137}Cs concentrations at about 39 ft are probably from contamination collecting or spreading at the base of the tank farm excavation. This anomalous gamma activity is apparent in the earliest gross gamma logs available, indicating that the contamination was present in 1975 or earlier. Welty (1988) also notes elevated gamma activity at 23 ft in April 1974 but not in June 1973.

The ^{137}Cs contamination detected from about 41 to 64 ft is probably the result of a tank 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 distinctive peak is present in this interval at about 52 ft. Anomalously high gamma activity is present at this depth in the earliest historical gross gamma logs, indicating that the contamination was present in 1975 or earlier.

The ^{60}Co contamination from 85 to 90.5 ft and at 93 ft is probably the result of a tank 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 slightly elevated gamma activity is present in this interval in the earliest historical gross gamma logs, indicating that the contamination was present in 1975 or earlier.

The ^{137}Cs contamination at the bottom of the borehole may be from particles that have been blown down into the borehole. This contamination could also have been carried down during drilling activities.

5.0 Discussion of Results

A plot of the man-made radionuclide concentration profiles for the seven boreholes surrounding tank C-103 is presented in Figure 3. The plot shows widespread ^{137}Cs contamination and less extensive ^{60}Co, ^{152}Eu, and ^{154}Eu contamination.

The SGLS detected elevated ^{137}Cs concentrations in the upper 10 ft of boreholes 30-03-07, 30-03-09, and 30-06-04. These boreholes are located on the west side of tank C-103, and the contamination is most likely from surface spills. On the basis of historical gross gamma logs, contamination was present in this interval near borehole 30-06-04 by January 1975 (the earliest logs available). Although near-surface contamination was present before May 1980 near boreholes 30-03-07 and 30-03-09, activity in this interval increased significantly during May 1980, indicating that an additional surface spill probably occurred at that time. Additionally, a comparison of the 1994 and 1997 spectral data indicates that ^{137}Cs concentrations at about 10 ft near borehole 30-03-07 have increased since 1994. This is probably from continued migration of contamination from these surface spills along the domed top of the tank and into the vicinity of this borehole. Evidence of surface spills (i.e., near-surface contamination) is present in all the boreholes surrounding tank C-103.

All the boreholes, except borehole 30-00-03, have continuous ^{137}Cs contamination from 10 to 40 ft. As noted in Section 4.0, the upper 54 ft of borehole 30-00-03 is double cased; therefore, contamination present in this interval may not be detected with the SGLS. The widespread distribution of this contamination and the lack of any zones of relatively high contamination (the depth interval of the tank) do not indicate a tank leak. The contamination in this interval of the boreholes appears to be from surface spills and transfer-line leaks that infiltrated the backfill material around the tank. However, a tank leak cannot be positively ruled out.

^{137}Cs contamination detected below about 42.5 ft in borehole 30-03-07, below 45 ft in borehole 30-03-09, below 51 ft in borehole 30-03-01, and below 54.5 ft in borehole 30-03-05 may be from a tank leak, a subsurface pipeline leak, or, as concluded in Kos (1995), a surface spill that migrated down the sides of the tank and penetrated the base of the tank farm excavation. One concern of a surface-spill hypothesis is that the contamination is not continuous below the ground surface near boreholes 30-03-05, 30-03-07, and 30-03-09. In addition, the contamination was present before borehole construction, meaning that a surface spill would have to have been large enough to infiltrate the vadose zone to this depth without migrating down the outside of a borehole casing. However, it is possible a surface spill of sufficient quantity followed preferential pathways and created the features noted previously.

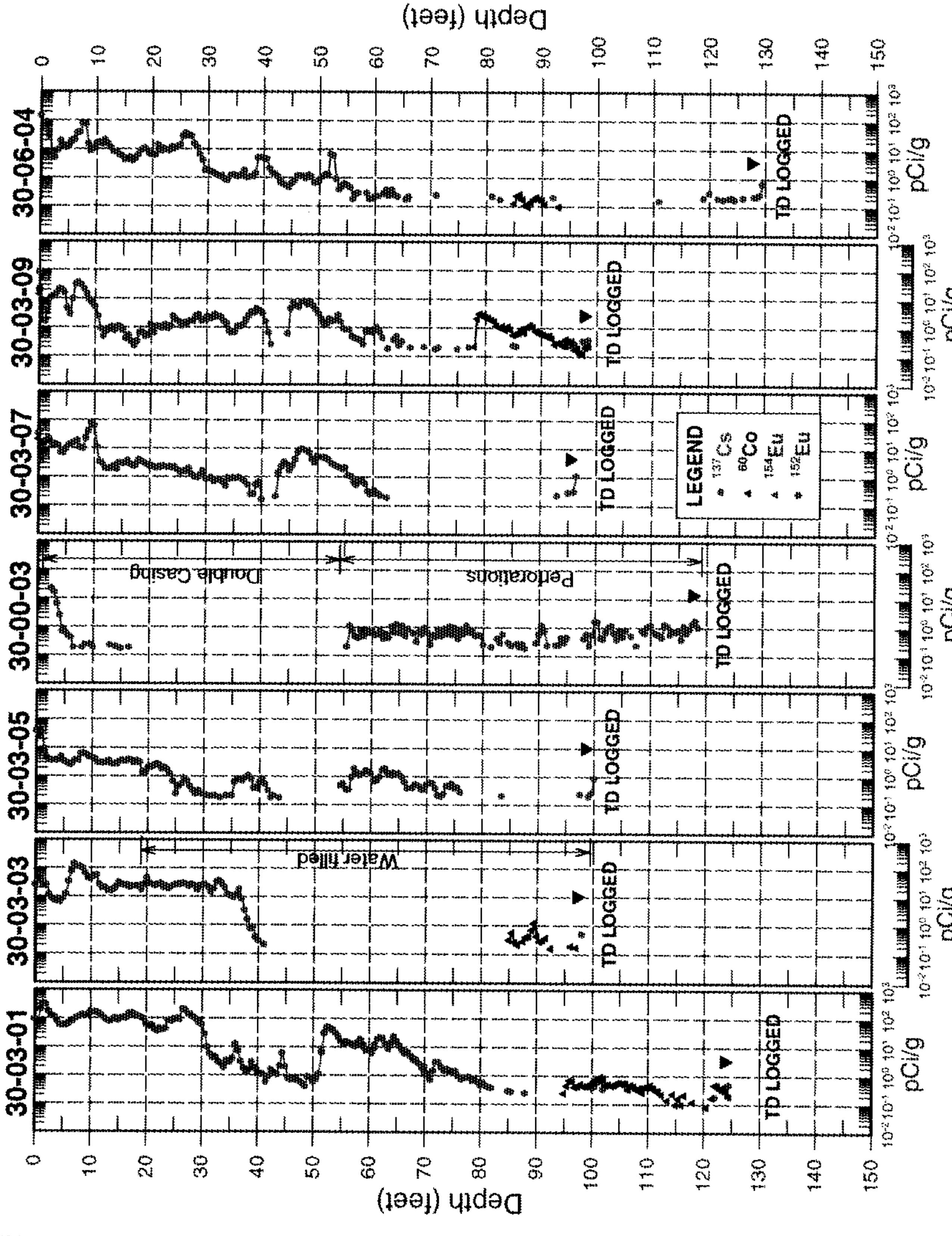

Figure 3. Correlation Plot of ^{137}Cs, ^{60}Co, ^{152}Eu, and ^{154}Eu Concentrations in Boreholes Surrounding Tank C-103

The ^{60}Co contamination detected in boreholes 30-03-01, 30-03-03, 30-03-09, and 30-06-04 probably resulted from a pipeline or tank leak. The ^{60}Co contamination occurs in intervals of relatively elevated ^{40}K concentrations in all four boreholes. Figure 4 presents a plot of ^{40}K concentrations and ^{60}Co occurrences. It should be noted that the scale necessary to show ^{40}K concentrations changes does not lend itself to show ^{60}Co concentrations; therefore, ^{60}Co occurrences rather than concentrations are shown on the figure. The leak source could be any of the tanks or associated pipelines in the vicinity of tank C-103. Tank C-103 seems an unlikely source of the ^{60}Co contamination because ^{60}Co contamination was not detected above about 78 ft.

A comparison of the 1993 and 1994 RLS data with the 1997 SGLS data indicates that ^{60}Co contamination below 90 ft near borehole 30-03-09 may have increased since 1994. This apparent increase could indicate that the ^{60}Co contamination at this depth is continuing to migrate and further monitoring is warranted.

The SGLS detected ^{137}Cs contamination from 55 ft to the bottom of the logged interval near 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-103 was completed using the SGLS. Data obtained with the SGLS and geologic and historical information indicate that the source of ^{137}Cs contamination around this tank is a combination of surface spills and pipeline and/or tank leaks. The source of the pipeline or tank leaks could not be identified. Any of the tanks adjacent to tank C-103, tank C-103 itself, or associated piping could be the source of this contamination.

The ^{60}Co contamination appears to have originated from a tank other than tank C-103, although the available data are insufficient to rule out tank C-103 as a source of this contamination. The source of this contamination will be better defined as the C Tank Farm Report (to be published) is developed.

A comparison of spectral gamma data collected in 1993 and 1994 to data collected in 1997 with the SGLS indicates that ^{60}Co contamination may still be migrating as suggested by the data from one borehole.

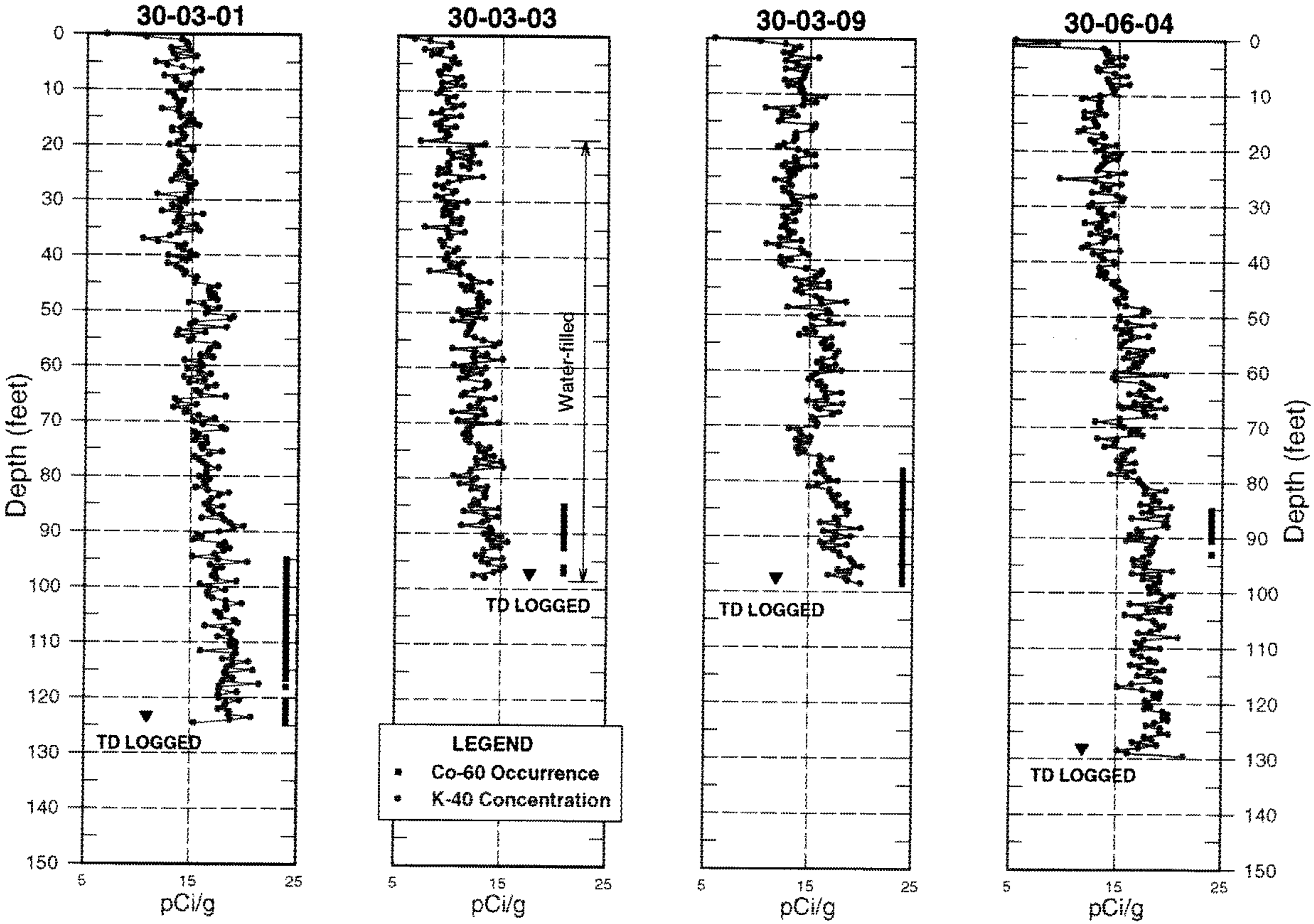

Figure 4. Correlation Plot of ^{60}Co Occurrences and ^{40}K Concentrations

7.0 Recommendations

Approximately 133,000 gal of drainable and pumpable supernate and 62,000 gal of sludge remain in tank C-103 (Hanlon 1997). It is recommended that logging of the boreholes surrounding this tank be continued to detect potential future leakage from the tank and associated tank facilities and to monitor the potential spread of contaminant plumes detected during this study. Changes in the contamination profiles would show contaminant migration or additional leakage from this tank.

It is recommended that borehole 30-00-03 be sealed and destroyed. The perforations in the borehole casing are not needed and may enhance downward migration of contamination. A new monitoring borehole could be constructed in this general area to monitor possible contaminant migration.

It is further recommended that shape factor analysis of the spectral data be conducted to determine the distribution of contaminants in the vadose zone. It is suspected that contamination in some intervals may be confined to the borehole casing, while in other intervals, contamination is distributed in the formation.

8.0 References

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-103

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-03-01

Borehole Information

Farm :	C	**Tank :**	C-103	**Site Number :**	299-E27-74
N-Coord :	42,901	**W-Coord :**	48,168	**TOC Elevation :**	Unknown
Water Level, ft :	123.9 0	**Date Drilled :**	6/30/74		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	125		

Cement Bottom, ft. : 127 **Cement Top, ft. :** 125

Borehole Notes:

This borehole was drilled in June 1974 to a depth of 100 ft. It was deepened in July 1983 to 127 ft and completed to 125 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. The borehole was plugged with grout from 125 to 127 ft. No information concerning perforations was available; therefore, it is assumed that the borehole was not 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 :**	4/17/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	17.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	4/18/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	124.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	40.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	4/21/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	41.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	16.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Event A

Borehole 30-03-01

Log Run Number :	4	Log Run Date :	4/21/97	Logging Engineer:	Alan Pearson
Start Depth, ft.:	70.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	50.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Analysis Information

Analyst :	D.L. Parker		
Data Processing Reference :	P-GJPO-1787	Analysis Date :	5/6/97

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 interval of 50 to 70 ft was relogged as an additional quality check. 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. 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 82 ft, intermittently from 85 to 88 ft, continuously from 100 to 102 ft, and intermittently from 122 ft to the bottom of the logged interval. Co-60 contamination was detected continuously from 95 to 112.5 ft, intermittently from 113.5 to 120.5 ft, and continuously from 121.5 ft to the bottom of the borehole.

The KUT concentrations gradually increase from 42 to 51 ft and very gradually increase again from 72 to 89 ft. The concentrations generally remain elevated to the bottom of the logged interval (124.5 ft).

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank 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.

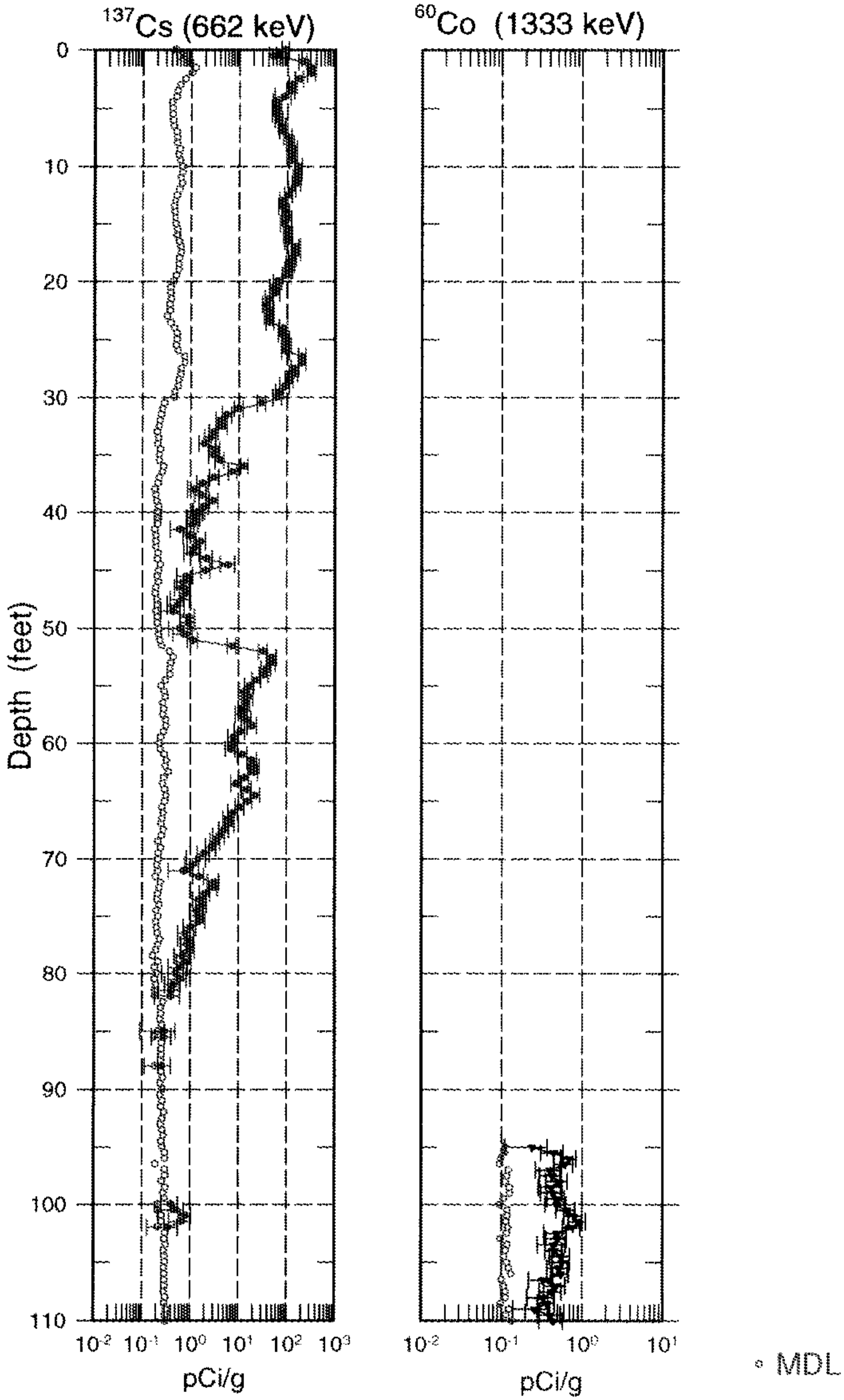
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

A re-run plot is provided that presents data from the re-run log along with data from the original run to show the repeatability of the results.

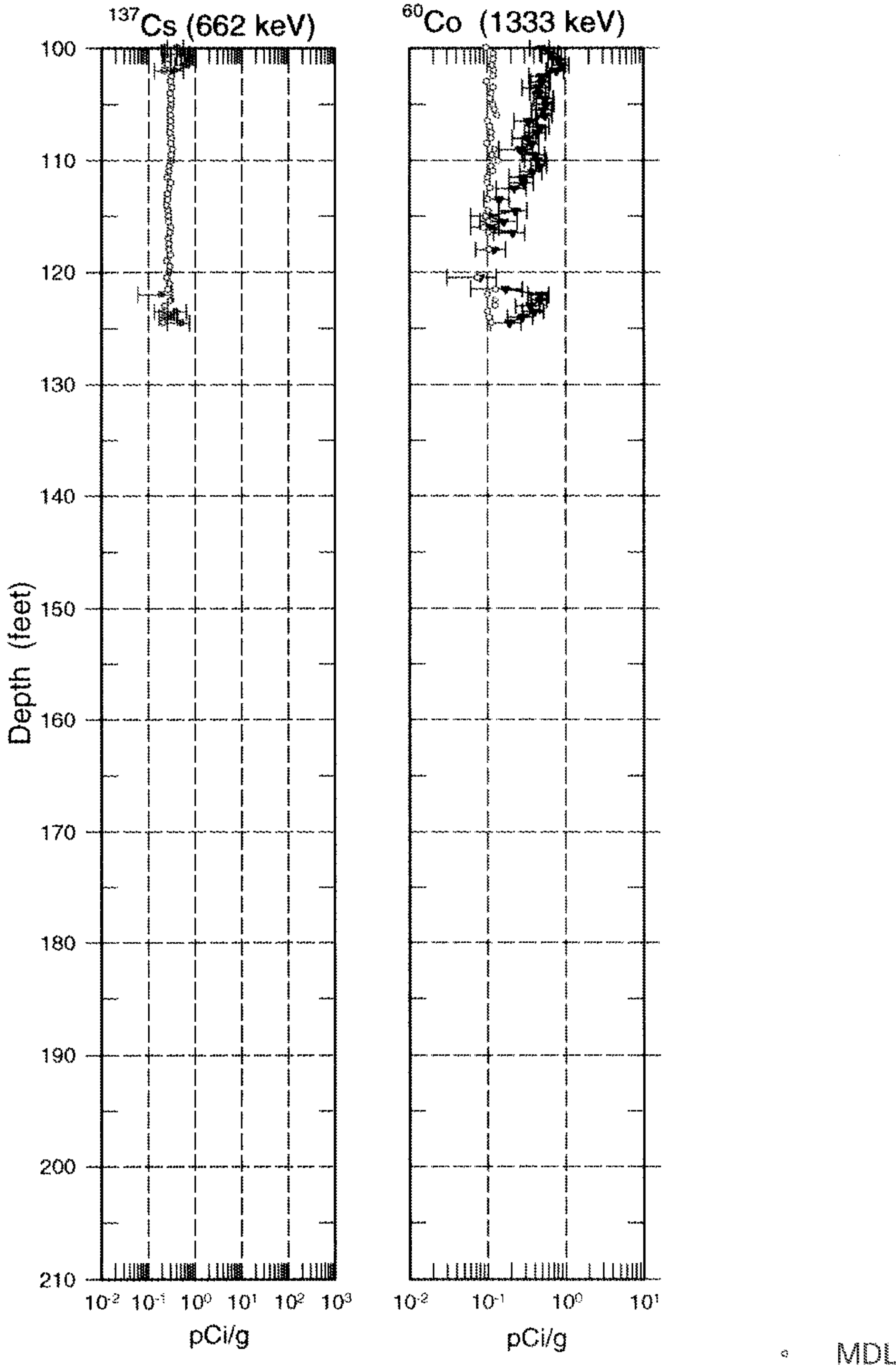
A comparison plot is also provided showing the Cs-137 and Co-60 concentrations determined from the SGLS and those determined from the Radionuclide Logging System (RLS) in 1994.

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

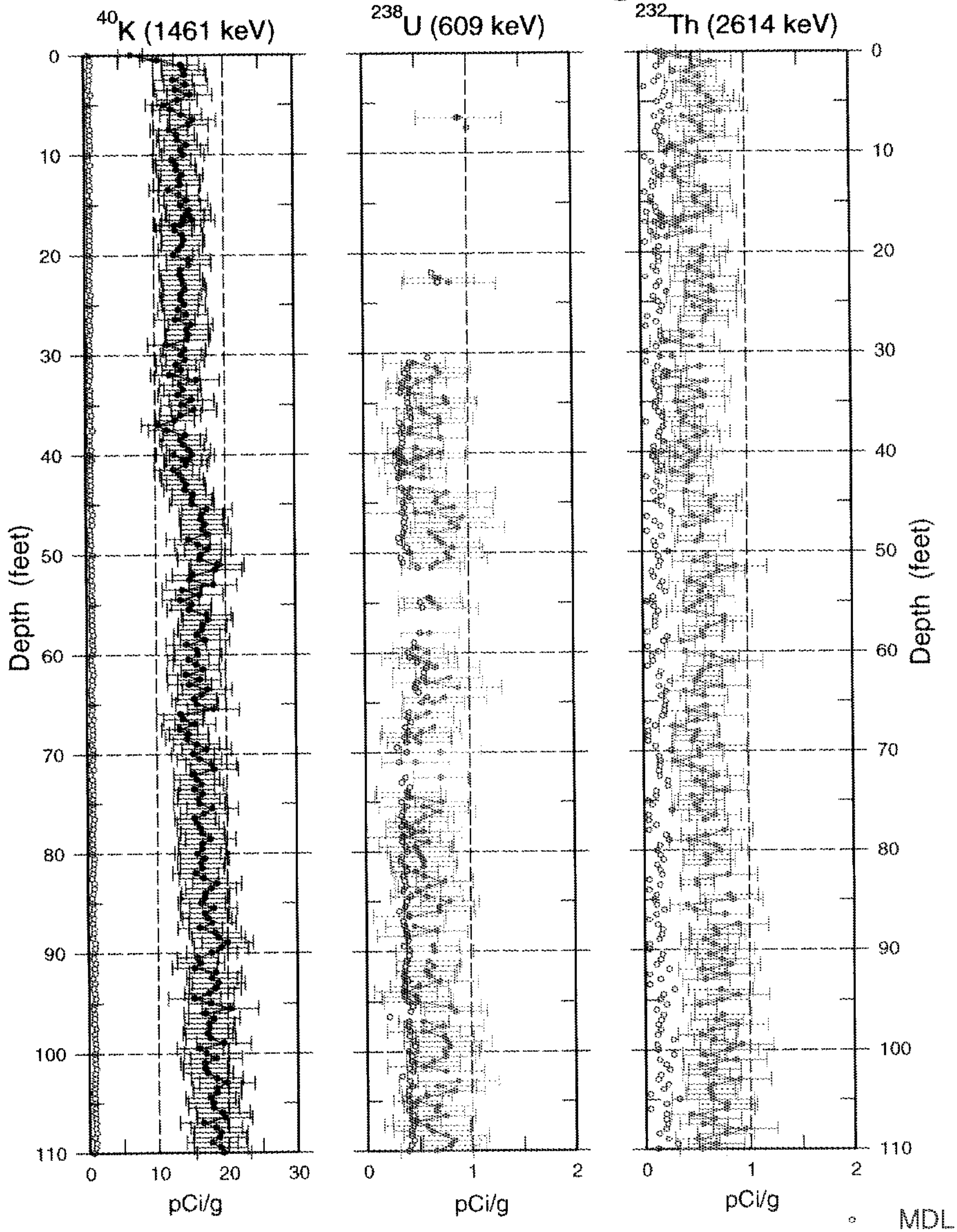
30-03-01
Man-Made Radionuclide Concentrations



30-03-01
Man-Made Radionuclide Concentrations



30-03-01
Natural Gamma Logs



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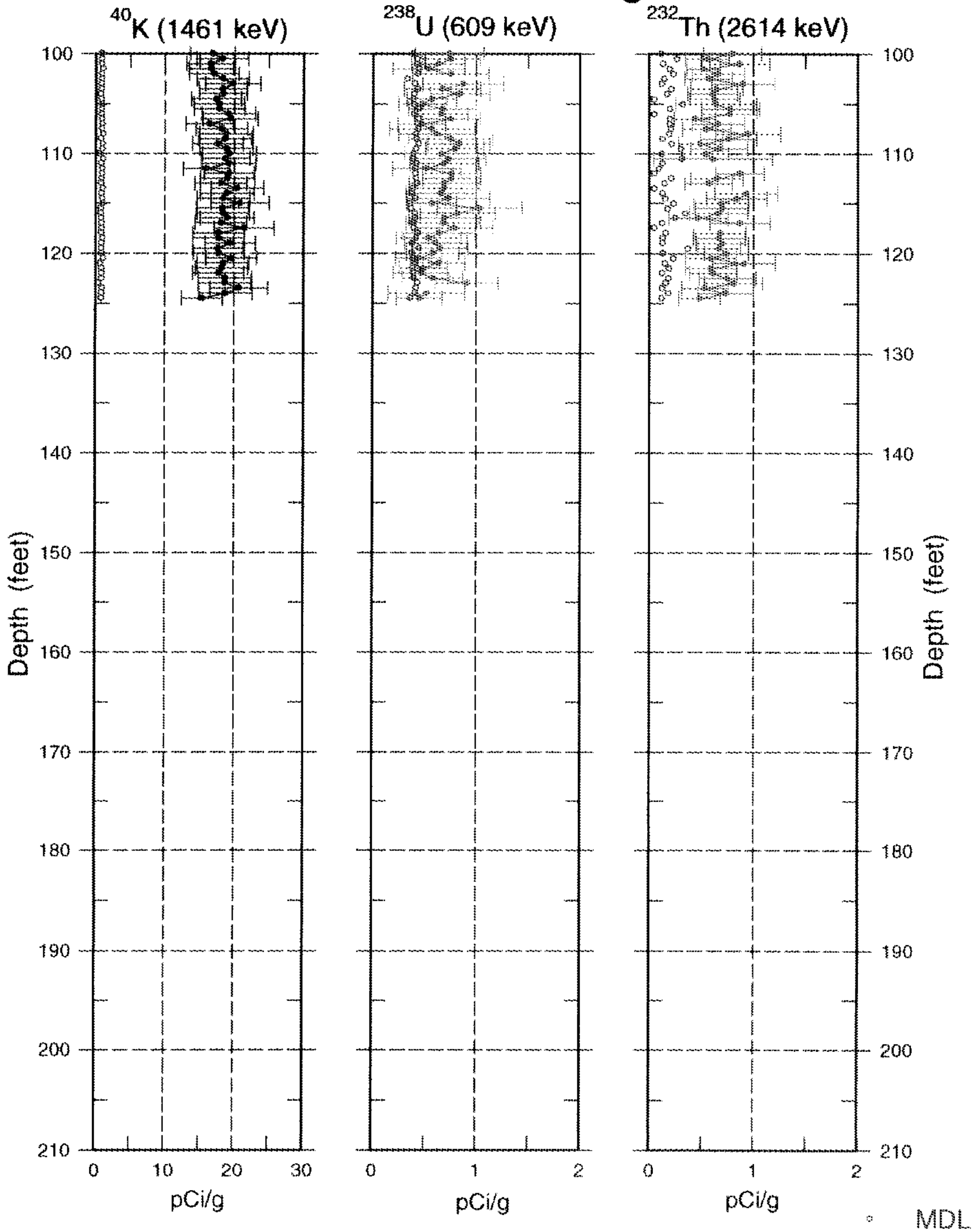
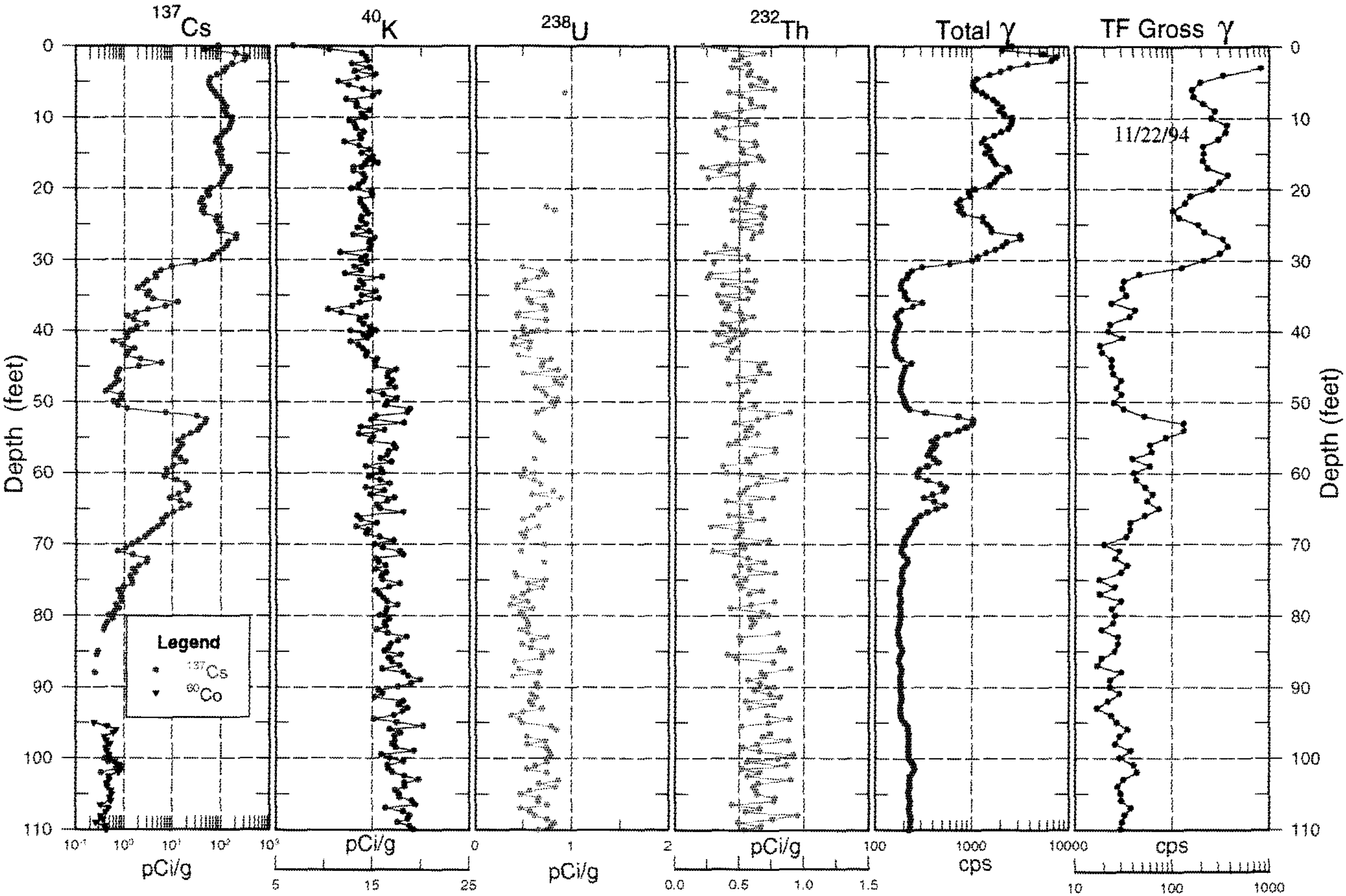
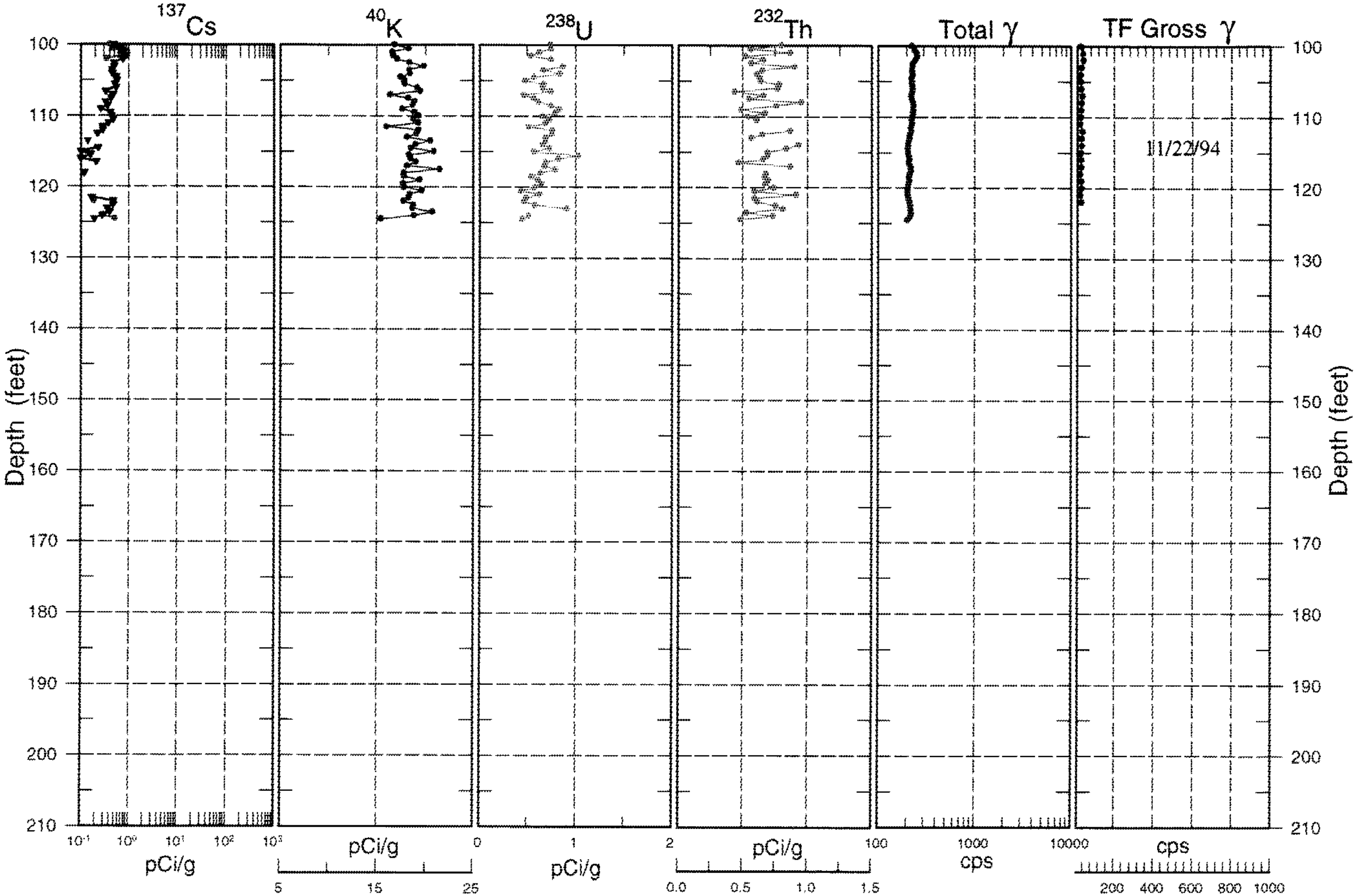
Natural Gamma Logs



30-03-01 Combination Plot

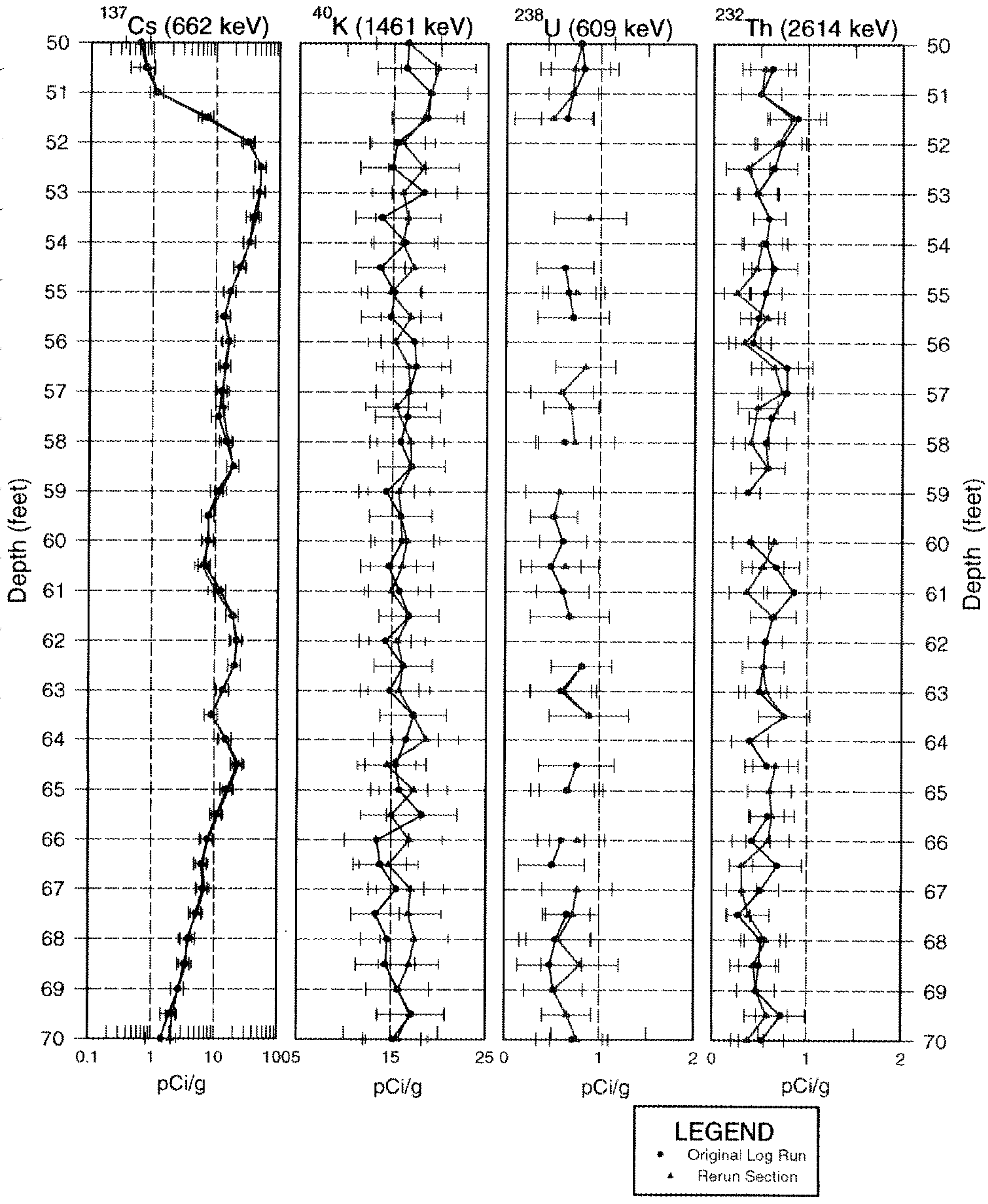


30-03-01 Combination Plot

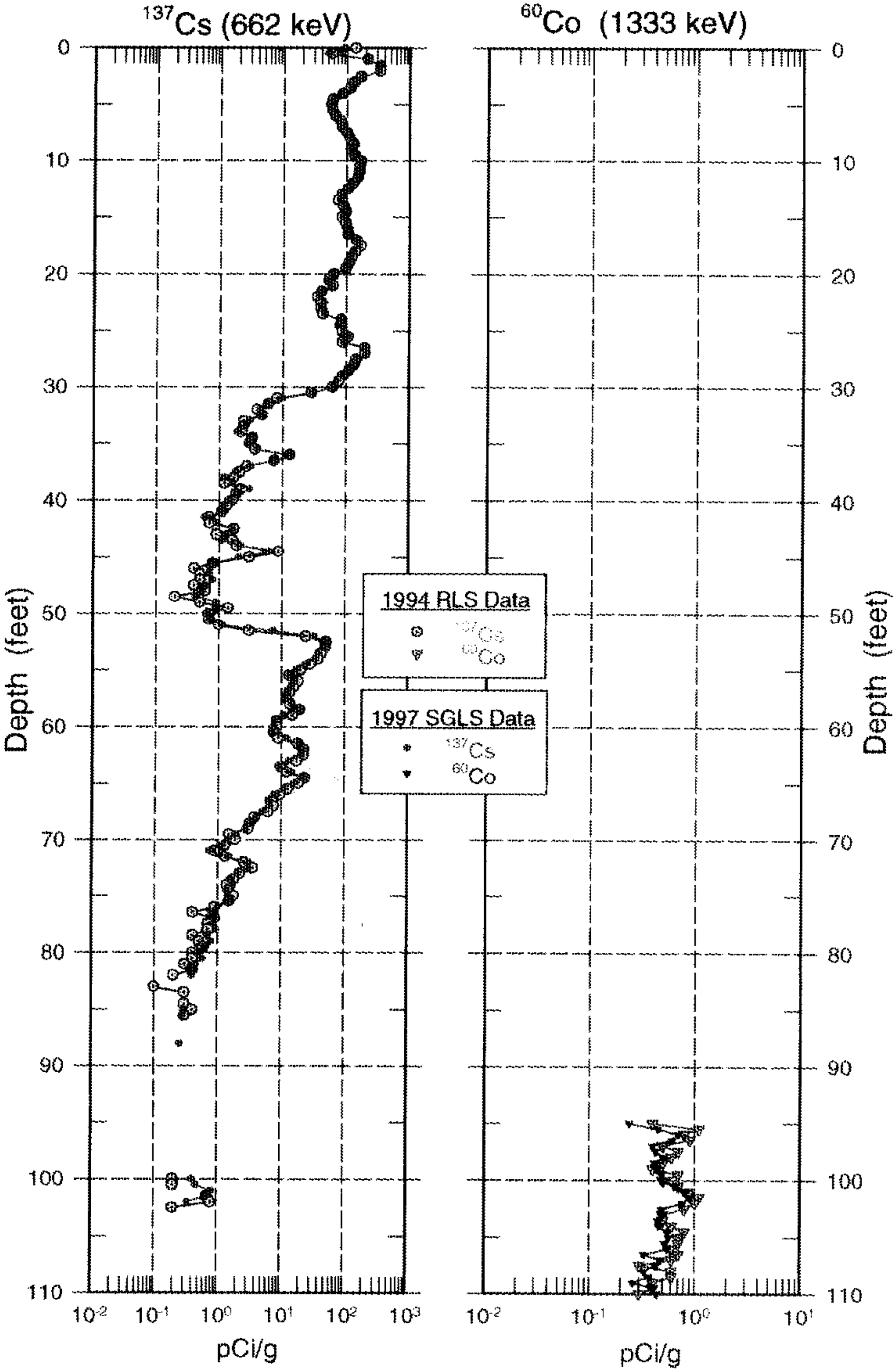


30-03-01

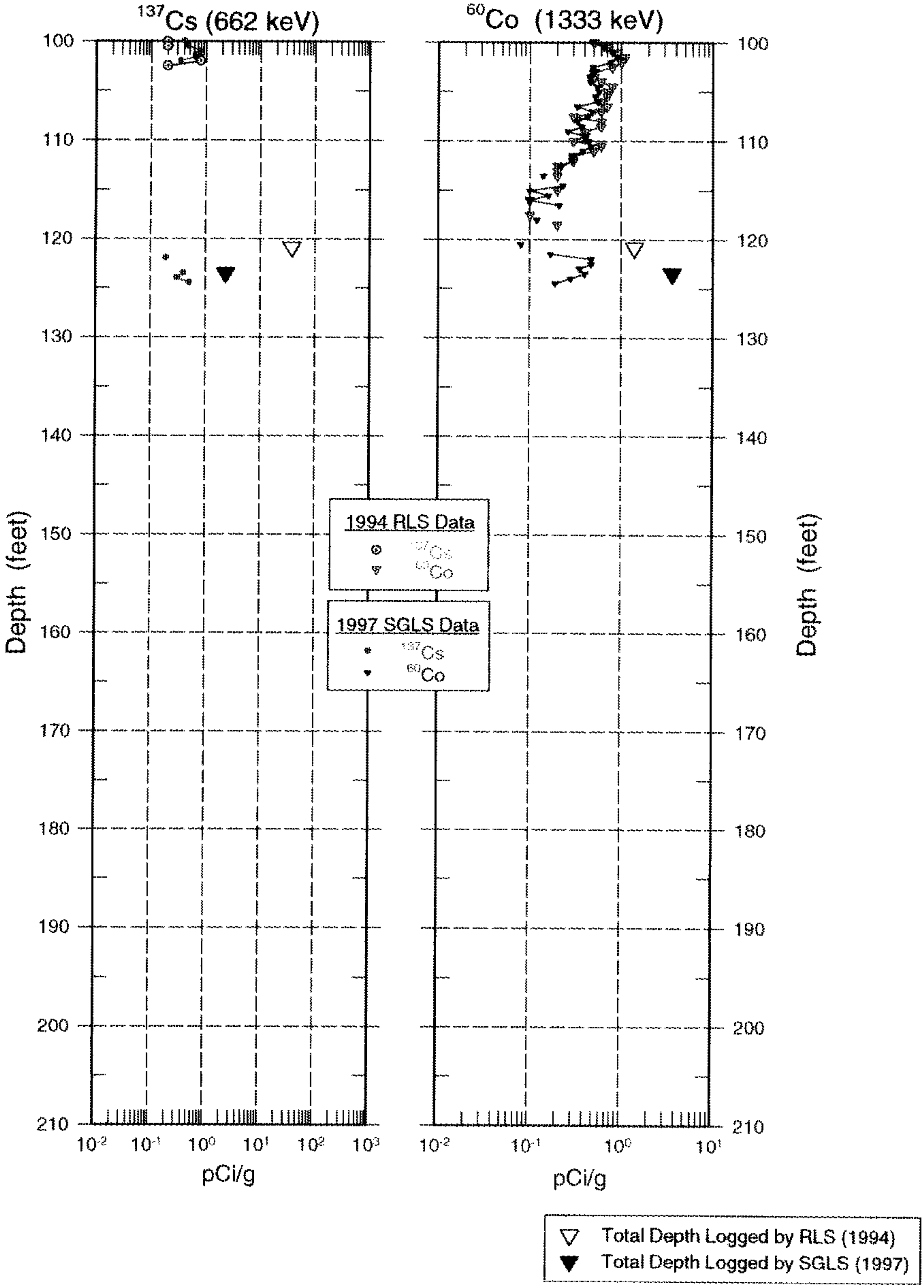
Rerun Section of the Man-Made and Natural Gamma Logs



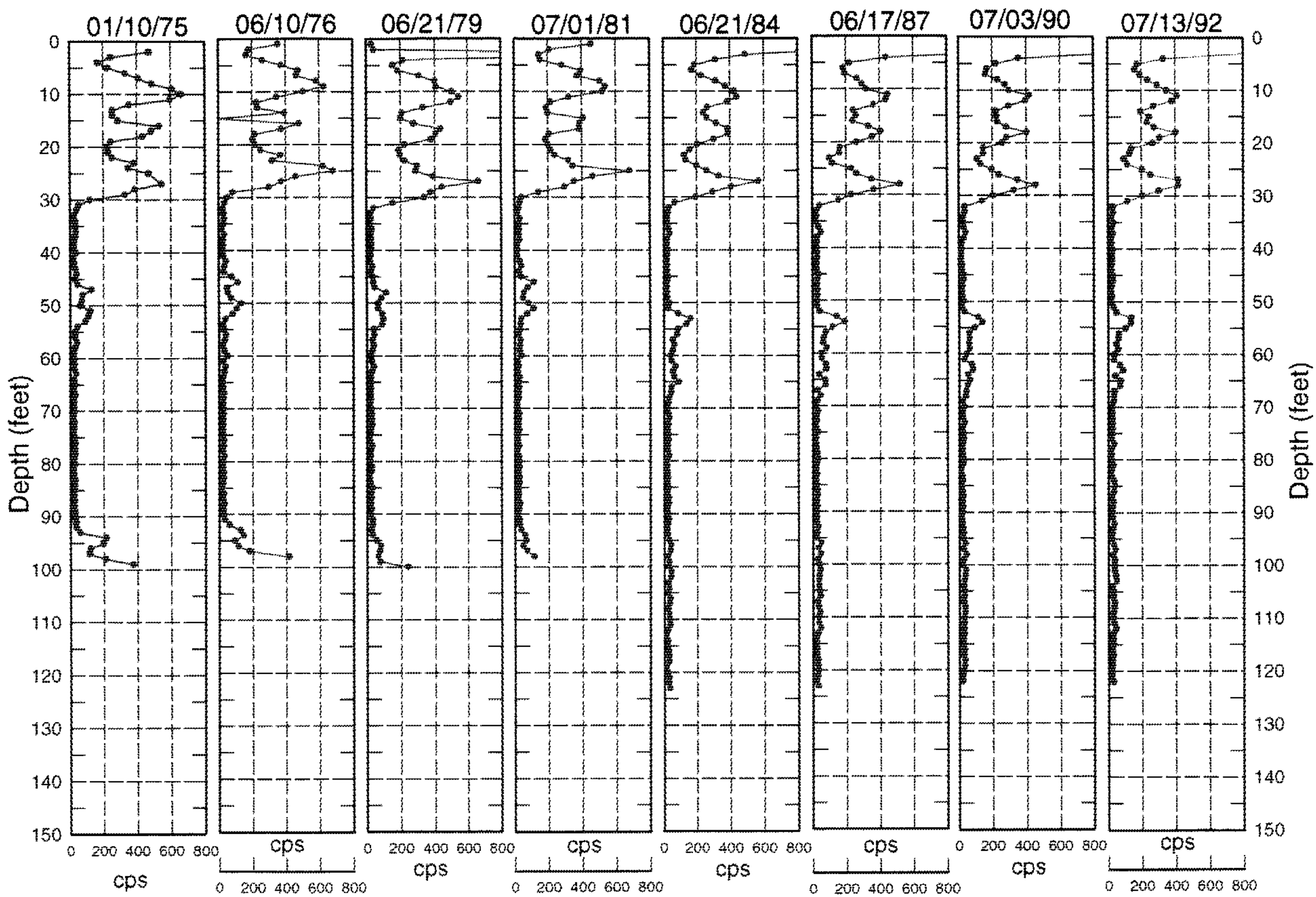
30-03-01
Man-Made Radionuclide Concentrations
1994/1997 Spectral Gamma Data Comparison



30-03-01
Man-Made Radionuclide Concentrations
1994/1997 Spectral Gamma Data Comparison



Historical Gross Gamma Logs for Borehole 30-03-01



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-03-03

Borehole Information

Farm :	C	Tank :	C-103	Site Number :	299-E27-75
N-Coord :	42,861	W-Coord :	48,140	TOC Elevation :	Unknown
Water Level, ft :	18.75	Date Drilled :	7/31/74		

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 and July 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. The borehole was filled with water below a depth of 18.8 ft.

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 :	4/11/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	98.0	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:	Bob Spatz
Start Depth, ft.:	24.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Borehole 30-03-03

Log Event A

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 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. A water correction was applied to the data collected from 19 ft and deeper in the borehole.

The man-made radionuclides Cs-137 and Co-60 were detected in this borehole. Cs-137 contamination was measured almost continuously from the ground surface to a depth of 41 ft and at 98 ft. Co-60 contamination was detected almost continuously from 85 to 92.5 ft, at 96 ft, and at 97 ft.

The K-40 and Th-232 concentrations increase below a depth of 19 ft. This increase corresponds to the top of the water in the borehole and indicates the water correction applied to the data from 19 ft and deeper is too large and is probably overestimating both the natural and man-made radionuclide concentrations throughout the water-filled interval. K-40 concentrations increase below a depth of about 43.5 ft from a background of about 10 to about 13 pCi/g. The KUT concentrations increase again below a depth of about 54 ft. Intervals of relatively low K-40 concentrations were detected from 70.5 to 74 ft and 78.5 to 81 ft. K-40 concentrations increase below 85 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank 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.

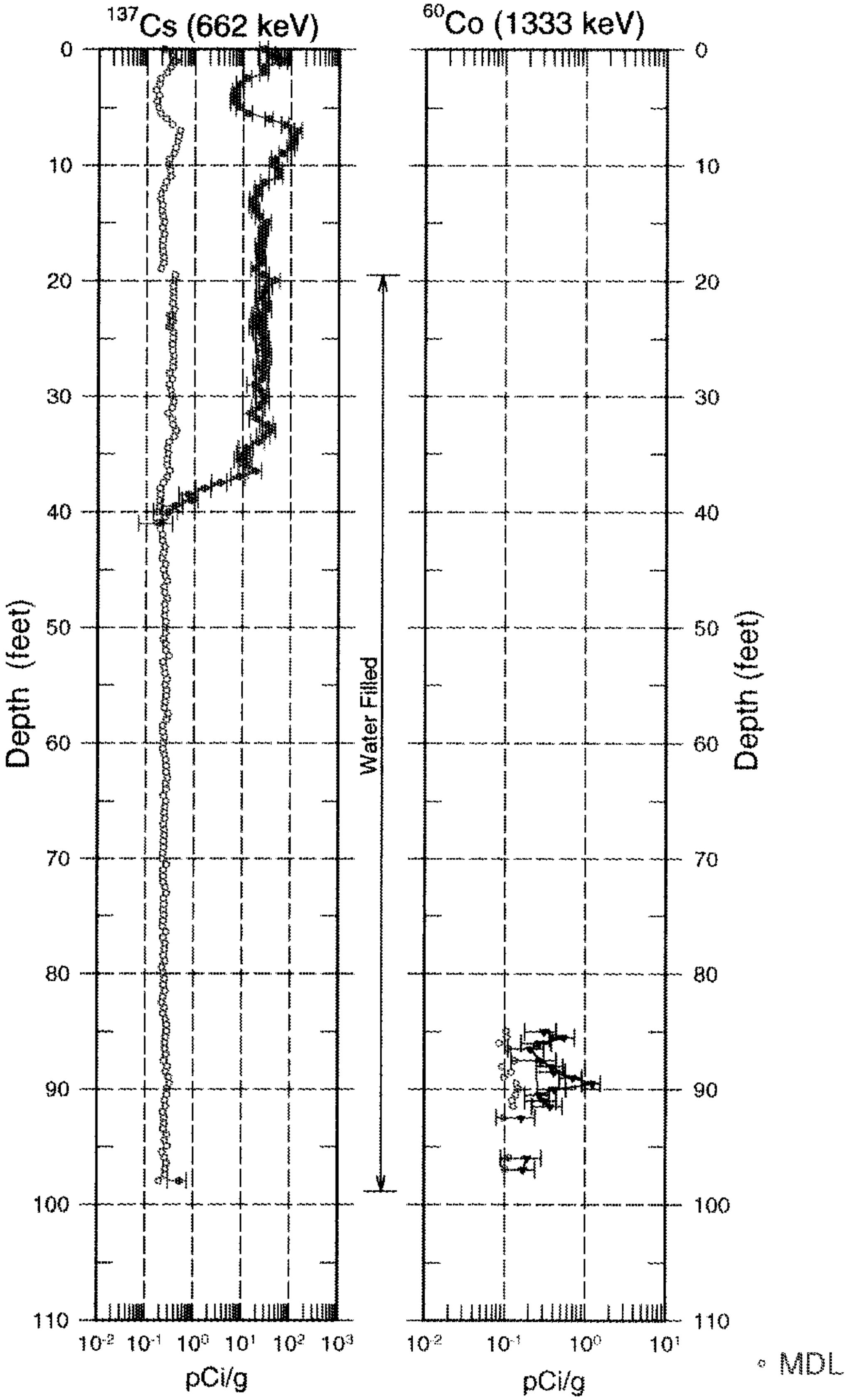
A comparison plot is also provided showing the Cs-137 and Co-60 concentrations determined from the SGLS and those determined from the Radionuclide Logging System (RLS) in 1994.

Borehole 30-03-03

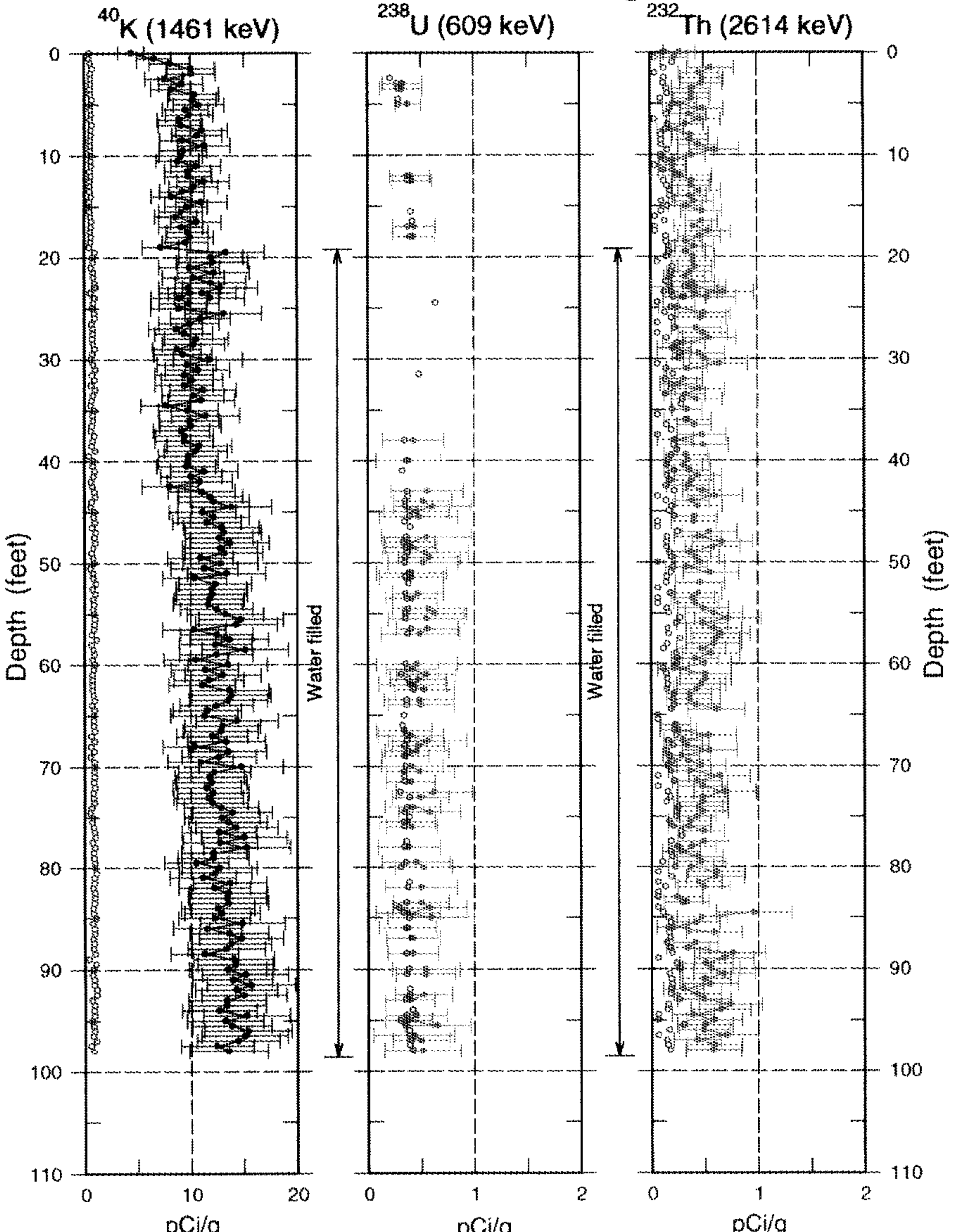
Log Event A

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.

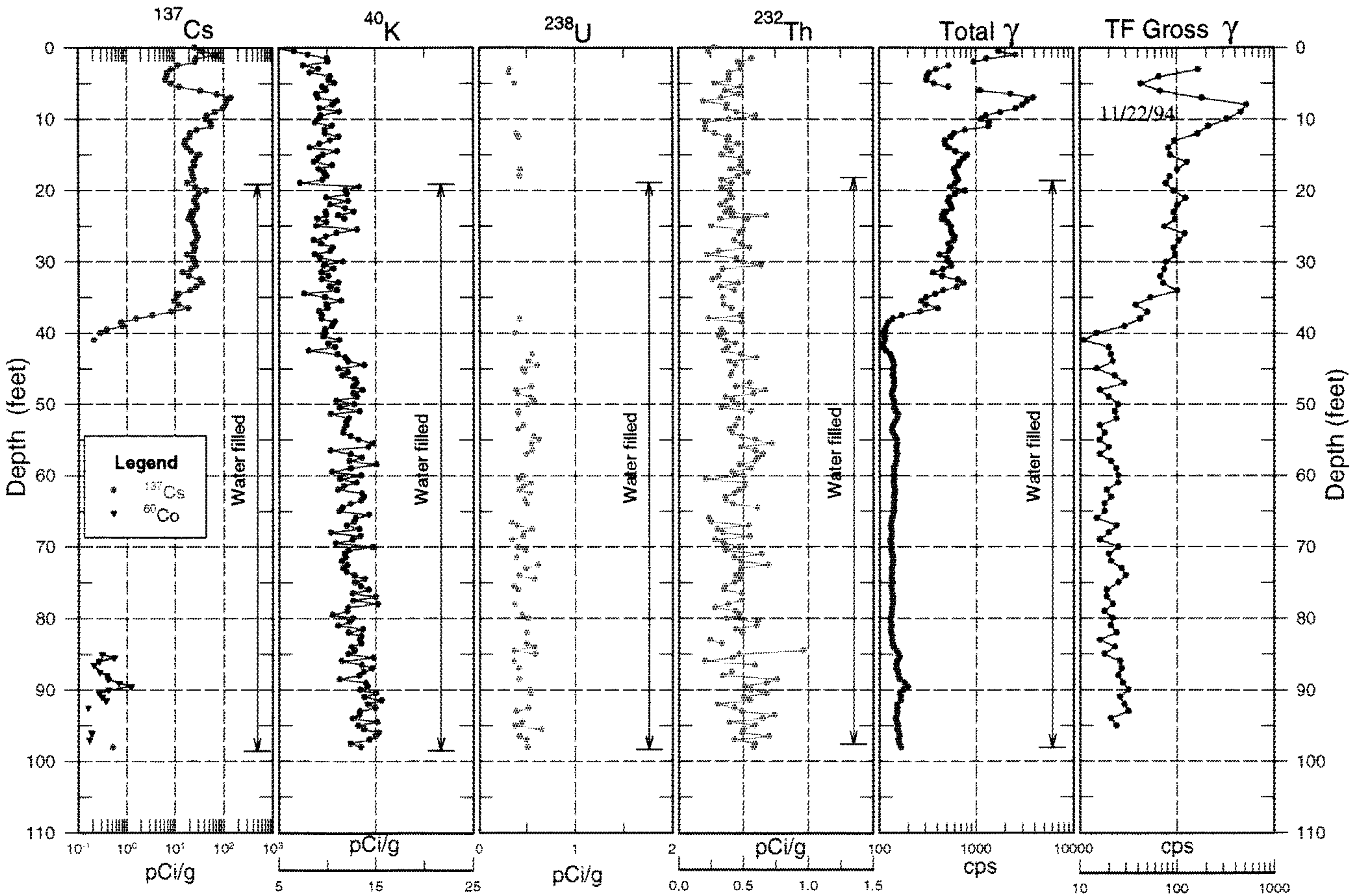
30-03-03
Man-Made Radionuclide Concentrations



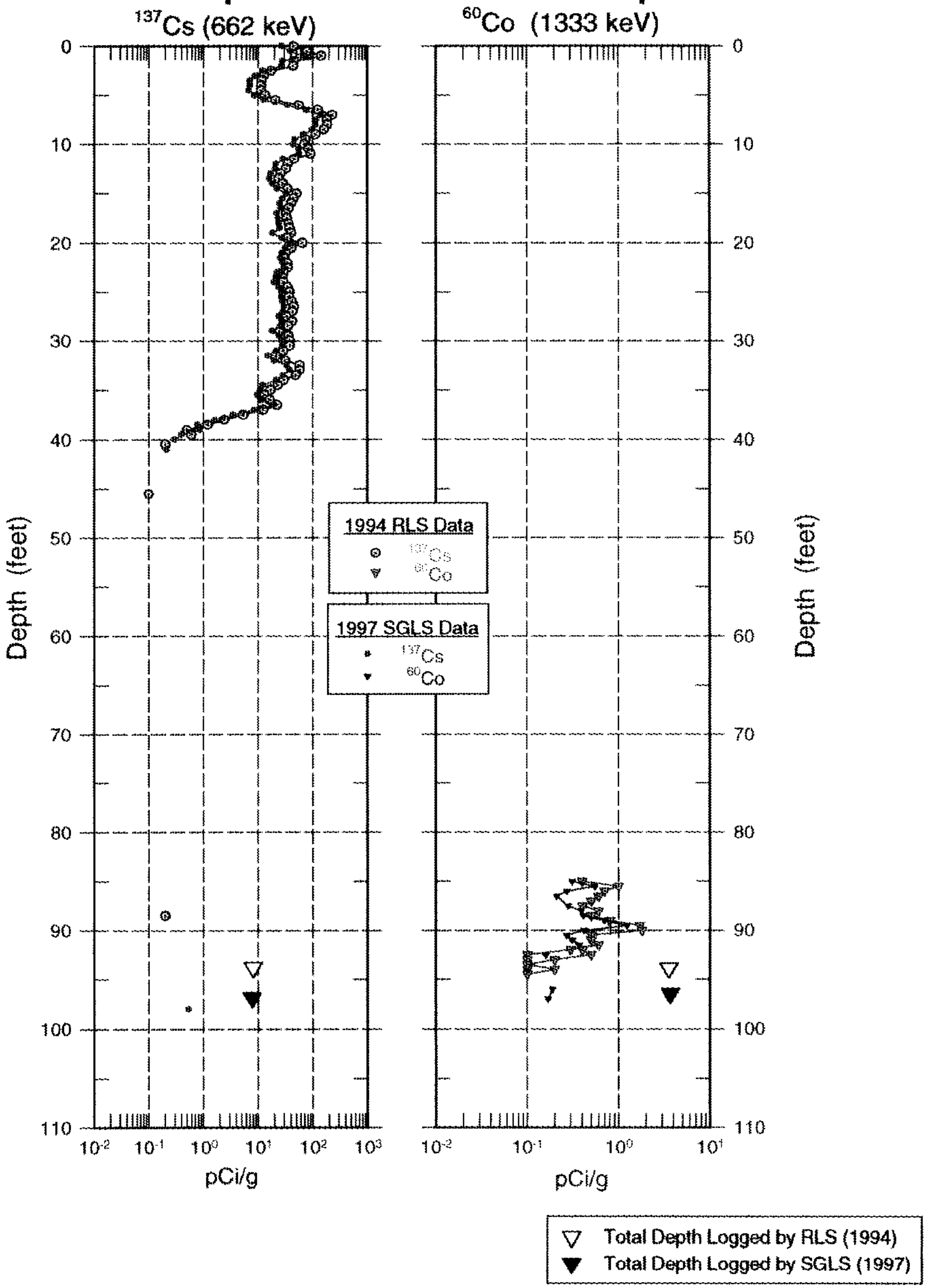
30-03-03
Natural Gamma Logs



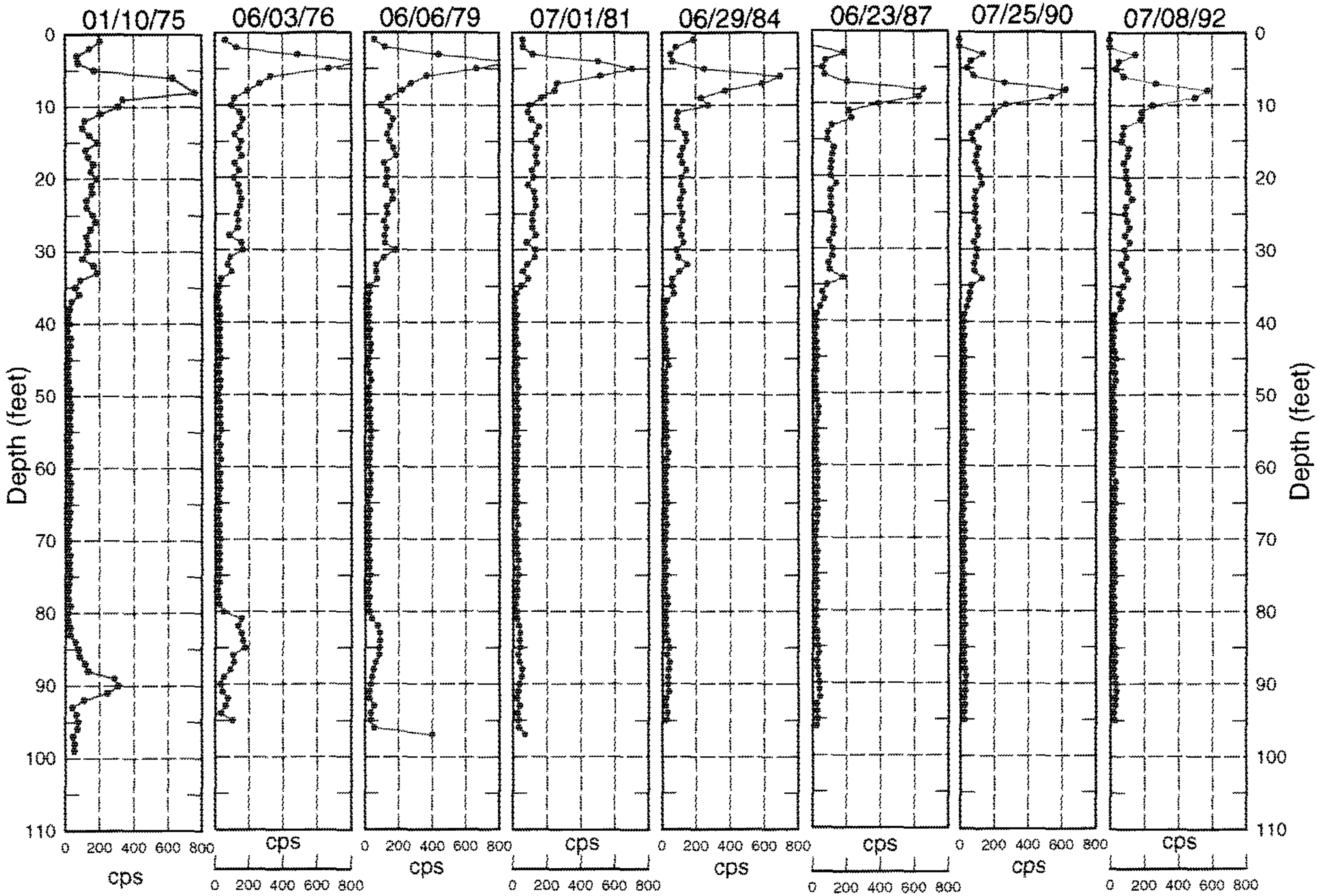
30-03-03 Combination Plot



30-03-03
Man-Made Radionuclide Concentrations
1994/1997 Spectral Gamma Data Comparison



Historical Gross Gamma Logs for Borehole 30-03-03



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-03-05

Borehole Information

Farm :	C	Tank :	C-103	Site Number :	299-E27-76
N-Coord :	42,820	W-Coord :	48,165	TOC Elevation :	Unknown
Water Level, ft :	None	Date Drilled :	7/31/74		

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 July 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 found; 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 :	4/14/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	34.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	4/15/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	100.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	33.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Borehole 30-03-05

Log Event A

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 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 almost continuously from the ground surface to 43 ft, continuously from 54.5 to 76 ft, and near the bottom of the borehole.

The K-40 concentrations increase gradually from 39 to 48 ft and remain relatively constant between 48 and 84 ft. The K-40 concentrations increase slightly at 84 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank 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.

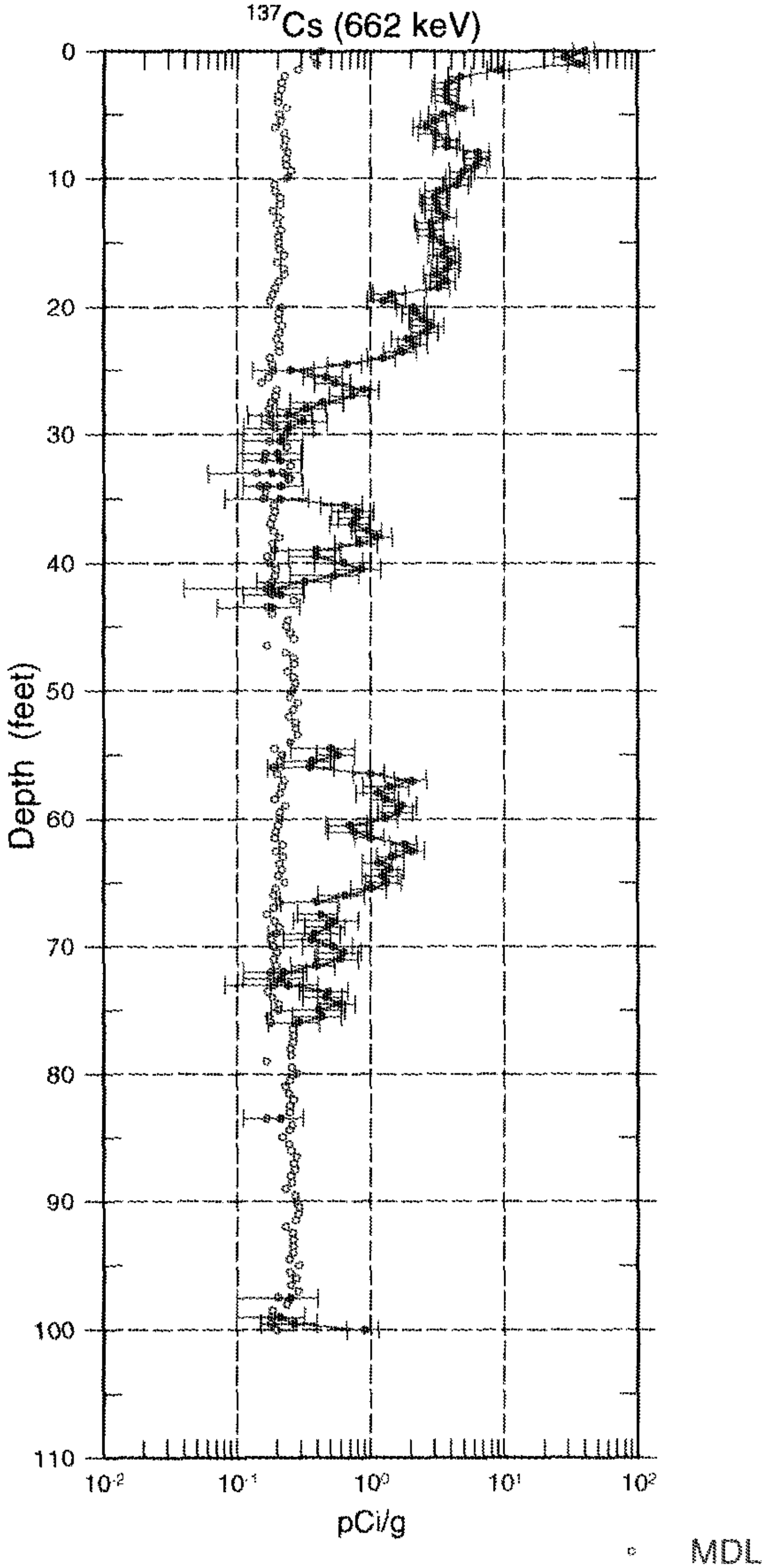
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

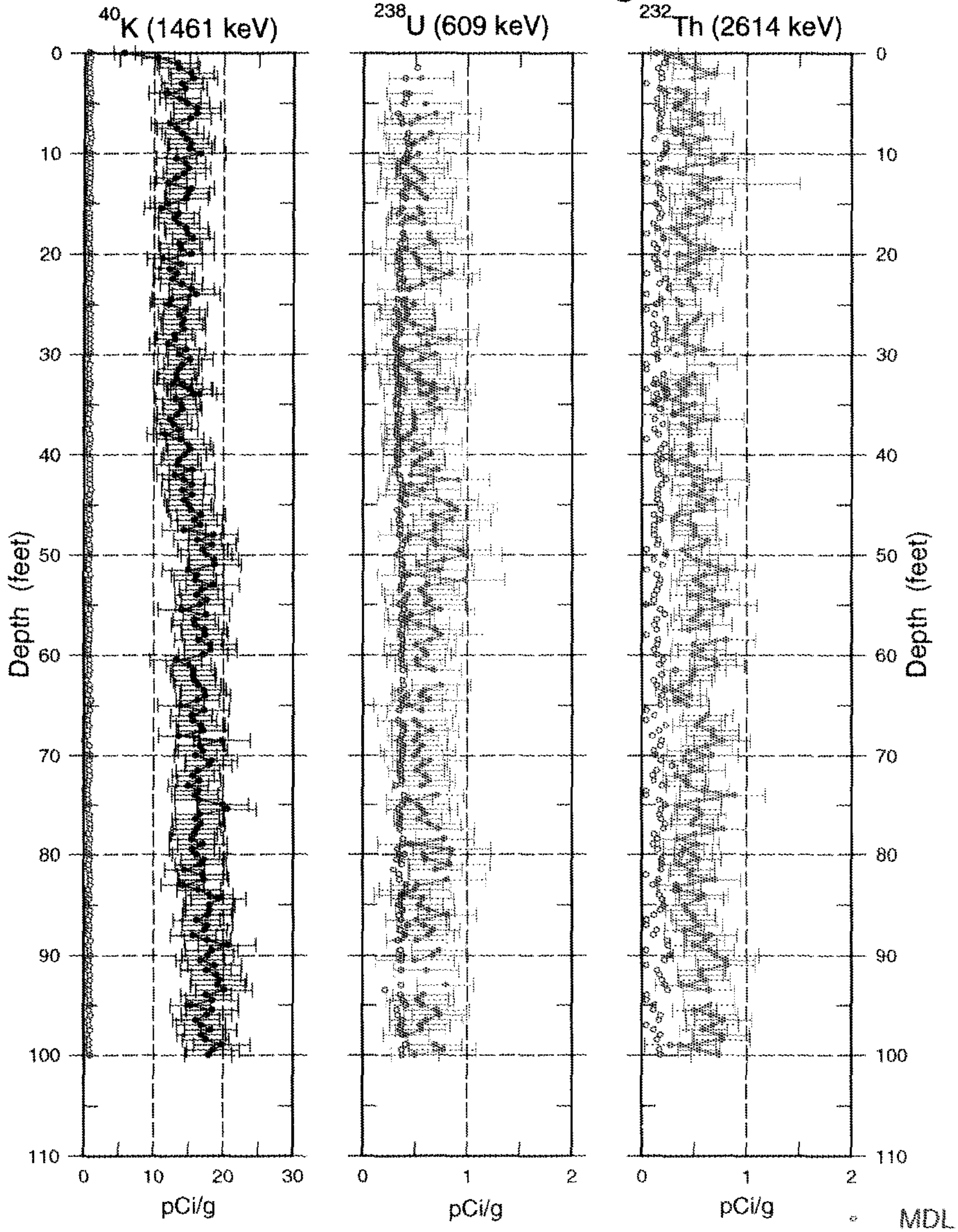
A plot of representative historical gross gamma-ray logs from 1975 to 1982 is also included. The headings of the plots identify the date on which the data in the plots were gathered.

30-03-05

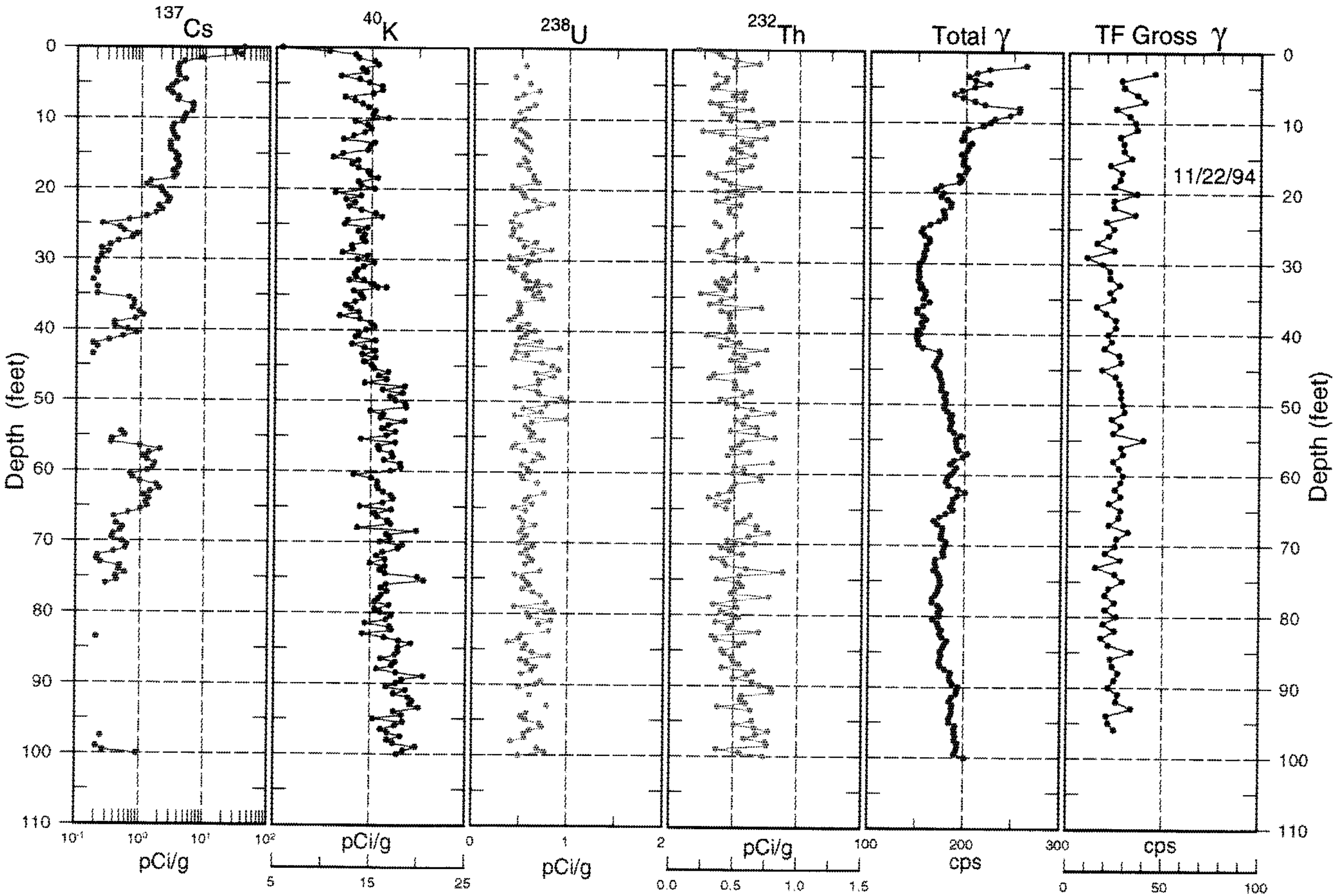
Man-Made Radionuclide Concentrations



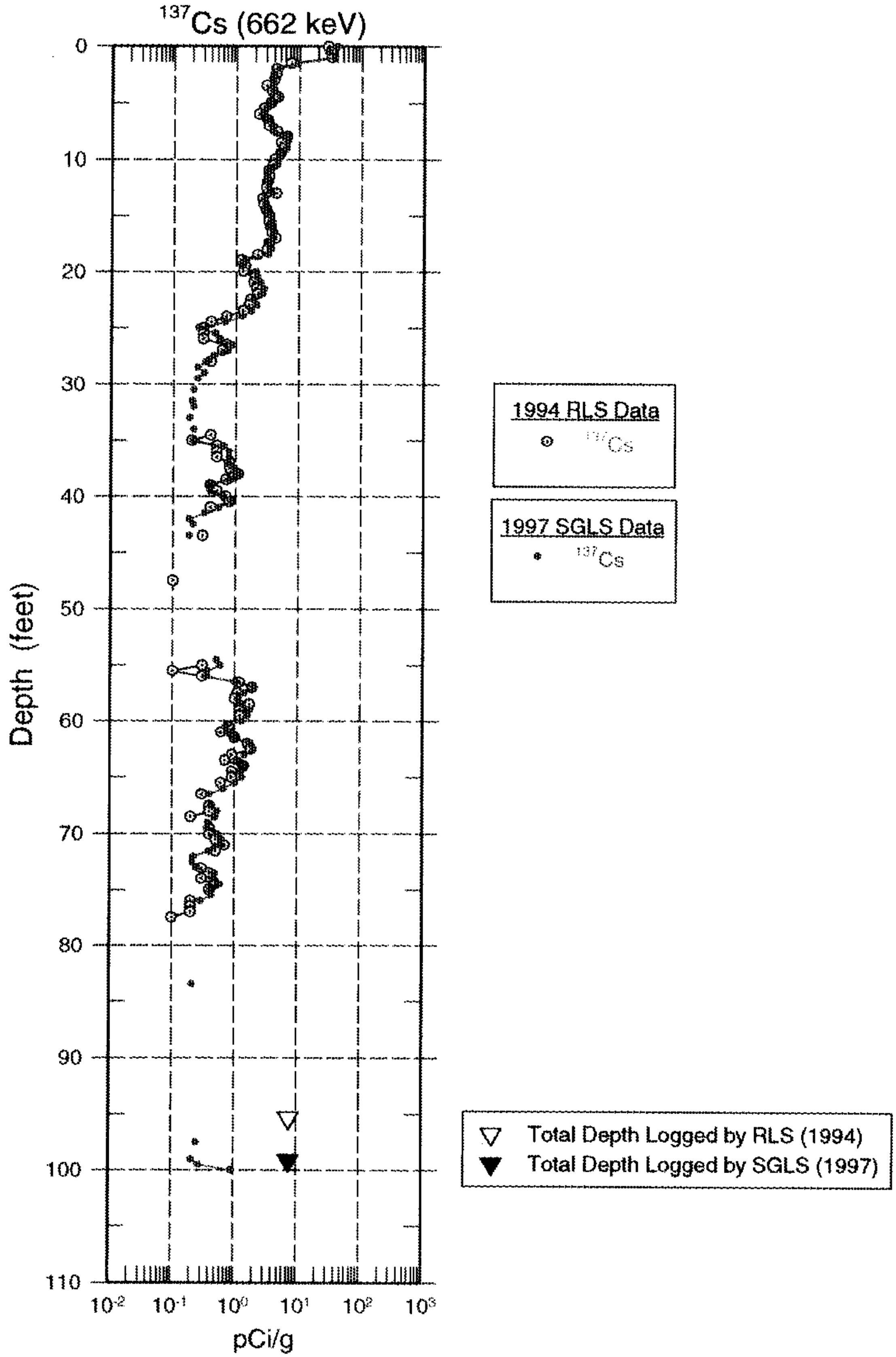
30-03-05
Natural Gamma Logs



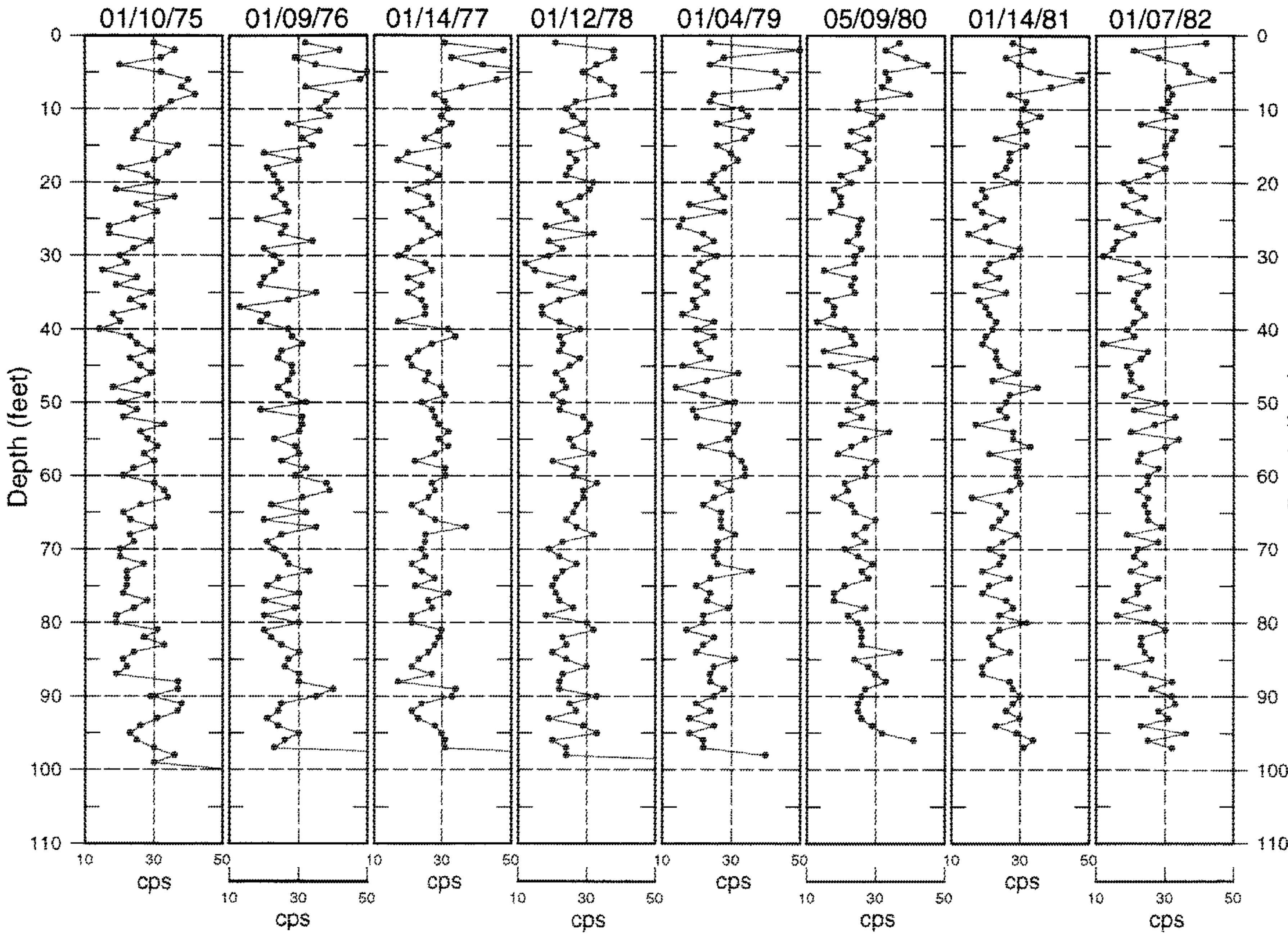
30-03-05 Combination Plot



30-03-05
Man-Made Radionuclide Concentrations
1994/1997 Spectral Gamma Data Comparison



Historical Gross Gamma Logs for Borehole 30-03-05



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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 and extends from about 2 ft below the top of the borehole 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 borehole was perforated between 54 and 154 ft with five perforations per foot. 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 in 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 E-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 : GJPO-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

Log Event A

Borehole 30-00-03

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 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 54 ft and significantly underestimated above 54 ft.

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 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.

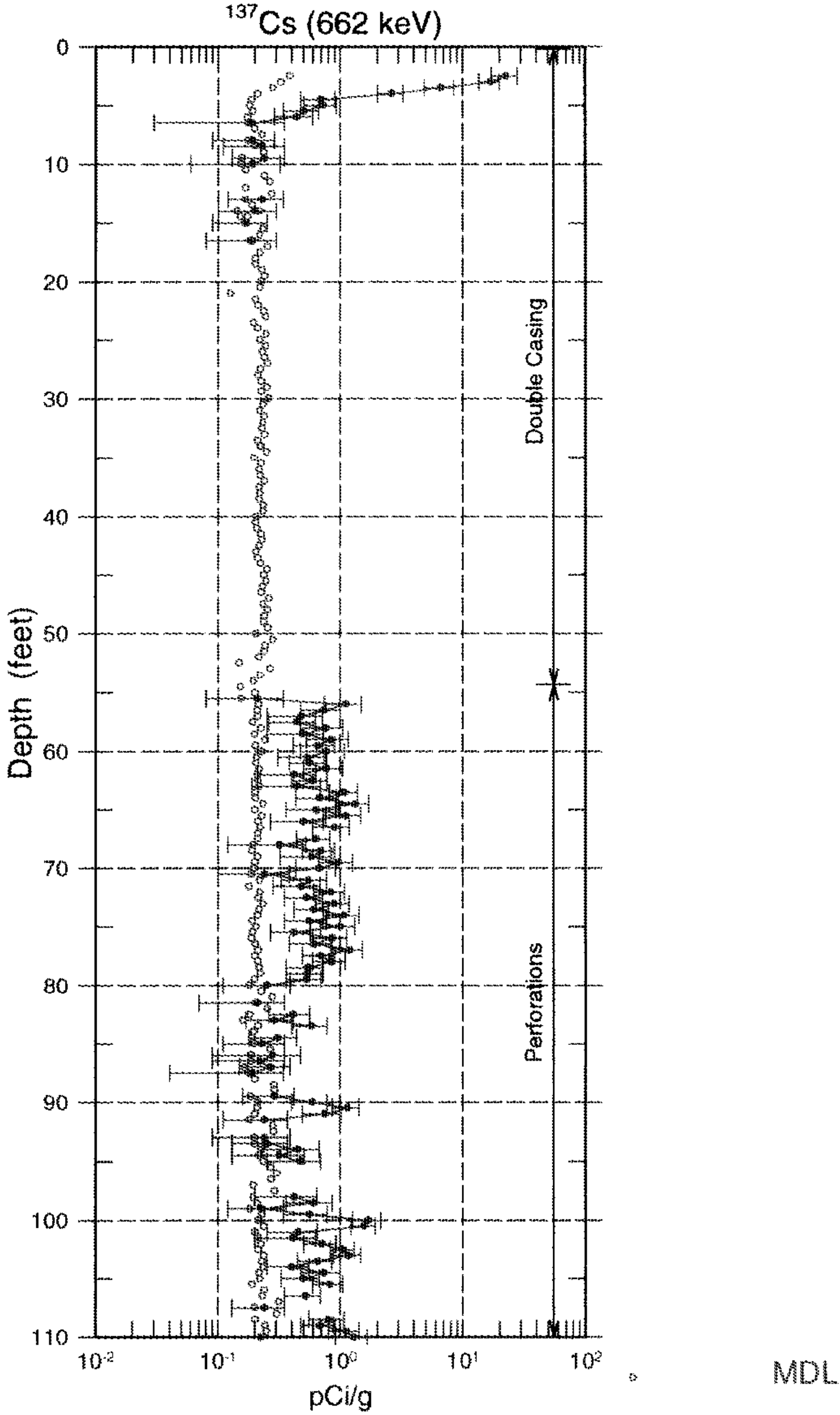
Details concerning the interpretation of data for this borehole are presented in the Tank Summary Data Reports for tanks C-102 and C-103.

Log Plot Notes:

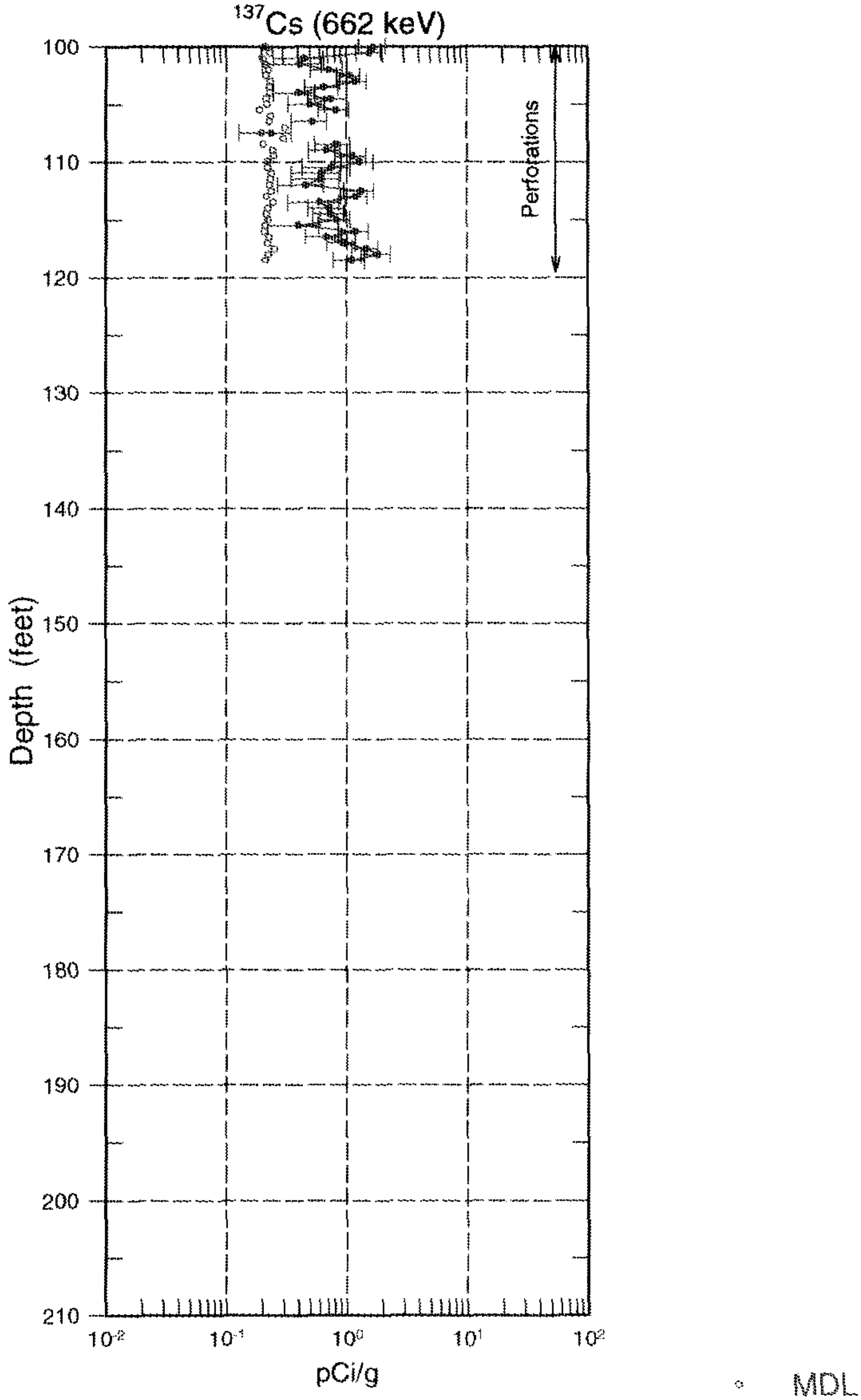
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties 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.

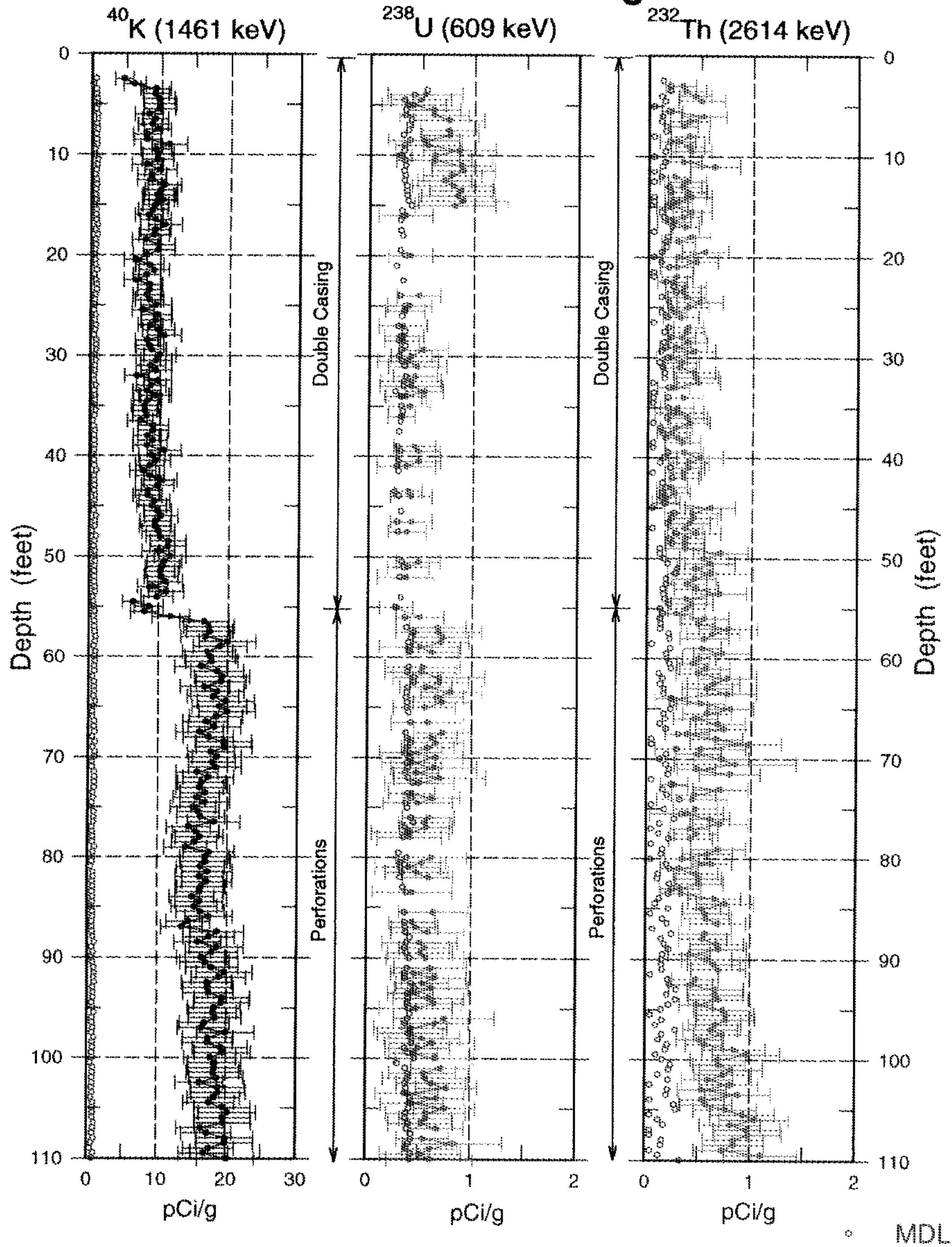
30-00-03
Man-Made Radionuclide Concentrations



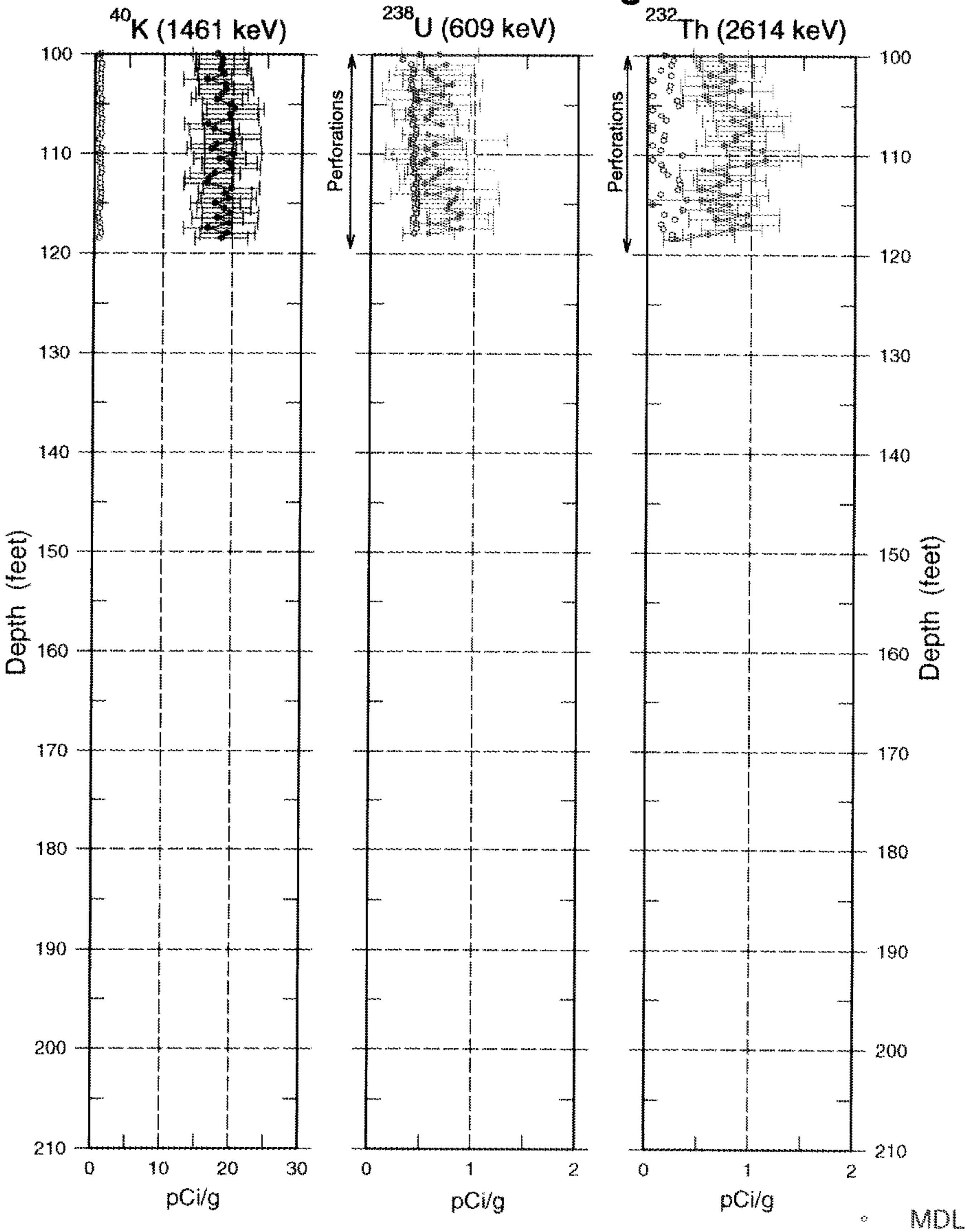
30-00-03
Man-Made Radionuclide Concentrations



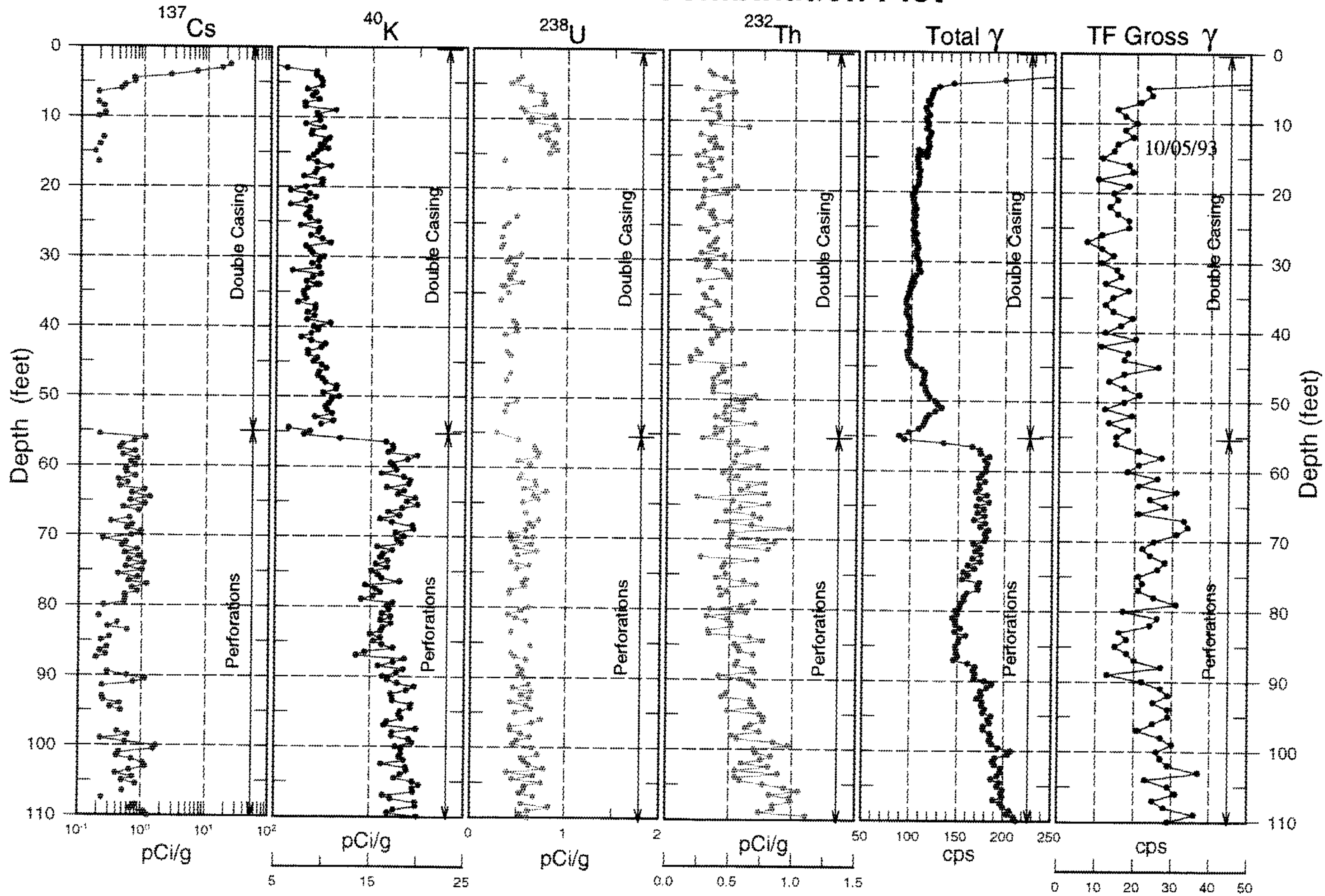
30-00-03
Natural Gamma Logs



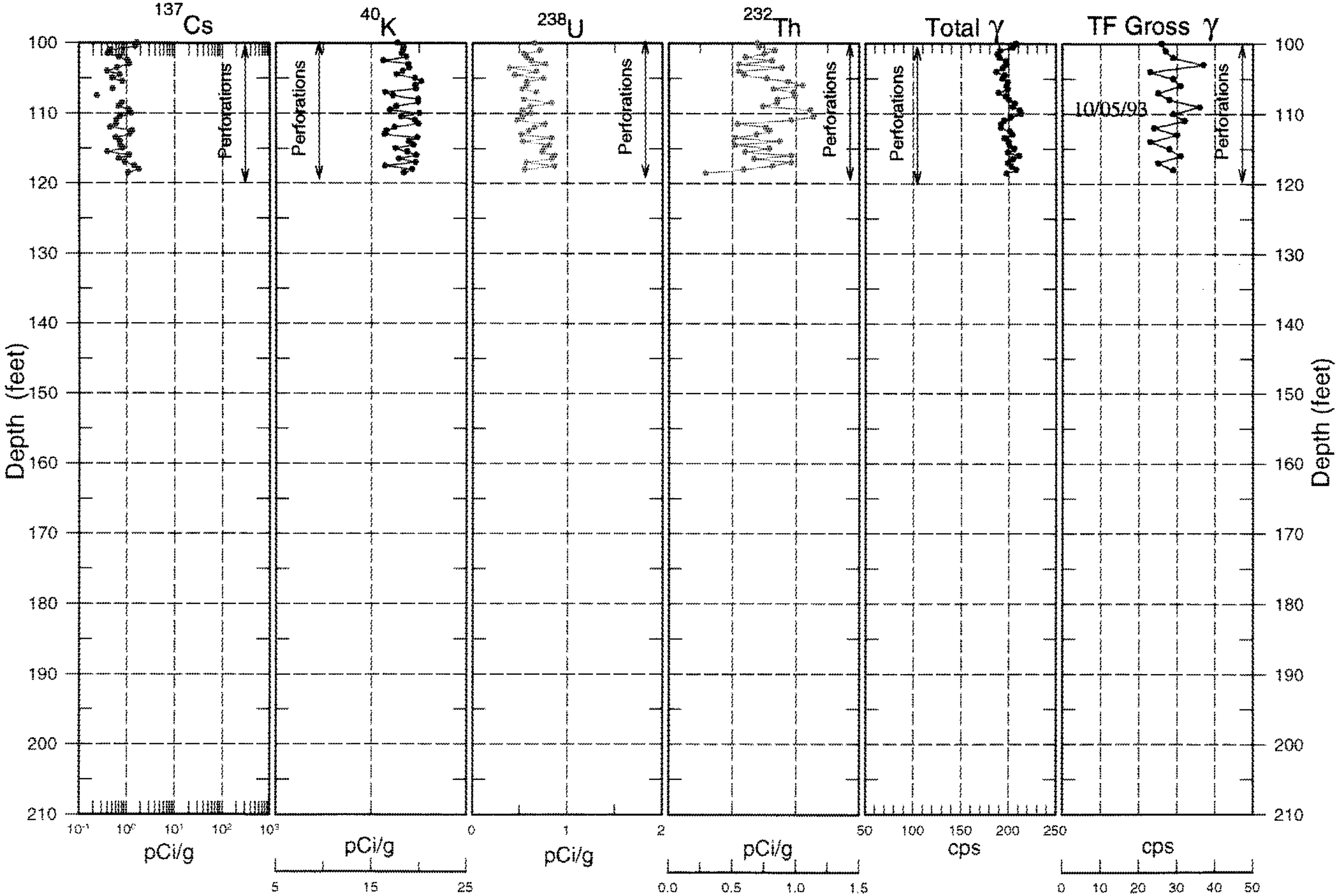
30-00-03
Natural Gamma Logs



30-00-03 Combination Plot



30-00-03 Combination Plot



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 :**	Unknown
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 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.

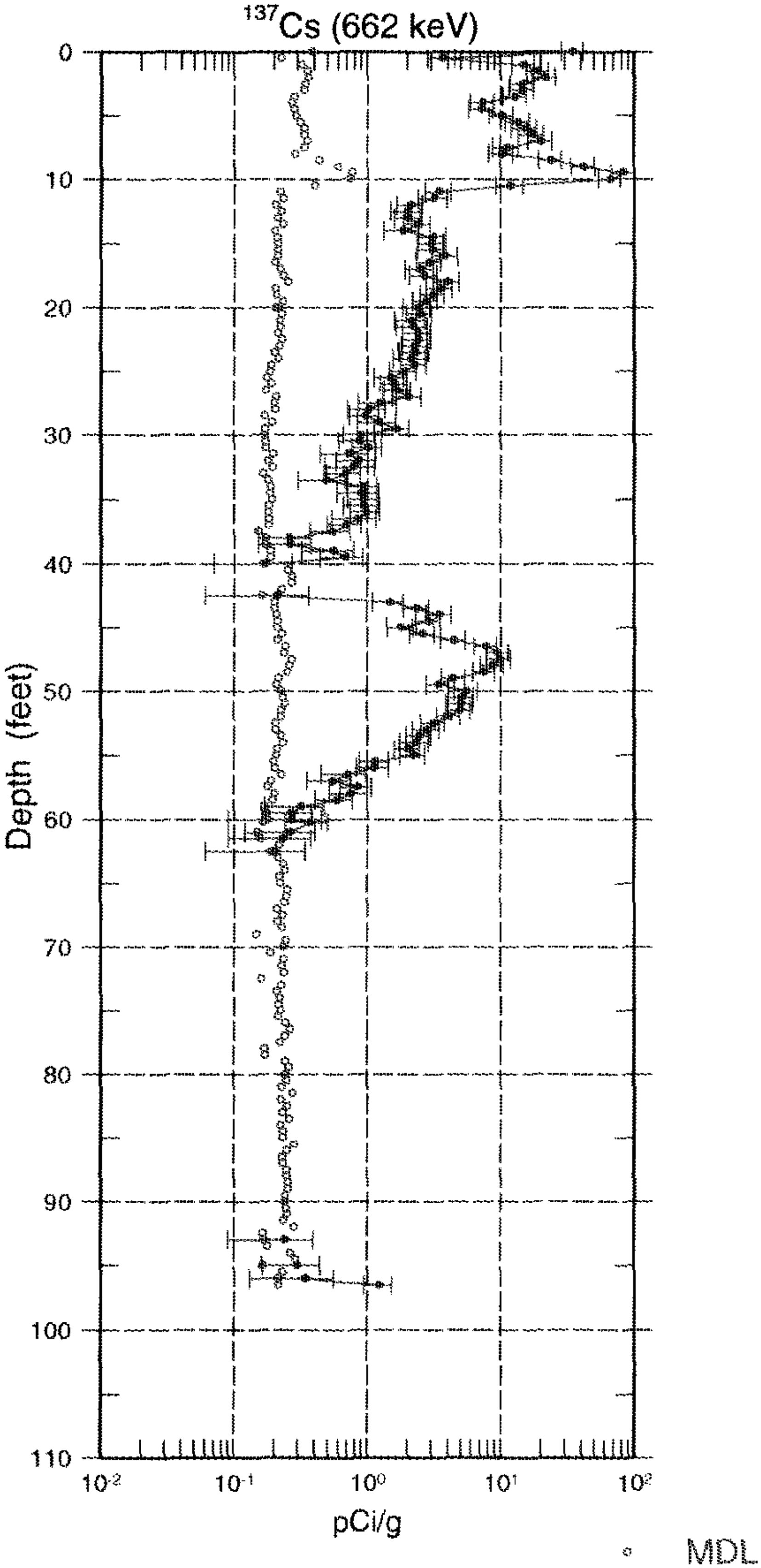
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

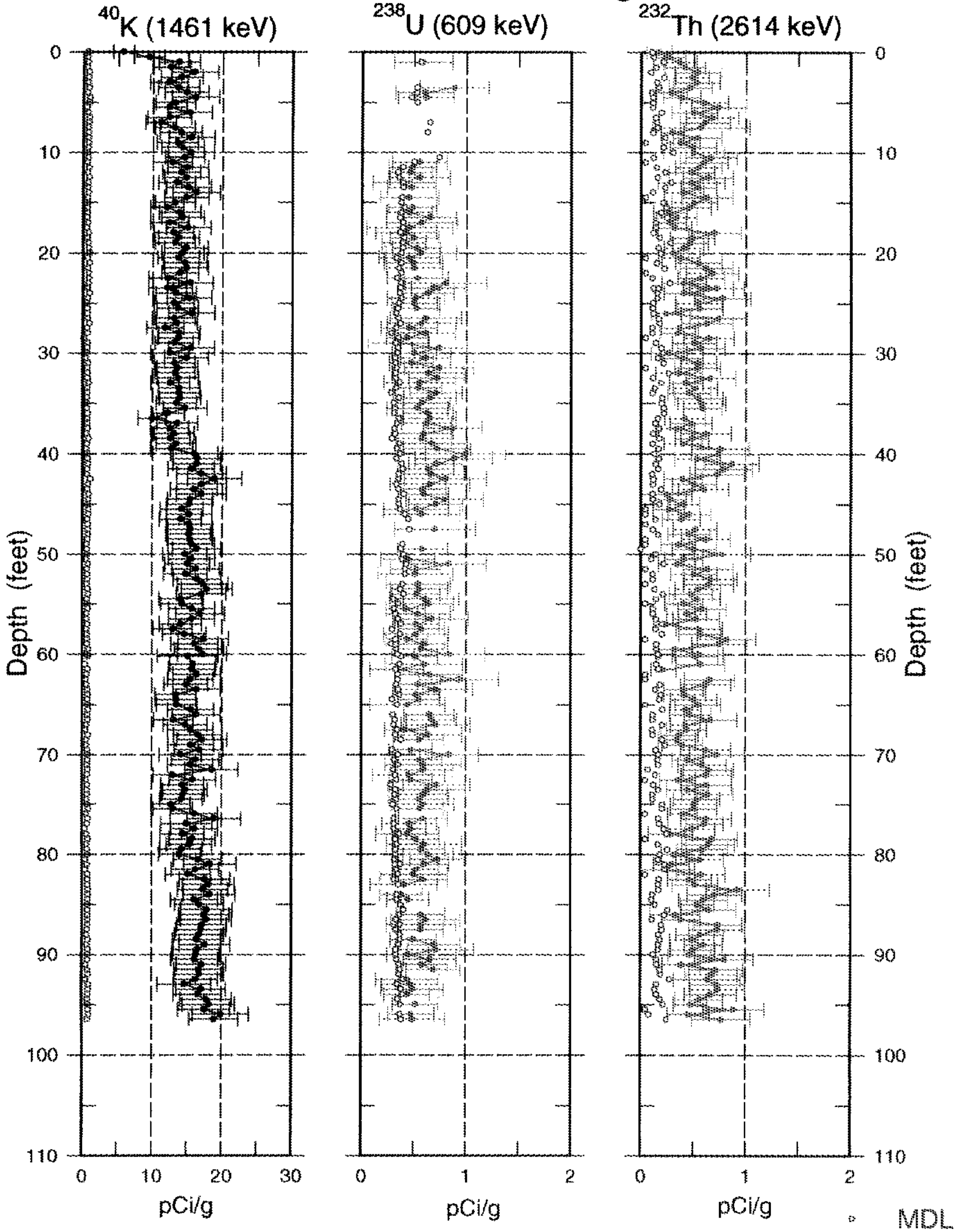
A plot of representative historical gross gamma-ray logs from 1975 to 1982 is included. The headings of the plots identify the date on which the data in the plots were gathered.

30-03-07

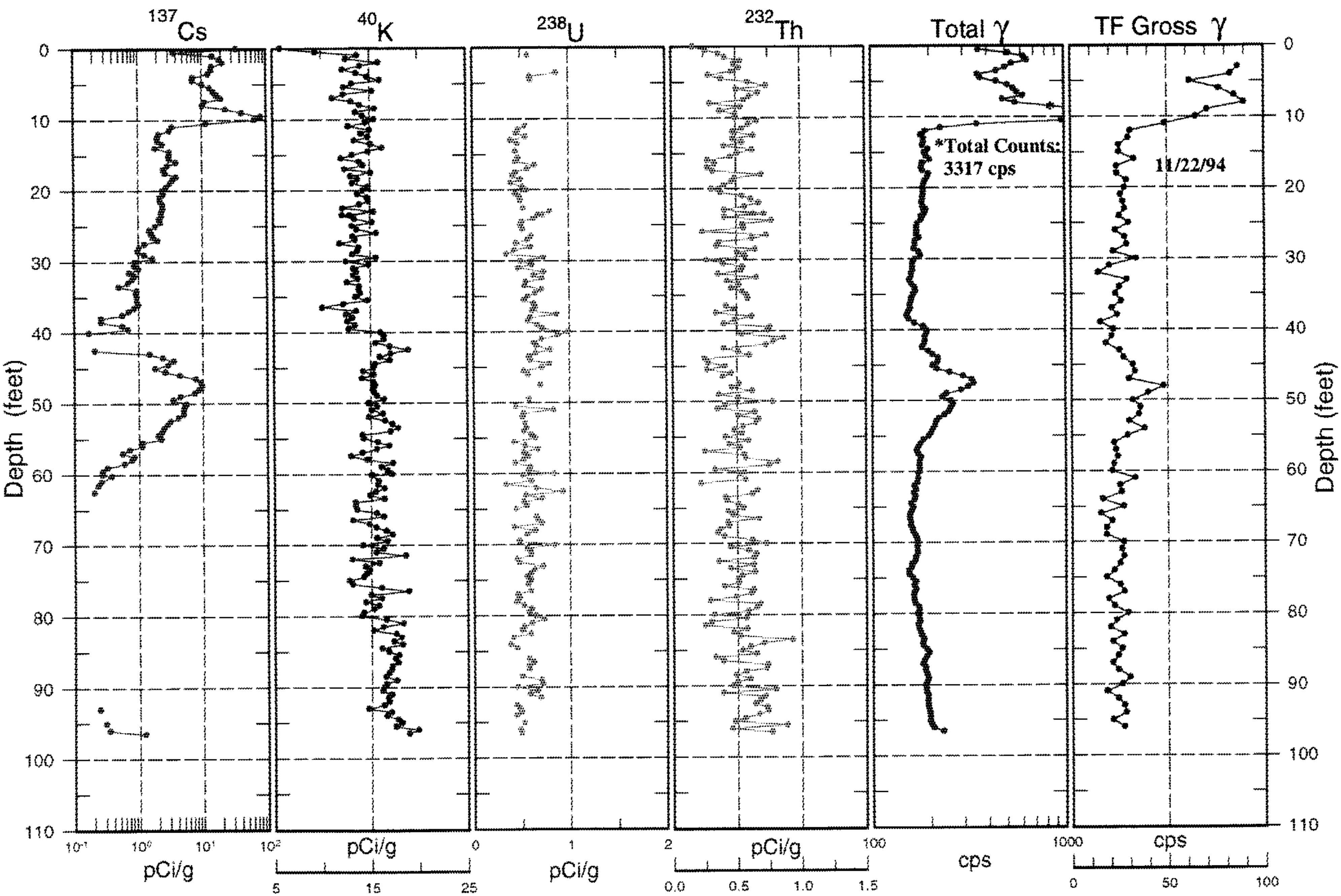
Man-Made Radionuclide Concentrations



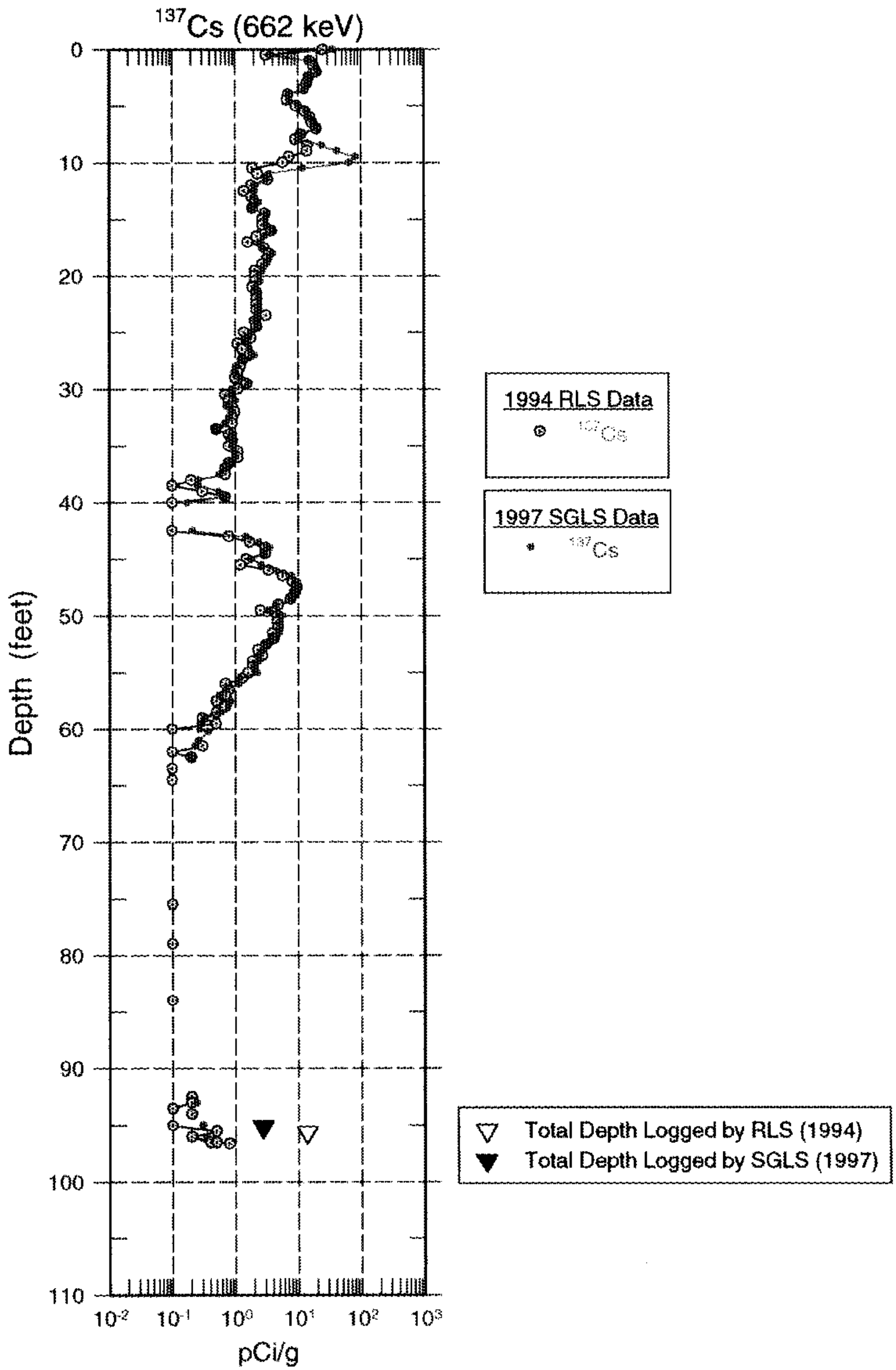
30-03-07
Natural Gamma Logs



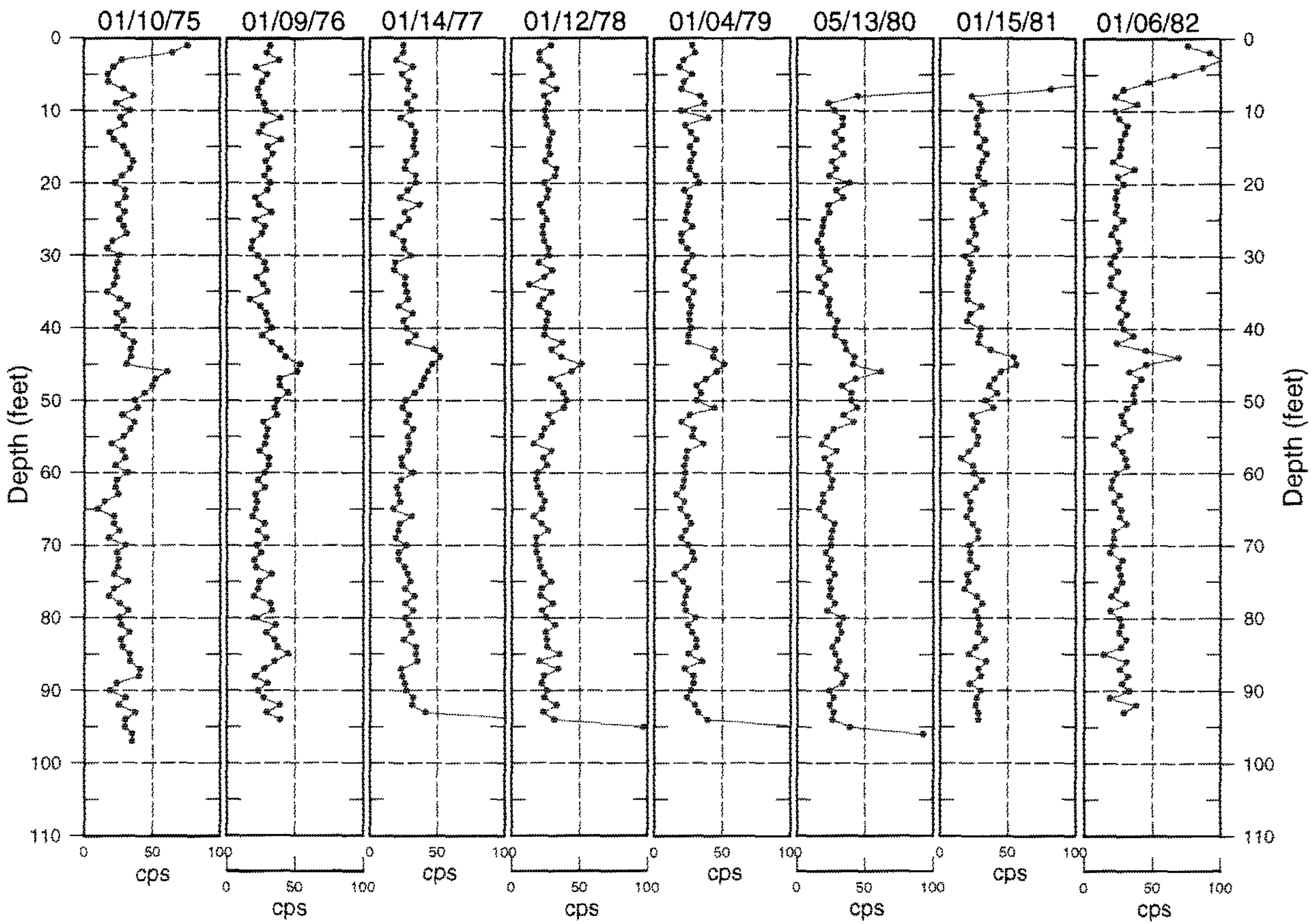
30-03-07 Combination Plot



30-03-07
Man-Made Radionuclide Concentrations
1994/1997 Spectral Gamma Data Comparison



Historical Gross Gamma Logs for Borehole 30-03-07



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-03-09

Borehole Information

Farm : C
Tank : C-103
Site Number : 299-E27-78
N-Coord : 42,861
W-Coord : 48,231
TOC Elevation : Unknown
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 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 found; 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 : 1B
Detector Type : HPGe
Detector Efficiency : 35.0 %
Calibration Date : 2/97
Calibration Reference :
Logging Procedure : P-GJPO-1783

Log Run Information

Log Run Number : 1
Log Run Date : 4/8/97
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 Run Number : 2
Log Run Date : 4/9/97
Logging Engineer: Alan Pearson
Start Depth, ft.: 98.5
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 23.0
MSA Interval, ft. : .5
Log Speed, ft/min.: n/a

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. All pre- and post-survey field verification spectra, except one, met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The post-survey field from the last logging run failed due to a faulty high voltage power supply. The energy calibration and peak-shape calibration from the spectra that best matched the data were used to establish the 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 man-made radionuclides detected in this borehole were Cs-137, Co-60, Eu-152, and Eu-154. The presence of Cs-137 was measured continuously from the ground surface to 41.5 ft, continuously from 44.5 to 61.5 ft, and intermittently from 62.5 to the bottom of the borehole. Co-60 contamination was detected continuously from 78 ft to the bottom of the logged interval. Eu-152 and Eu-154 contamination was detected only at the ground surface.

The K-40 concentration values gradually increase from 41 to 51.5 ft, decrease from 70.5 to 75 ft, and then gradually increase from 75.5 to the bottom of the logged interval (98.5 ft). A definitive peak occurs on the U-238 plot at a depth of 42 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank 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.

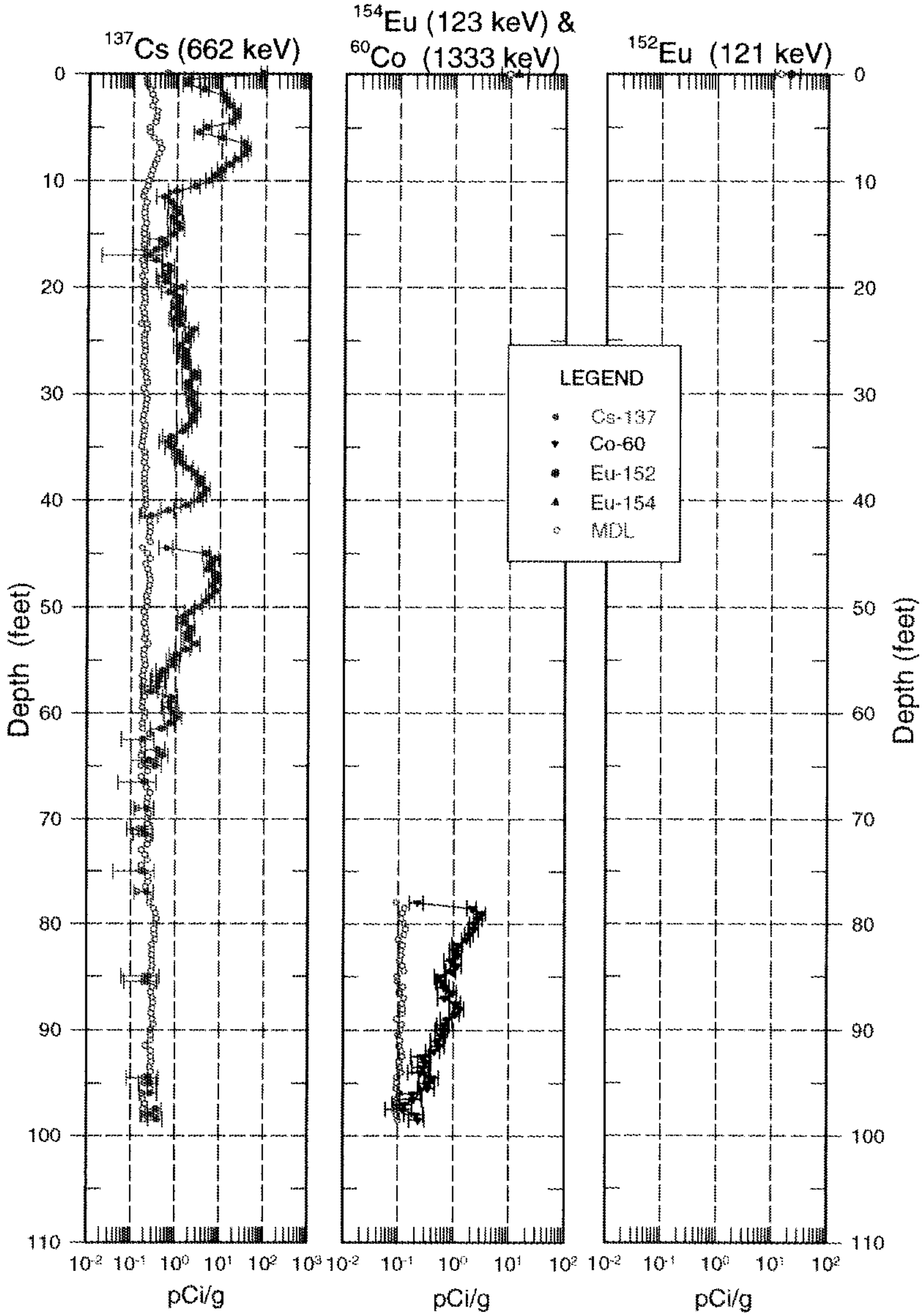
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

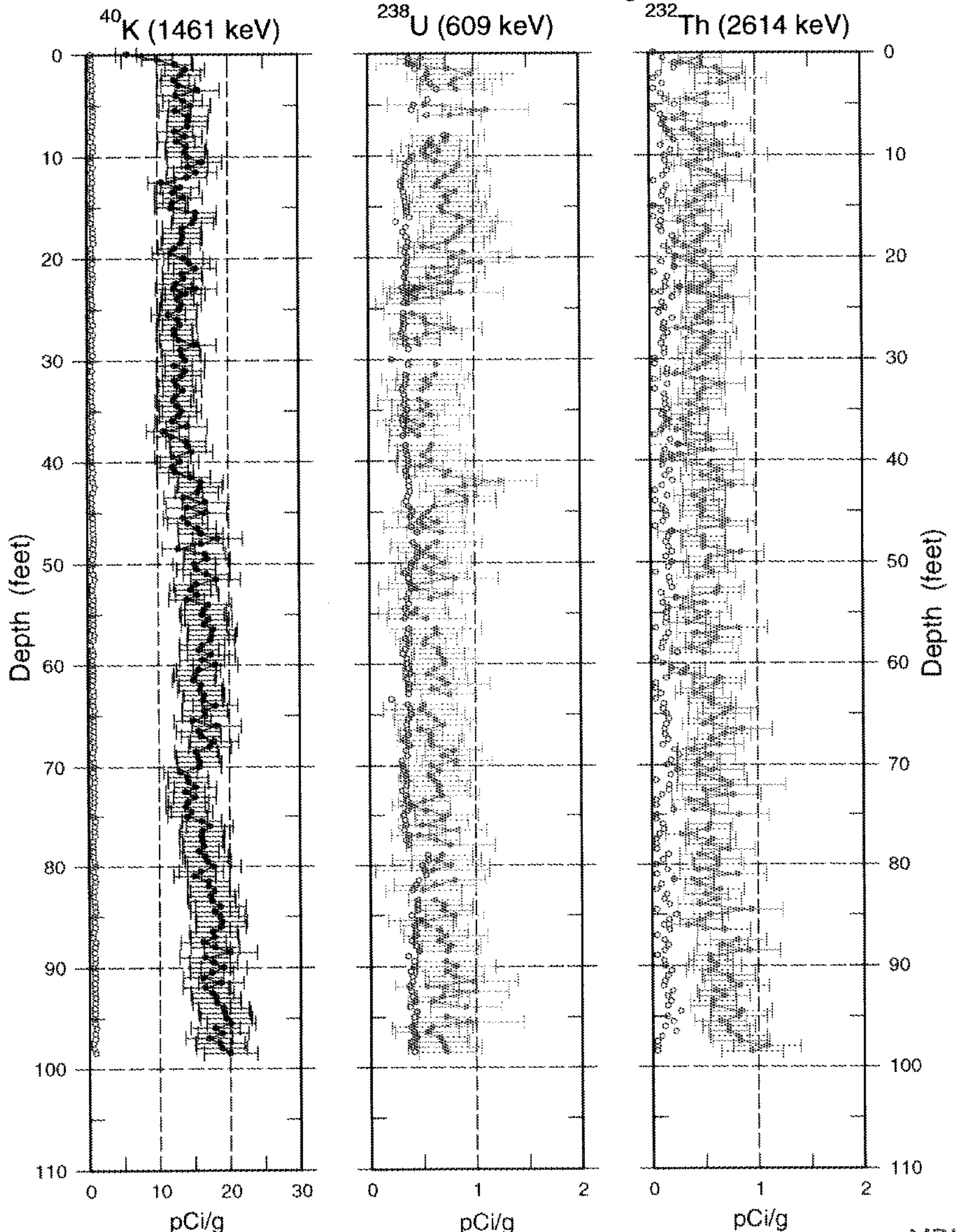
Borehole 30-03-09

A plot of representative historical gross gamma-ray logs from 1975 to 1994 is included. The headings of the plots identify the date on which the data in the plots were gathered.

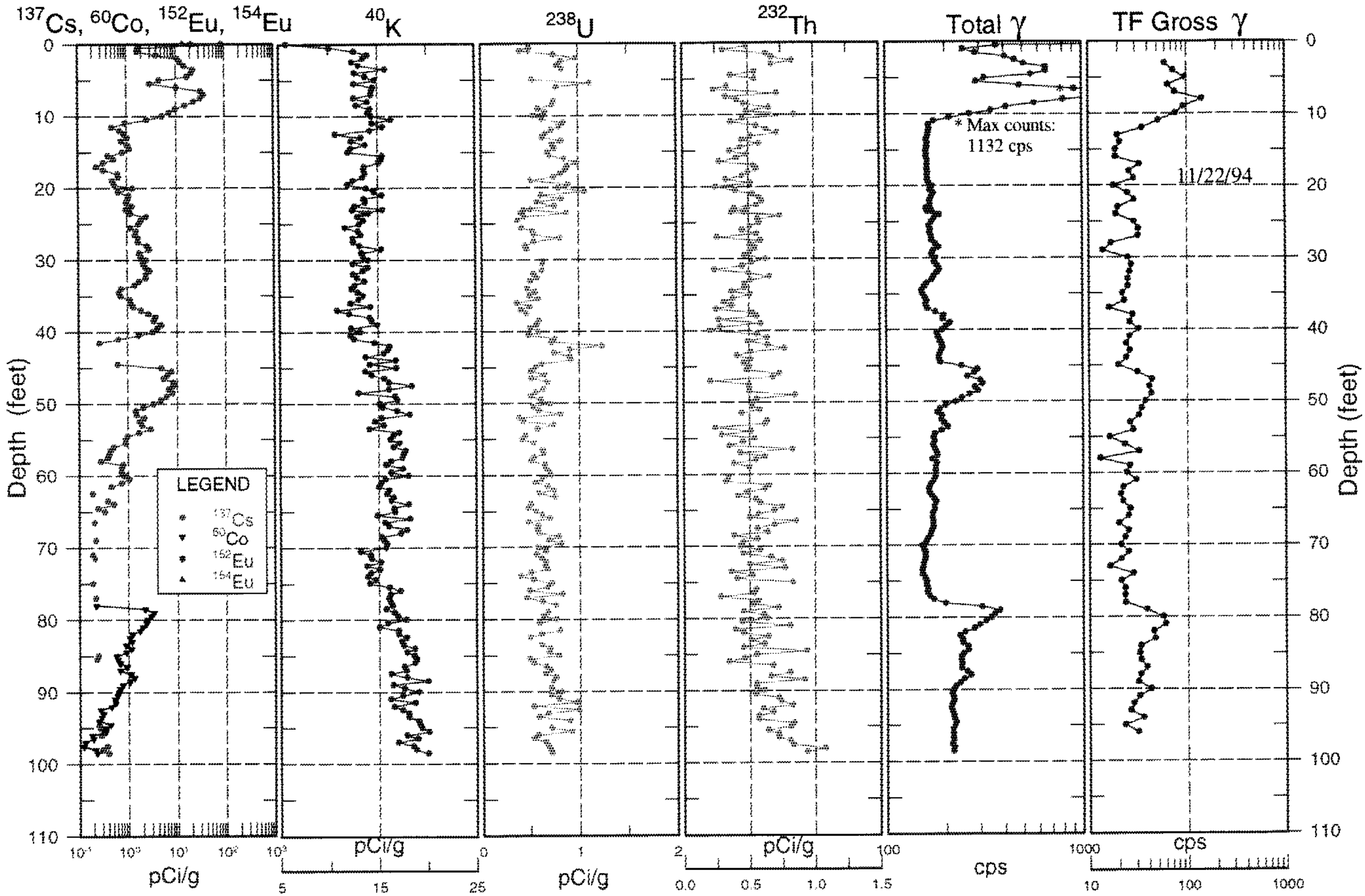
30-03-09
Man-Made Radionuclide Concentrations



30-03-09
Natural Gamma Logs



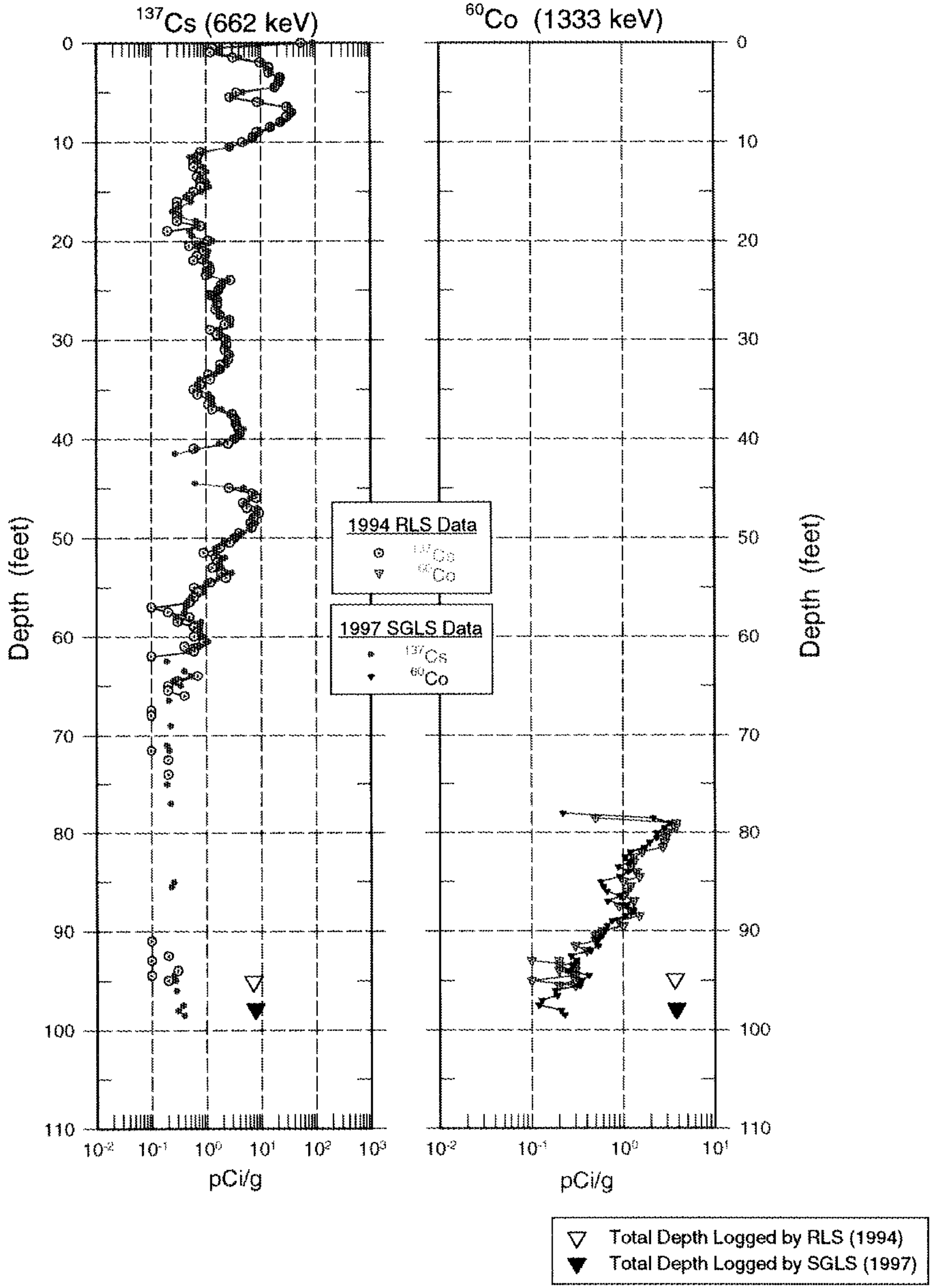
30-03-09 Combination Plot



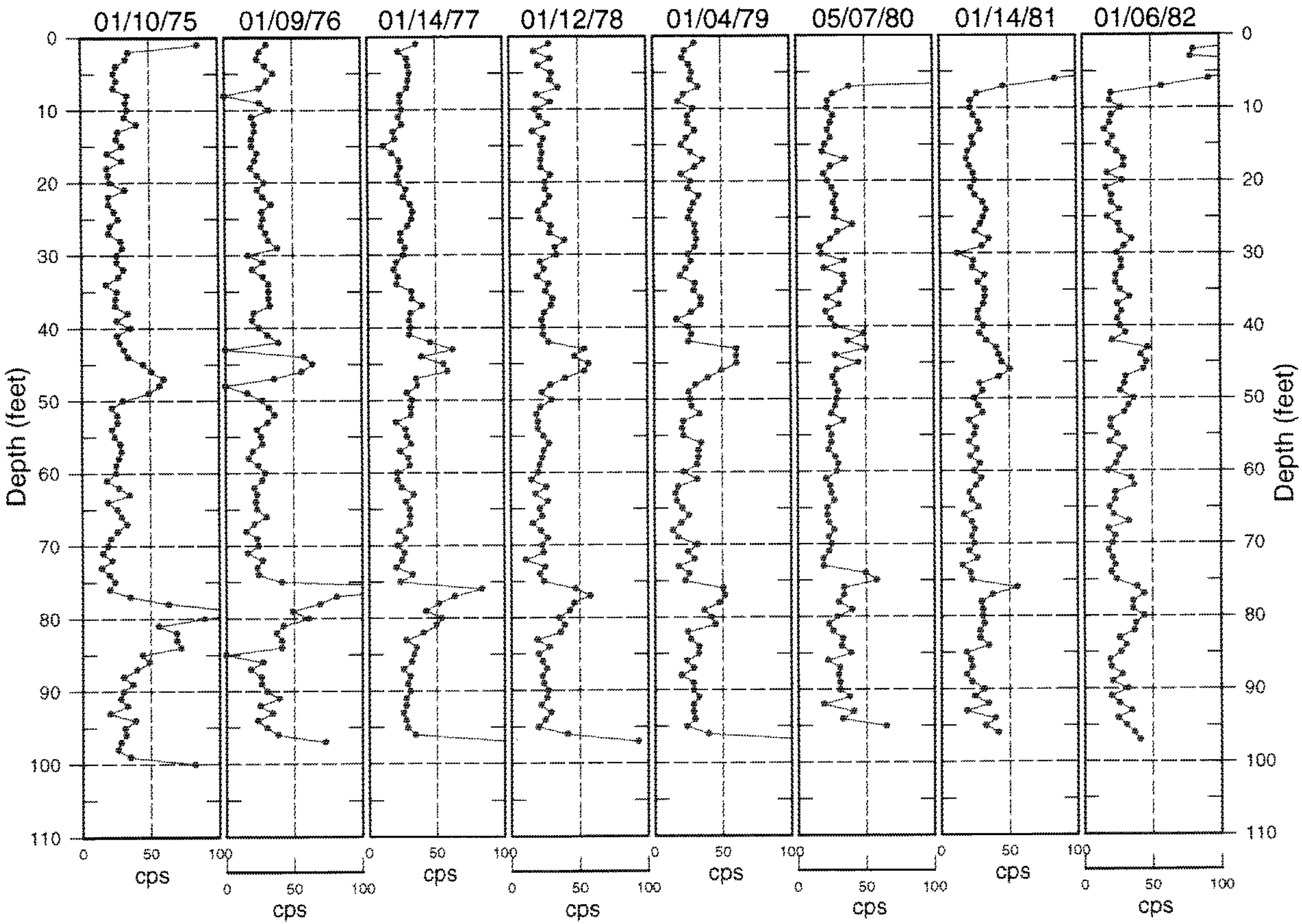
30-03-09

Man-Made Radionuclide Concentrations

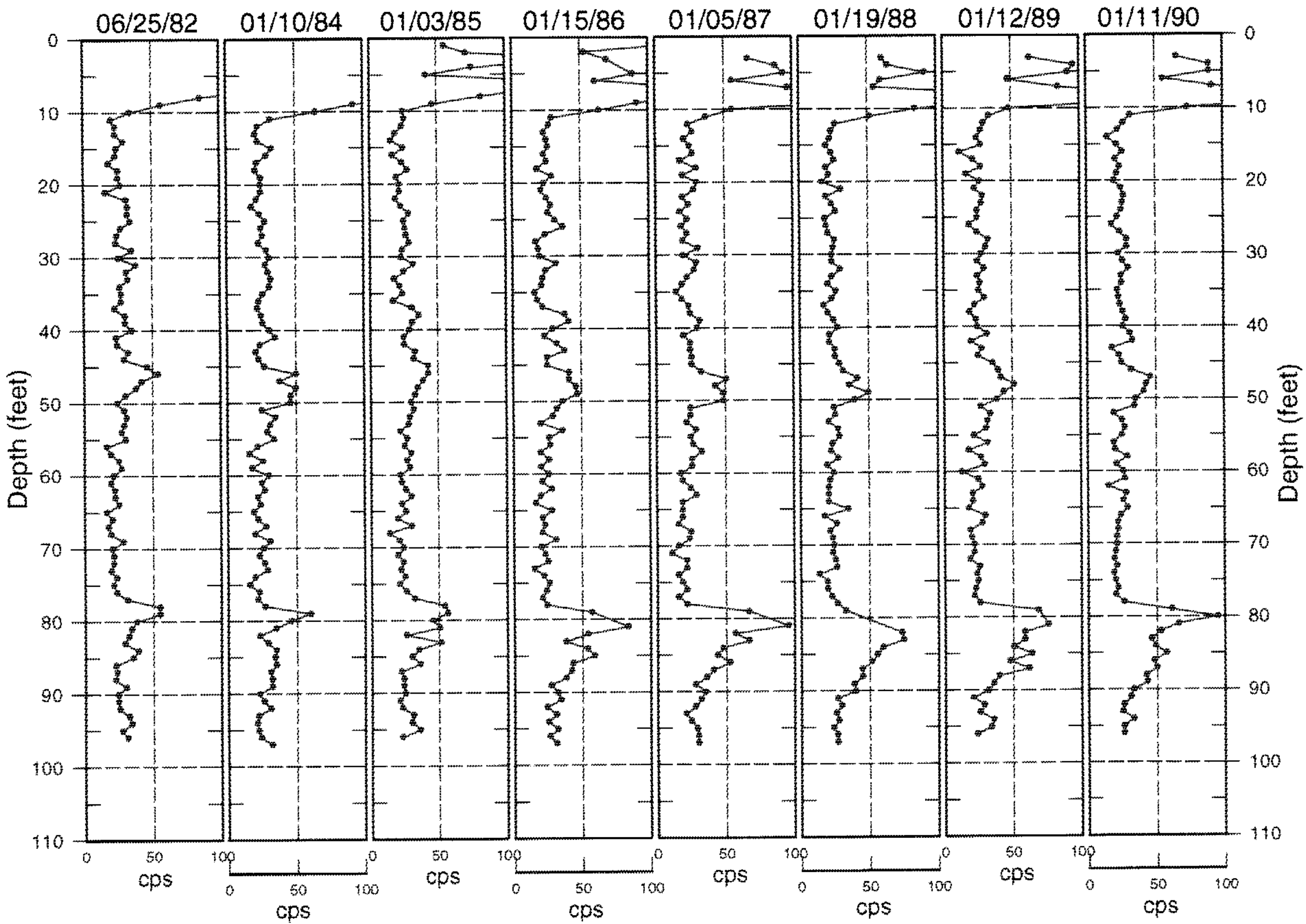
1994/1997 Spectral Gamma Data Comparison



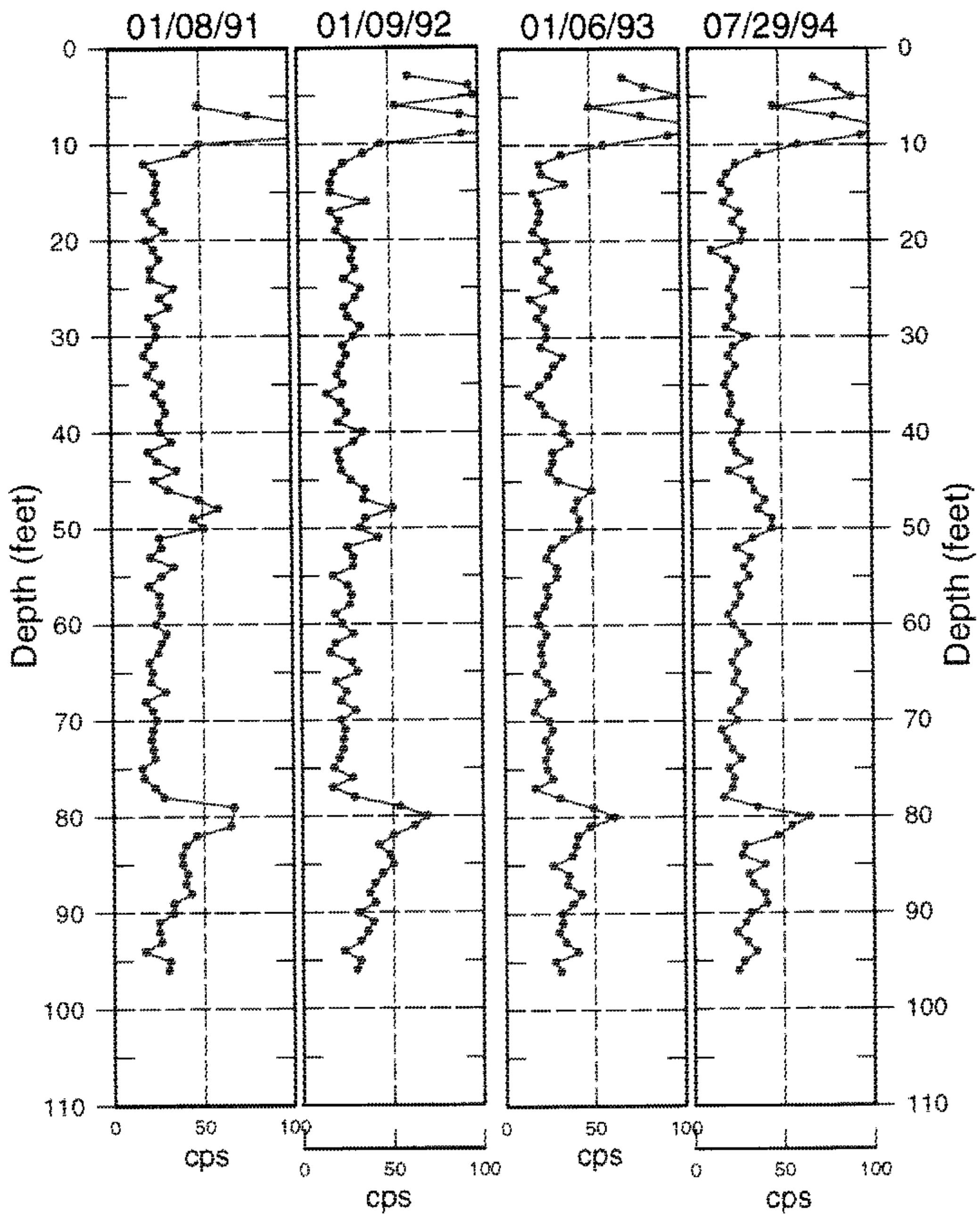
Historical Gross Gamma Logs for Borehole 30-03-09



Historical Gross Gamma Logs for Borehole 30-03-09



Historical Gross Gamma Logs for Borehole 30-03-09



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-06-04

Borehole Information

Farm :	C	Tank :	C-106	Site Number :	299-E27-73
N-Coord :	42,897	W-Coord :	48,288	TOC Elevation :	644.71
Water Level, ft :	None	Date Drilled :	11/30/72		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	130		

Borehole Notes:
This borehole was drilled in November 1972 to a depth of 130 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 :	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 :	2/5/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	129.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	66.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	2/6/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	67.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Borehole 30-06-04

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 5/16/97

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. Cs-137 contamination was detected from the ground surface to about 66 ft with the contamination level generally decreasing with depth. Isolated concentrations of Cs-137 were also detected between 71 and 111 ft. The presence of Co-60 was detected continuously from 85 to 90.5 ft and at 93 ft.

The K-40 concentration values increase gradually from 43 to 49 ft, remain elevated and become increasingly variable to a depth of 75 ft, increase again at 79 ft, and remain elevated to bottom of the logged interval.

It was not possible to identify many of the 609-keV peaks used to derive the U-238 concentrations between the ground surface and 27 ft because of an elevated Compton continuum from the Cs-137.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-102, C-103, and C-106.

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.

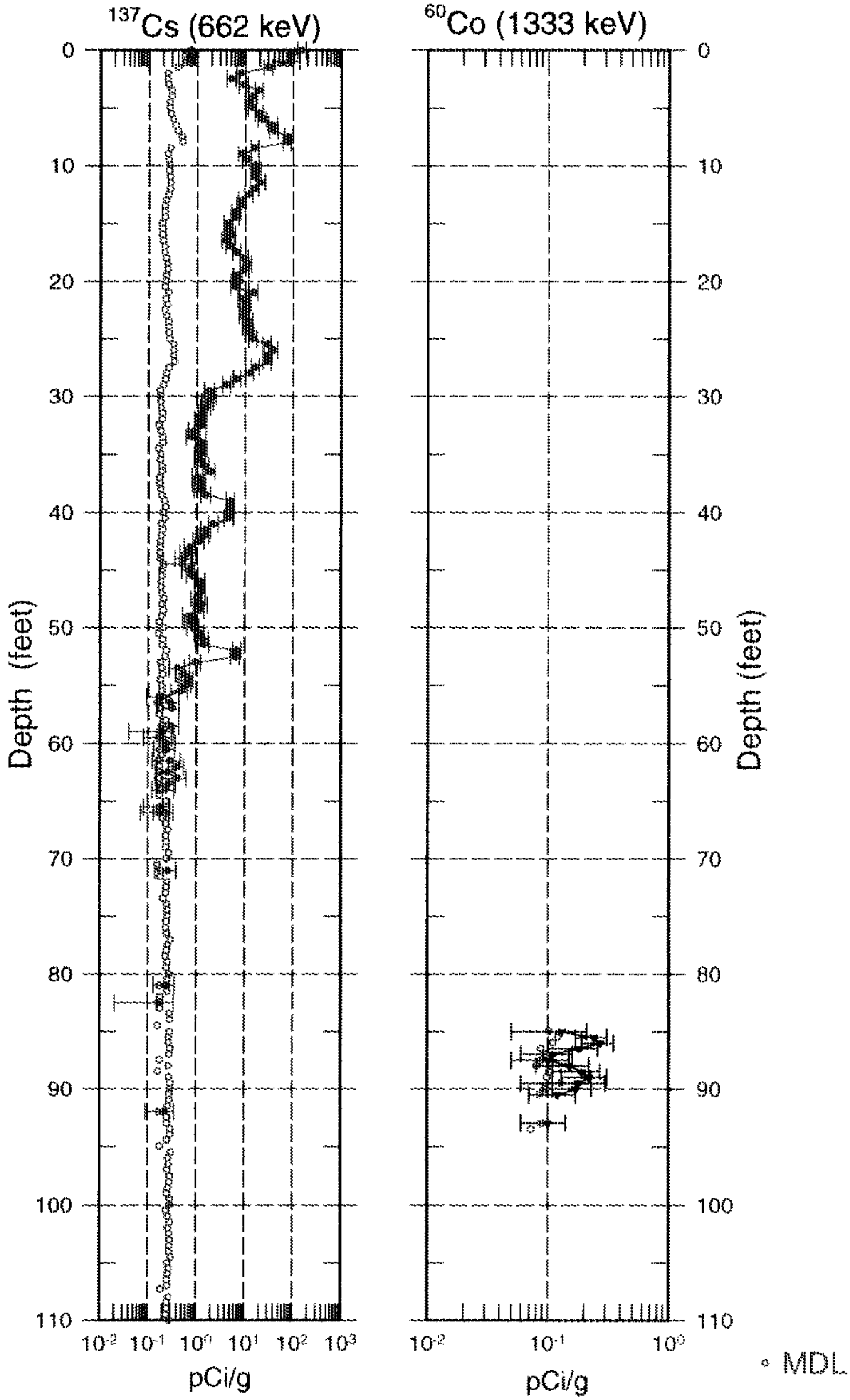
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

A comparison plot is also provided showing the Cs-137 and Co-60 concentrations determined from the SGLS in 1997 and those determined from the Radionuclide Logging System (RLS) in 1993.

A plot of representative historical gross gamma-ray logs from 1975 to 1993 is included. The headings of the plots identify the date on which the data in the plots were gathered.

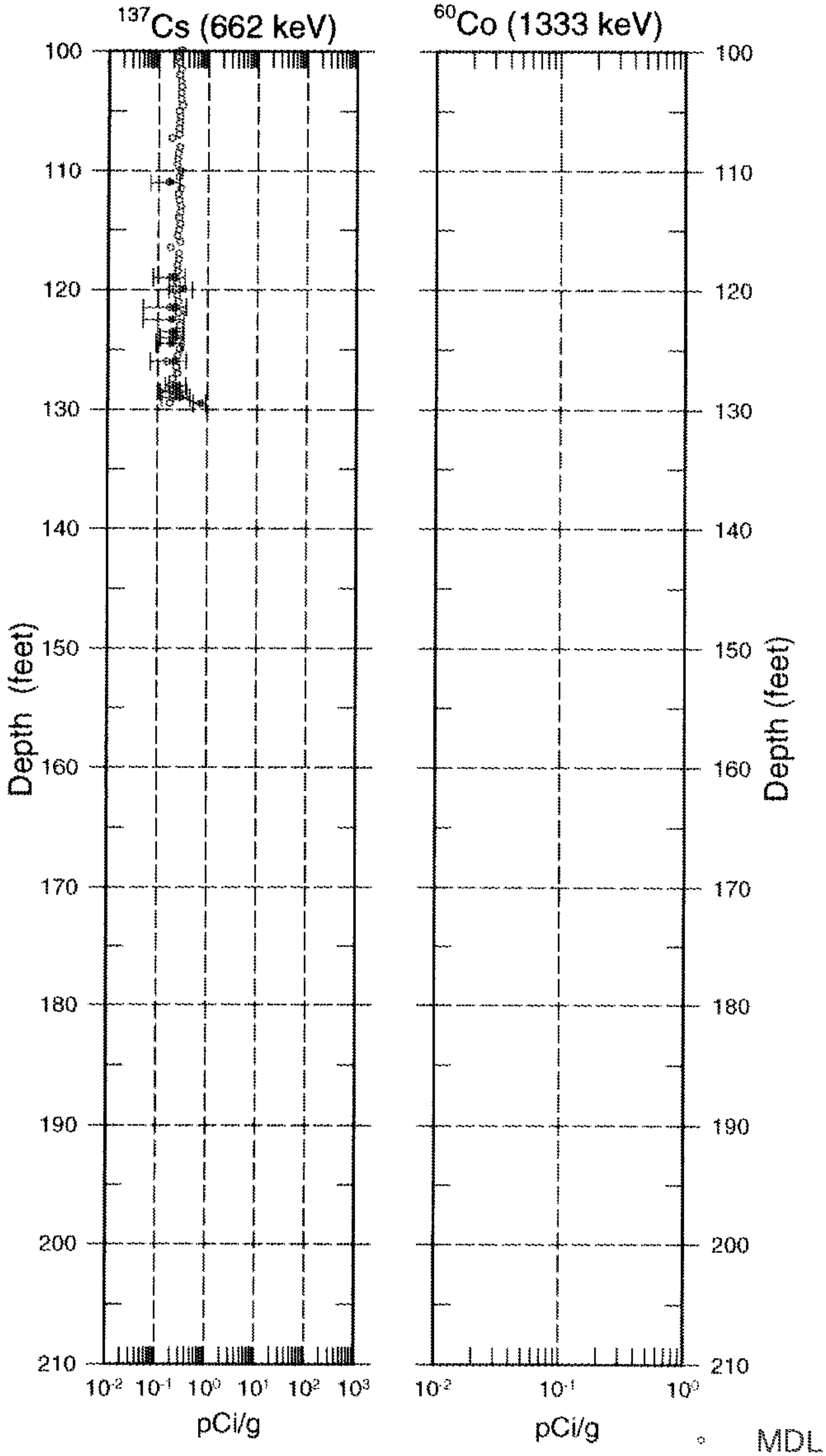
30-06-04

Man-Made Radionuclide Concentrations

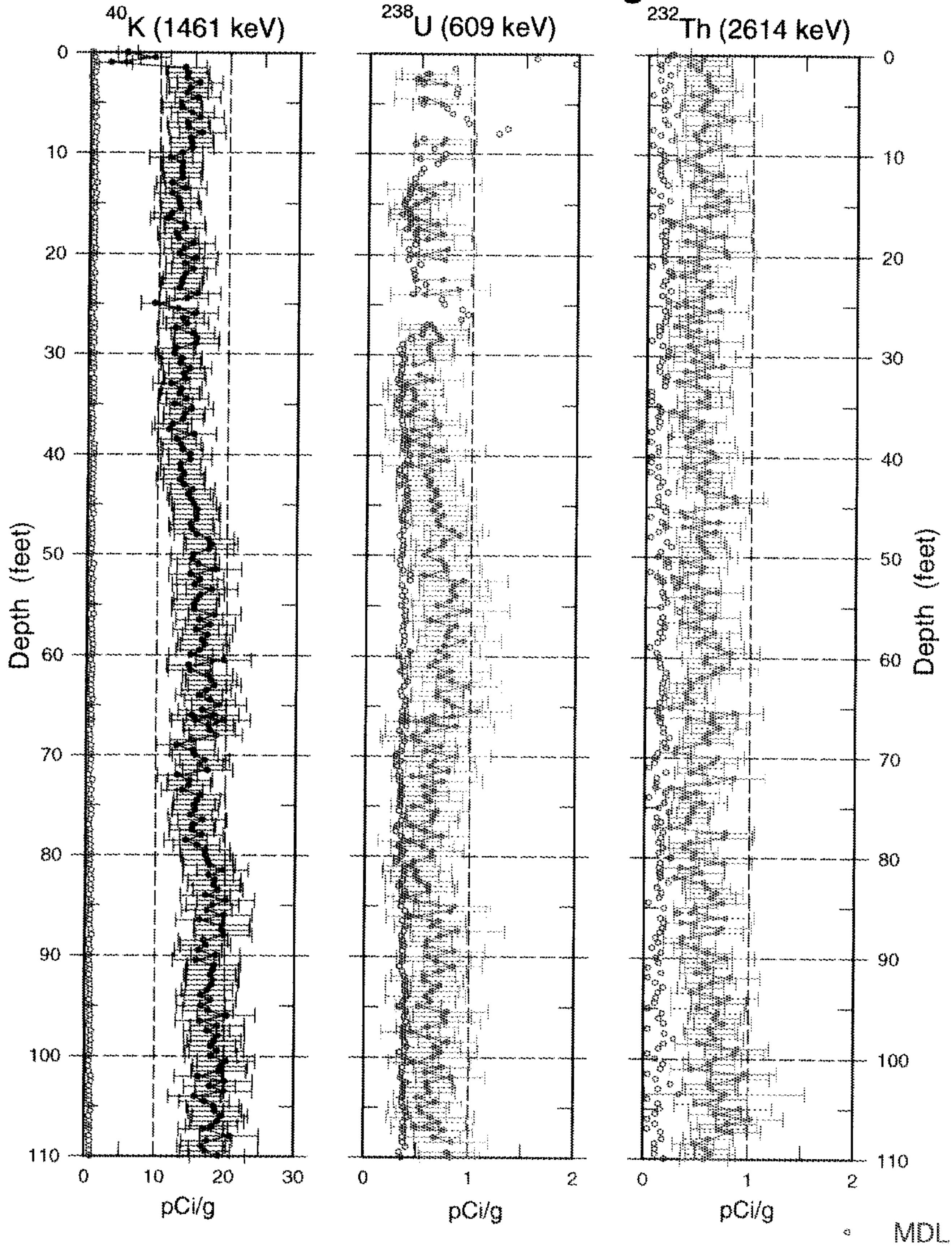


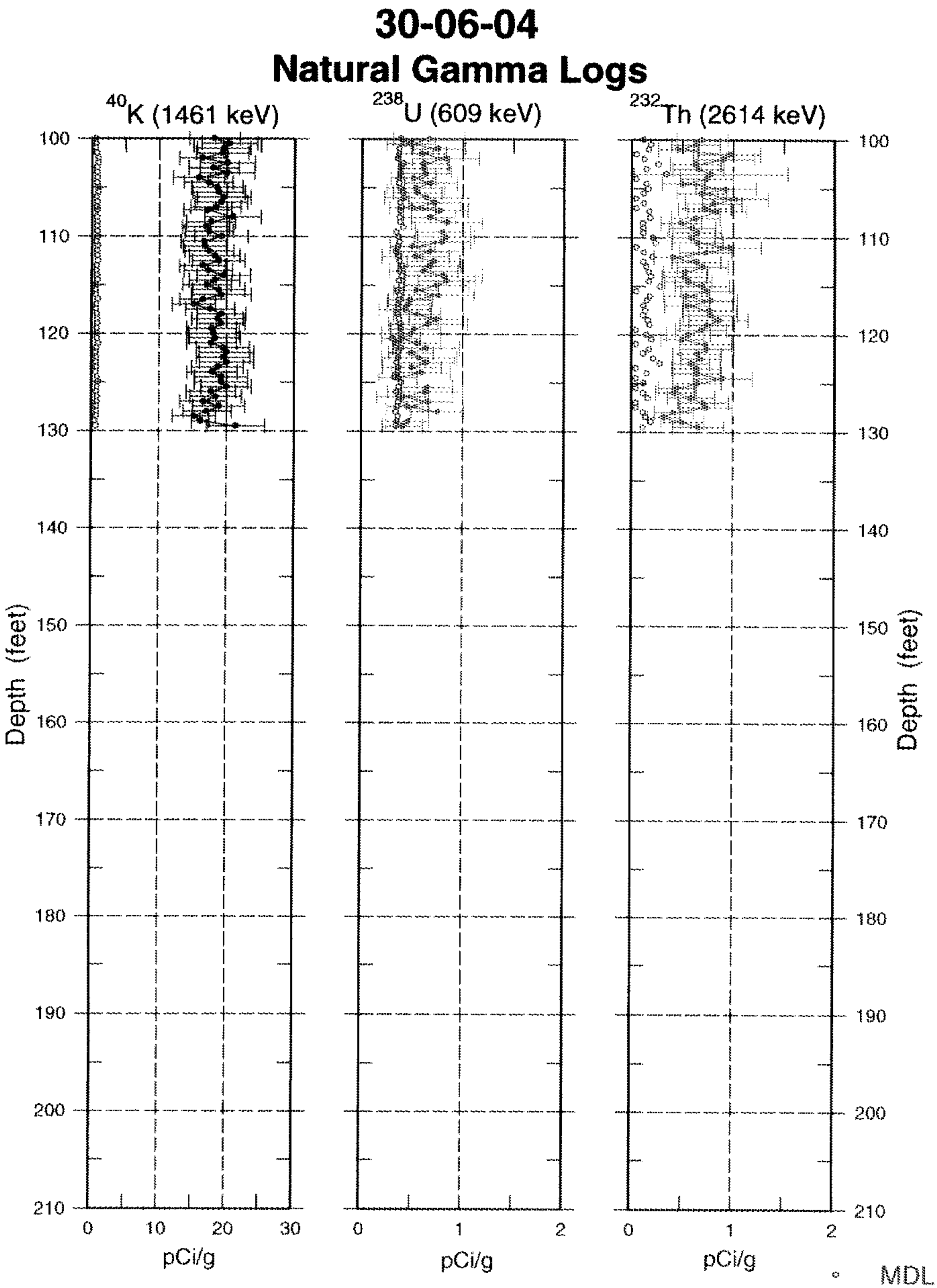
30-06-04

Man-Made Radionuclide Concentrations

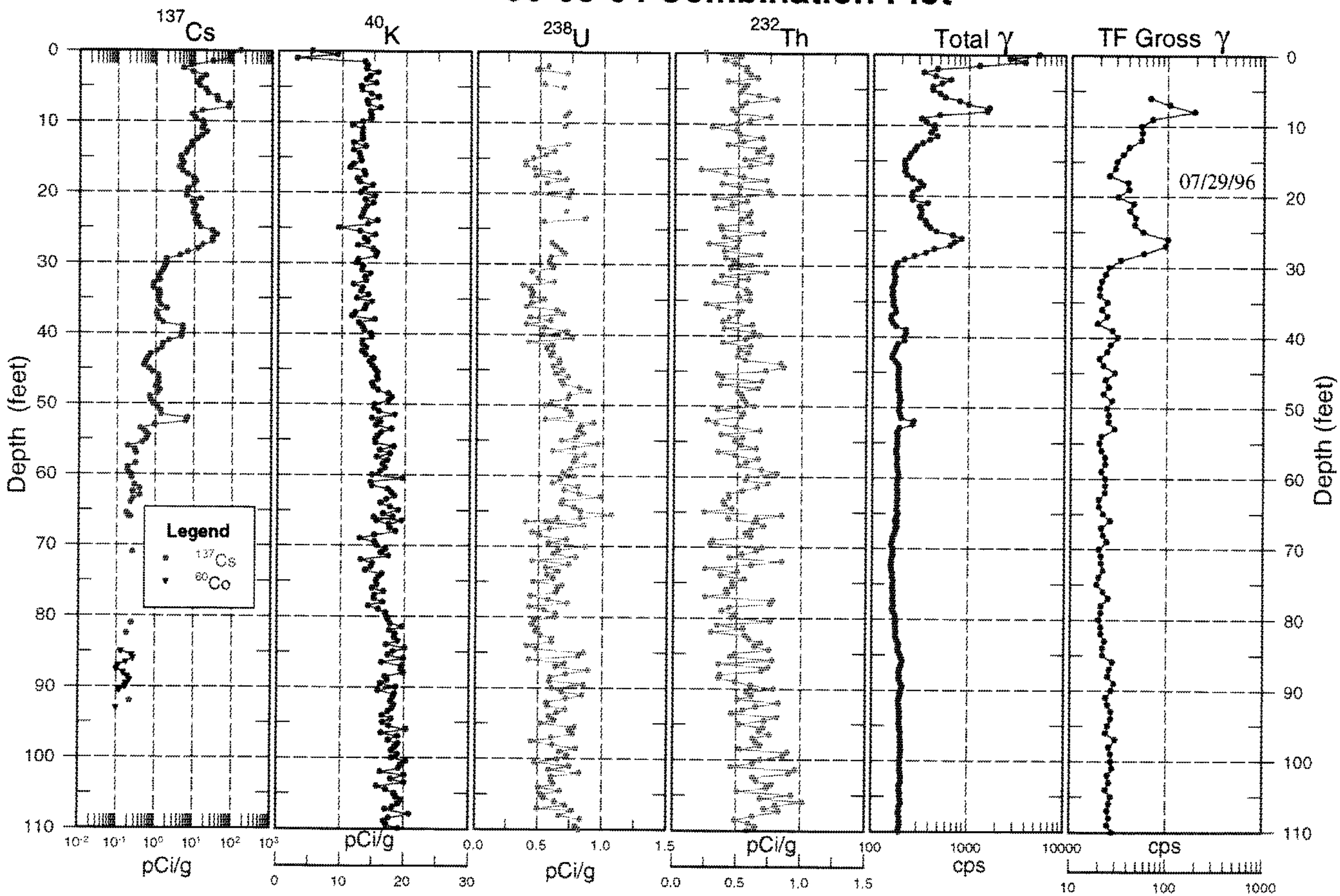


30-06-04
Natural Gamma Logs

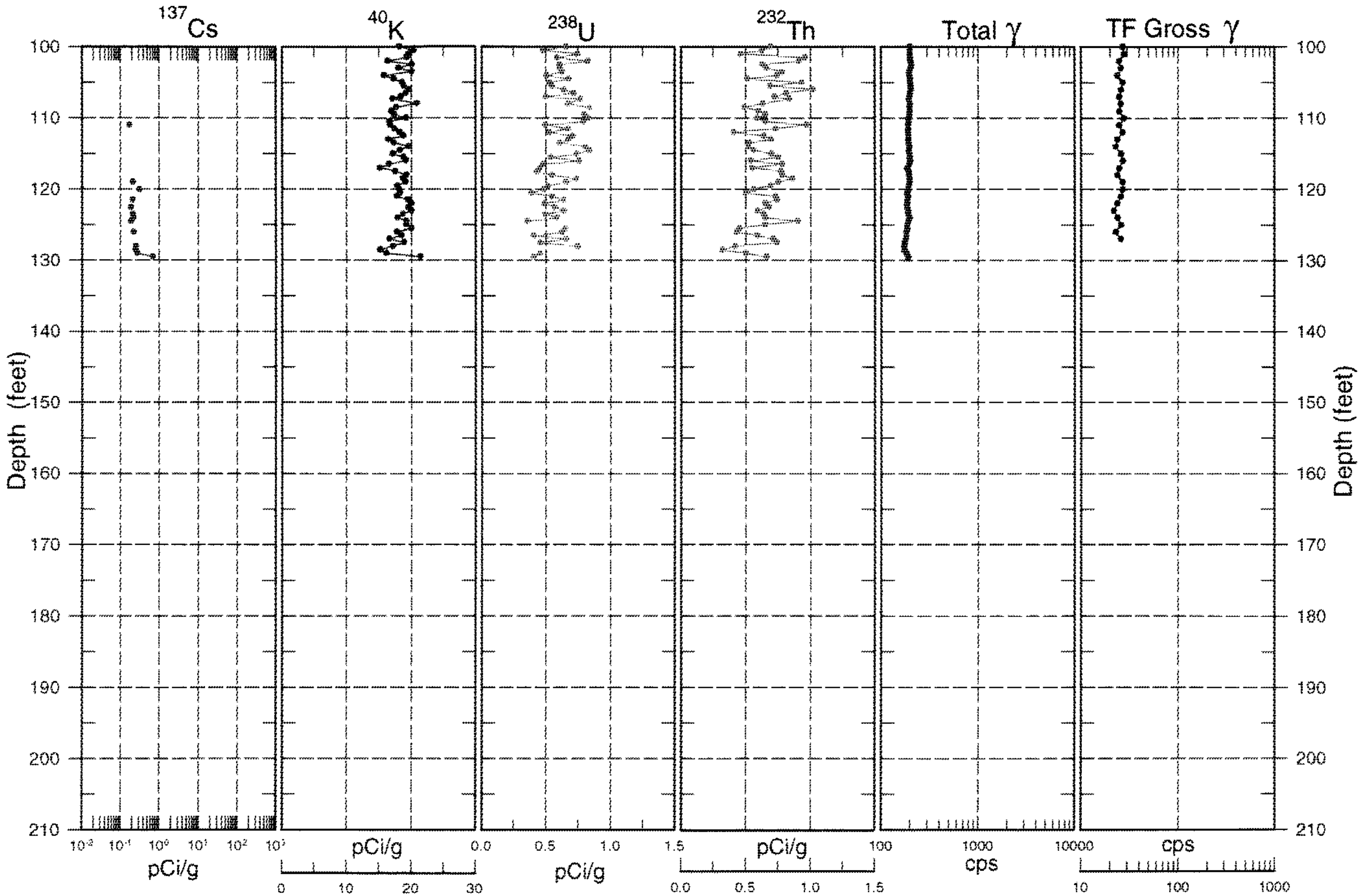



30-06-04
Natural Gamma Logs
40K (1461 keV)
238U (609 keV)
232Th (2614 keV)
Depth (feet)
100
110
120
130
140
150
160
170
180
190
200
210
0
10
20
30
0
1
2
pCi/g
MDL

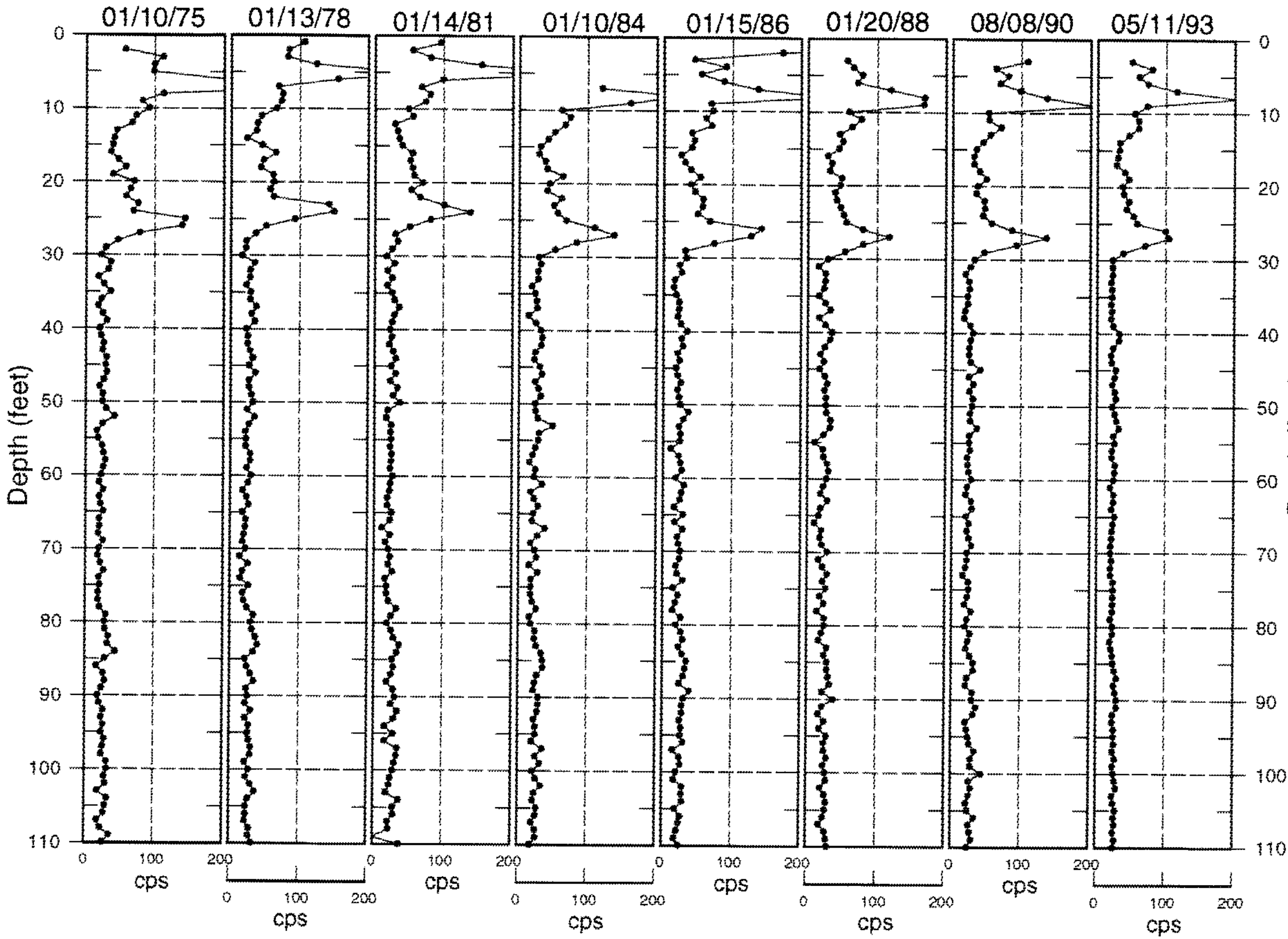
30-06-04 Combination Plot



30-06-04 Combination Plot



Historical Gross Gamma Logs for Borehole 30-06-04



Historical Gross Gamma Logs for Borehole 30-06-04