GJ-HAN-87
Tank C-104

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-104

September 1997

U.S. Department of Energy

GRAND JUNCTION OFFICE

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

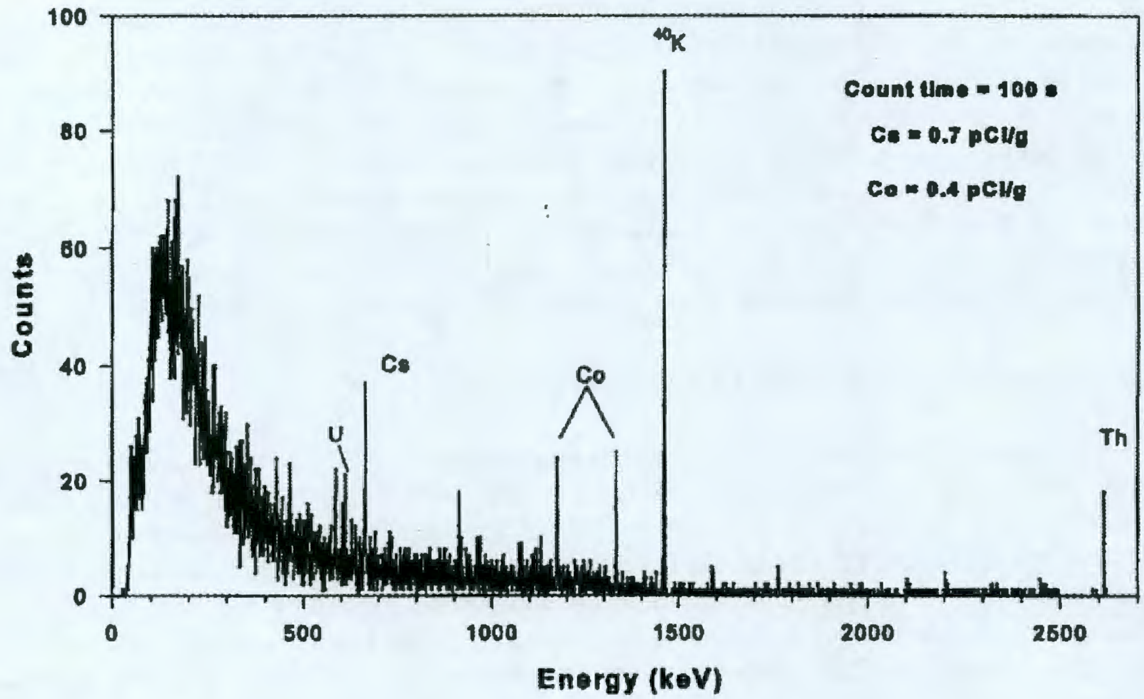

Figure 1. Gamma-Ray Spectrum

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-104," are grouped into a set of data for each borehole. Each set includes a Log Data Report and log plots showing radionuclide concentration versus depth.

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

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

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

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

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

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

3.0 Review of Tank History

3.1 C Tank Farm

3.1.1 Construction History

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

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

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

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

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

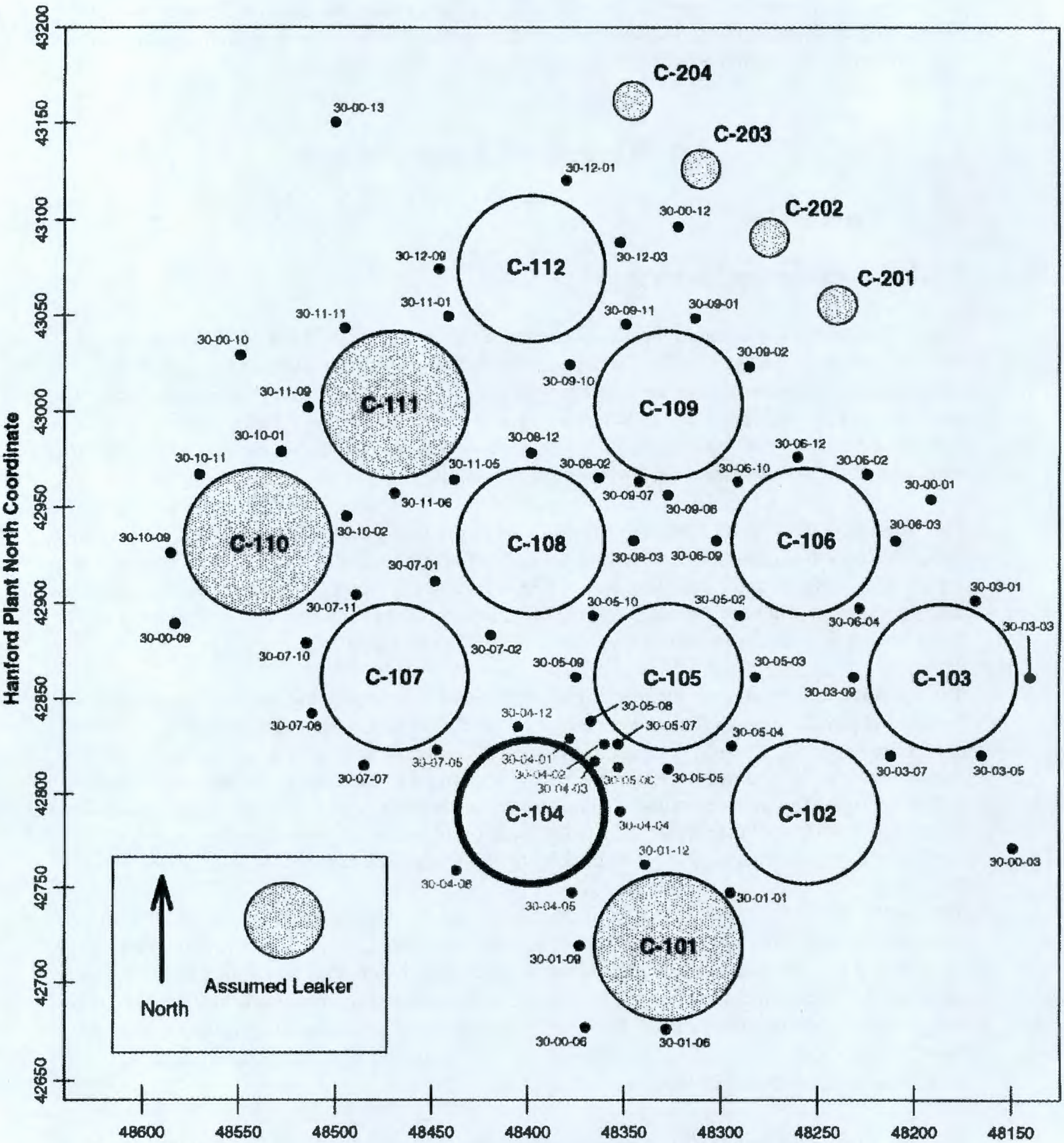

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

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

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

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

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

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

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

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

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

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

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

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

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

3.1.3 Tank Contents

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

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

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

3.1.4 Tank Farm Status

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

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

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

3.2 Tank C-104

Tank C-104 was constructed during 1943 and 1944 and was placed into service in October 1946 (Welty 1988). The tank received metal waste from the fourth quarter of 1946 until the fourth quarter of 1947 (Agnew 1995). The metal waste from tank C-104 was cascaded into tank C-105 beginning in February 1947. The cascade also transferred waste to tank C-106 beginning in July 1947. The cascade series was full by the fourth quarter of 1947, and the metal waste was sluiced to recover uranium in the fourth quarter of 1953 (Anderson 1990). The supernatant was sent to the 244-CR Process Vault during 1954, and the tank was declared empty in the first quarter of 1955. U Plant waste was stored in the tank during the fourth quarter of

1955 (Anderson 1990). After being emptied again, tank C-104 received numerous waste types between 1956 and 1977, including coating waste, PUREX cladding waste, decontamination waste, PUREX organic wash waste, PUREX low-level and high-level waste, and waste water (Anderson 1990; Agnew 1996). The tank presently contains complexant-concentrated waste (Brevick et al. 1994a).

Data collected from borehole 30-04-02, which is located halfway between tanks C-104 and C-105, showed an increase in radiation at a depth of 40 ft during March 1974 (Dukelow 1974). Boreholes 30-05-05, 30-05-06, 30-05-08, and 30-05-09 were drilled in an effort to identify the source of the contamination detected in borehole 30-04-02 (Welty 1988). The investigation indicated the contamination was the result of overfilling tank C-105 and the subsequent leakage from spare inlets and cascade-line packing (Welty 1988).

The tank received approximately 11,000 gal of insoluble, strontium-leached sluicing solids (terminal solids) during 1977. Welty (1988) reports the ^{89}Sr and ^{90}Sr contents of this material was no more than 255 kilocuries; Bath (1977) reports the quantity was anticipated to result in a high-heat load after removal of interstitial liquid.

Two Operating Limit Deviation Reports were issued in 1982 because of surface-level measurements exceeding the decrease criterion (Prince 1982a and 1982b). In both instances, the liquid-level decreases were attributed to evaporation. An Environmental Protection Deviation Report was issued in November 1983 because the liquid-level measurement in tank C-104 exceeded the decrease criterion. The decrease was attributed to evaporation, reduced liquid area, and the Food Instrument Corporation (FIC) plummet contacting soft sludge (Dickman 1983).

Tank C-104 was declared inactive in March 1980 (Brevick et al. 1994b). Waste-level adjustments were made in July 1982 and April 1983. The tank was declared interim stabilized in September 1989, after salt-well pumping was completed. Another waste-level adjustment was made in September 1989, and intrusion prevention was completed in February 1991 (Brevick et al. 1994b).

The surface level of the waste in tank C-104 is monitored with an FIC gauge. The liquid waste volume is determined by the FIC gauge and photographic evaluation; the solid waste volume is determined by photographic evaluation. The surface level of the tank waste, measured from 1991 to 1994, indicates fluctuating data in a decreasing trend with the readings ranging between 90.2 and 87.1 in. (Brevick et al. 1994a). The tank is not equipped with liquid observation instrumentation (Hanlon 1997). The monitoring boreholes surrounding tank C-104 are the primary means of leak detection (Welty 1988).

Tank C-104 is categorized as "sound/deactivated" (Welty 1988). The tank is currently listed as containing concentrated complexant waste and is presently classified as interim stabilized and partially interim isolated. The tank contains 295,000 gal of sludge that includes 11,000 gal of drainable, interstitial liquid (Hanlon 1997).

4.0 Boreholes in the Vicinity of Tank C-104

Ten vadose zone monitoring boreholes surround tank C-104. These boreholes are 30-04-01, 30-04-02, 30-04-03, 30-05-06, 30-04-04, 30-01-12, 30-04-05, 30-04-08, 30-07-05, and 30-04-12. All the boreholes are associated with tank C-104, except boreholes 30-01-12, 30-05-06, and 30-07-05, which are associated with tanks C-101, -105, and -107, respectively. Figure 2 shows the location of each borehole in red.

The algorithms used for the calculation of the radionuclide concentrations from the SGLS data incorporate a correction for the attenuation of the gamma-ray intensity by the borehole casing walls. The 10 boreholes were constructed between March 1970 and October 1974 using 6-in. casing. 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. Therefore, the casing wall thicknesses for the ten 6-in. boreholes are assumed to be 0.280 in., on the basis of the published thickness for schedule-40, carbon-steel casing, which was the typical casing used for 6-in.-diameter boreholes in the 1970s.

The boreholes surrounding tank C-104 are completed above the water table and contain no water. The SGLS data were collected in the move/stop/acquire logging mode with a 100-s acquisition time at 0.5-ft depth intervals.

In 1993, Westinghouse Hanford Company (WHC) performed spectral gamma logging of 14 boreholes surrounding tanks C-105 and C-106 using the Radionuclide Logging System (RLS). This system is the intrinsic germanium logging system that was the predecessor to the SGLS. Borehole 30-05-06 was one of the 14 boreholes included in the RLS logging operation; it is also one of the boreholes located near tank C-104 that was logged by the SGLS. The 1993 RLS data are quantitative spectral gamma-ray log data and are of high quality that allow comparison to the 1997 SGLS data. Individual plots that compare the measured concentrations of man-made radionuclides for borehole 30-05-06 from 1993 and 1997 are included in Appendix A. A more detailed discussion about the characteristics of the RLS detector is included in the TSDRs for tanks C-105 (DOE 1997a) and C-106 (DOE 1997b).

The following sections present results of the spectral gamma-ray log data collected from these boreholes. Appendix A contains the plots of the SGLS log data and a plot of the RLS log data from borehole 30-05-06. 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 1996, the RLS log data for borehole 30-05-06, and results from other investigations were used in the preparation of this report.

4.1 Borehole 30-04-01

Borehole 30-04-01 is located approximately 2 ft from the northeast side of tank C-104 and was given the Hanford Site designation 299-E27-115. This borehole was drilled in July 1974 to a depth of 50 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 49.0 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. ^{137}Cs contamination was detected nearly continuously from the ground surface to the bottom of the logged interval. A near-surface zone of moderate ^{137}Cs contamination (25 to 100 pCi/g) extends to a depth of 5 ft. Between 5 and 16.5 ft, the ^{137}Cs contamination decreases to about 10 to 20 pCi/g. Individual zones of elevated ^{137}Cs contamination ranging in concentration from 0.5 to 3 pCi/g occur between 25 and 45 ft. The highest ^{137}Cs concentration (99 pCi/g) was detected at 4.5 ft.

The ^{40}K concentration values increase from 37.5 to 38.5 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 37.5 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 5 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 ^{238}U concentration values decrease sharply at about 25 ft, which corresponds to the beginning and end of individual log runs. This concentration decrease is most likely the result of radon venting up the borehole between log runs. The variability in the ^{238}U background is not related to changes in the efficiency of the logging system, but more likely to the weather conditions during a particular run. The 609-keV spectral peak used to calculate the ^{238}U concentration is actually emitted by ^{214}Bi, and the calculated ^{238}U concentration is only accurate if the ^{214}Bi and ^{238}U are in secular equilibrium. Because radon gas is an intermediate member of the ^{238}U decay chain, the equilibrium condition will be disturbed by changes in the weather conditions in the vicinity of the borehole. Wind, or the absence of it, affects the rate of radon venting from the borehole. The variations in the calculated ^{238}U background do not affect the determination of man-made gamma-ray-emitting nuclides from the SGLS data set.

The SGLS total gamma-ray plot reflects the presence of the man-made radionuclides. The total count-rate profile is sensitive to ^{137}Cs concentrations greater than 1 pCi/g.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The gross gamma activity reflects the shallow subsurface ^{137}Cs contamination. The earliest recorded historical gross gamma-ray log data (January 1975) show a higher count-rate anomaly in this region, indicating the ^{137}Cs contamination was deposited before 1975 and suggesting that other short-lived radionuclides were also present in this region but have decayed away.

Summaries of the historical gross gamma log data from 1973 to 1987 presented in Welty (1988) identify the peak gamma-ray activity levels below a depth of 20 ft. However, no subsurface gross gamma anomalies were identified in this borehole.

Most of the contamination detected around this borehole appears to have originated from the infiltration and deposition of surface contamination. The shallow subsurface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated down into the backfill surrounding the borehole.

Zones of slightly elevated ^{137}Cs contamination were detected at 26 ft, 33 ft, and 40 ft. Elevated levels of ^{137}Cs contamination were detected at approximately the same depths in other nearby boreholes and may be related to a leak from the C-104-to-C-105 cascade line described in Welty (1988). The distribution of this contamination may represent the accumulation of ^{137}Cs contamination on top of finer grained sediments within the backfill material and at the base of the tank farm excavation.

Some of the ^{137}Cs contamination detected near the bottom of the logged interval may have been carried down during the drilling of this borehole or later migrated down the outside of the borehole casing and accumulated around the bottom of the borehole.

4.2 Borehole 30-04-02

Borehole 30-04-02 is located approximately 8 ft from the northeast side of tank C-104. It was given the Hanford Site designation 299-E27-67. This borehole was drilled in December 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 134.5 ft.

The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{235}U were detected in this borehole. Continuous ^{137}Cs contamination was detected from the ground surface to 27 ft, 50 to 56.5 ft, and 61.5 to 64.5 ft. A near-surface zone of moderate ^{137}Cs contamination (25 to 45 pCi/g) extends to a depth of 2.5 ft. The ^{137}Cs contamination decreases to less than 20 pCi/g below this zone and continues to gradually decrease to less than 1 pCi/g below 22 ft. Discrete layers of elevated ^{137}Cs contamination, ranging in concentration from 1 to 8 pCi/g, occur between 20 and 32 ft. A few small zones of ^{137}Cs contamination were detected at low concentrations between 35 ft and the bottom of the logged interval. The highest ^{137}Cs concentration (70 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

A significant zone of ^{60}Co contamination was detected from 38 to 58.5 ft. The highest ^{60}Co concentrations (about 1 pCi/g) were detected near the top of this zone. A few occurrences of ^{60}Co were detected at very low concentrations (0.1 pCi/g) between 60.5 and 63.5 ft. The ^{60}Co

contamination delineates a significant contaminant plume located at considerable depth below the majority of the ^{137}Cs contamination.

A single occurrence of ^{235}U was detected at the ground surface with a concentration of 5.8 pCi/g. This is probably not an accurate concentration value for reasons discussed previously. The gamma rays probably originated from an above-ground source such as nearby contaminated equipment or contamination that is localized to the ground surface.

The increase in the ^{40}K concentration values at about 39 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The drilling log reports a change in lithology from sand, gravel, and wood to very coarse sand at this depth. The ^{40}K concentration values increase from 63.5 to 65.5 ft and remain elevated to the bottom of the logged interval. The drilling log reports a change in lithology from coarse sand and fine gravel to medium sand at a depth of about 60 ft. The lithologic information reported in the drilling log supports the interpretation that the increase in the ^{40}K concentration values at about 64 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 11.5 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 distribution of ^{137}Cs and ^{60}Co contamination in the upper region of the vadose zone and the naturally occurring radionuclides elsewhere. The distinctive peak in the total count rate at 40 ft corresponds with the peaks in the ^{60}Co, ^{40}K, and ^{238}U concentrations shown on the combination plot. The count rate increases sharply at about 63 ft, corresponding to increases in the KUT concentrations at this depth.

The interval between 30 and 50 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 ^{137}Cs and naturally occurring 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 very good repeatability of the measured gamma-ray spectral peak intensities used to calculate the radionuclide assays.

The historical gross gamma log data from 1975 to 1996 were reviewed. The most recently acquired historical gross gamma data are presented on the combination plot. The profile of the gross gamma-ray plot generally reflects the ^{137}Cs and ^{60}Co contamination detected by the SGLS. This profile was evident at significantly higher count rates on the earliest recorded historical gross gamma log (January 1975), indicating that the contamination was deposited before 1975 and that the ^{60}Co was probably present at higher concentrations but underwent significant radioactive decay since that time.

Summaries of the historical gross gamma log data from 1973 to 1987 are presented in Welty (1988). An activity peak was identified at a depth of 41 ft in early 1973, which correlates to the depth of the ^{60}Co contamination detected on the SGLS plot. The activity peak shifted upward and downward as much as 4 ft in depth during the reporting period, which is probably attributable to depth control problems associated with the gross gamma system. The peak amplitude slowly increased until June 1974, then gradually decreased to stable levels by June 1983, indicating the deposition and subsequent decay of the ^{60}Co contamination at this depth.

The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The slightly elevated ^{137}Cs contamination at a depth of 8 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone.

The zones of slightly elevated ^{137}Cs contamination detected at depths of 20.5, 26, 31.5, and 53 ft may be related to the C-104-to-C-105 cascade-line leak. The distribution of this contamination is very similar to the distribution observed in borehole 30-04-01 and may represent accumulation of ^{137}Cs contamination on top of finer grained sediments within the backfill material.

Much of the ^{137}Cs contamination detected below about 35 ft was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination detected at the bottom of the logged interval is probably from particulate matter that has fallen down the inside of the borehole.

The zone of ^{60}Co contamination between 38 and 63.5 ft probably represents the remnant of a plume related to the cascade-line leak that occurred between tanks C-104 and C-105. The top of the ^{60}Co contamination zone correlates with the base of the tank farm excavation. The vertical extent of the ^{60}Co plume is confined to the sediments of the gravel-dominated facies of the Hanford formation.

4.3 Borehole 30-04-03

Borehole 30-04-03 is located approximately 2 ft from the northeast side of tank C-104. It was given the Hanford Site designation 299-E27-116. This borehole was drilled in July 1974 to a depth of 50 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 49.0 ft.

The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{235}U were detected in this borehole. ^{137}Cs contamination was detected continuously from the ground surface to 28 ft and at the bottom of the logged interval (48 to 49 ft). A near-surface zone of moderate ^{137}Cs contamination (10 to 50 pCi/g) extends to a depth of about 3 ft. The ^{137}Cs contamination decreases to less than 10 pCi/g below this zone and continues to gradually decrease to less than 3 pCi/g below 14 ft. A very distinct zone of ^{137}Cs contamination occurs between 21 and 26 ft. The highest concentration of ^{137}Cs (531 pCi/g) was detected within this zone at a depth of 23 ft.

^{60}Co contamination was detected continuously from 26 ft to the bottom of the logged interval, delineating a large plume located directly below the zone of high ^{137}Cs contamination. The ^{60}Co concentrations within this plume generally range from 3 to 6 pCi/g.

A single occurrence of ^{235}U was detected at the ground surface with a concentration of 4.1 pCi/g. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration. The gamma rays probably originated from an above-ground source such as nearby contaminated equipment or contamination that is localized to the ground surface.

The ^{40}K concentration values increase from 37 to 38 ft and generally remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentration at 37 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations from 21 to 40.5 ft and along several short intervals above and below this region. In addition, it was not possible to identify any of the 1460- and 2614-keV peaks used to derive the ^{40}K and ^{232}Th concentrations between 22 and 24 ft. The KUT data were absent between 22 and 24 ft because this interval was logged by the SGLS in real time since the dead time exceeded 50 percent. Outside this region, the 609-keV peaks were not identified because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV region, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the presence of the ^{137}Cs contamination in the upper portion of the borehole and the extensive ^{60}Co plume in the lower portion.

The historical gross gamma log data from 1980 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The plot does not illustrate the near-surface peak shown on the SGLS plot because no data were collected at the 1- and 2-ft intervals. The gross gamma plot does reflect the distinct zone of highly concentrated ^{137}Cs contamination between 21 and 28 ft. Slightly anomalous count rates occur below this zone that probably represent the elevated ^{60}Co concentrations detected by the SGLS within this region. The earliest recorded historical gross gamma data available (July 1980) indicate that the zone of high ^{137}Cs contamination and the extensive ^{60}Co plume detected by the SGLS were present around this borehole at that time.

A group of representative historical gross gamma-ray logs acquired between 1980 and 1994 are presented in Appendix A. The log plot sequence shows that the ^{137}Cs contamination appears to have migrated downward as much as 4 ft through the vadose zone since 1980. The log plots also show a higher count-rate anomaly in 1980 and 1981 within the region of ^{60}Co contamination.

The activity in this region has since decreased to about one quarter or less of the original activity. The ^{60}Co contamination was probably introduced into this region at a higher concentration but has undergone radioactive decay since that time.

Summaries of the historical gross gamma log data from 1974 to 1987 are presented in Welty (1988). A significant activity peak was identified at a depth of 23 ft in August 1974, suggesting that the ^{137}Cs contamination detected by the SGLS at this depth was present in the vadose zone before 1974. The anomalous activity generally decreased in intensity between 1975 and 1983, but increased from 1983 until the end of the reporting period in 1987. The activity peak moved downward from 21 to 24 ft between 1981 and 1987, corresponding with the downward migration of the ^{137}Cs contamination shown on the log plot sequence.

The ^{137}Cs distribution in the upper 20 ft of this borehole is very similar to the distribution in borehole 30-04-02. The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The slightly increased ^{137}Cs concentration at a depth of 12 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone.

The distinct zone of high ^{137}Cs contamination detected between 21 and 26 ft and the extensive plume of ^{60}Co contamination that underlies it probably resulted from the C-104-to-C-105 cascade-line leak. The discrete nature of both contaminant plumes suggests that this borehole lies within proximity of the leak source. Although the ^{137}Cs contamination around this borehole appears to be confined to the backfill material, the lateral extent of the ^{137}Cs plume is unknown. The vertical extent of the ^{60}Co contamination is unknown because of the limited depth of the borehole.

The zone of increasing ^{137}Cs contamination at the bottom of the logged interval is probably from particulate matter that has either fallen down the inside of the borehole or has migrated down the outside of the borehole casing and accumulated around the bottom of the borehole.

4.4 Borehole 30-05-06

Borehole 30-05-06 is located approximately 10 ft from the northeast side of tank C-104. It was given the Hanford Site designation 299-E27-119. This borehole was drilled in July 1974 to a depth of 60 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, rises approximately 4 in. above the ground surface. The total logging depth achieved by the SGLS was 57.5 ft.

The man-made radionuclides ^{137}Cs and ^{235}U were detected in this borehole. The ^{137}Cs contamination was detected continuously from the ground surface to 33.5 ft and from 37.5 ft to the bottom of the logged interval (57.5 ft). A near-surface zone of moderate ^{137}Cs contamination (10 to 30 pCi/g) extends to a depth of 2 ft. The ^{137}Cs contamination decreases to less than 10 pCi/g below this zone and continues to gradually decrease to less than 1 pCi/g below 26 ft. A region of relatively higher ^{137}Cs contamination, with concentrations generally ranging from 0.5 to

1 pCi/g, was detected between 41 and 52 ft. The highest ^{137}Cs concentration (70 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

A single occurrence of ^{235}U was detected at the ground surface with a concentration of 3.6 pCi/g. This is probably not an accurate concentration value for reasons discussed previously. The gamma rays probably originated from an above-ground source such as nearby contaminated equipment or contamination that is localized to the ground surface.

The significant increase in the ^{40}K concentration values between 38.5 and 39.5 ft may represent a change in lithology from backfill material to the undisturbed Hanford formation. The ^{40}K concentration values become variable from about 40 to 53.5 ft and may represent sand or silt interbeds within the gravel-dominated facies. Because the lithology reported on the drilling log contains minimal detail, it cannot be used to support or contradict the interpretation of the concentration changes shown on the ^{40}K plot.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 2.5 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 ^{137}Cs concentration profile in this borehole. The numerous count-rate peaks shown on the total gamma-ray plot generally correspond to the peaks shown on the ^{137}Cs concentration plot.

A plot included in Appendix A compares spectral gamma data collected with the RLS in 1993 to spectral gamma data collected with the SGLS in 1997. The plot shows good repeatability of the ^{137}Cs data in the upper 25 ft of the vadose zone where the ^{137}Cs concentrations range from 2 to 10 pCi/g. The data repeat less closely along the region below 25 ft, where ^{137}Cs concentrations were generally 1 pCi/g or less. Although ^{60}Co contamination was not detected by the SGLS, the RLS detected numerous low ^{60}Co concentrations between 42.5 ft and the bottom of the logged interval. The ^{60}Co contamination was just barely detectable in 1993 when the RLS log was acquired. Since that time, the ^{60}Co concentrations have probably decayed to levels below the detection limit of the SGLS.

The historical gross gamma log data from 1975 to 1996 were reviewed. The most recent historical gross gamma data are presented on the combination plot. Although no data were collected at the 1- and 2-ft intervals of the gross gamma-ray log, the plot generally reflects the ^{137}Cs contamination profile in the upper 15 ft of the borehole. The earliest recorded historical gross gamma log data available (January 1975) indicate that the ^{137}Cs contamination detected by the SGLS was present around this borehole at that time. The gross gamma data also indicate that the distribution of this contamination has remained unchanged since 1975, other than a slight decrease in the count-rate values.

Summaries of the historical gross gamma log data from 1974 to 1987 are presented in Welty (1988). An activity peak was identified at a depth of 43 ft in mid-1974. The activity peak shifted in depth as much as 4 ft during the reporting period, which is probably attributable to depth-control problems associated with the gross gamma system. The anomalous activity gradually decreased in intensity to less than reportable levels (50 cps) by 1979. This activity corresponds with the zone of relatively higher ^{137}Cs contamination shown on the SGLS plot and with a zone of minor ^{60}Co contamination detected by the RLS in 1993. The anomalous gamma-ray activity suggests that certain other short-lived radionuclides were introduced into the region along with ^{137}Cs and ^{60}Co, but have since decayed away to concentrations below the SGLS detection level.

The majority of the ^{137}Cs contamination located around the upper 26 ft this borehole appears to be the result of downward migration of surface contamination. The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated down into the backfill surrounding the borehole. The slightly increased ^{137}Cs contamination at a depth of about 9 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone.

The zone of ^{137}Cs contamination between 41 and 52 ft may have resulted from the cascade-line leak between tanks C-104 and C-105. The contamination detected at this depth may also have migrated downward and laterally from the contaminant source.

The low levels of ^{137}Cs contamination detected below 26 and 52 ft were probably carried down during drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination at the bottom of the logged interval may be particulate matter that has migrated down the outside of the borehole casing and accumulated around the bottom of the borehole.

4.5 Borehole 30-04-04

Borehole 30-04-04 is located approximately 4 ft from the east side of tank C-104. It was given the Hanford Site designation 299-E27-79. This borehole was drilled in June 1974 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 98.5 ft. This borehole is located approximately 8 ft west of a transfer pit.

The man-made radionuclide ^{137}Cs was detected in this borehole. ^{137}Cs contamination was measured continuously from the ground surface to 37 ft and nearly continuously from 41.5 to 59.5 ft. Numerous small zones of ^{137}Cs contamination were detected between 62.5 ft and the bottom of the logged interval (98.5 ft). A near-surface zone of very high ^{137}Cs contamination (as much as 1,450 pCi/g) occurs between 1 and 5 ft. A relatively homogeneous region of ^{137}Cs contamination, with concentrations ranging from 9 to 14 pCi/g, underlies the near-surface zone and extends to a depth of about 22 ft. The ^{137}Cs concentrations decrease abruptly below 22 ft and remain less than 1 pCi/g between 25 and 44 ft. A distinct zone of elevated ^{137}Cs contamination was detected between 45 and 56 ft at concentrations ranging from 1 to 4 pCi/g. The ^{137}Cs concentrations detected below this zone were less than 0.5 pCi/g except toward the bottom of the logged interval where concentrations increased to 7 pCi/g.

The ^{40}K concentration values increase from 36.5 to 37.5 ft and generally remain elevated to a depth of 61 ft. The ^{40}K concentrations increase again at 61 ft and remain elevated to the bottom of the logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 36.5 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The increase in the ^{40}K concentration values at 61 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

It was not possible to identify any of the 609-keV peaks used to derive the ^{238}U concentrations from the ground surface to 6.5 ft. In addition, it was not possible to identify any of the 1460- and 2614-keV peaks used to derive the ^{40}K and ^{232}Th concentrations between 2.5 and 4.5 ft. The KUT data were absent between 2.5 and 4.5 ft because this interval was logged by the SGLS in real time since the dead time exceeded 50 percent. Outside this region, the 609-keV peaks in some spectra were not identified because high gamma-ray activity associated with the nearby ^{137}Cs peak (661 keV) created an elevated Compton continuum extending to the 609-keV peak, causing the MDL to exceed the measured ^{238}U concentration.

The SGLS total gamma-ray plot reflects the presence of the man-made radionuclides where they occur and the changes in the naturally occurring radionuclides elsewhere. The increase in the SGLS total count rate at about 38 ft corresponds with increases in the ^{40}K concentrations at this depth. The sharp increase in the count rate at the bottom of the logged interval corresponds closely to the peak shown on the ^{137}Cs concentration plot.

The historical gross gamma log data from 1975 to 1994 were reviewed. The uppermost portion of the near-surface contamination zone is absent on the gross gamma plot because no data were collected at the 1-ft and 2-ft intervals. Near-surface anomalous activity evident on the earliest recorded historical gross gamma log (January 1975) indicates that the contamination was present in this region at that time.

Summaries of the historical gross gamma log data from 1974 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

The near-surface zone of very high ^{137}Cs contamination may be the result of a leak from a nearby transfer line since this borehole is located within proximity to a transfer-line valve pit. Historical gross gamma data indicate that this zone of contamination has remained in place since 1975. The relatively homogeneous region of ^{137}Cs contamination that underlies the near-surface plume was probably carried down during the drilling of this borehole.

The distinct zone of elevated ^{137}Cs contamination detected between 45 and 56 ft may have resulted from the cascade-line leak between tanks C-104 and C-105 or possibly from a leak in tank C-101. The contamination detected at this depth may also have migrated downward and laterally from the contaminant source.

The low ^{137}Cs concentrations detected between 22 and 45 ft and below 56 ft were probably carried down during drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination at the bottom of the logged interval may be particulate matter that has migrated down the outside of the borehole casing and accumulated around the bottom of the borehole.

4.6 Borehole 30-01-12

Borehole 30-01-12 is located approximately 24 ft from the southeast side of tank C-104 and was given the Hanford Site designation 299-E27-61. This borehole was drilled in March 1970 to a depth of 100 ft using 6-in. casing. The drilling log for this borehole was not available. Information presented in Chamness and Merz (1993) does not indicate that the borehole was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, rises approximately 6 in. above the ground surface. Total logging depth achieved by the SGLS was 99.5 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. The ^{137}Cs contamination was measured nearly continuously from the ground surface to 40.5 ft. A near-surface zone of moderate to high ^{137}Cs contamination (10 to 85 pCi/g) occurs from 1 to 5.5 ft. A discrete layer of elevated ^{137}Cs contamination, ranging in concentration from 1 to 6 pCi/g, occurs between 13 and 19 ft. The ^{137}Cs contamination decreases to less than 0.5 pCi/g below 23 ft. Isolated occurrences of ^{137}Cs were detected at 45, 60, and 66.5 ft, and at the bottom of the logged interval. The highest concentration of ^{137}Cs (98.5 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used during calibration.

The ^{40}K concentration values increase at about 38.5 ft and remain elevated to a depth of 50.5 ft. The ^{40}K concentrations are slightly decreased from 51 to about 58 ft, possibly indicating a decreased percentage of fine-grained sediments within this interval. The ^{40}K concentration values increase at about 59.5 ft and continue to gradually increase below this depth. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 38.5 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The increase in the ^{40}K concentration values at 59.5 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

It was not possible to identify most of the 609-keV peaks used to derive the ^{238}U concentrations between the ground surface and 8 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 contamination from the ground surface to about 20 ft is clearly reflected on the total gamma-ray plot. The increase in the SGLS total count rate at 39 and 59 ft corresponds with increases in the ^{40}K concentration values at these depths.

Historical gross gamma-ray logs from January 1975 through June 1994 were reviewed. An increase in gamma-ray activity occurred between June 6 and June 13, 1975. Anomalously high gamma-ray activity does not appear within this interval in the historical logs before June 13, 1975, but is very evident after June 26, 1975.

The near-surface ^{137}Cs contamination is probably the result of a surface spill that migrated into the backfill material around the borehole.

The zone of increased ^{137}Cs contamination detected between 14 and 20 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone. The earliest historical gross gamma logs available (January 1975) indicate that anomalous gamma-ray activity was present in this region at that time.

The ^{137}Cs contamination below about 20 ft was carried down during drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination at the bottom of the logged interval is probably from particulate matter that has fallen down the inside of the borehole.

4.7 Borehole 30-04-05

Borehole 30-04-05 is located approximately 7 ft from the southeast side of tank C-104. It was given the Hanford Site designation 299-E27-80. This borehole was drilled in July 1974 to a depth of 100 ft using 6-in. casing. A drilling log was not available for this borehole; however, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 98.5 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. The ^{137}Cs contamination was measured nearly continuously from the ground surface to a depth of 57.5 ft, intermittently from 69.5 to 91.5 ft, and continuously from 94.5 ft to the bottom of the logged interval. A near-surface zone of relatively homogenous ^{137}Cs contamination extends from 1 to 11 ft with concentrations generally ranging from 10 to 15 pCi/g. A small zone of relatively higher ^{137}Cs contamination was detected from about 11 to 13.5 ft. Between 14 and 43 ft, the ^{137}Cs concentrations gradually decrease from about 20 pCi/g to less than 0.5 pCi/g. A distinct zone of elevated ^{137}Cs contamination was detected from 45 to 54 ft at concentrations ranging from 1 to 5 pCi/g. The ^{137}Cs concentrations detected below this zone were generally less than 0.5 pCi/g, except at the bottom of the logged interval where concentrations increased to greater than 1 pCi/g.

The ^{40}K concentration values increase from about 38 to 45 ft. The ^{40}K concentrations are slightly decreased and variable from 45.5 to about 58 ft, possibly indicating a decrease in the percentage of fine-grained sediments within this interval. The ^{40}K concentration values increase at about 59 ft and continue to gradually increase below this depth. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 38 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The increase in the ^{40}K concentration values at 59 ft may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

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 14.5 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 contamination detected from the ground surface to about 54 ft is clearly reflected on the total gamma-ray plot. The increase in the total count rate at 58.5 ft corresponds with the increase in the ^{40}K concentration values at this depth.

Historical gross gamma-ray logs from January 1975 through July 1994 were reviewed. Two plots of representative historical logs for this borehole are included in Appendix A. The first plot shows a zone of anomalous gamma-ray activity between 11 and 15 ft that was present in January 1975, increased significantly by June 1976, then stabilized by June 1984. In addition, Welty (1988) indicates that the anomalous gamma-ray activity was present in this interval by at least September 1974, the earliest data provided for this borehole in Welty (1988).

The historical logs indicate that the gross gamma activity at 11.5 ft increased from about 444 to 9,000 cps from January 10, 1975 to March 7, 1975. However, activities in this interval fluctuate widely over the span of the historical logs available. The second plot contains historical gross gamma logs from January to March 1978 and illustrates these fluctuations, which may be the result of different detectors being used to log the borehole during the period.

The near-surface contamination is probably the result of a surface spill that migrated into the backfill material around the borehole. The ^{137}Cs contamination detected between 11 and 18 ft may be the result of a leak from a pipeline or transfer line. The earliest historical gross gamma logs available indicate that gamma activity was present at this depth at that time. It is possible that some of this contamination may have migrated laterally along the surface of the tank dome and into this region of the vadose zone.

The ^{137}Cs contamination from 45 to 57.5 ft may have resulted from the C-104-to-C-105 cascade-line leak or possibly from a nearby tank leak. The occurrence of the ^{137}Cs contamination coincides with an interval of relatively lower ^{40}K concentrations. This zone of low ^{40}K concentrations may have acted as a preferential pathway for contaminants to migrate into this region. The earliest historical gross gamma logs available indicate that gamma activity was present at this depth at that time.

The ^{137}Cs contamination detected below 20 and 69 ft was probably carried down during drilling of this borehole or later migrated down the outside of the borehole casing. The ^{137}Cs contamination at the bottom of the logged interval may be particulate matter that has migrated down the outside of the borehole casing and accumulated around the bottom of the borehole.

4.8 Borehole 30-04-08

Borehole 30-04-08 is located approximately 9 ft from the southwest side of tank C-104. It was given the Hanford Site designation 299-E27-66. This borehole was drilled in November 1972 to a depth of 145 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, rises approximately 2 ft above the ground surface. The total logging depth achieved by the SGLS was 143.0 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. Nearly continuous ^{137}Cs contamination was detected from the ground surface to 38.5 ft and 45 to 70.5 ft A significant zone of generally moderate ^{137}Cs contamination was measured from the ground surface to a depth of about 25 ft. Within this zone, a region of elevated ^{137}Cs contamination (10 to 125 pCi/g) occurs from 17 to 21.5 ft. Two discrete layers of elevated ^{137}Cs contamination occur between 30 and 40 ft. An isolated zone of elevated ^{137}Cs contamination (1 to 10 pCi/g) was detected between 45 and 51 ft. The ^{137}Cs concentrations decrease to less than 1 pCi/g below this zone.

The increase in the ^{40}K concentration values at about 39 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The drilling log reports a change in lithology from sand, gravel, and silt to coarse sand at this depth. The ^{40}K concentration values are slightly variable from 39 to 49 ft and increase from 52.5 to 71.5 ft. The drilling log reports a change in lithology from coarse sand to medium sand at a depth of about 50 ft. The lithologic information reported in the drilling log supports the interpretation that the increase in the ^{40}K concentration values between 52.5 and 71.5 ft is probably caused by a gradual increase in fine-grained sediments along this interval.

The SGLS total gamma-ray plot reflects the ^{137}Cs contamination in the upper portion of this borehole. The SGLS total count rate is sensitive to ^{137}Cs concentrations that exceed 1 pCi/g.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. Although no data were collected at the 1-ft and 2-ft intervals of the gross gamma-ray log, the plot generally reflects the ^{137}Cs contamination profile in the upper 50 ft of the borehole. The earliest recorded historical gross gamma log data available (January 1975) indicate that ^{137}Cs contamination was present around this borehole at that time. The gross gamma data also indicate that the distribution of this contamination has remained unchanged since 1975, other than a slight decrease in the count-rate values.

Summaries of the historical gross gamma log data from 1973 to 1987 are presented in Welty (1988). An activity peak was identified at a depth of 33 ft in early 1975. The activity peak shifted in depth as much as 4 ft during the reporting period, which is probably attributable to depth control problems associated with the gross gamma system. The anomalous activity corresponds with the isolated zone of elevated ^{137}Cs contamination shown on the SGLS plot.

The majority of the ^{137}Cs contamination located around the upper 17 ft this borehole appears to be the result of downward migration of surface contamination. The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated down into the shallow backfill surrounding the borehole. The zone of increased ^{137}Cs contamination between 7 and 17 ft may represent surface contamination that has migrated along the surface of the tank dome into this region of the vadose zone.

The significant zone of ^{137}Cs contamination detected between 17 and 21 ft may be the result of a leak from a pipeline or transfer line. The discrete layers of elevated ^{137}Cs contamination detected at 34 and 37.5 ft may represent contamination from a leak that has accumulated near the base of the tank farm excavation.

The zone of elevated ^{137}Cs contamination from 45 to 51 ft may have resulted from the C-104-to-C-105 cascade-line leak or possibly from a nearby tank leak. This contamination occurs at approximately the same depth interval as the ^{137}Cs contamination detected in borehole 30-04-05, and it may be related to the same subsurface source.

The low ^{137}Cs concentrations detected below 52 ft were probably carried down during drilling of this borehole or later migrated down the outside of the borehole casing.

4.9 Borehole 30-07-05

Borehole 30-07-05 is located approximately 18 ft from the northwest side of tank C-104. It was given the Hanford Site designation 299-E27-89. This borehole was drilled in October 1974 to a depth of 100 ft using 6-in. casing. Although a drilling log was not available for this borehole, information presented in Chamness and Merz (1993) does not indicate that the borehole was grouted or perforated. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 99.5 ft.

The man-made radionuclide ^{137}Cs was detected in this borehole. Intermittent to continuous ^{137}Cs contamination was detected from the ground surface to a depth of 35.5 ft. ^{137}Cs contamination was detected continuously from 49 to 53.5 ft and intermittently from 56 to 77 ft. The ^{137}Cs concentrations detected around this borehole generally ranged from 0.2 to 0.7 pCi/g. The highest ^{137}Cs concentration (19.8 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

The ^{40}K concentration values increase at 39 ft and remain elevated to 48.5 ft. A sharp decrease in the ^{40}K concentrations occurs at about 50 ft. The ^{40}K concentration values remain elevated and exhibit moderate variability from 52 ft to the bottom of logged interval. Although a drilling log was not available to support or contradict the KUT data, the increase in the ^{40}K concentrations at 39 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The decrease in the ^{40}K concentration values at 50 ft may represent an increased percentage of coarse-grained material.

The SGLS total gamma-ray plot reflects the presence of ^{137}Cs contamination around the uppermost portion of the borehole and the naturally occurring radionuclides elsewhere. The total count rate increases at 39 and 52 ft, corresponding to increases in the ^{40}K and ^{238}U concentrations at these depths.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The uppermost portion of the near-surface contaminant zone is absent on the gross gamma plot because no data were collected at the 1-ft and 2-ft intervals. The earliest recorded historical gross gamma log data (January 1975) indicate that the near-surface ^{137}Cs contamination was present at that time.

Summaries of the historical gross gamma log data from 1973 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated a short distance down into the backfill surrounding the borehole. The ^{137}Cs contamination directly below this zone was probably carried down during the drilling of this borehole.

The zone of slightly elevated ^{137}Cs contamination from 49 to 53 ft may have resulted from the C-104-to-C-105 cascade-line leak or possibly from a nearby tank leak. Although this is a weak zone of ^{137}Cs contamination, it occurs at approximately the same depth interval as the ^{137}Cs contamination detected in boreholes 30-04-05 and 30-04-08 and may be related to the same subsurface source. The ^{137}Cs contamination detected directly below this zone most likely migrated down the outside of the borehole casing.

4.10 Borehole 30-04-12

Borehole 30-04-12 is located approximately 4 ft from the north side of tank C-104. It was given the Hanford Site designation 299-E27-65. This borehole was drilled in December 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The top of the casing, which is the zero depth reference for the SGLS, is approximately flush with the ground surface. The total logging depth achieved by the SGLS was 135.0 ft.

The man-made radionuclides ^{137}Cs and ^{60}Co were detected in this borehole. The ^{137}Cs contamination was detected nearly continuously from the ground surface to a depth of 62 ft. Isolated occurrences of ^{137}Cs contamination were detected at 66.5 ft, 89 ft, and the bottom of the logged interval (135 ft). The ^{137}Cs concentrations detected around this borehole generally ranged from 0.2 to 0.7 pCi/g. The highest ^{137}Cs concentration (48.5 pCi/g) was detected at the ground surface. However, as described in Section 2.1, this is not an accurate concentration value because the source-to-detector geometry at the top of the borehole casing differs from source-to-detector geometry used in the calibration.

A few occurrences of ^{60}Co contamination were detected at very low concentrations (less than 0.1 pCi/g) between 43 and 47.5 ft.

The increase in the ^{40}K concentration values at 38 ft probably represents a change in lithology from backfill material to the undisturbed Hanford formation. The drilling log reports a change in lithology from sand and gravel to coarse sand at this depth. The ^{40}K concentration values increase at about 59 ft and generally remain elevated to the bottom of the logged interval. The drilling log reports a change in lithology from coarse sand and pea gravel to medium sand at a depth of about 55 ft. The lithologic information reported in the drilling log supports the interpretation that the increase in the ^{40}K concentration values at about 59 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

The SGLS total gamma-ray plot reflects the near-surface ^{137}Cs contamination and the naturally occurring radionuclides elsewhere. The total count rate increases at 40 and 58 ft, corresponding to increases in the ^{40}K concentrations at these depths.

The historical gross gamma log data from 1975 to 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. The near-surface peak detected by the SGLS is absent on the gross gamma plot because no data were collected at the 1-ft and 2-ft intervals. In addition, the near-surface ^{137}Cs contamination is not evident on the earliest recorded historical gross gamma log (January 1975) or subsequent historical logs, indicating that the ^{137}Cs activity was below the detection level of the gross gamma system.

Summaries of the historical gross gamma log data from 1973 to 1987 included in Welty (1988) do not identify any zones of anomalous gamma-ray activity.

The near-surface zone of ^{137}Cs contamination probably resulted from surface spills that have migrated a short distance down into the backfill surrounding the borehole. The ^{137}Cs contamination directly below this zone was probably carried down during the drilling of this borehole or later migrated down the outside of the borehole casing. The trace amount of ^{137}Cs contamination at the bottom of the logged interval is probably from particulate matter that has fallen down the inside of the borehole.

The small amount of ^{60}Co contamination detected between 43 and 47.5 ft may represent the outer extent of the plume related to the cascade-line leak that occurred between tanks C-104 and C-105.

5.0 Discussion of Results

A plot of the man-made radionuclide concentration profiles for the ten boreholes surrounding tank C-104 is presented on Figure 3. The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{235}U were detected by the SGLS.

The SGLS detected moderate to high ^{137}Cs concentrations at the ground surface in all the boreholes. Isolated occurrences of ^{235}U were detected at the ground surface in boreholes 30-04-02, 30-04-03, and 30-05-06. The source of this contamination is probably direct gamma radiation from nearby contaminated equipment or contamination that is localized to the ground surface. As described in Section 2.1, the concentration values calculated at the ground surface are not considered accurate because the source-to-detector geometry at the top of the borehole casing differs from the source-to-detector geometry used in the calibration. As a result, the ^{137}Cs and ^{235}U concentration values detected using the SGLS are probably higher than the actual concentration levels of these radionuclides at the ground surface.

The SGLS detected surface, near-surface, and shallow subsurface ^{137}Cs contamination around all the boreholes. This contamination could have resulted from surface spills, airborne contamination releases, or a combination of these. The contamination may have migrated, in some undetermined manner, down around the outside of the boreholes. It is also possible that the contamination has been driven downward as much as 25 ft into the backfill material by precipitation infiltration. This region of the tank farm is known for having standing water on the surface. If the contamination in the upper portions of the boreholes has migrated downward along the borehole casings, then the total contamination in the near-surface vadose zone is minor. If the contamination has migrated downward into the backfill material, then the volume of contaminated material is large and is a significant portion of the overall contamination in the vadose zone around this tank.

A near-surface zone of very high ^{137}Cs contamination was detected around borehole 30-04-04. This contamination probably resulted from a shallow transfer-line leak because it occurs within proximity of a transfer-line valve pit. The contamination was not detected at similar concentrations in any other nearby boreholes, indicating that it is probably isolated to this region of the vadose zone.

Small zones of relatively higher ^{137}Cs contamination were detected between 8 and 17 ft in boreholes 30-04-02, 30-04-03, 30-05-06, 30-01-12, 30-04-05, and 30-04-08. This may represent surface contamination that has migrated laterally along the surface of the tank dome into these regions of the backfill material.

All the boreholes surrounding tank C-104, except 30-07-05 and 30-04-12, contain subsurface ^{137}Cs contamination that does not appear to be strictly the result of downward migration of surface contamination through the vadose zone sediments.

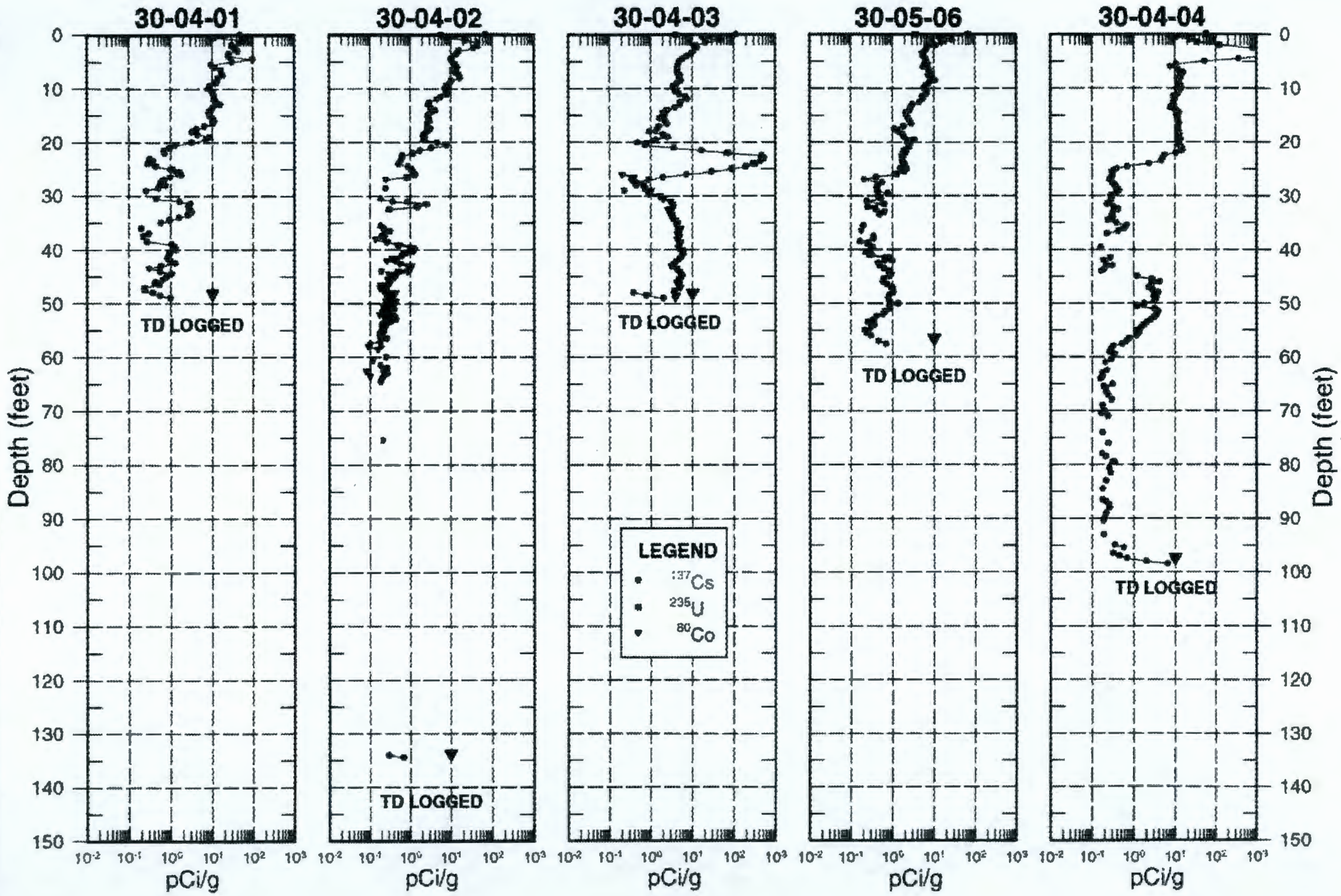

Figure 3. Correlation Plot of ^{137}Cs, ^{60}Co, and ^{235}U Concentrations in Boreholes Surrounding Tank C-104

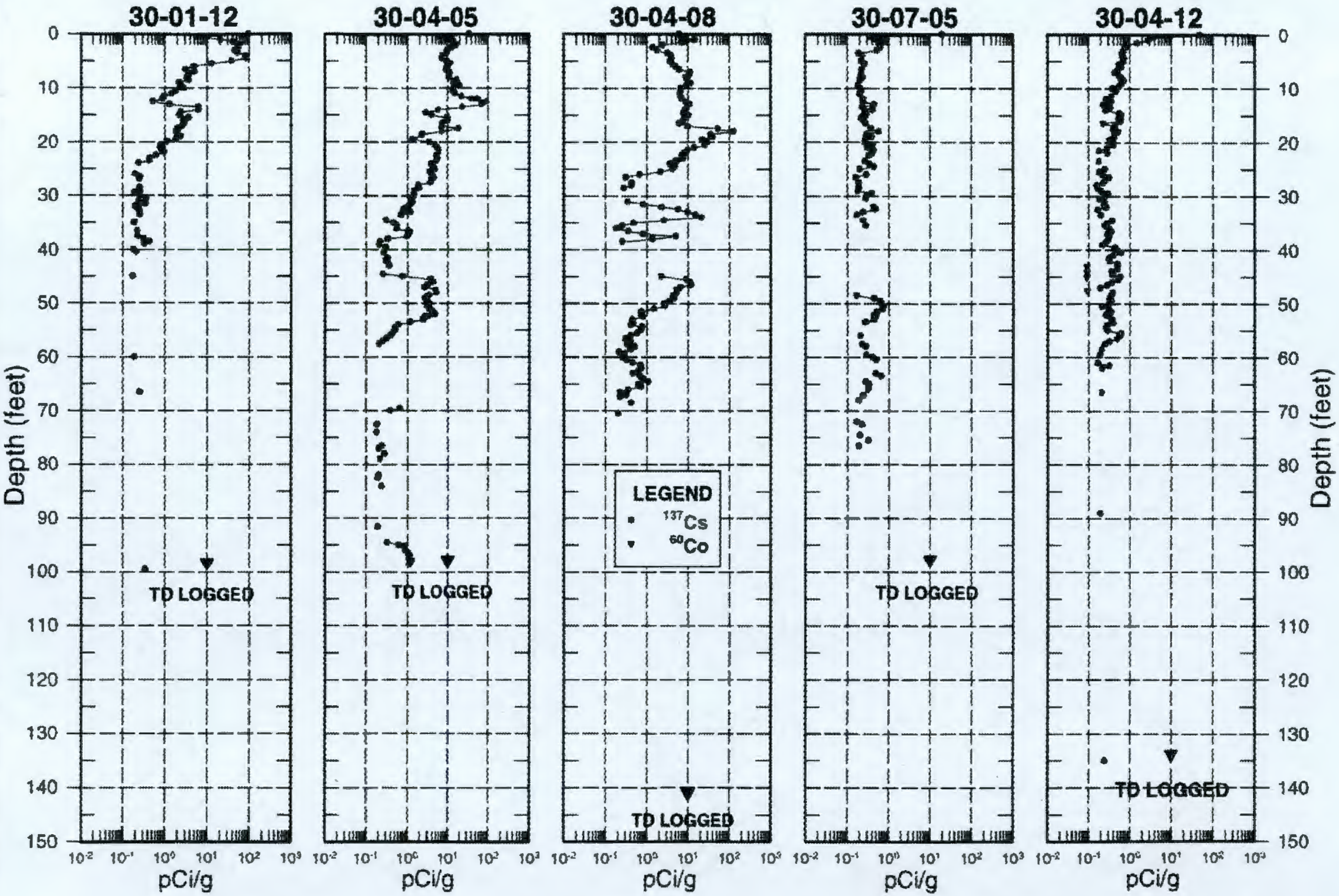

Figure 3 (continued). Correlation Plot of ^{137}Cs, ^{60}Co, and ^{235}U Concentrations in Boreholes Surrounding Tank C-104

A zone of moderate to high ^{137}Cs contamination was detected between 12 and 21 ft in boreholes 30-04-05 and 30-04-08. This contamination probably resulted from a transfer-line leak because it occurs as an isolated zone at significantly higher concentrations than the overlying contamination. In borehole 30-04-05, some of this contamination may represent surface contamination that has migrated laterally along the surface of the tank dome into this region of the vadose zone. In borehole 30-04-08, the discrete layers of elevated ^{137}Cs contamination between 31 and 39 ft may represent contamination from a subsurface leak that has accumulated near the base of the tank farm excavation.

In borehole 30-04-03, the distinct zone of high ^{137}Cs contamination detected between 21 and 26 ft and the underlying plume of extensive ^{60}Co contamination probably resulted from the C-104-to-C-105 cascade-line leak described in Welty (1988) and discussed in Section 3.2. The discrete nature of both contaminant plumes indicates that this borehole is located near the leak source. Zones of elevated ^{137}Cs contamination occur at similar depths in nearby boreholes 30-04-01 and 30-04-02, suggesting that the ^{137}Cs contamination from the cascade leak may have migrated laterally within this region of the vadose zone. The significant plume of ^{60}Co contamination that occurs between 38 and 60 ft in borehole 30-04-02 indicates that a ^{60}Co plume probably resulted from the cascade-line leak and has migrated both downward and laterally through the vadose zone.

Isolated zones of elevated ^{137}Cs contamination generally occur between 40 and 55 ft in boreholes 30-04-01, 30-04-02, 30-05-06, 30-04-04, 30-04-05, and 30-04-08 and correspond to the base of the tank. These contaminant zones probably originated from the C-104-to-C-105 cascade-line leak. It is possible that the ^{137}Cs contamination from the leak traveled down along the outside of tank C-104 and spread horizontally along the base of the tank. The data indicate that some of this contamination then migrated both downward and laterally through the native sediments below the tank farm excavation. This contamination occurs in the gravel-dominated facies of the Hanford formation, just above the east and south dipping contact with the sand-dominated facies and appears to have been confined within the gravelly unit. It is also possible that the ^{137}Cs contamination detected between 45 and 55 ft in boreholes 30-04-04, 30-04-05, 30-04-08, and 30-07-05 may be the result of a leak from an unknown source, such as a nearby tank.

The comparison of the 1993 RLS and 1997 SGLS data collected from borehole 30-05-06 shows good correlation of the ^{137}Cs distribution. The shapes of the RLS and SGLS ^{137}Cs profiles were very similar, suggesting that the ^{137}Cs contamination in this borehole is not actively mobile and has remained fixed in the vadose zone since 1993.

6.0 Conclusions

The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-104 was completed using the SGLS. The data obtained using the SGLS and the geologic and historical information available from other sources do not identify any large active leaks from tank C-104. However, the data indicate that surface spills and subsurface leaks have previously occurred in the vicinity of this tank and may be related to activities associated with tank C-104 or other nearby tanks.

7.0 Recommendations

Approximately 11,000 gal of drainable, interstitial liquid remain in tank C-104 (Hanlon 1997). It is recommended that monitoring of the boreholes surrounding tank C-104 be continued annually to detect potential future leakage from the tank and associated tank facilities and to monitor the potential movement of contaminant plumes. Because the lithology appears to play an important role in the radionuclide distribution beneath this tank, especially ^{60}Co, further lithologic characterization is recommended by logging a few of the boreholes using a long counting time or with a very high efficiency system. This system can properly define the individual natural radionuclide concentrations and thus better characterize site-specific geology.

The intervals of boreholes 30-04-03 and 30-04-05 in which anomalous historical gross gamma-ray activity occurred should be relogged using a long counting time. This work might identify the remnants of other short-lived, man-made radionuclides that may occur.

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-104

Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-04-01

Borehole Information

Farm :	C	Tank :	C-104	Site Number :	299-E27-115
N-Coord :	42,829	W-Coord :	48,378	TOC Elevation :	646.00
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. :	50		

Borehole Notes:
This borehole was drilled in July 1974 and completed to a depth of 50 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	2/24/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	49.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	25.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	2/25/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	26.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-04-01

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/29/97

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 radionuclide Cs-137 was detected in this borehole. The Cs-137 contamination was detected nearly continuously from the ground surface to the bottom of the logged interval (49 ft).

The U-238 concentrations decrease sharply at about 25 ft. The K-40 concentration values increase from 37.5 to 38.5 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-104.

Log Plot Notes:

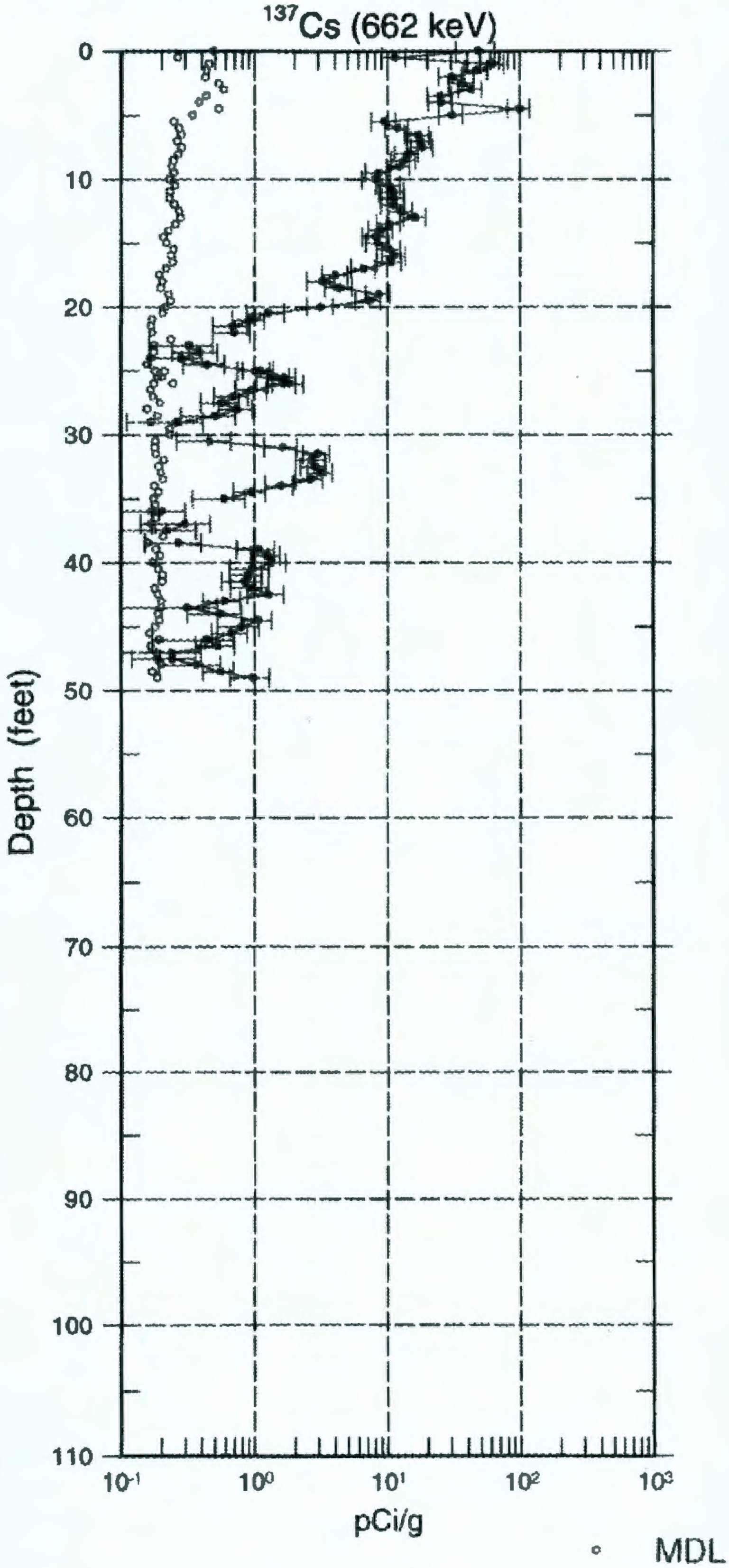
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

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.

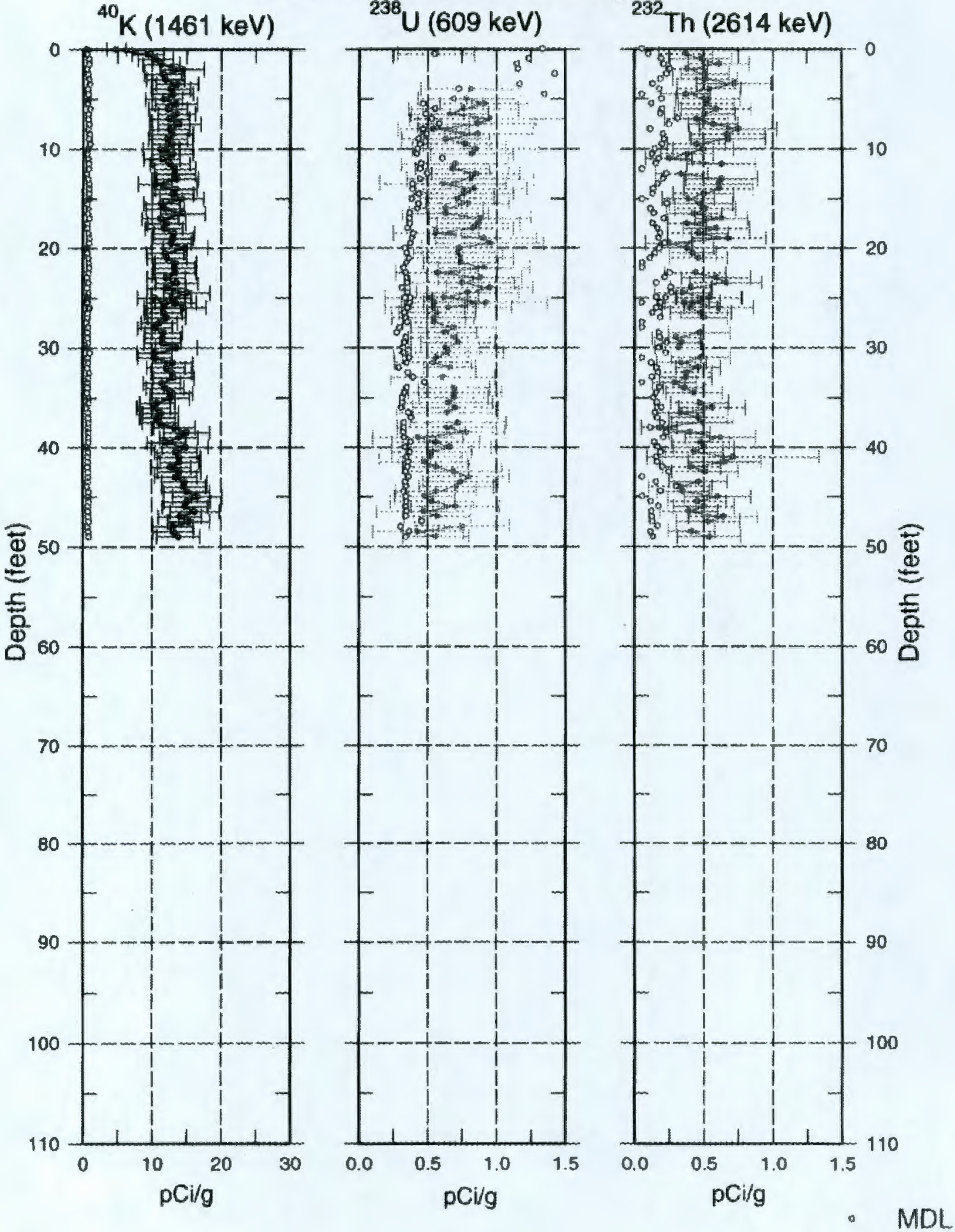
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-04-01

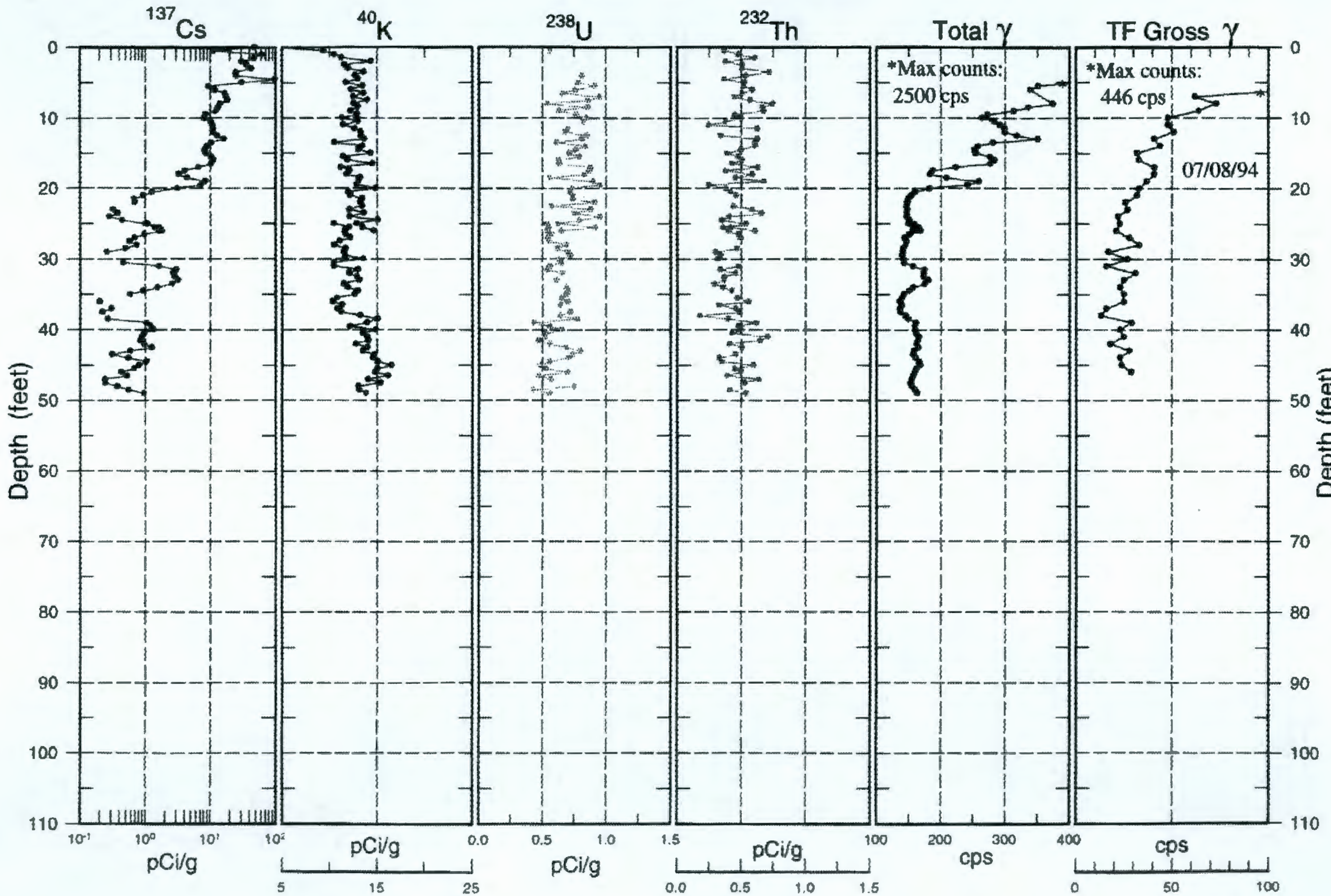
Man-Made Radionuclide Concentrations



30-04-01
Natural Gamma Logs



30-04-01 Combination Plot



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-04-02

Borehole Information

Farm :	C	**Tank :**	C-104	**Site Number :**	299-E27-67
N-Coord :	42,827	**W-Coord :**	48,365	**TOC Elevation :**	646.65
Water Level, ft :	None	**Date Drilled :**	12/31/72		

Casing Record

Type :	Steel-welded	**Thickness, in. :**	0.280	**ID, in. :**	6
Top Depth, ft. :	0	**Bottom Depth, ft. :**	135		

Borehole Notes:

This borehole was drilled in December 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	**Log Run Date :**	2/19/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	26.5	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	2/20/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	134.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	Y
Finish Depth, ft. :	103.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	2/20/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	25.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	52.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	4	Log Run Date :	2/21/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	104.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	73.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	5	Log Run Date :	2/21/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	51.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	64.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	6	Log Run Date :	2/24/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	74.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	64.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	7	Log Run Date :	2/24/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	50.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	30.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : E. Larsen

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

Analysis Notes :

This borehole was logged by the SGLS in seven log runs. Six log runs were required to the log the length of the borehole. The seventh log run was performed as an additional quality assurance check on a segment of one of the primary 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, Co-60, and U-235 were detected in this borehole. Continuous Cs-137 contamination was detected from the ground surface to 27 ft, 50 to 56.5 ft, and 61.5 to 64.5 ft. A few small zones of Cs-137 contamination were detected between 35 ft and at the bottom of the logged interval. A zone of Co-60 contamination was detected from 38 to 58.5 ft. A few occurrences of Co-60 were detected between 60.5 and 63.5 ft. A single occurrence of U-235 was detected at the ground surface.

Most of the U-238 concentration data are absent between the ground surface and 11.5 ft.

Borehole 30-04-02

The K-40 concentration values increase at 39 ft and remain elevated to a depth of 63 ft. The K-40 concentrations increase again from 63.5 to 65.5 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-104 and C-105.

Log Plot Notes:

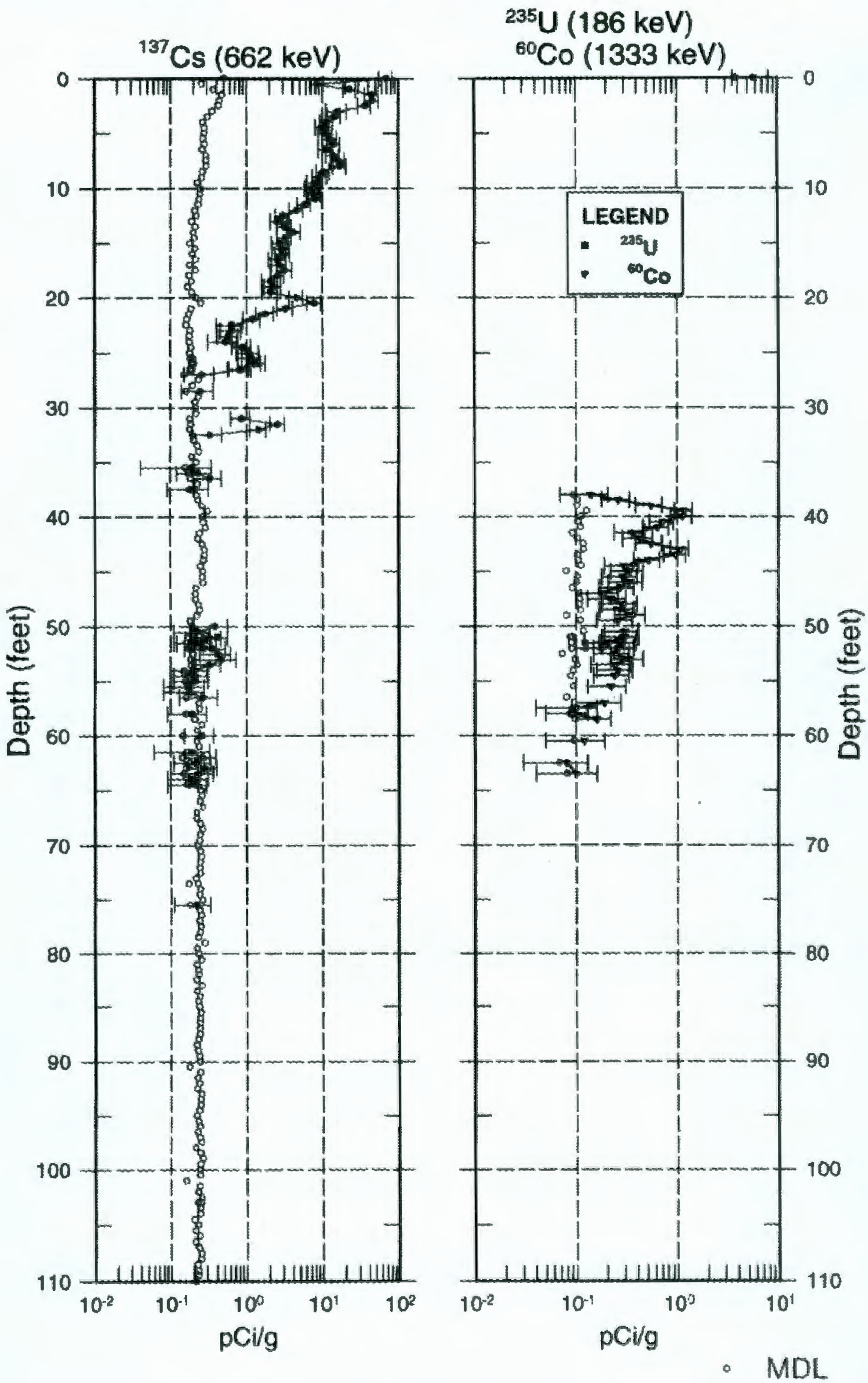
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

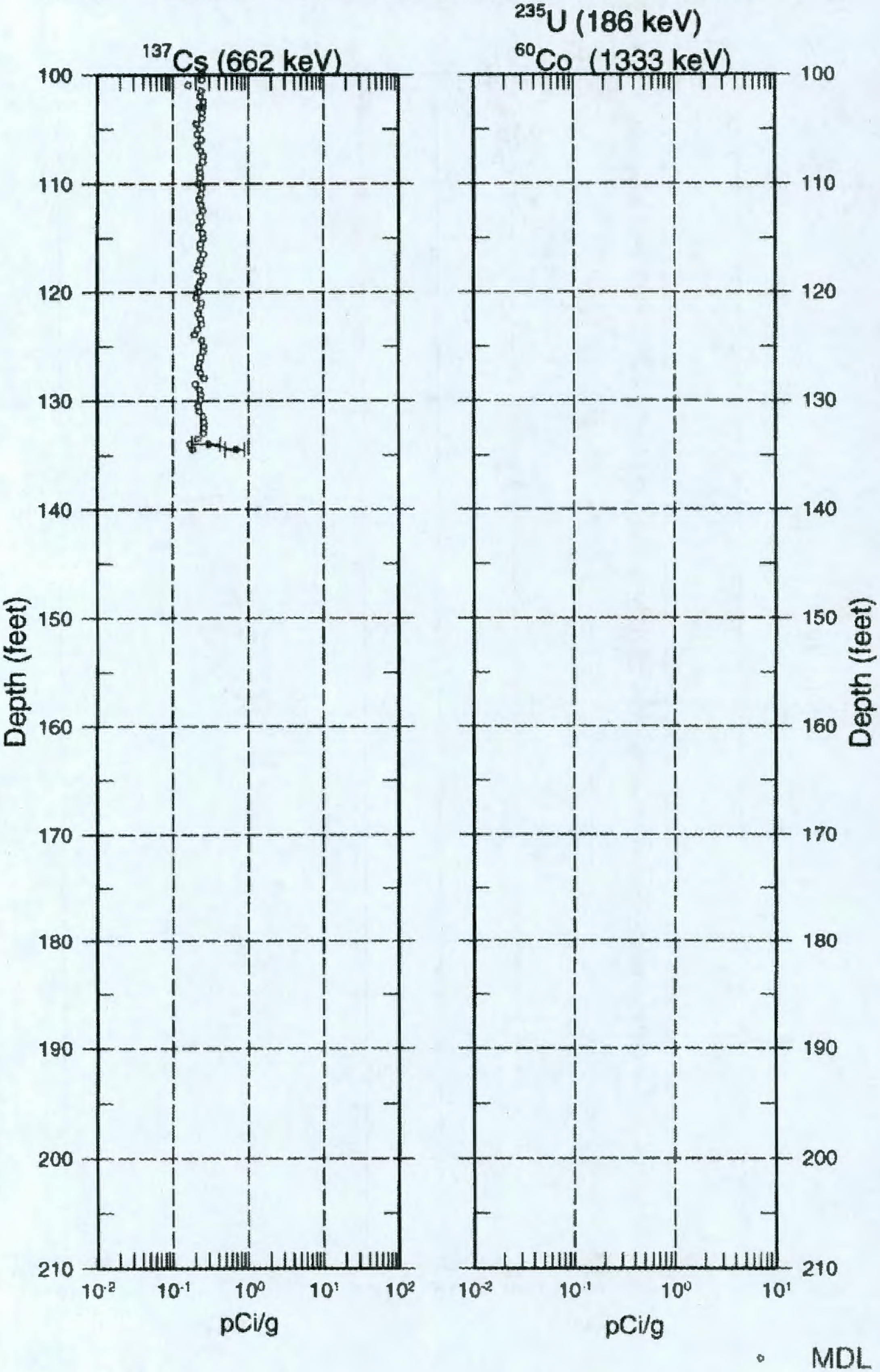
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

The interval between 30 and 50 ft was relogged as a quality assurance measure to establish the repeatability of the radionuclide concentration measurements. The radionuclide concentrations shown were calculated using the separate data sets provided by the original and rerun logging runs.

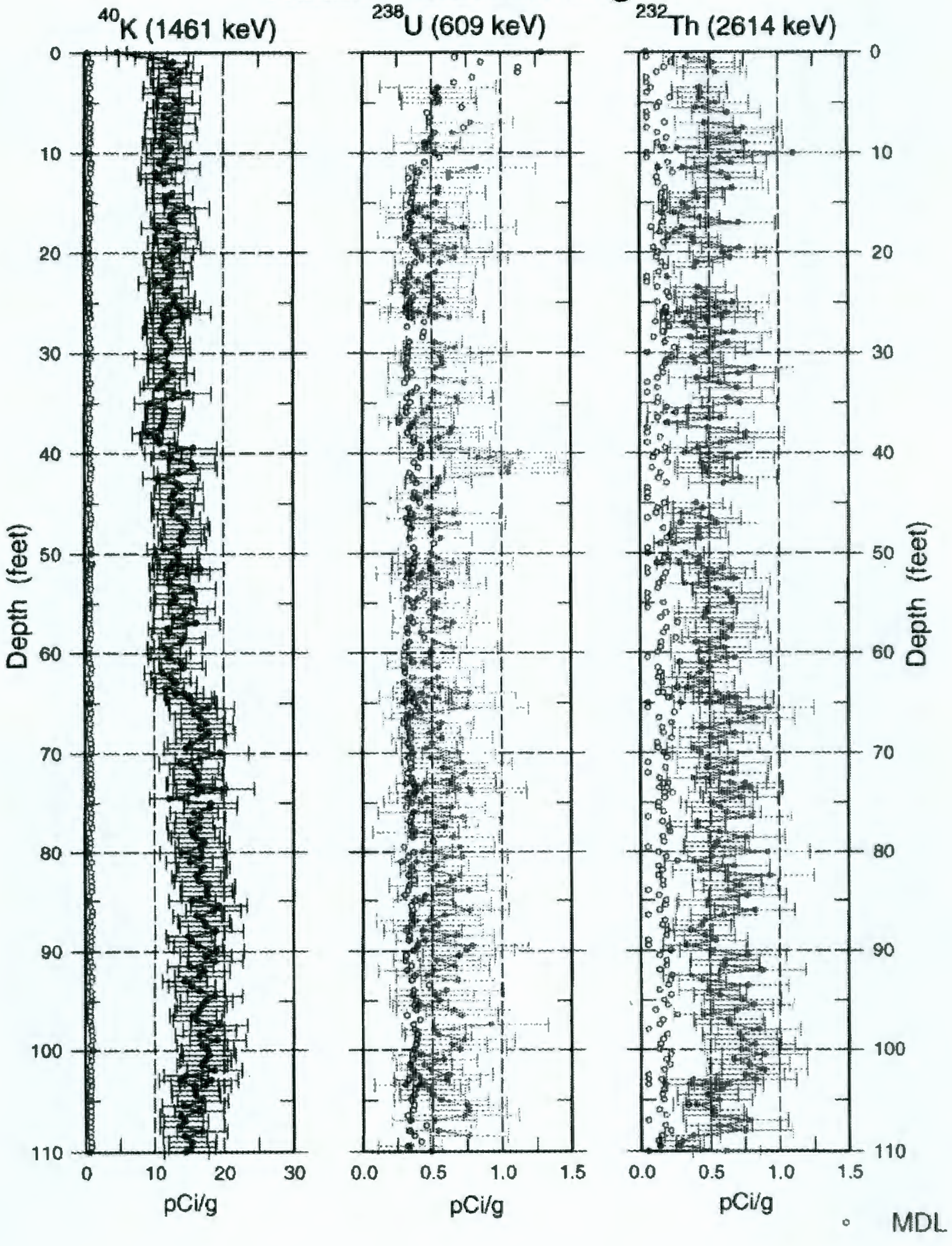
30-04-02
Man-Made Radionuclide Concentrations



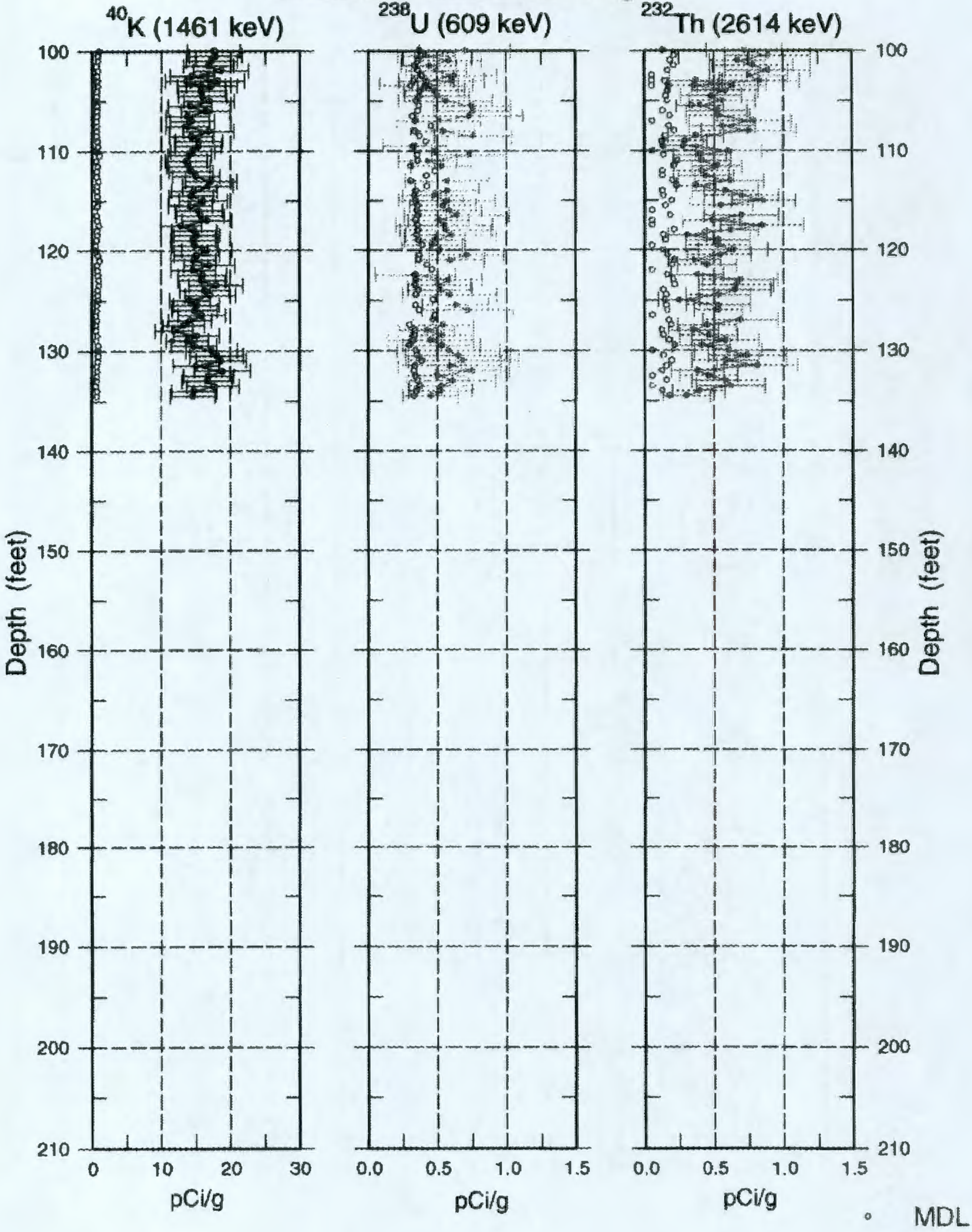
30-04-02
Man-Made Radionuclide Concentrations



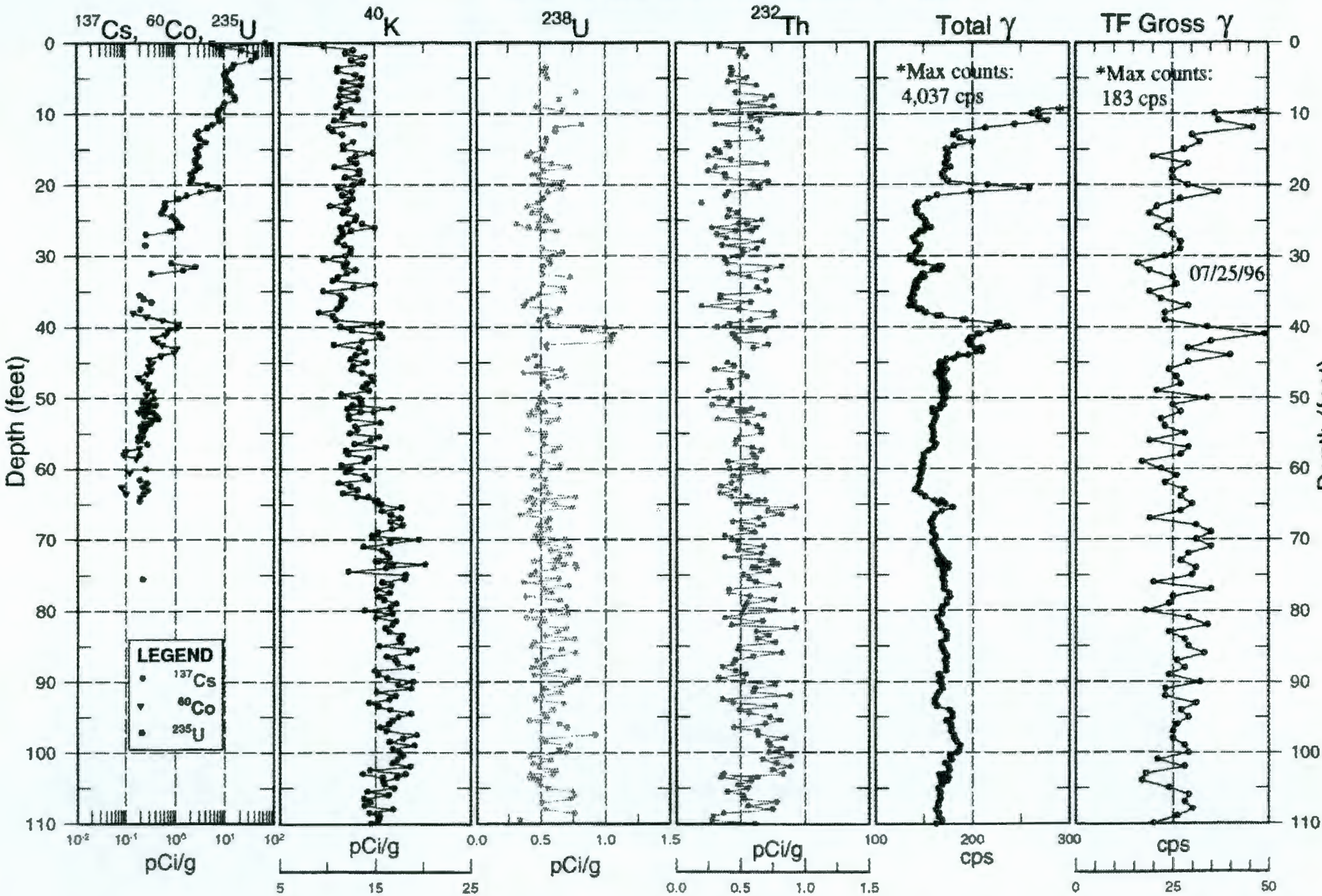
30-04-02
Natural Gamma Logs



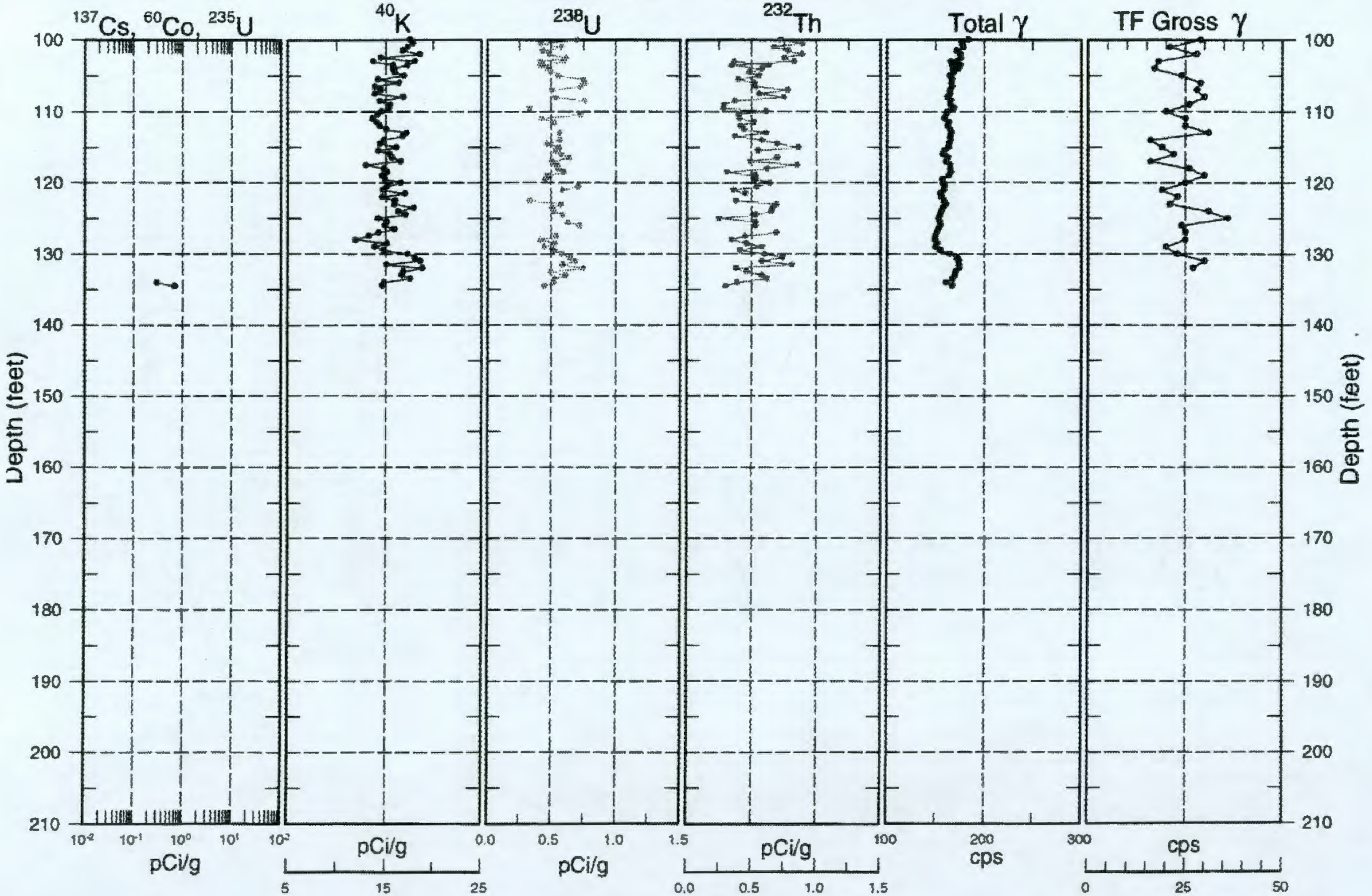
30-04-02
Natural Gamma Logs



30-04-02 Combination Plot

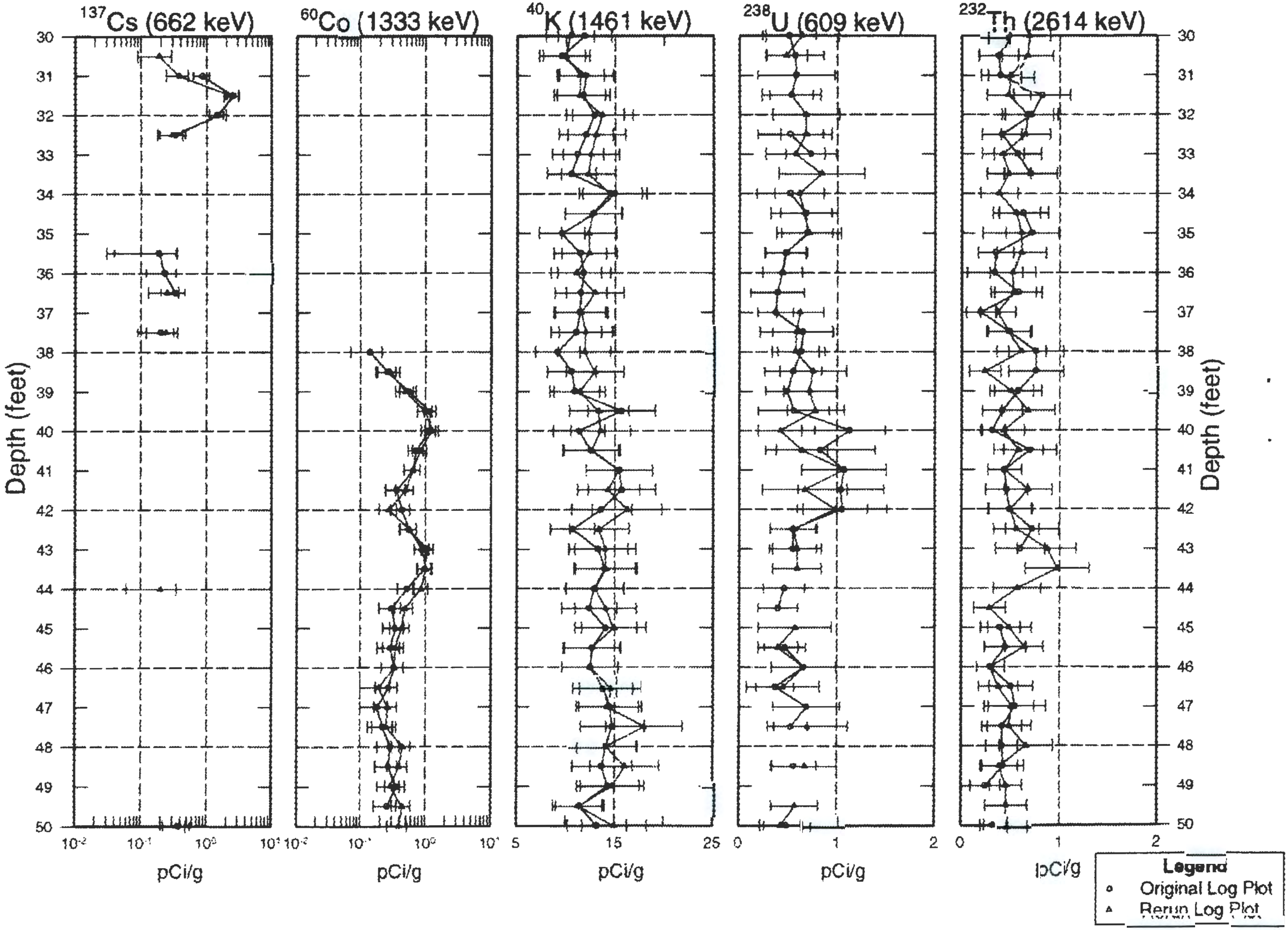


30-04-02 Combination Plot



30-04-02

Rerun Section of the Man-Made and Natural Gamma Logs



Log Event A

Borehole 30-04-03

Borehole Information

Farm :	C	Tank :	C-104	Site Number :	299-E27-116
N-Coord :	42,817	W-Coord :	48,365	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	7/31/74		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	50		

Borehole Notes:

This borehole was drilled in July 1974 and completed to a depth of 50 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or the borehole grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	2/14/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	0.0	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 Run Number :	2	Log Run Date :	2/18/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	15.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	22.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	2/18/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	22.0	Counting Time, sec.:	100	L/R :	R	Shield :	N
Finish Depth, ft. :	25.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

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Log Event A

Borehole 30-04-03

Log Run Number :	4	Log Run Date :	2/19/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	49.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	24.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Analysis Information

Analyst :	E. Larsen		
Data Processing Reference :	P-GJPO-1787	Analysis Date :	7/29/97

Analysis Notes :

This borehole was logged by the SGLS in four log runs. High dead time (greater than 50 percent) was encountered during log run two at a depth of 22.5 ft. As a result, log run three was logged in real time from 22 to 25 ft. Log run four was logged in live time from 49 to 24 ft, after the dead time dropped below 50 percent.

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, Co-60, and U-235 were detected around this borehole. Cs-137 contamination was detected continuously from the ground surface to 28 ft and at the bottom of the logged interval (48 to 49 ft). The Co-60 contamination was detected continuously from 26 to 49 ft. A single occurrence of U-235 was detected at the ground surface.

The K-40 and Th-232 concentration data are absent between 22 and 24 ft. Most of the U-238 concentration data are absent between 21 and 40.5 ft.

The K-40 concentration values increase from 37 to 38 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-104.

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.

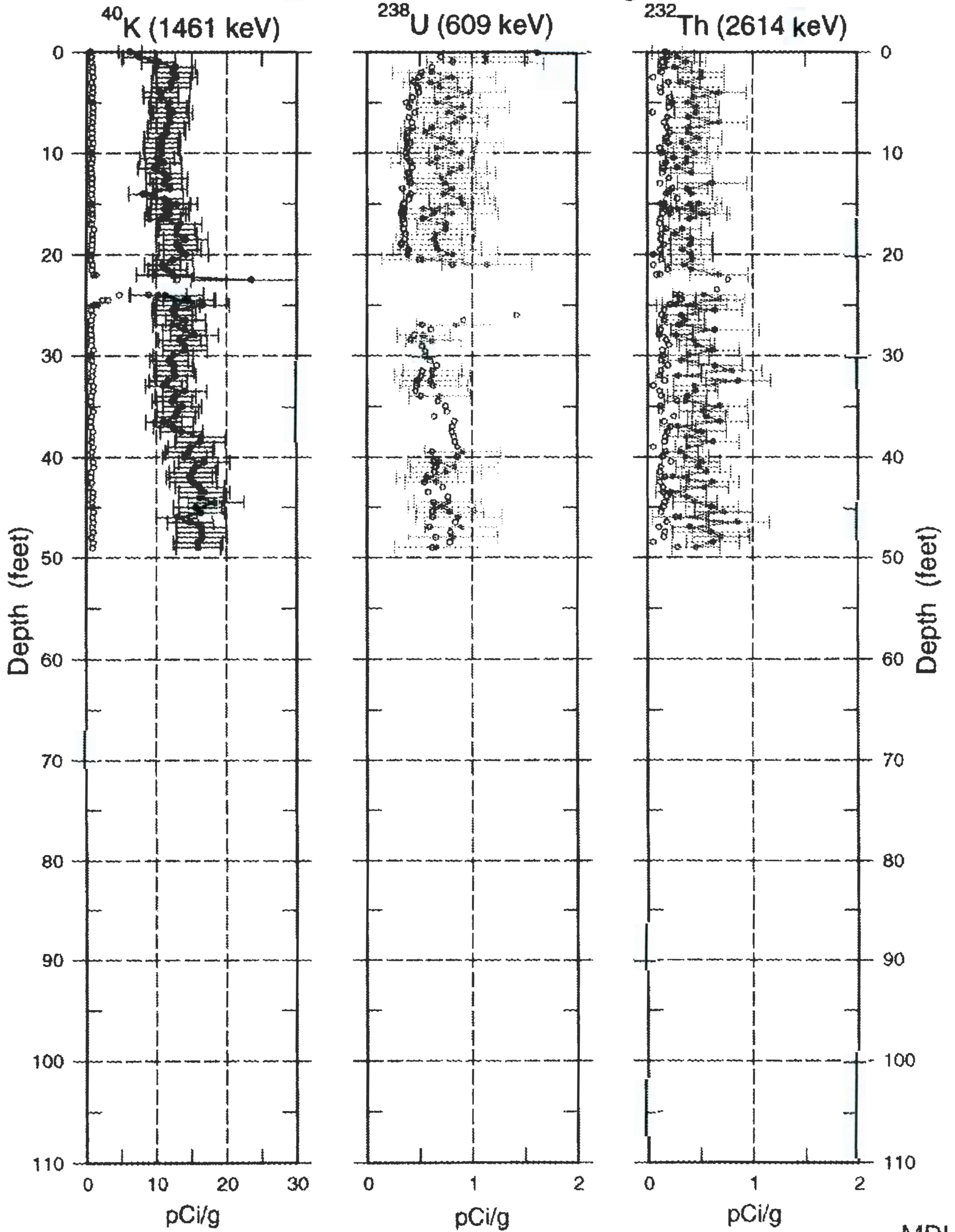
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

Borehole 30-04-03

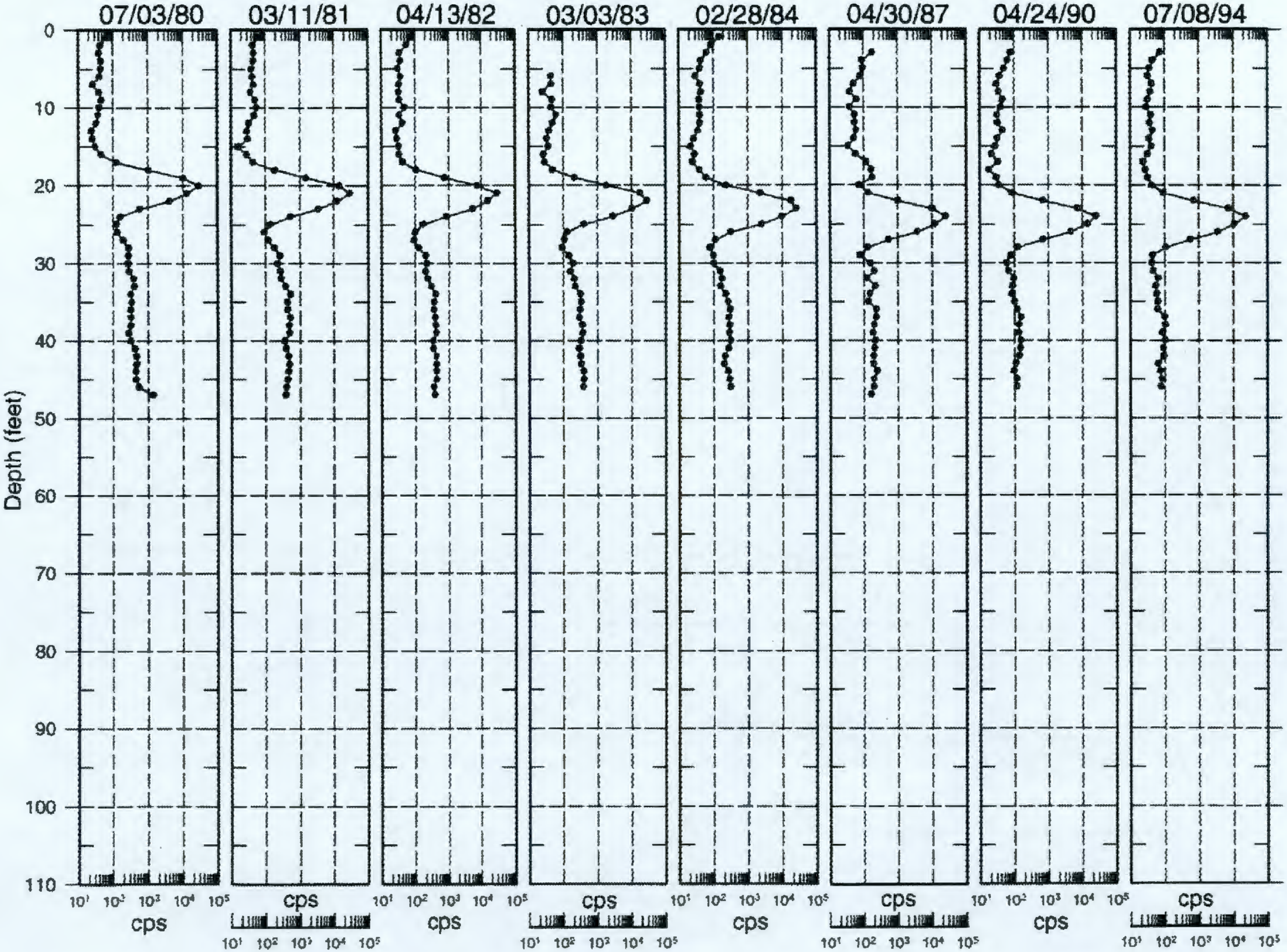
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

A plot of representative historical gross gamma-ray logs from 1980 to 1994 is included. The headings of the plots identify the date on which the data in the plots were gathered.

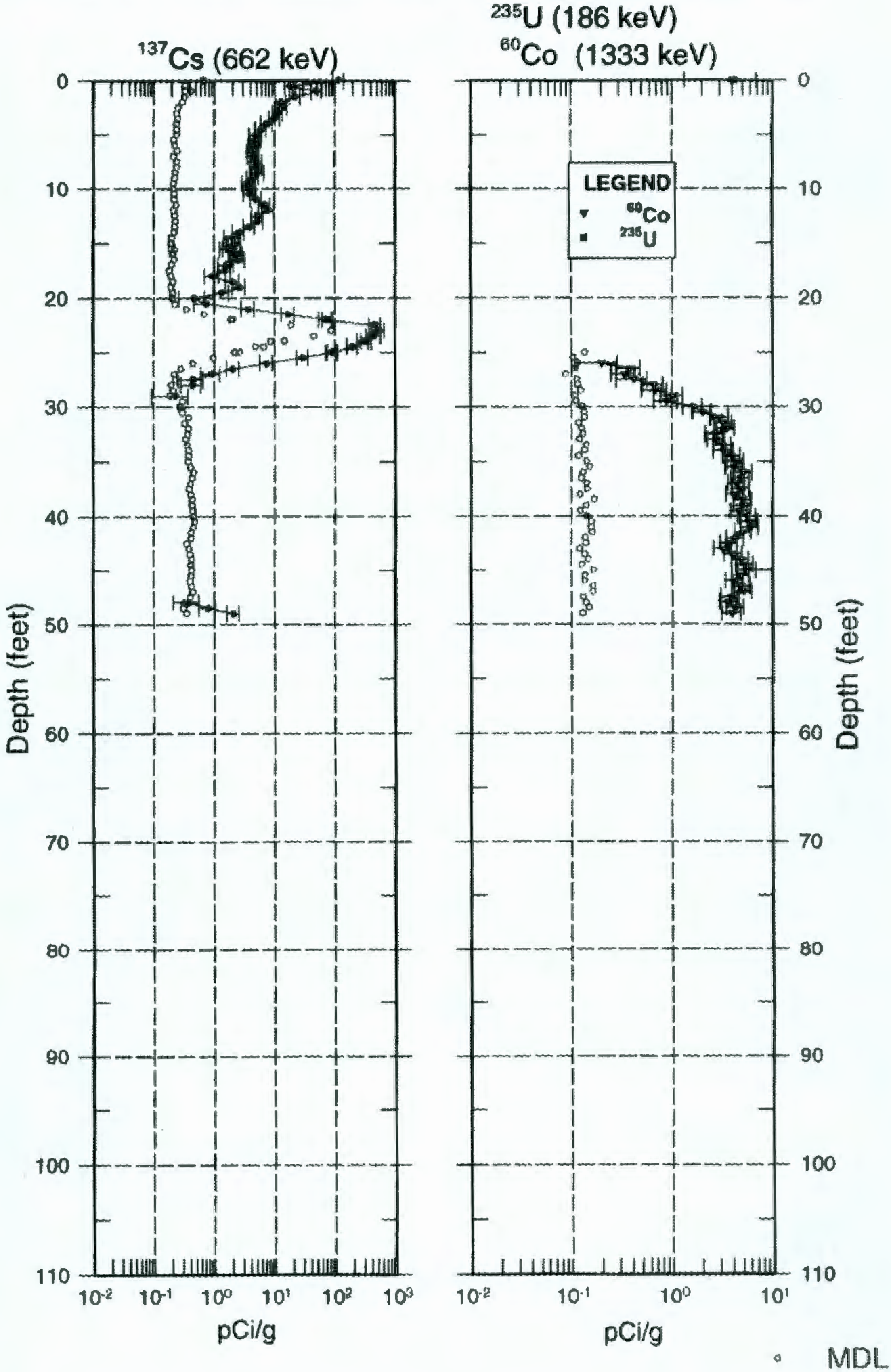
30-04-03
Natural Gamma Logs



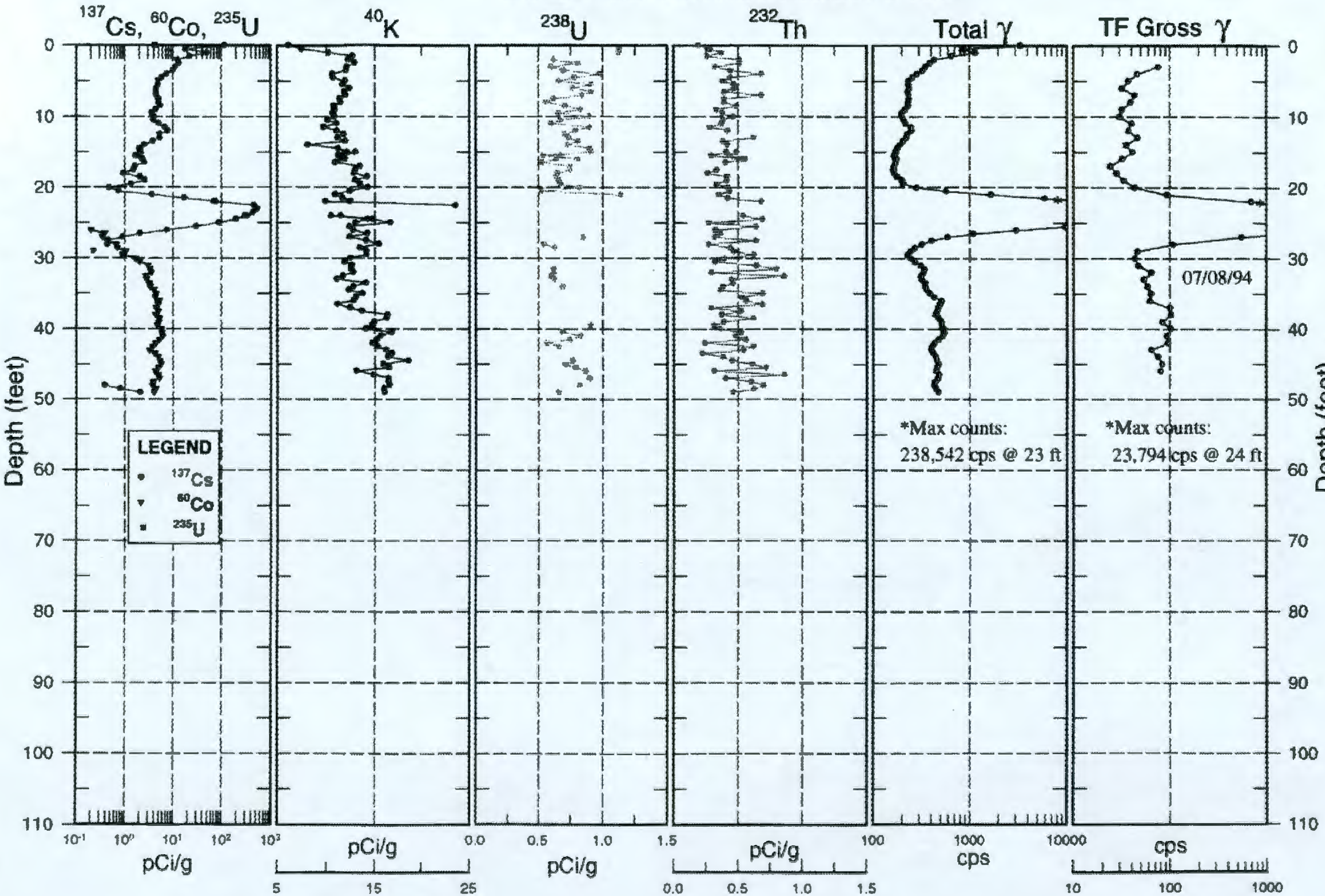
Historical Gross Gamma Logs for Borehole 30-04-03



30-04-03
Man-Made Radionuclide Concentrations



30-04-03 Combination Plot



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-05-06

Borehole Information

Farm :	C	Tank :	C-105	Site Number :	299-E27-119
N-Coord :	42,814	W-Coord :	48,353	TOC Elevation :	646.00
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. :	60		

Borehole Notes:

This borehole was drilled in July 1974 to a depth of 60 ft using 6-in. casing. The drilling report does not indicate that 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 4 in. above the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	1/22/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	25.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	1/22/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	57.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	41.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	1/23/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	42.0	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 30-05-06

Analysis Information

Analyst : E. Larsen

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

Analysis Notes :

This borehole was logged by the SGLS in three 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 U-235 were detected in this borehole. The Cs-137 contamination was detected continuously from the ground surface to 33.5 ft and from 37.5 ft to the bottom of the logged interval (57.5 ft). A single occurrence of U-235 was detected at the ground surface.

Most of the U-238 concentration data are absent from the ground surface to 2.5 ft.

The K-40 concentration values increase significantly from 38.5 to 39.5 ft and become variable from about 40 to 53.5 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-104 and C-105.

Log Plot Notes:

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

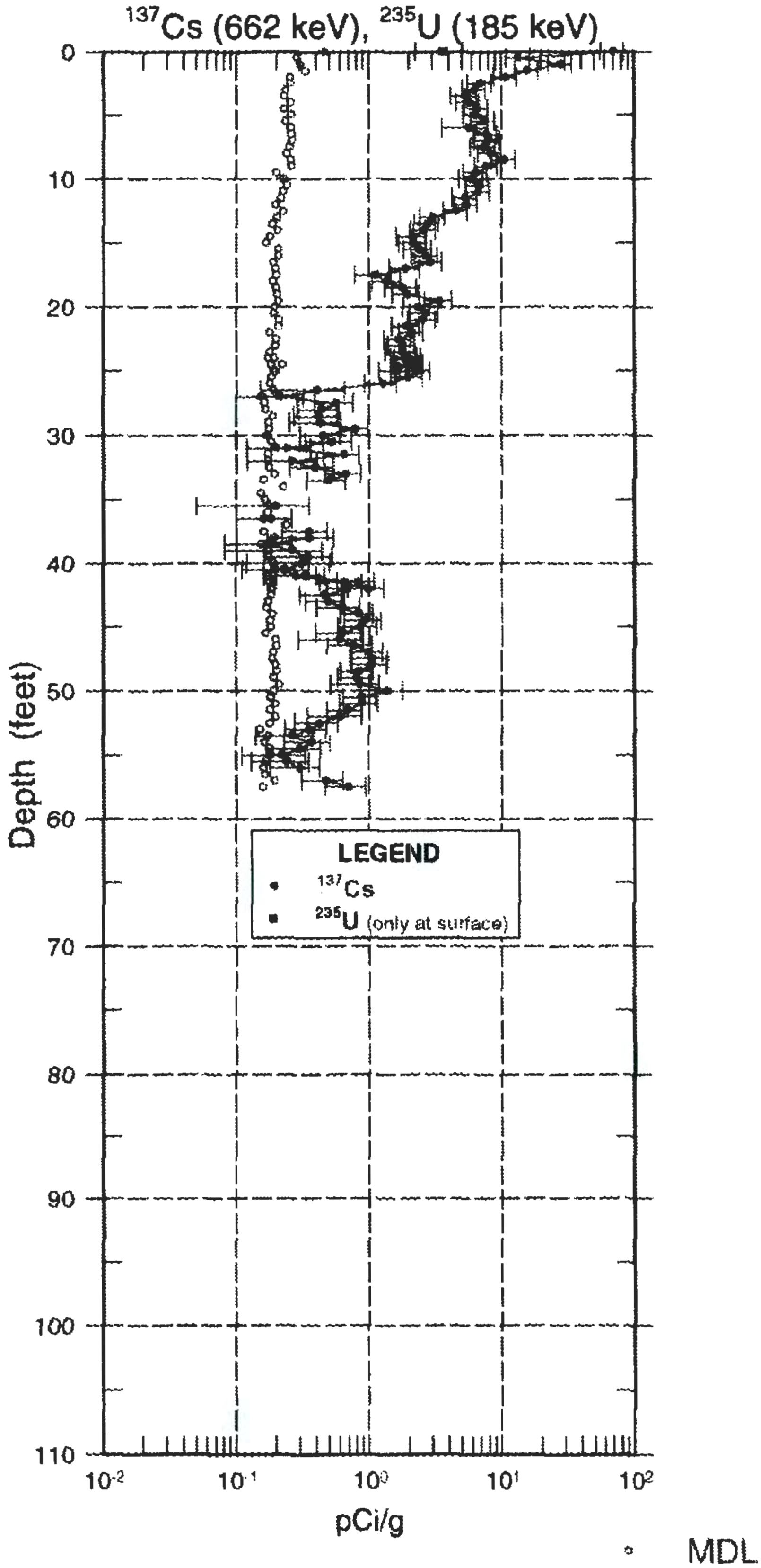
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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

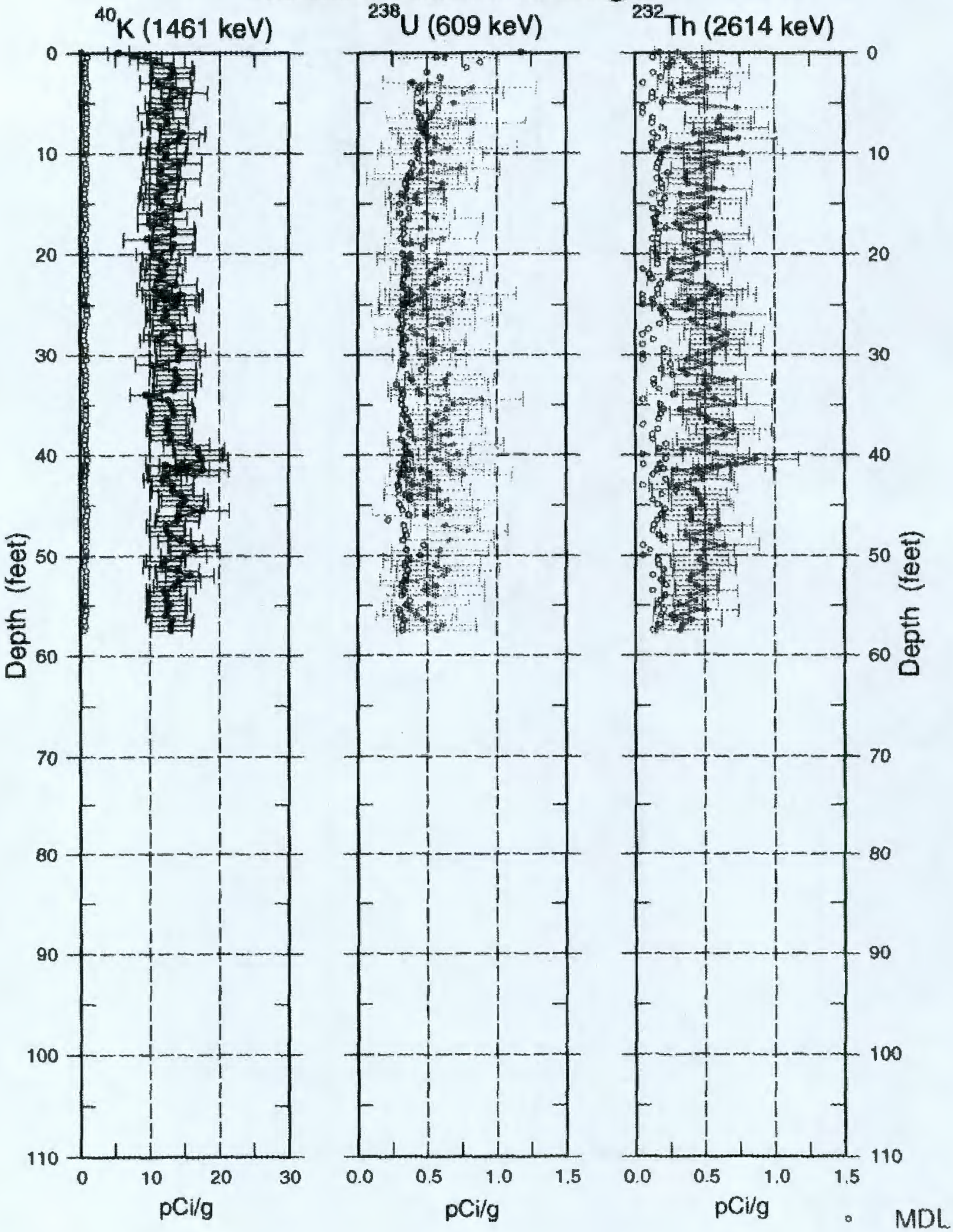
An additional log plot compares spectral gamma data collected with the Radionuclide Logging System (RLS) in 1993 with spectral gamma data collected with the SGLS in 1997. Uncertainty bars and MDLs are not included on these plots.

30-05-06

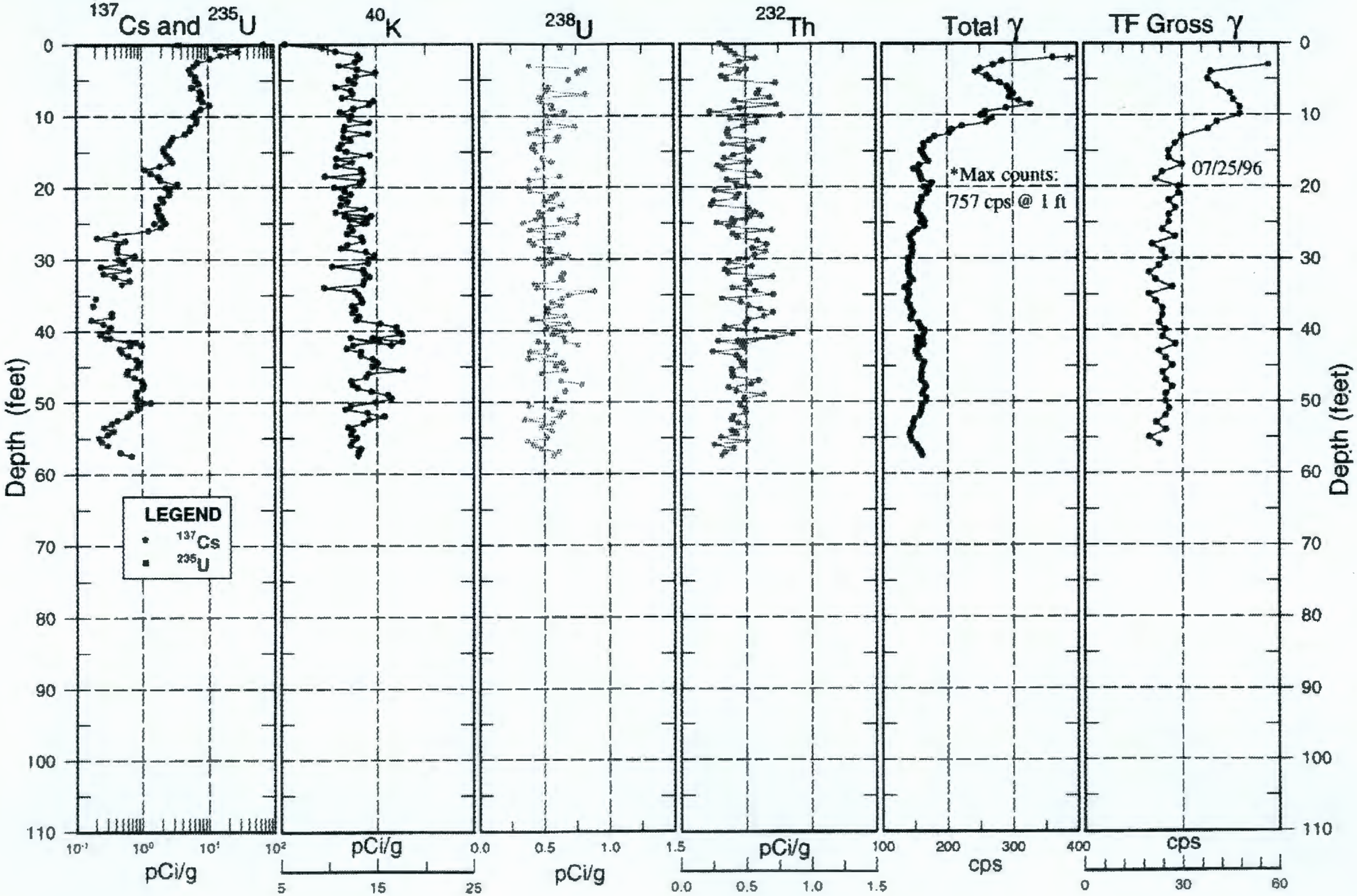
Man-Made Radionuclide Concentrations



30-05-06
Natural Gamma Logs



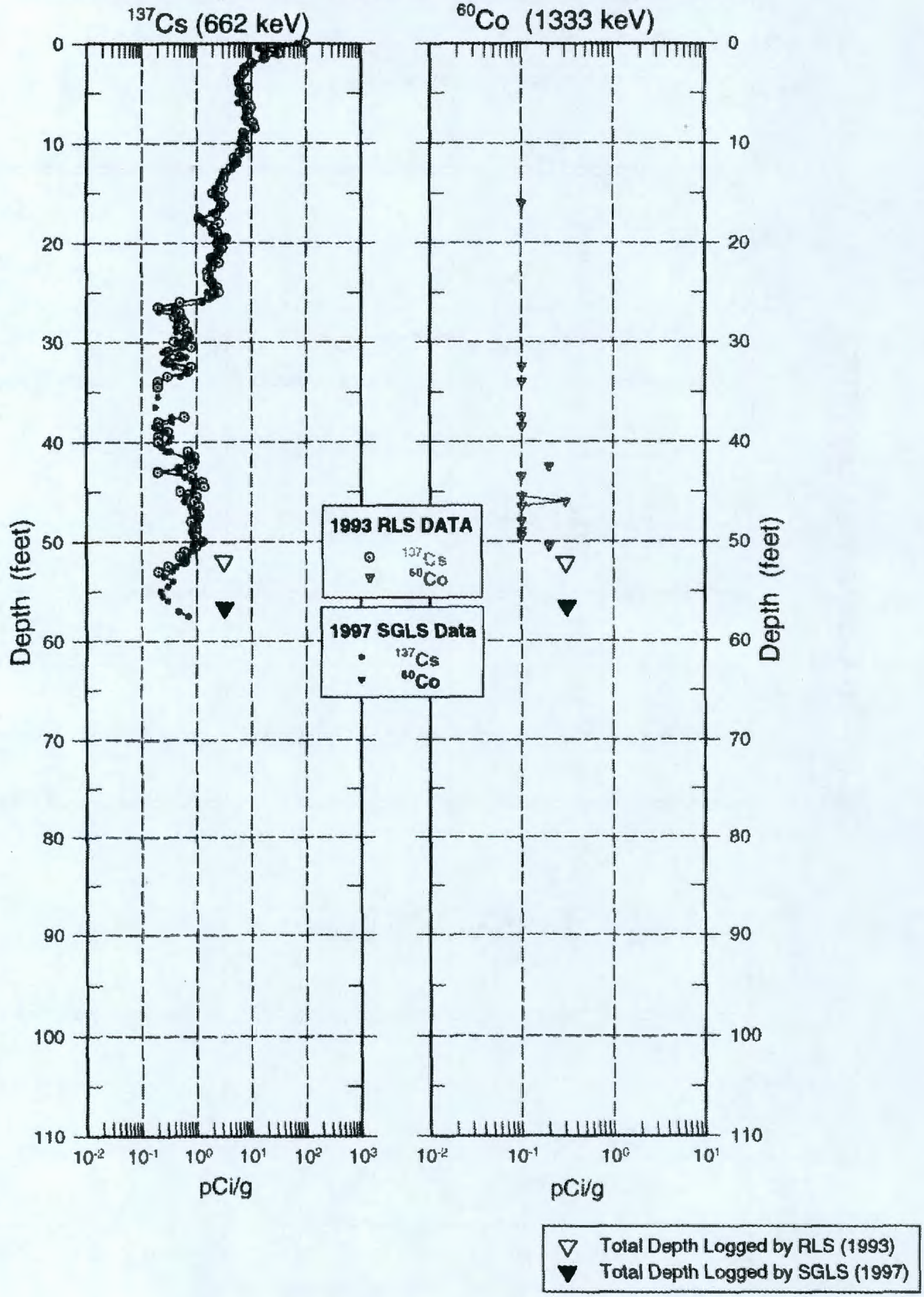
30-05-06 Combination Plot



30-05-06

Man-Made Radionuclide Concentrations

1993/1997 Spectral Gamma Data Comparison



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-04-04

Borehole Information

Farm :	C	**Tank :**	C-104	**Site Number :**	299-E27-79
N-Coord :	42,790	**W-Coord :**	48,352	**TOC Elevation :**	646.60
Water Level, ft :	None	**Date Drilled :**	6/30/74		

Casing Record

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

Borehole Notes:

This borehole was drilled in June 1974 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface. This borehole is located approximately 8 ft west of a transfer pit.

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 :**	2/11/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	98.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	78.5	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	2/12/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	2.5	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	2/12/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	2.5	**Counting Time, sec.:**	100	**L/R :**	R	**Shield :**	N
Finish Depth, ft. :	5.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-04-04

Log Run Number :	4	Log Run Date :	2/12/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	5.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	14.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	5	Log Run Date :	2/14/97	Logging Engineer:	Alan Pearson		
Start Depth, ft.:	79.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	13.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787   Analysis Date : 7/29/97

Analysis Notes :

This borehole was logged by the SGLS in five log runs. Excessive dead time (greater than 50 percent) was encountered during log run two at a depth of 2.5 ft. As a result, log run three was logged in real time from 2.5 to 5 ft. The remainder of the borehole (log runs four and five) was logged in live time, after the dead time dropped below 50 percent. 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 radionuclide Cs-137 was detected around this borehole. The Cs-137 contamination was detected continuously from the ground surface to 37 ft and nearly continuously from 41.5 to 59.5 ft. Numerous small zones of Cs-137 contamination were detected between 62.5 ft and the bottom of the logged interval (98.5 ft).

The K-40 and Th-232 concentration data are absent from 2.5 to 4.5 ft. The U-238 concentration data are absent from the ground surface to 6.5 ft.

The K-40 concentration values increase from 36.5 to 37.5 and generally remain elevated to a depth of 61 ft. The K-40 concentrations values increase again at 61 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-104.

Log Event A

Borehole 30-04-04

Log Plot Notes:

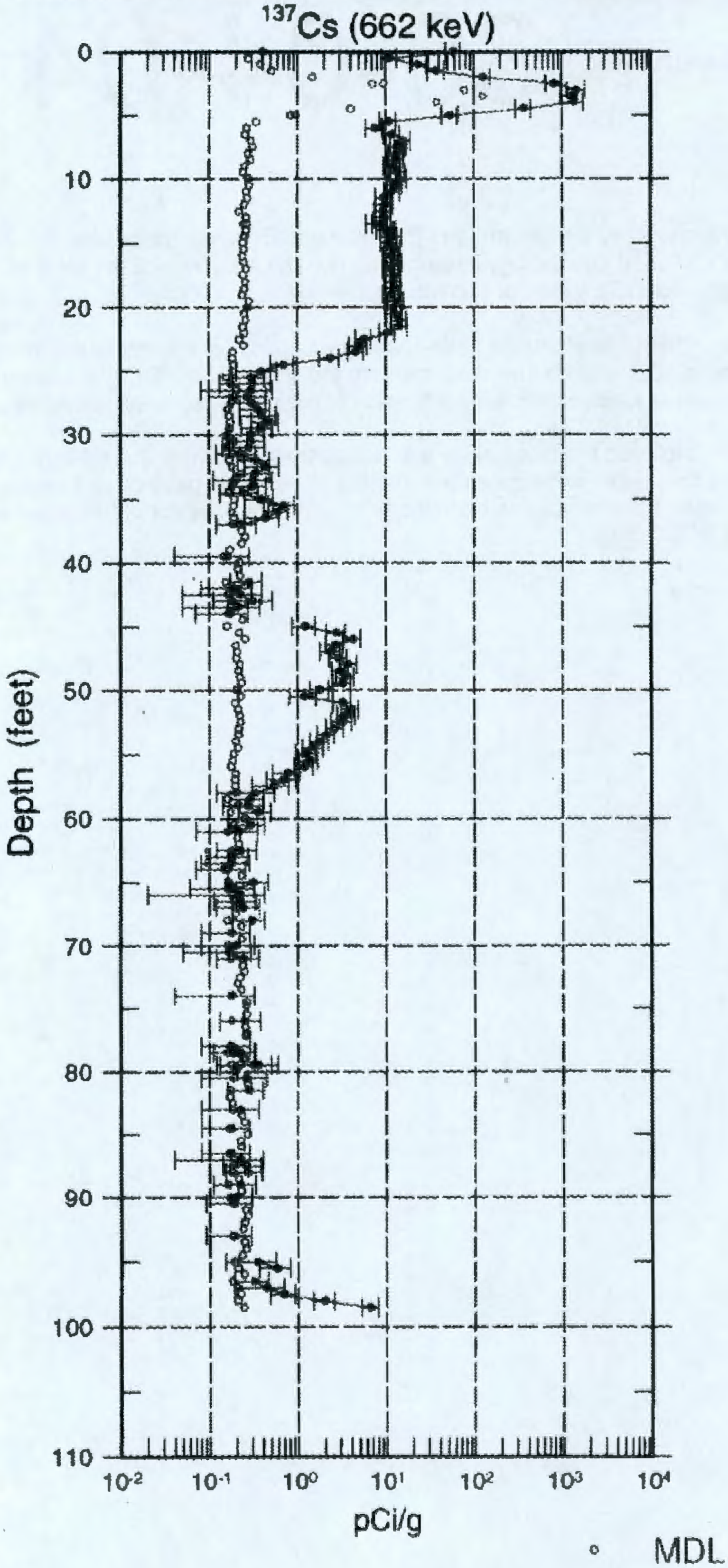
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

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.

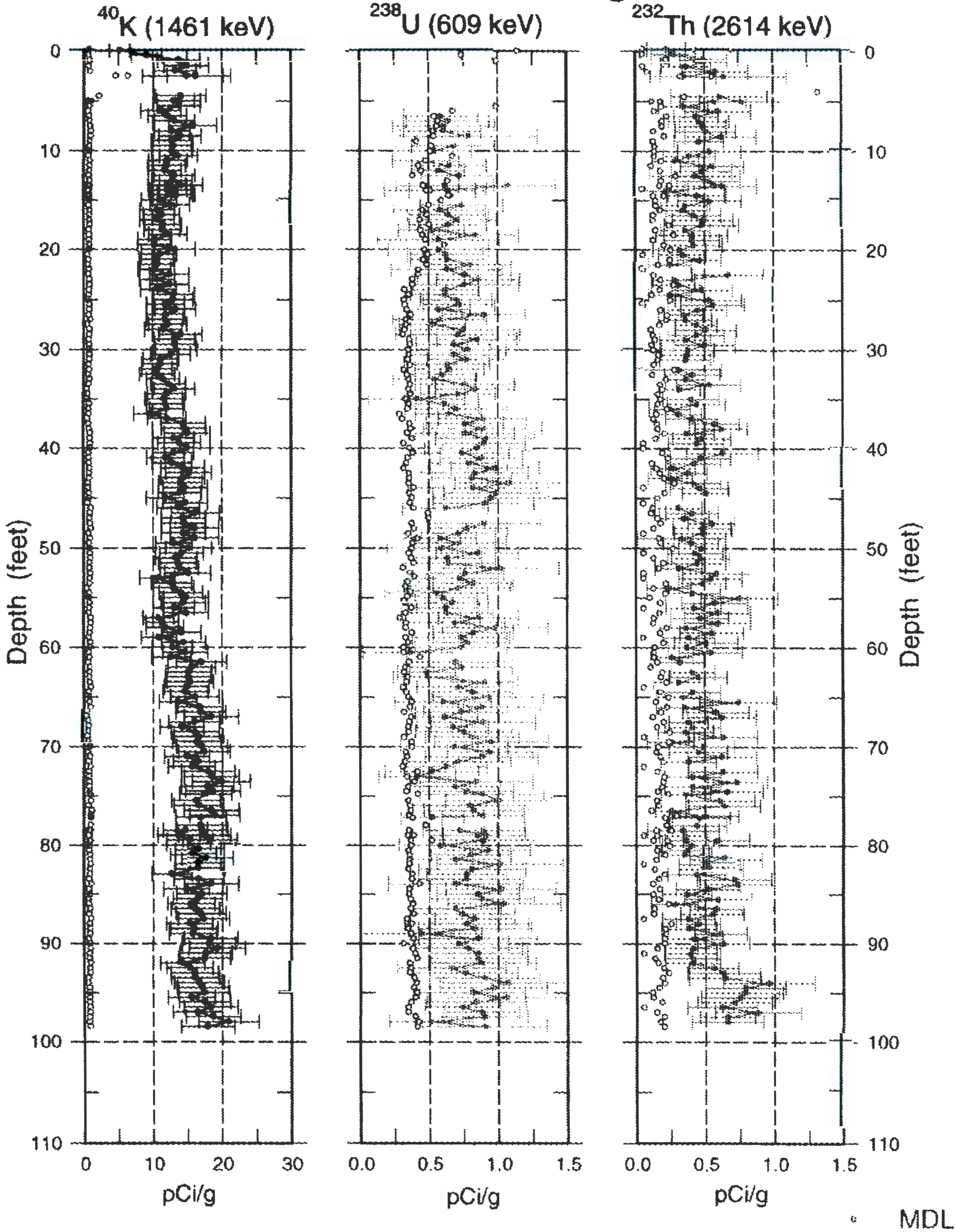
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-04-04

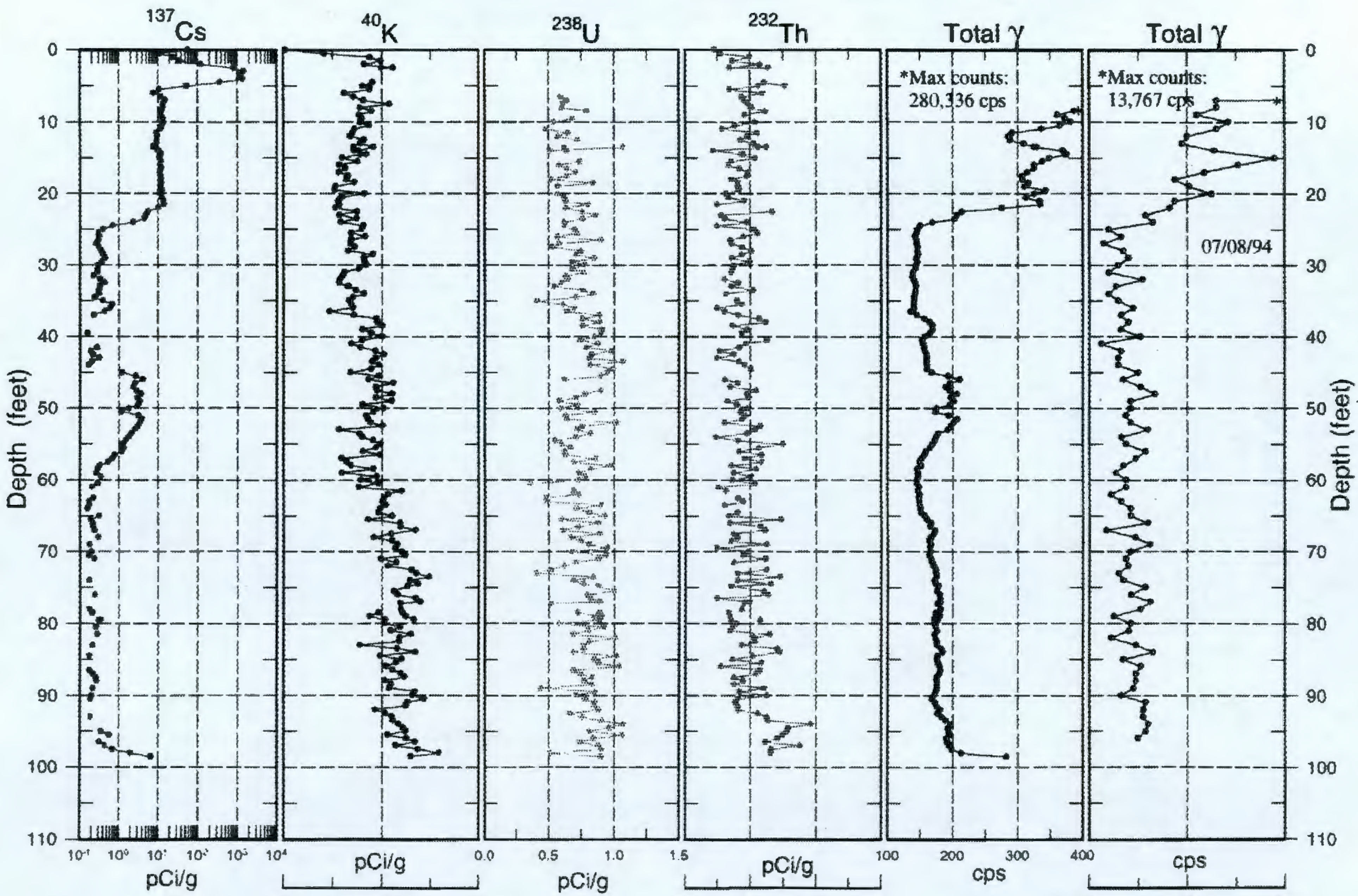
Man-Made Radionuclide Concentrations



30-04-04
Natural Gamma Logs



30-04-04 Combination Plot



Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-01-12

Borehole Information

Farm :	C	Tank :	C-101	Site Number :	299-E27-61
N-Coord :	42,762	W-Coord :	48,339	TOC Elevation :	646.82
Water Level, ft :	None	Date Drilled :	3/31/70		

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

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	3/20/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	18.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/21/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	99.5	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 Event A

Borehole 30-04-05

Log Run Number :	4	Log Run Date :	2/11/97	Logging Engineer:	Bob Spatz
Start Depth, ft.:	53.0	Counting Time, sec.:	100	L/R : L	Shield : N
Finish Depth, ft. :	11.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a

Analysis Information

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

Analysis Notes :

This borehole was logged by the SGLS in four log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy and peak-shape calibrations 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 radionuclide Cs-137 was detected in this borehole. The presence of Cs-137 was measured nearly continuously from the ground surface to a depth of 57.5 ft, intermittently from 69.5 to 91.5 ft, and continuously from 94.5 ft to the bottom of the logged interval.

The U-238 concentration data are absent between 11.5 and 14.5 ft and along numerous short intervals between the ground surface and 11 ft.

The K-40 concentrations increase to about 15 pCi/g from 38 to 45 ft. K-40 concentrations are slightly decreased and variable from 45.5 to about 58 ft, then increase gradually from 59 to 89 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-101 and C-104.

Log Plot Notes:

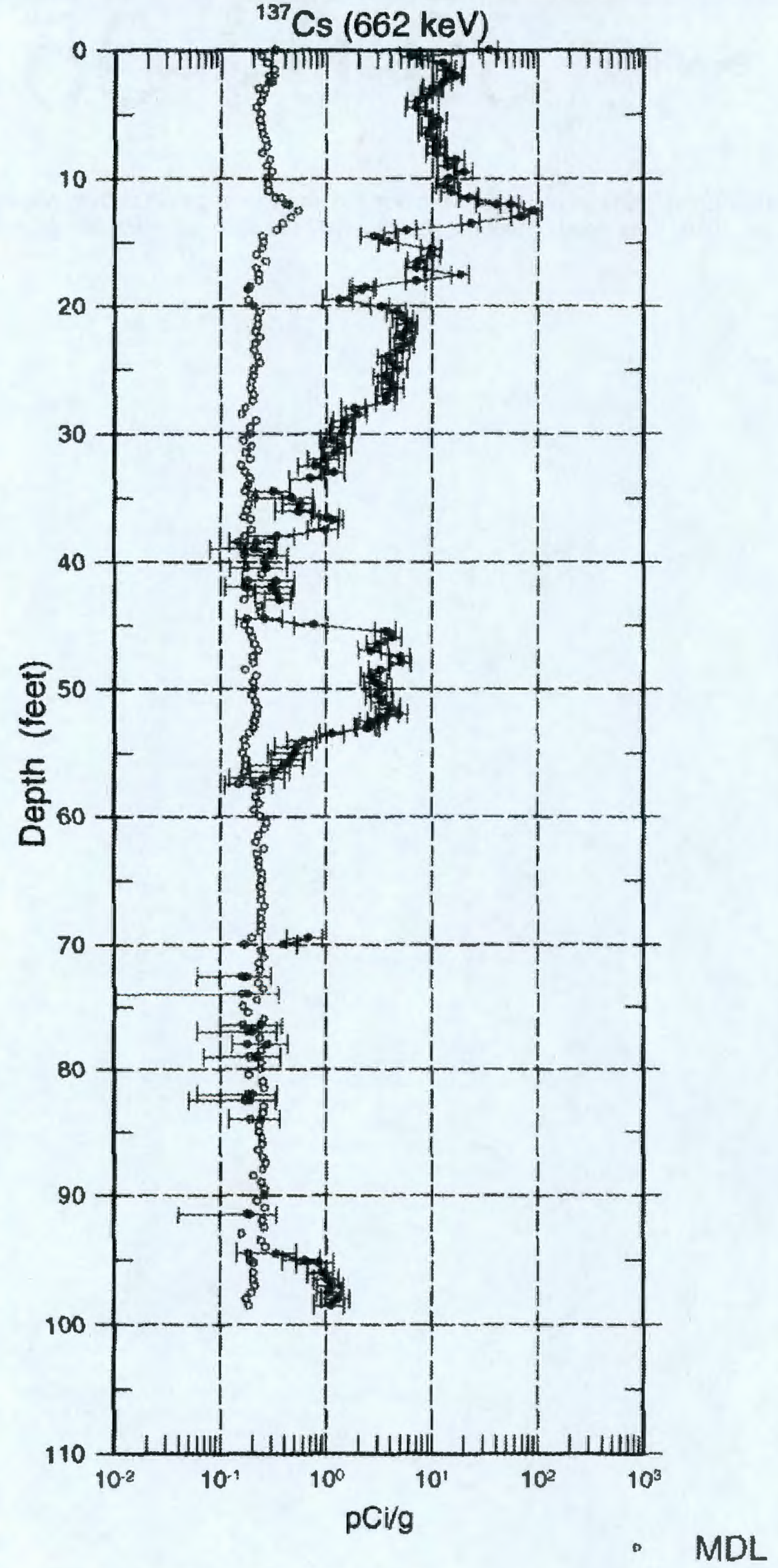
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties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

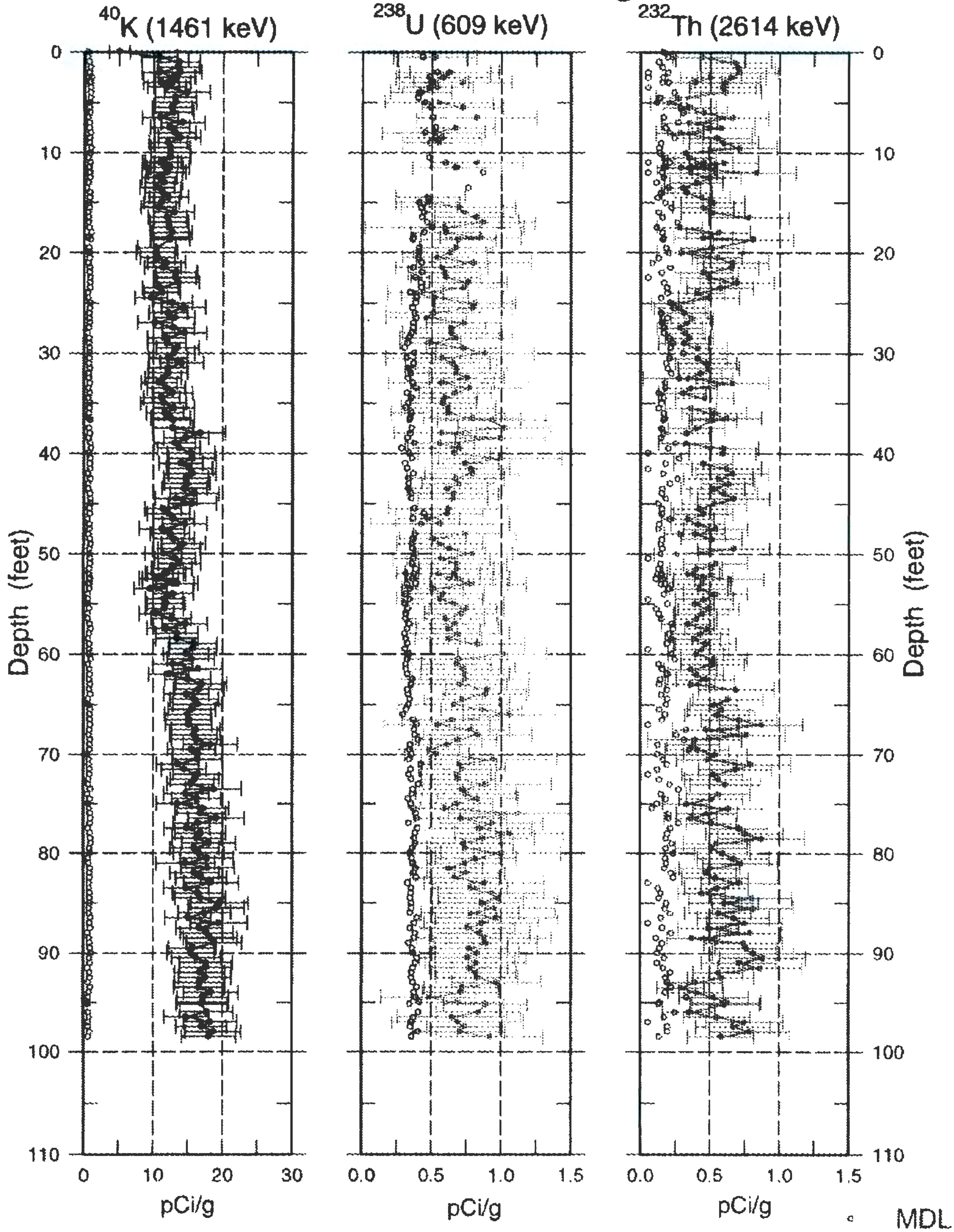
A plot of representative historical gross gamma-ray logs from 1975 to 1992 is included. An additional plot of historical gross gamma-ray logs is provided to show changes in activity recorded from January 1978 to March 1978. The headings of the plots identify the date on which the data in the plots were gathered.

30-04-05

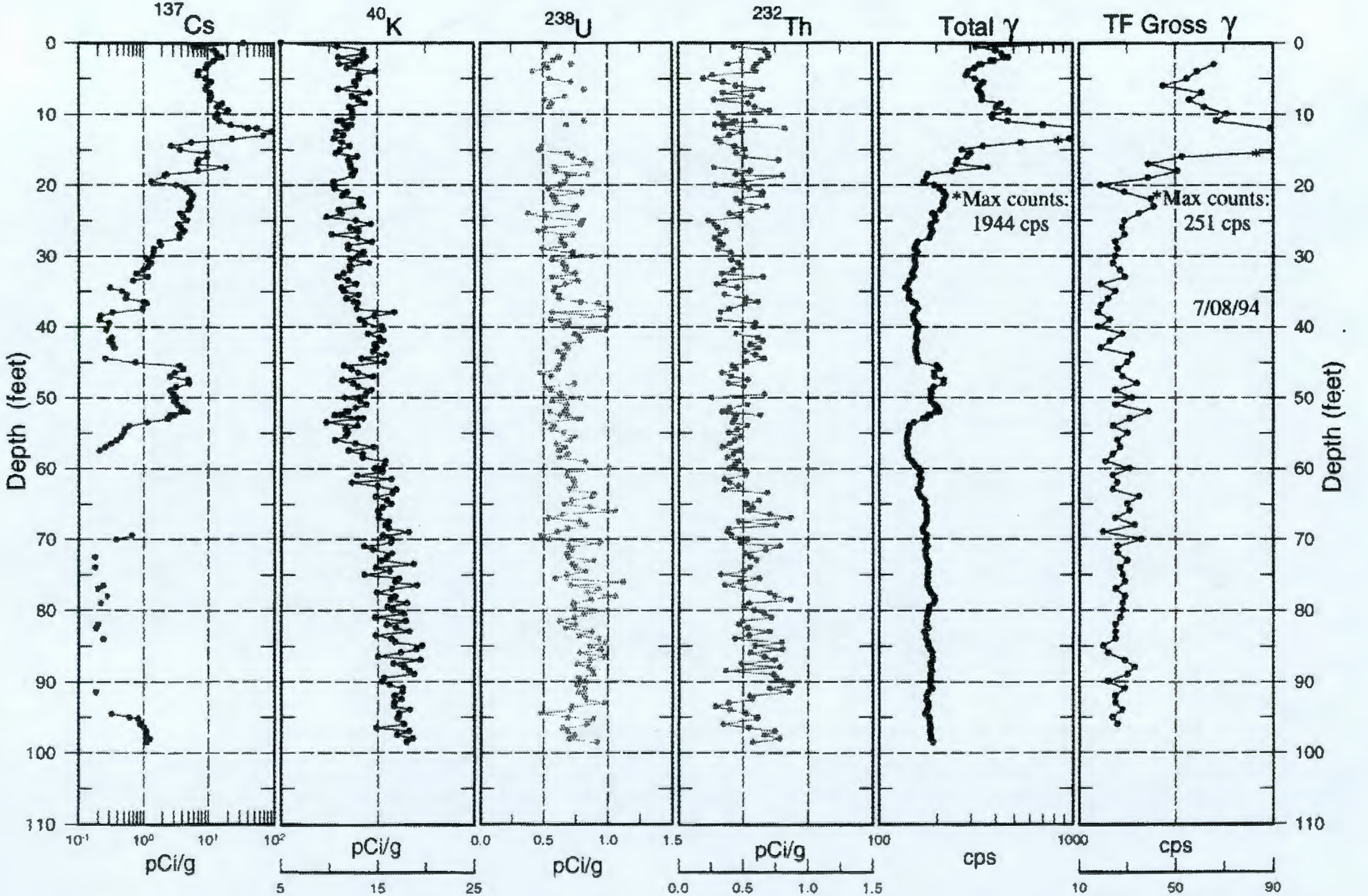
Man-Made Radionuclide Concentrations



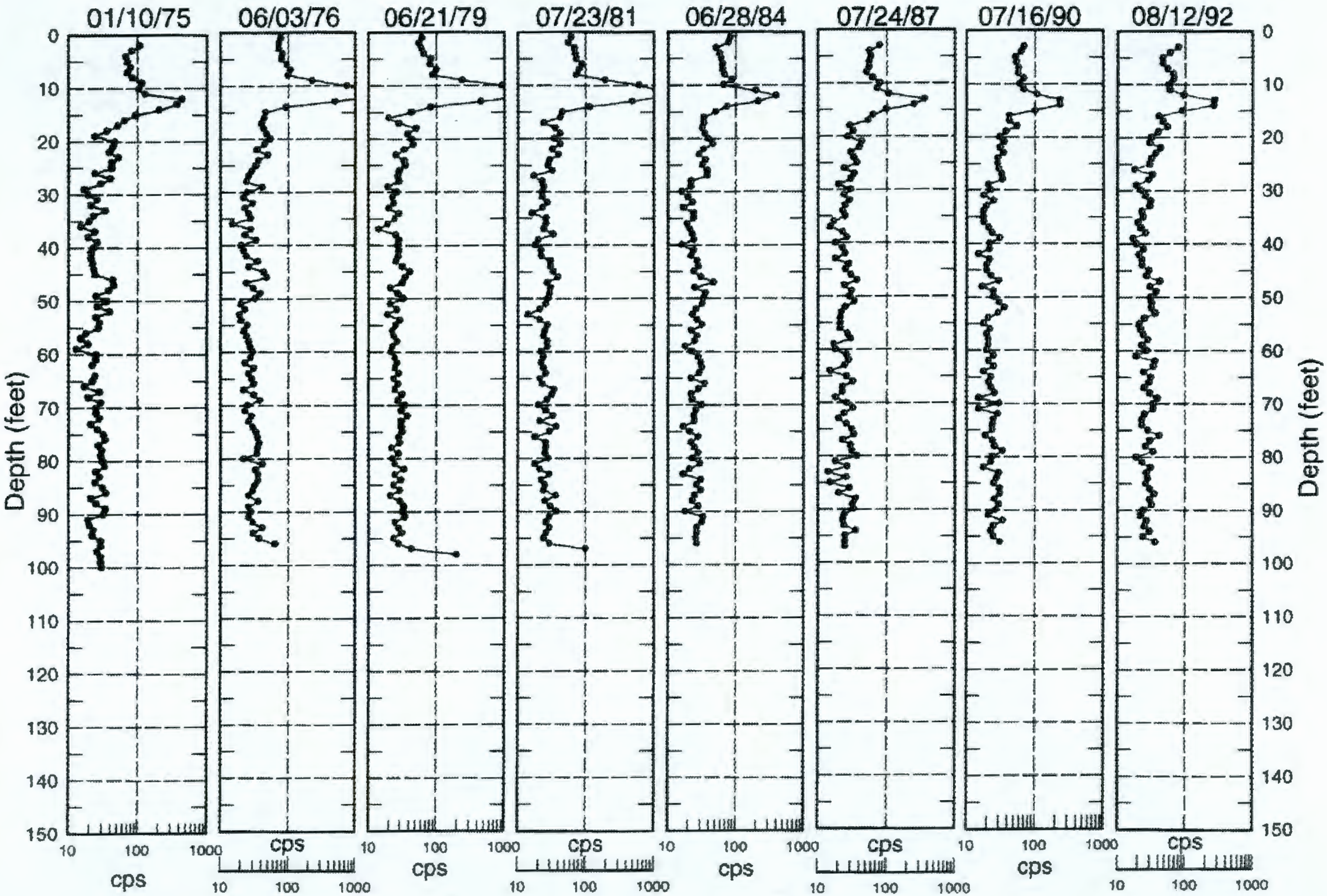
30-04-05
Natural Gamma Logs



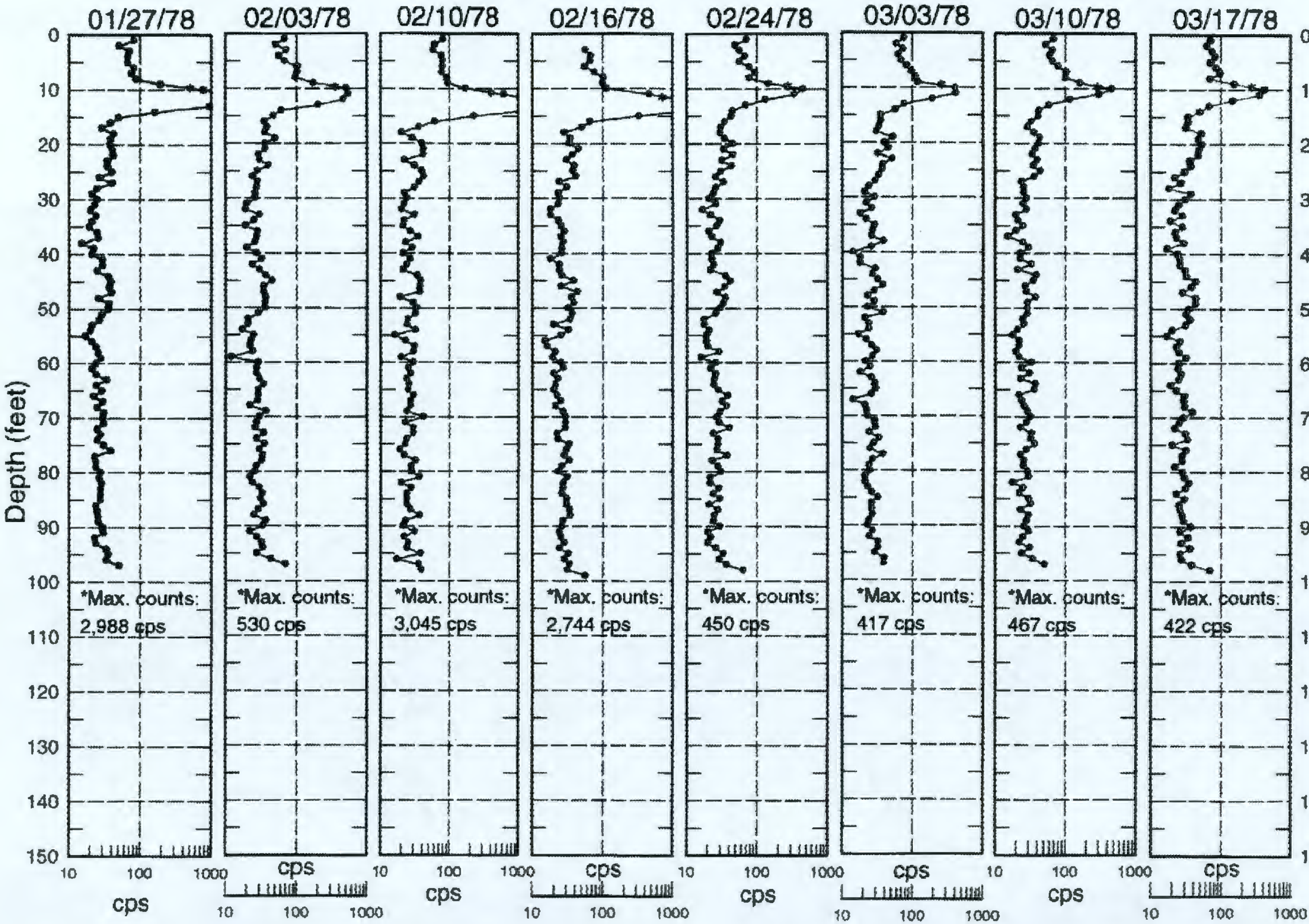
30-04-05 Combination Plot



Historical Gross Gamma Logs for Borehole 30-04-05



Changes in Gross Gamma Logs for Borehole 30-04-05



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-04-08

Borehole Information

Farm :	C	Tank :	C-104	Site Number :	299-E27-66
N-Coord :	42,759	W-Coord :	48,437	TOC Elevation :	649.06
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. :	145		

Borehole Notes:
This borehole was drilled in November 1972 and completed to a depth of 145 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole casing was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is approximately 2 ft above the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	4/18/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	24.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	4/21/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	143.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	71.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	4/22/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	72.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	23.5	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-04-08

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/29/97

Analysis Notes :

This borehole was logged by the SGLS in three 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 radionuclide Cs-137 was detected in this borehole. Mostly continuous Cs-137 contamination was detected from the ground surface to 38.5 ft and 45 to 70.5 ft.

The K-40 concentration values increase at 39 ft and show slight variability to a depth of 49 ft. K-40 concentrations increase gradually from 52.5 to 71.5 ft.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Report for tank C-104.

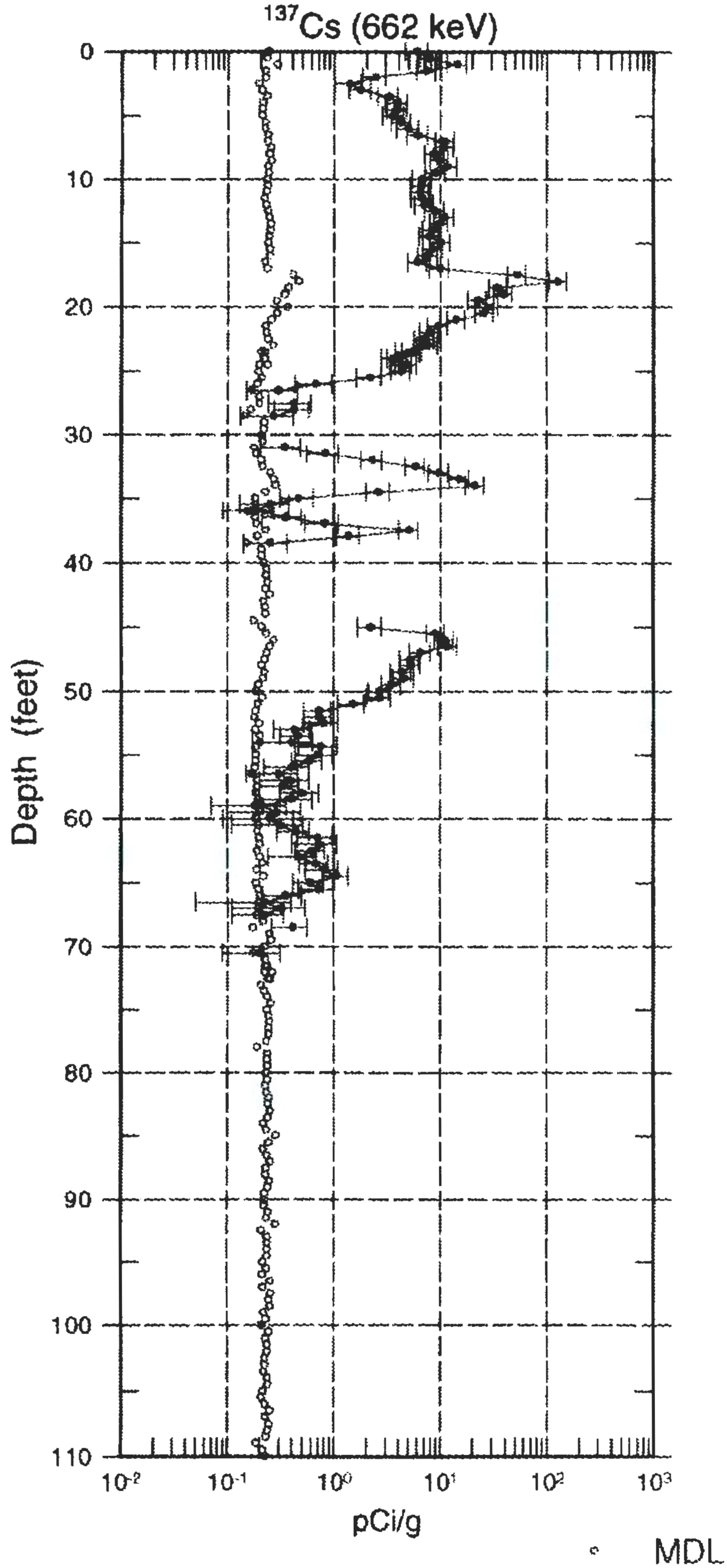
Log Plot Notes:

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.

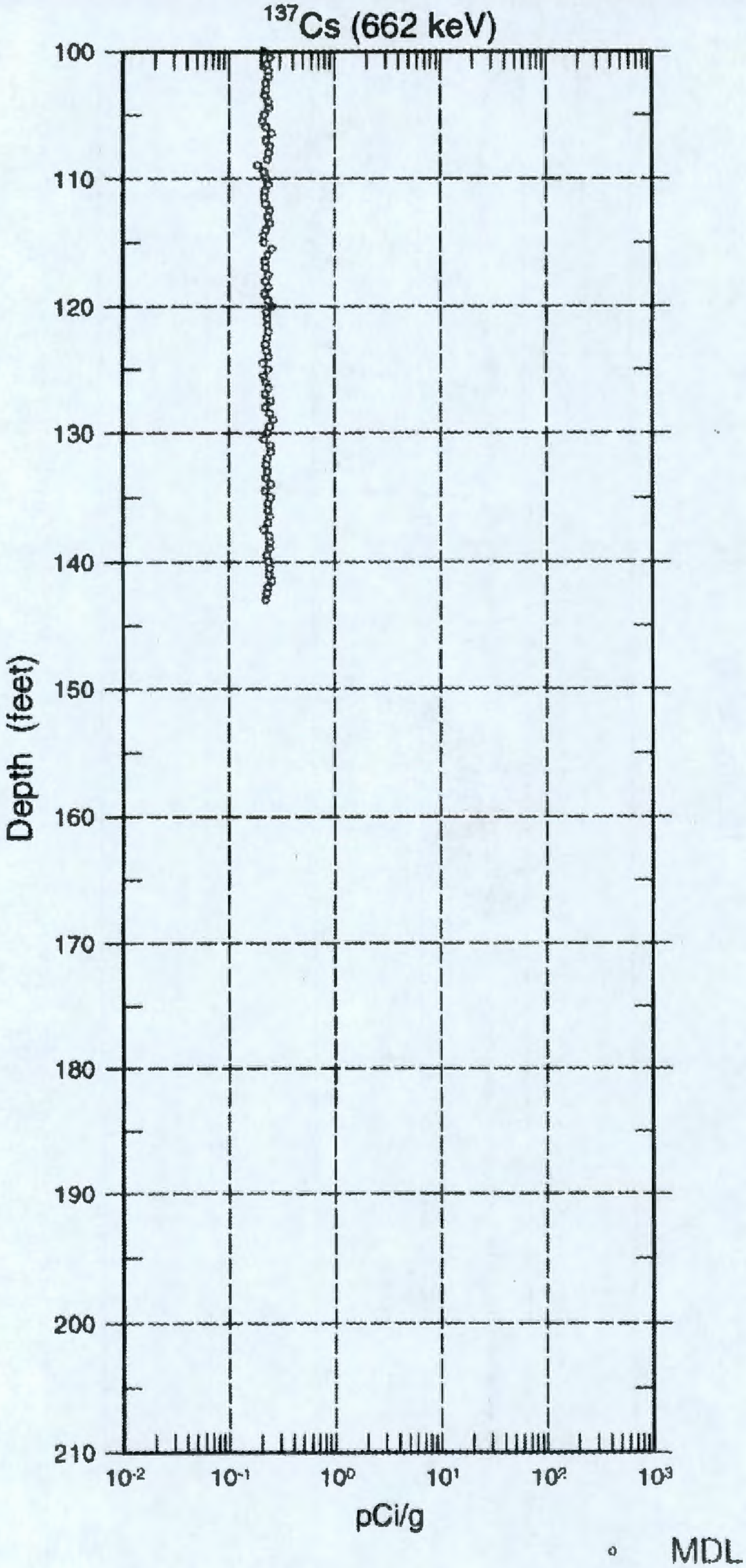
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-04-08
Man-Made Radionuclide Concentrations

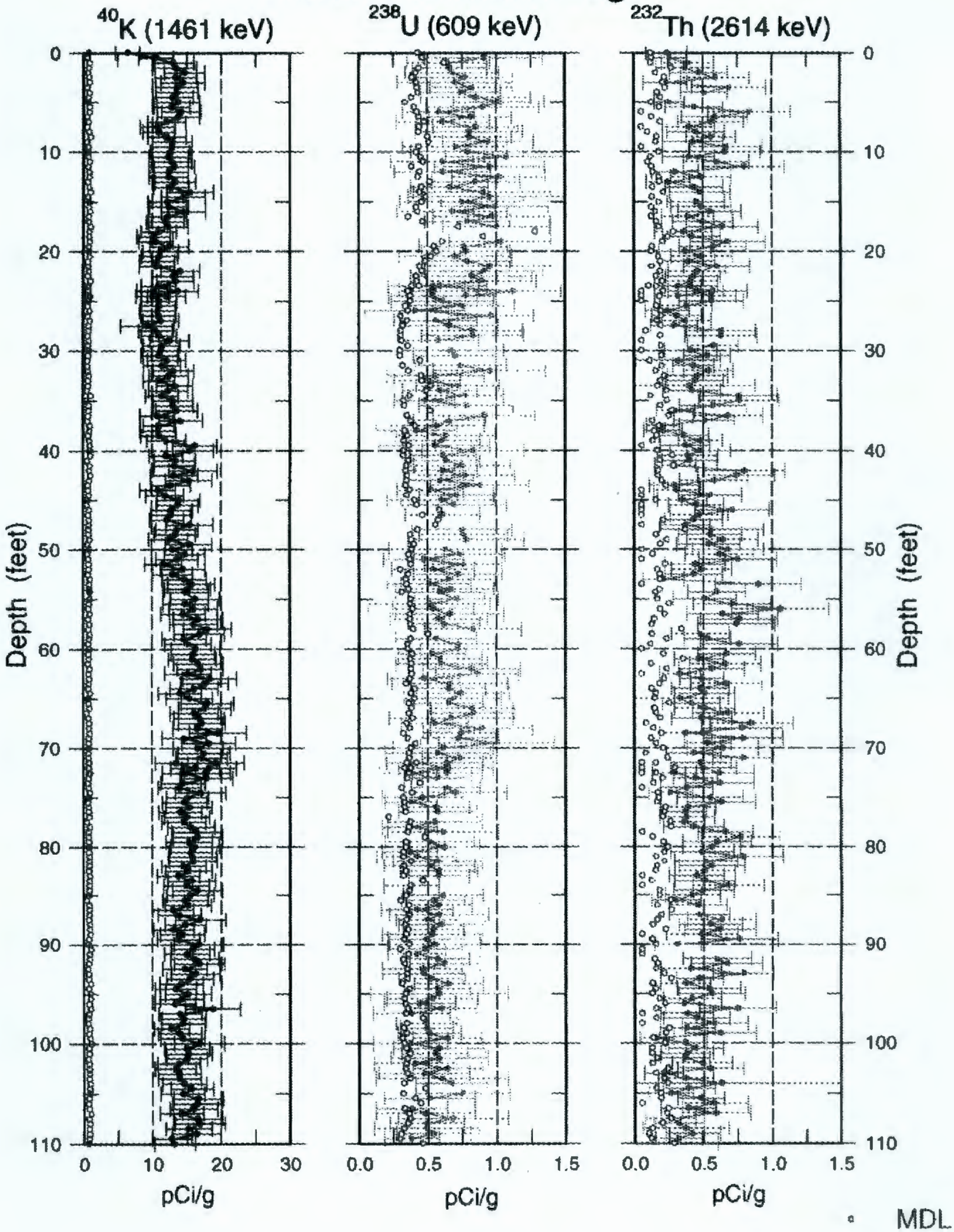


30-04-08

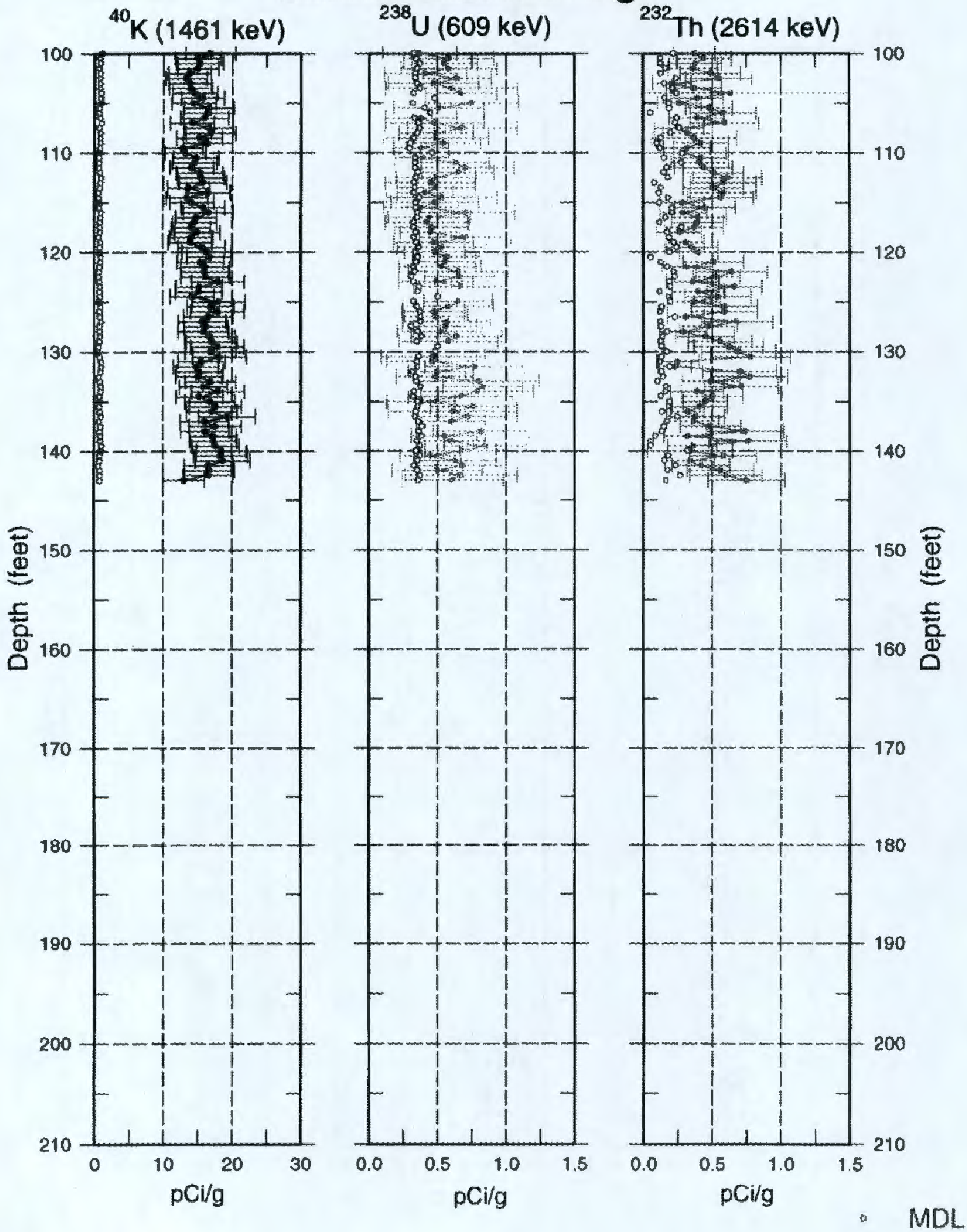
Man-Made Radionuclide Concentrations



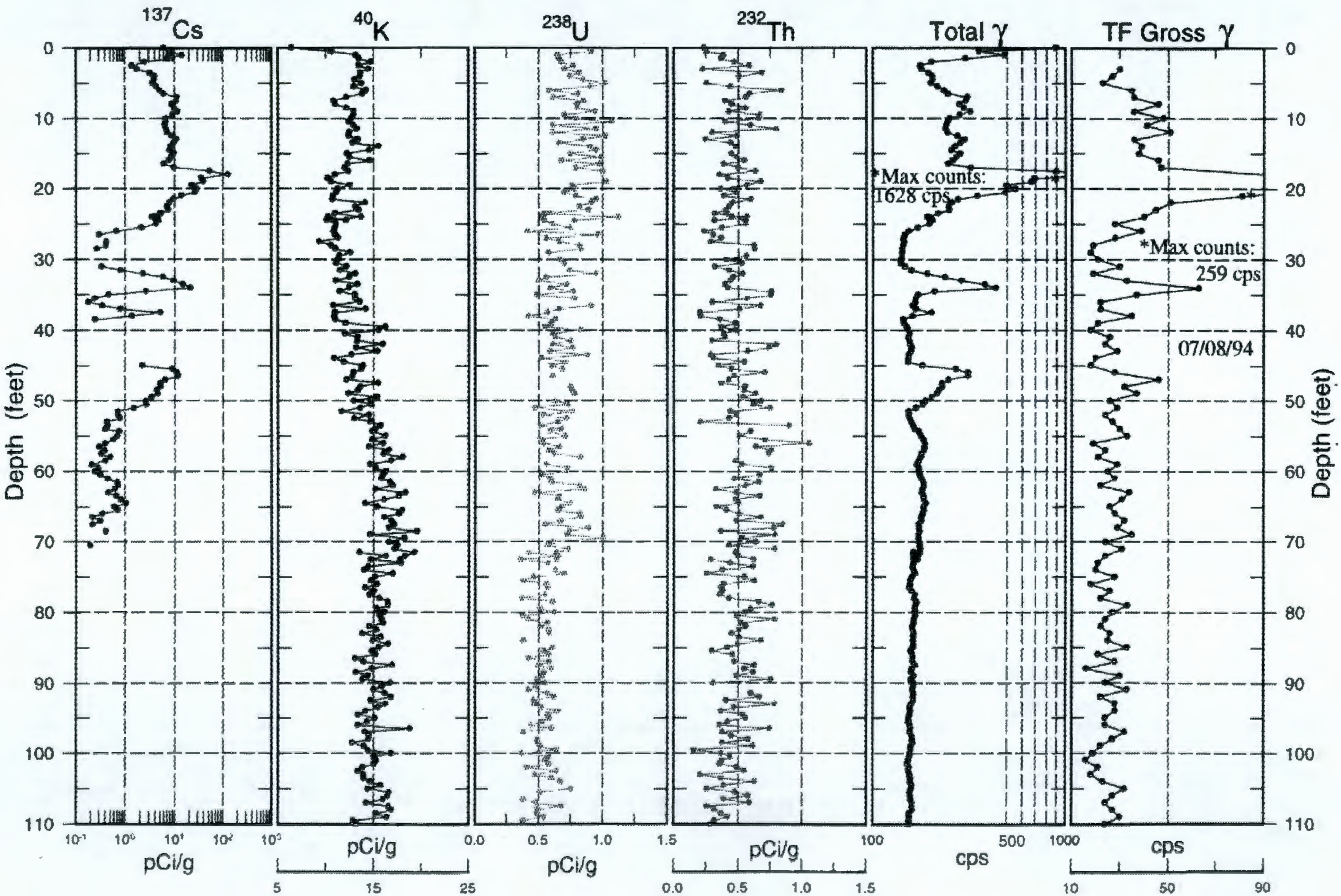
30-04-08
Natural Gamma Logs



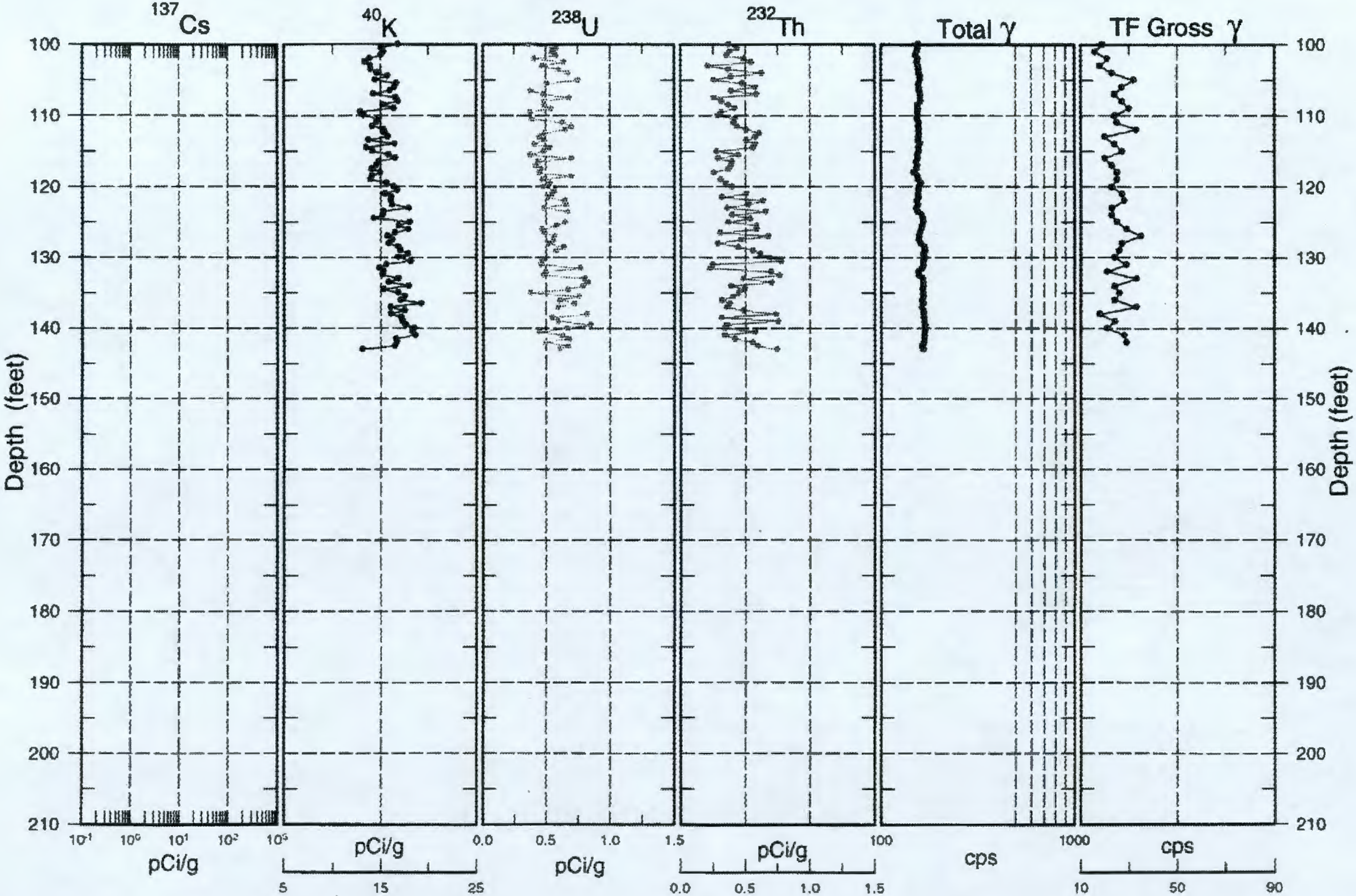
30-04-08
Natural Gamma Logs



30-04-08 Combination Plot



30-04-08 Combination Plot



Log Event A

Borehole 30-01-12

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : P-GJPO-1787 Analysis Date : 6/27/97

Analysis Notes :

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

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

The man-made radionuclide Cs-137 was detected in this borehole. The Cs-137 contamination was detected nearly continuously from the ground surface to a depth of 40.5 ft. Isolated occurrences of Cs-137 were detected at 45, 60, and 66.5 ft, and at the bottom of the logged interval (99.5 ft).

The U-238 concentration data are almost entirely absent from the ground surface to 8 ft.

The K-40 concentrations increase to about 14 pCi/g between 38.5 and 50.5 ft. K-40 concentrations are slightly decreased from 51 to about 58 ft. The K-40 background concentrations increase gradually from 59.5 to 92.5 ft.

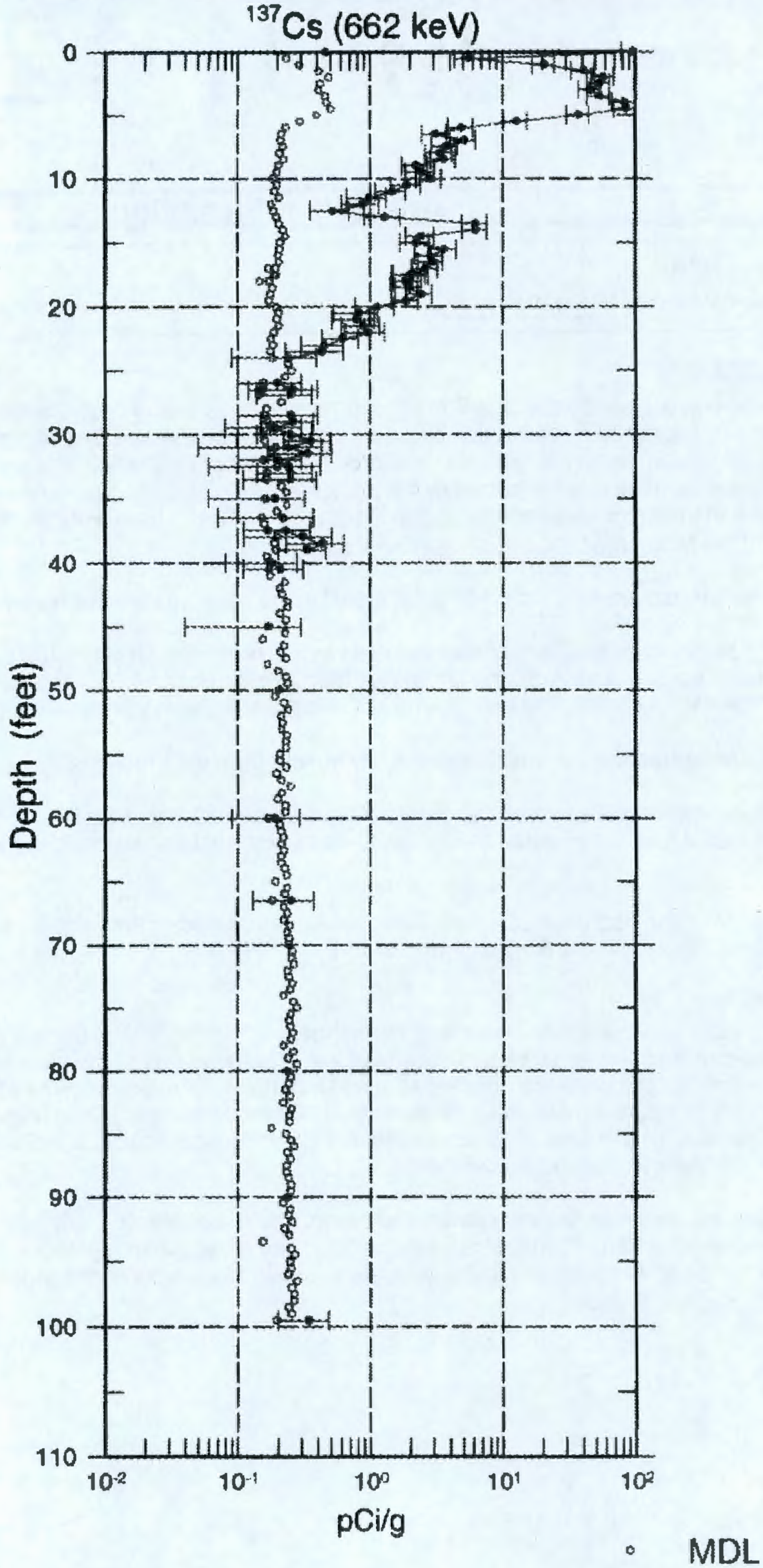
Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-101 and C-104.

Log Plot Notes:

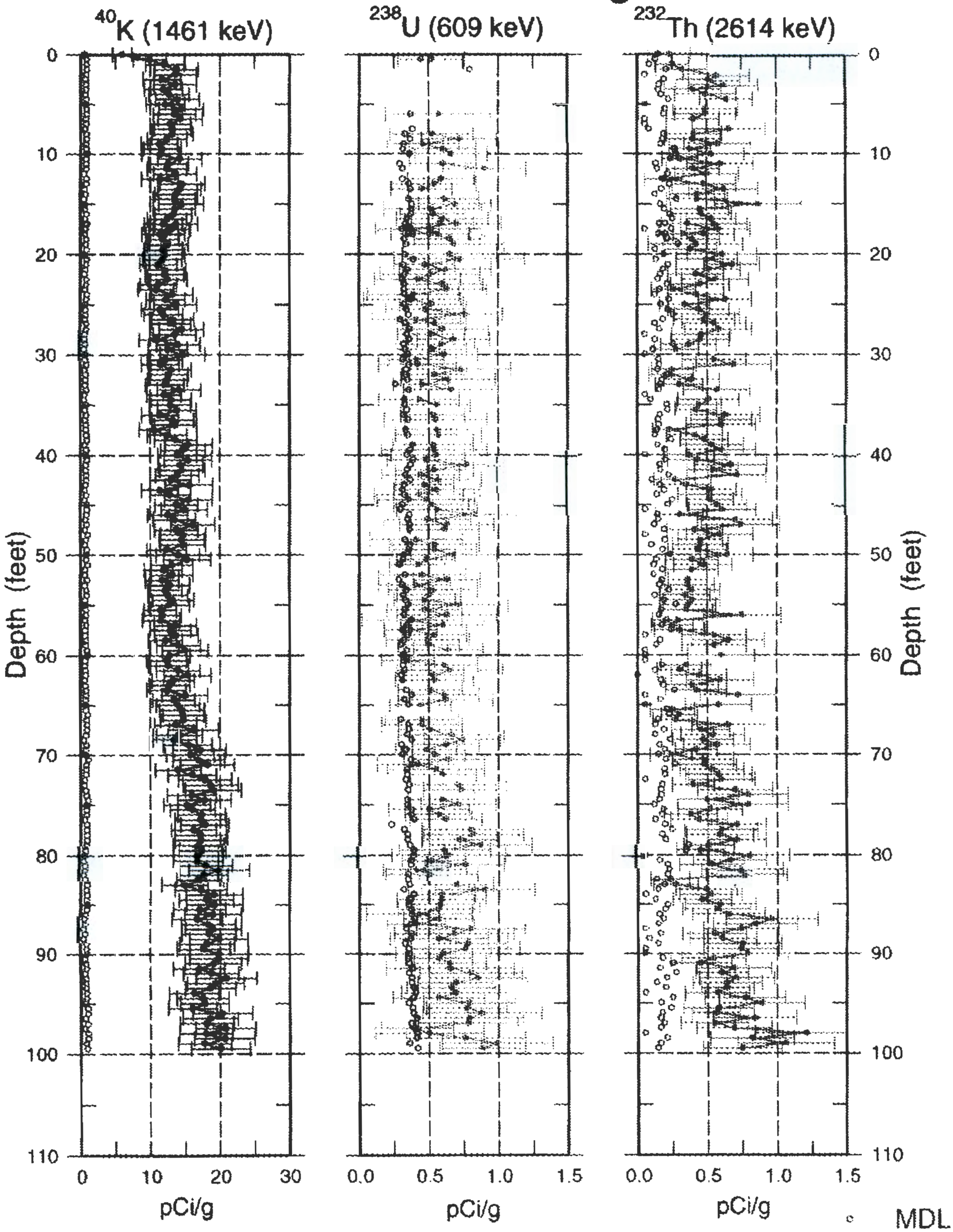
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations. Uncertainty bars on the plots show the statistical uncertainties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

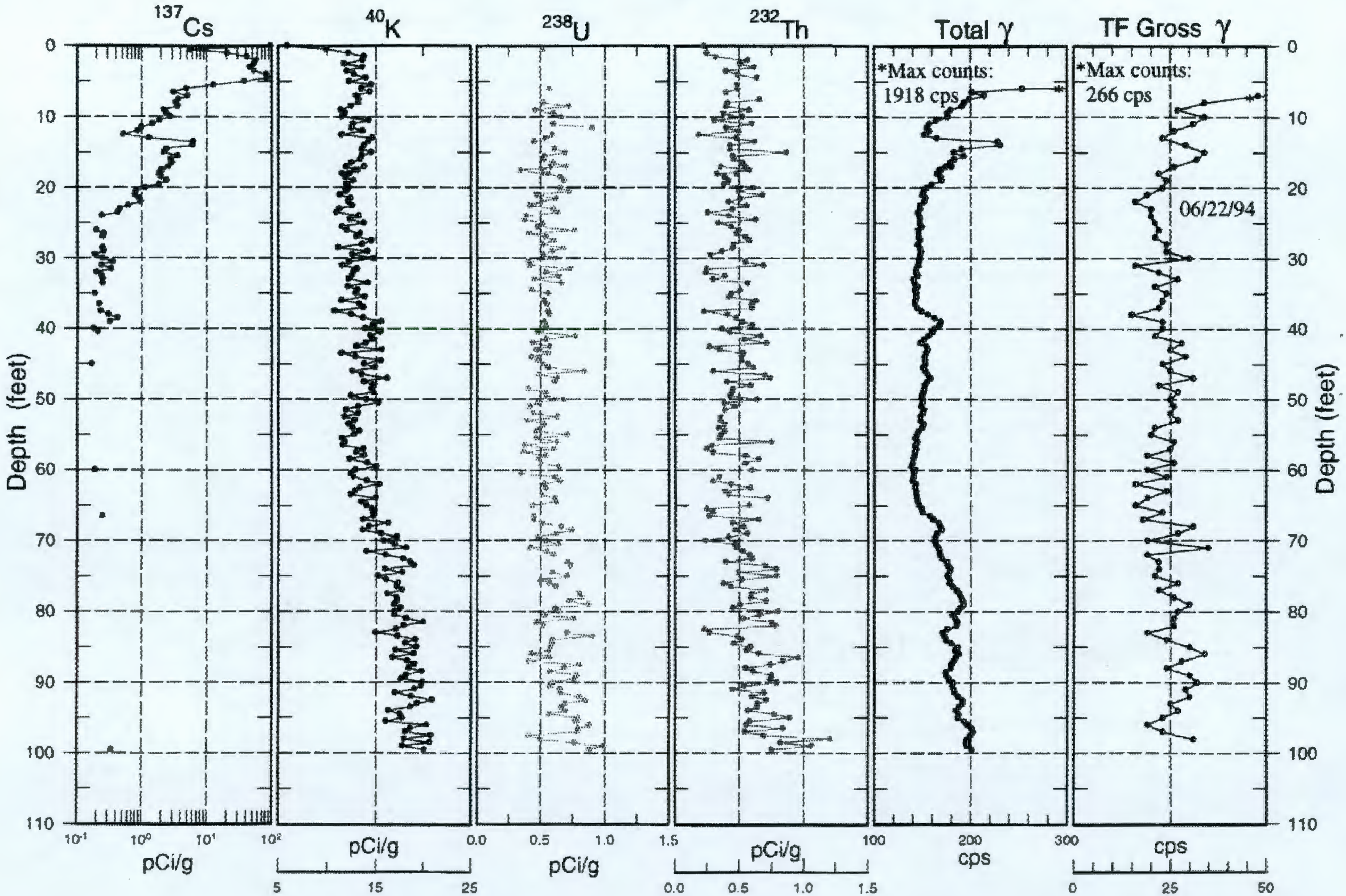
30-01-12
Man-Made Radionuclide Concentrations



30-01-12
Natural Gamma Logs



30-01-12 Combination Plot



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-04-05

Borehole Information

Farm :	C	**Tank :**	C-104	**Site Number :**	299-E27-80
N-Coord :	42,747	**W-Coord :**	48,377	**TOC Elevation :**	647.08
Water Level, ft :	None	**Date Drilled :**	7/31/74		

Casing Record

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

Borehole Notes:

This borehole was drilled in 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.

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 :**	2/6/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	3.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	2/7/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	98.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	52.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	3	**Log Run Date :**	2/10/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	2.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	12.0	**MSA Interval, ft. :**	.5	**Log Speed, ft/min.:**	n/a		

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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-07-05

Borehole Information

Farm : C | Tank : C-107 | Site Number : 299-E27-89
N-Coord : 42,823 | W-Coord : 48,447 | TOC Elevation : 646.00
Water Level, ft : None | Date Drilled : 10/31/74

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 October 1974 and completed to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information was available that indicated the borehole was perforated or grouted; therefore, it is assumed that the borehole was not perforated or grouted. The top of the casing, which is the zero reference for the SGLS, is flush with the ground surface.

Equipment Information

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

Log Run Information

Log Run Number : 1 | Log Run Date : 3/19/97 | Logging Engineer: Bob Spatz
Start Depth, ft.: 99.5 | Counting Time, sec.: 100 | L/R : L | Shield : N
Finish Depth, ft. : 53.0 | MSA Interval, ft. : .5 | Log Speed, ft/min.: n/a

Log Run Number : 2 | Log Run Date : 3/20/97 | Logging Engineer: Bob Spatz
Start Depth, ft.: 54.0 | Counting Time, sec.: 100 | L/R : L | Shield : N
Finish Depth, ft. : 0.0 | MSA Interval, ft. : .5 | Log Speed, ft/min.: n/a

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-05

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/29/97

Analysis Notes :

This borehole was logged by the SGLS in two log runs. The pre- and post-survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the SGLS was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the peak resolution and 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 radionuclide Cs-137 was detected in this borehole. Intermittent to continuous Cs-137 contamination was detected from the ground surface to 35.5 ft. The presence of Cs-137 was also detected continuously from 49 to 53.5 ft and intermittently from 56 to 77 ft.

The K-40 concentration values increase at 40 ft and remain elevated to depth of 48.5 ft. A sharp decrease in the K-40 concentrations occurs at about 50 ft. The K-40 concentration values remain elevated and exhibit moderate variability from 52 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-104 and C-107.

Log Plot Notes:

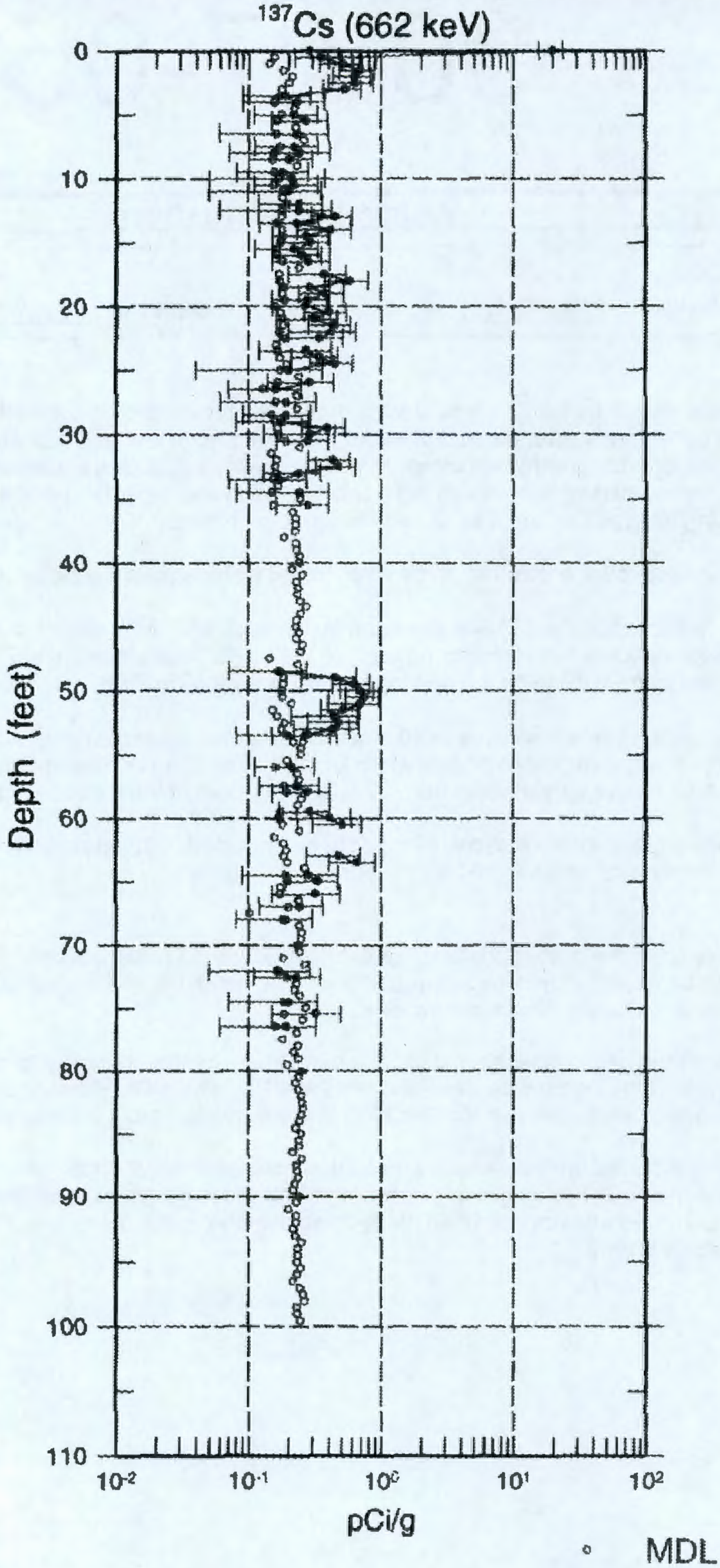
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

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.

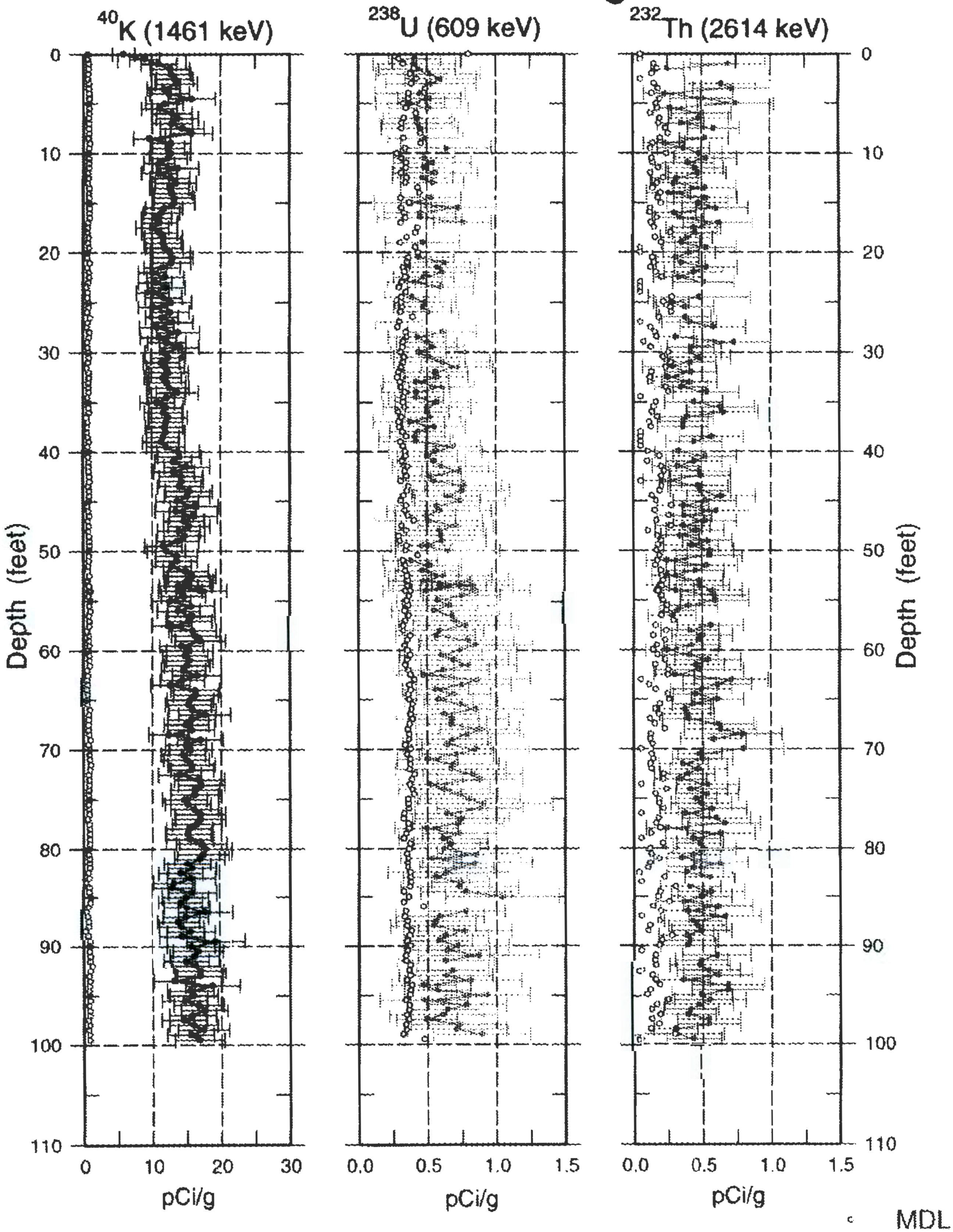
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-07-05

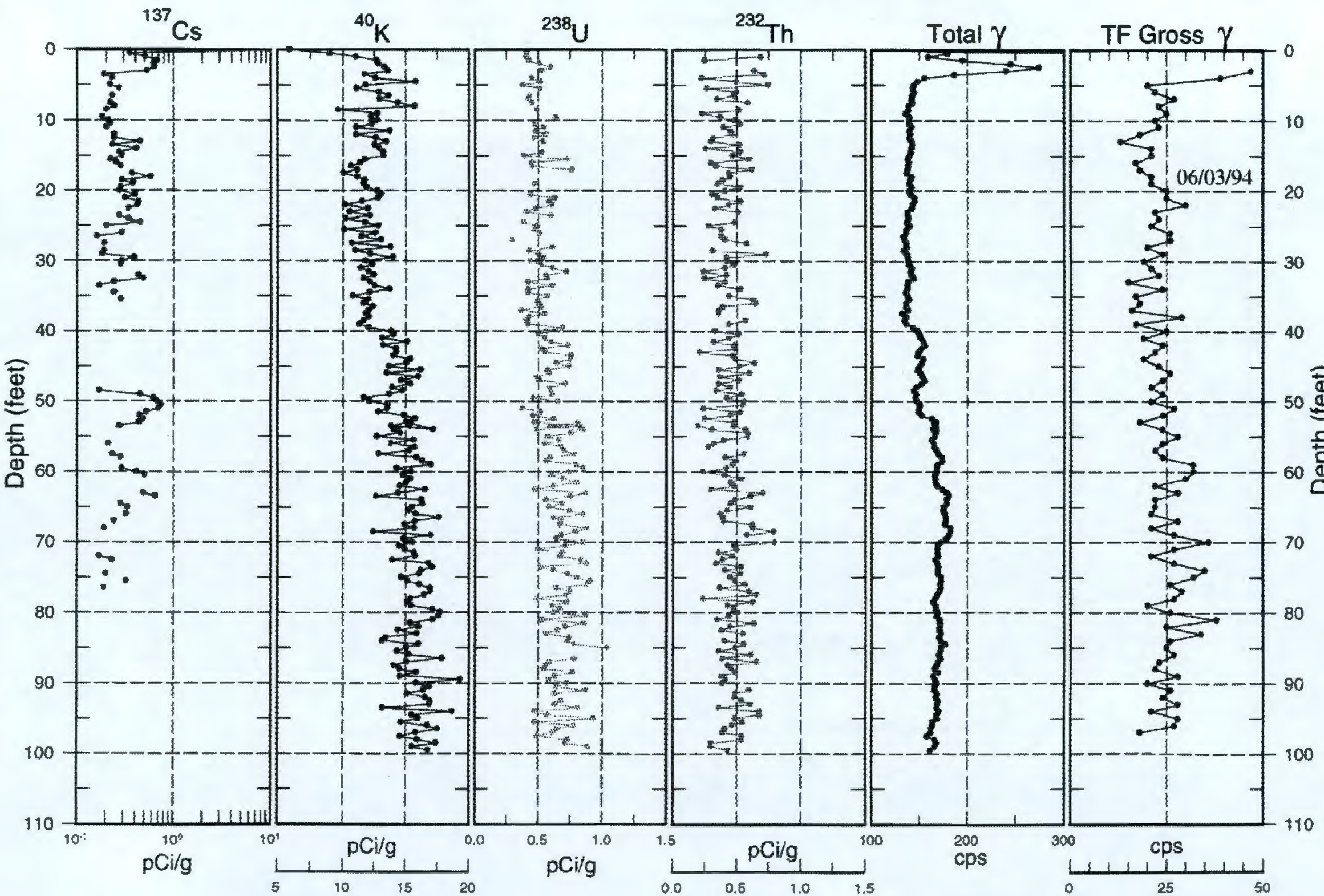
Man-Made Radionuclide Concentrations



30-07-05
Natural Gamma Logs



30-07-05 Combination Plot



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-04-12

Borehole Information

Farm :	C	Tank :	C-104	Site Number :	299-E27-65
N-Coord :	42,835	W-Coord :	48,405	TOC Elevation :	647.21
Water Level, ft :	None	Date Drilled :	12/31/72		

Casing Record

Type :	Steel-welded	Thickness :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	135		

Borehole Notes:
This borehole was drilled in December 1972 to a depth of 135 ft using 6-in. casing. The drilling report does not indicate if the borehole casing was perforated or grouted. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. The top of the casing, which is the zero reference for the SGLS, is approximately flush with the ground surface.

Equipment Information

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

Log Run Information

Log Run Number :	1	Log Run Date :	2/25/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	135.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	78.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	2/26/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	79.0	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 Run Number :	3	Log Run Date :	2/27/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	16.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-04-12

Analysis Information

Analyst : E. Larsen

Data Processing Reference : P-GJPO-1787 Analysis Date : 7/29/97

Analysis Notes :

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

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

The man-made radionuclides Cs-137 and Co-60 were detected in this borehole. The Cs-137 contamination was detected nearly continuously from the ground surface to a depth of 62 ft. Isolated occurrences of Cs-137 contamination were detected at 66.5 ft, 89 ft, and at the bottom of the logged interval (135 ft). A few occurrences of Co-60 were detected between 43 and 47.5 ft.

The K-40 concentration values increase at 39.5 ft, increase again at about 60 ft, and generally remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-104 and C-107.

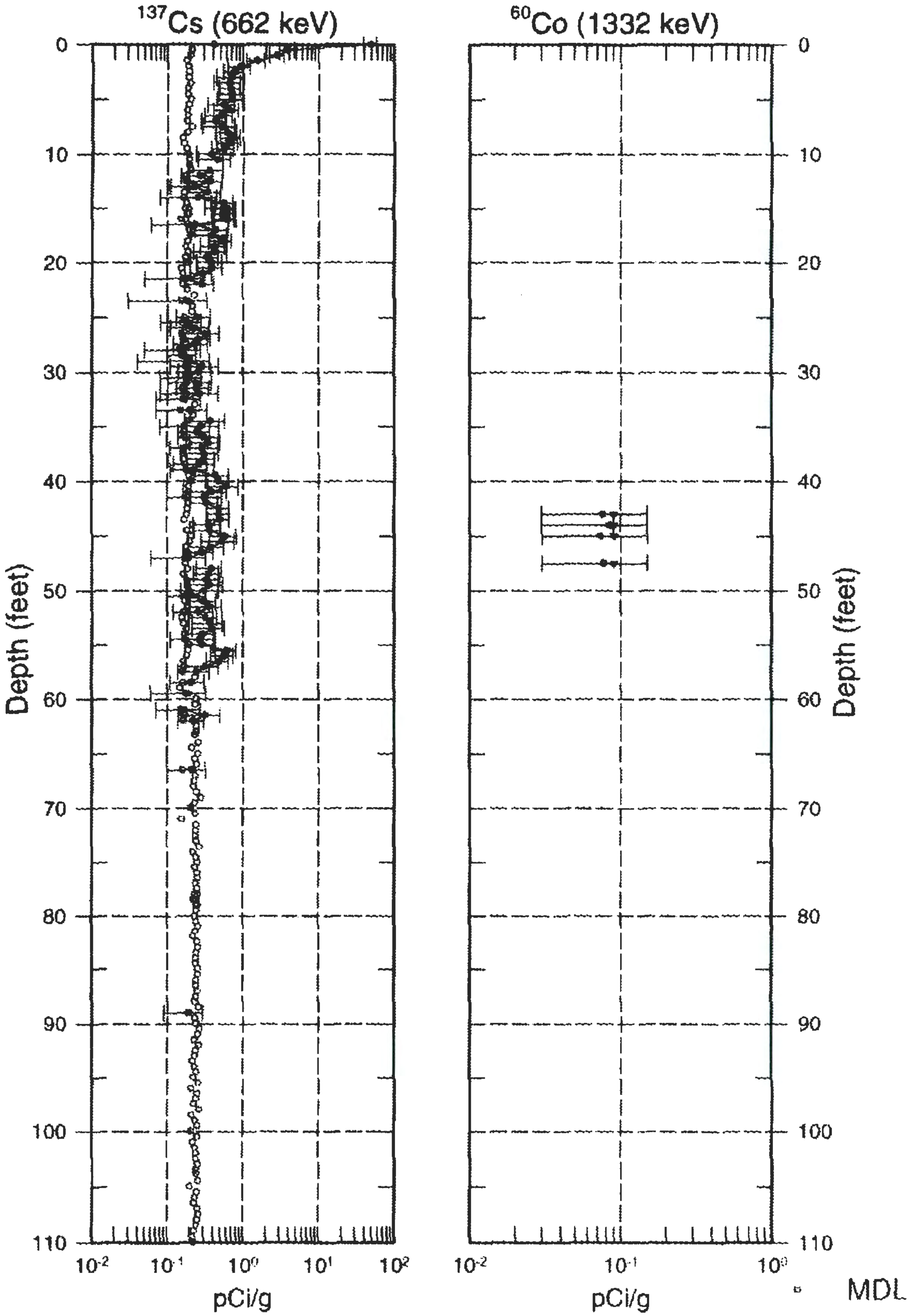
Log Plot Notes:

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.

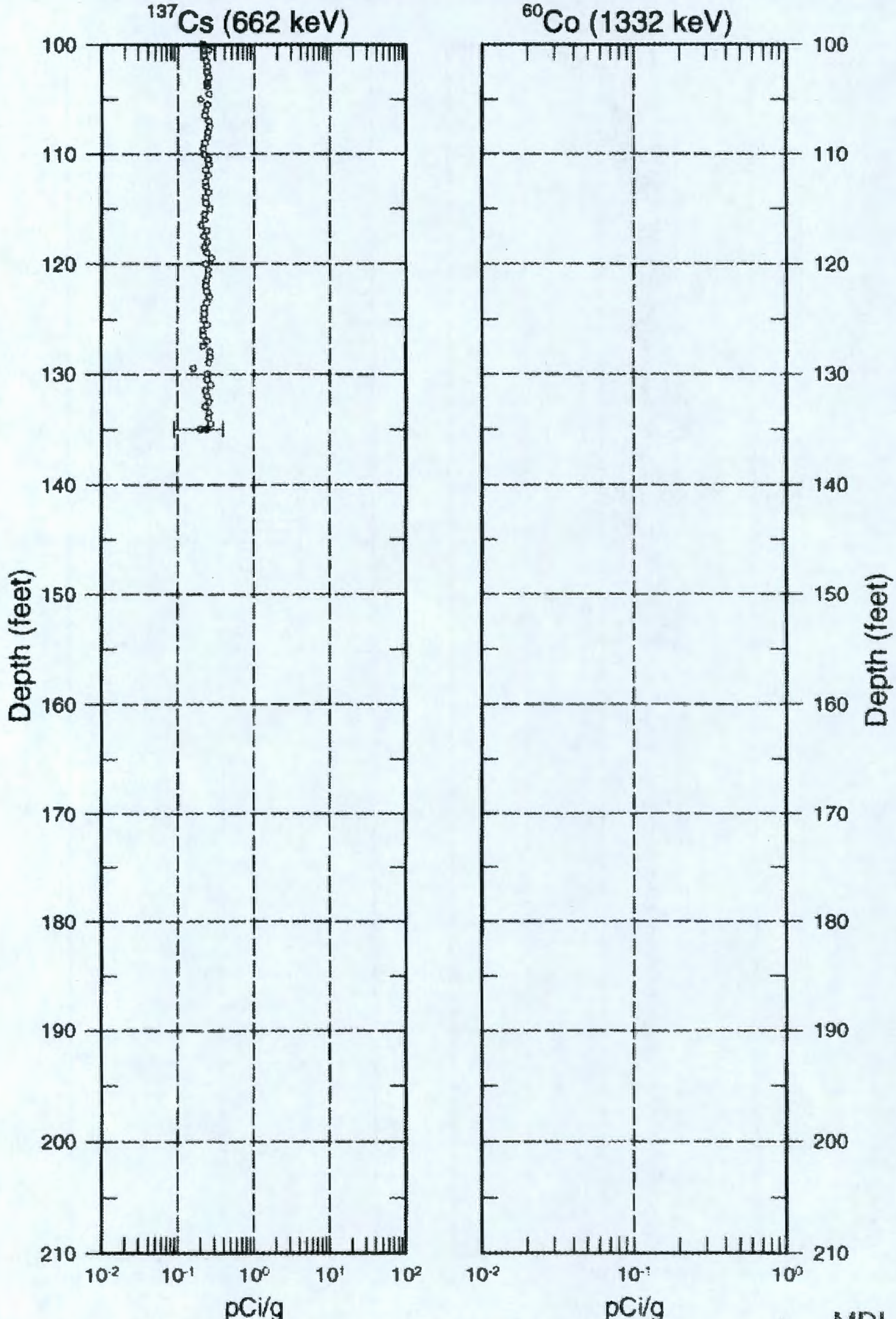
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-04-12
Man-Made Radionuclide Concentrations

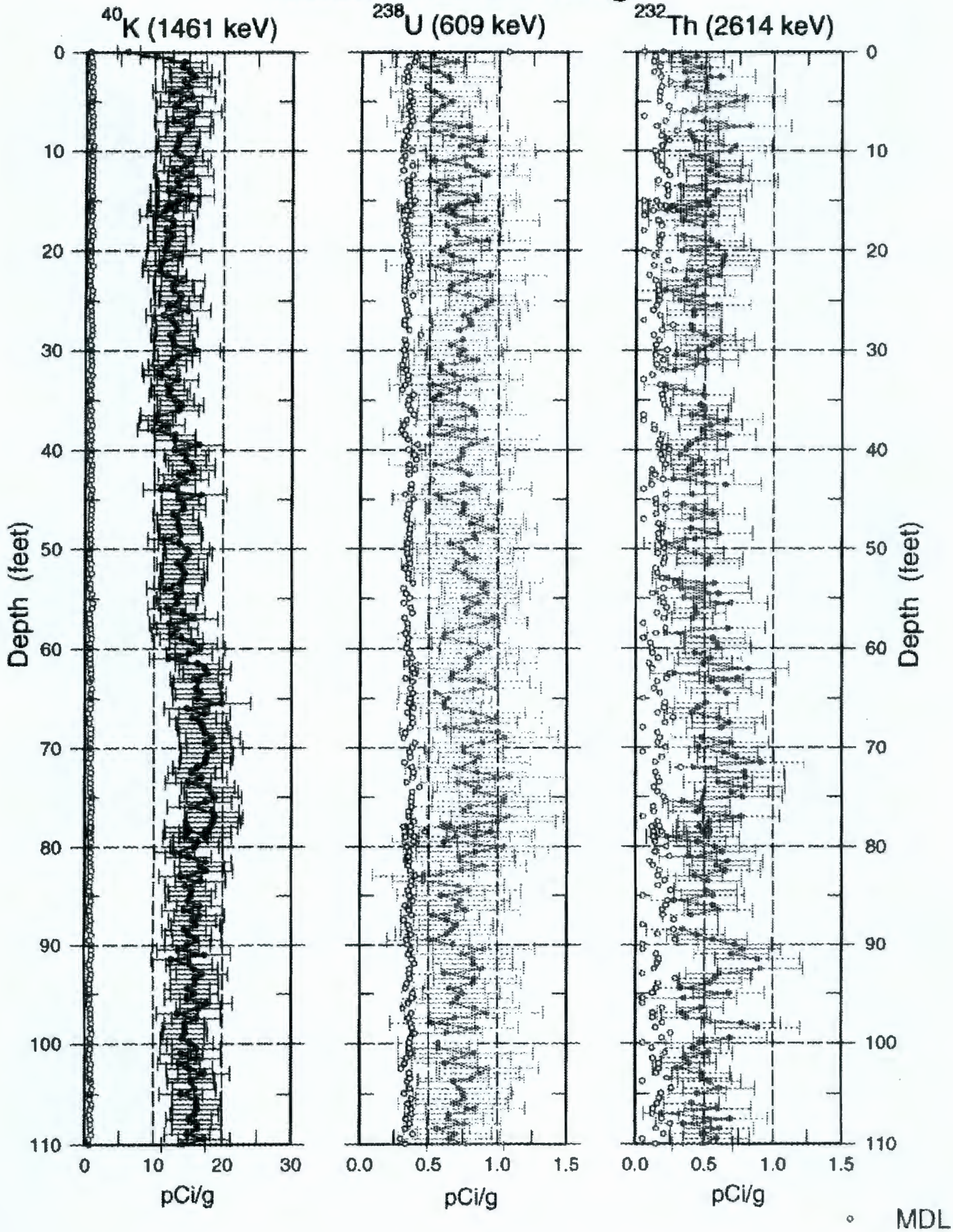


30-04-12

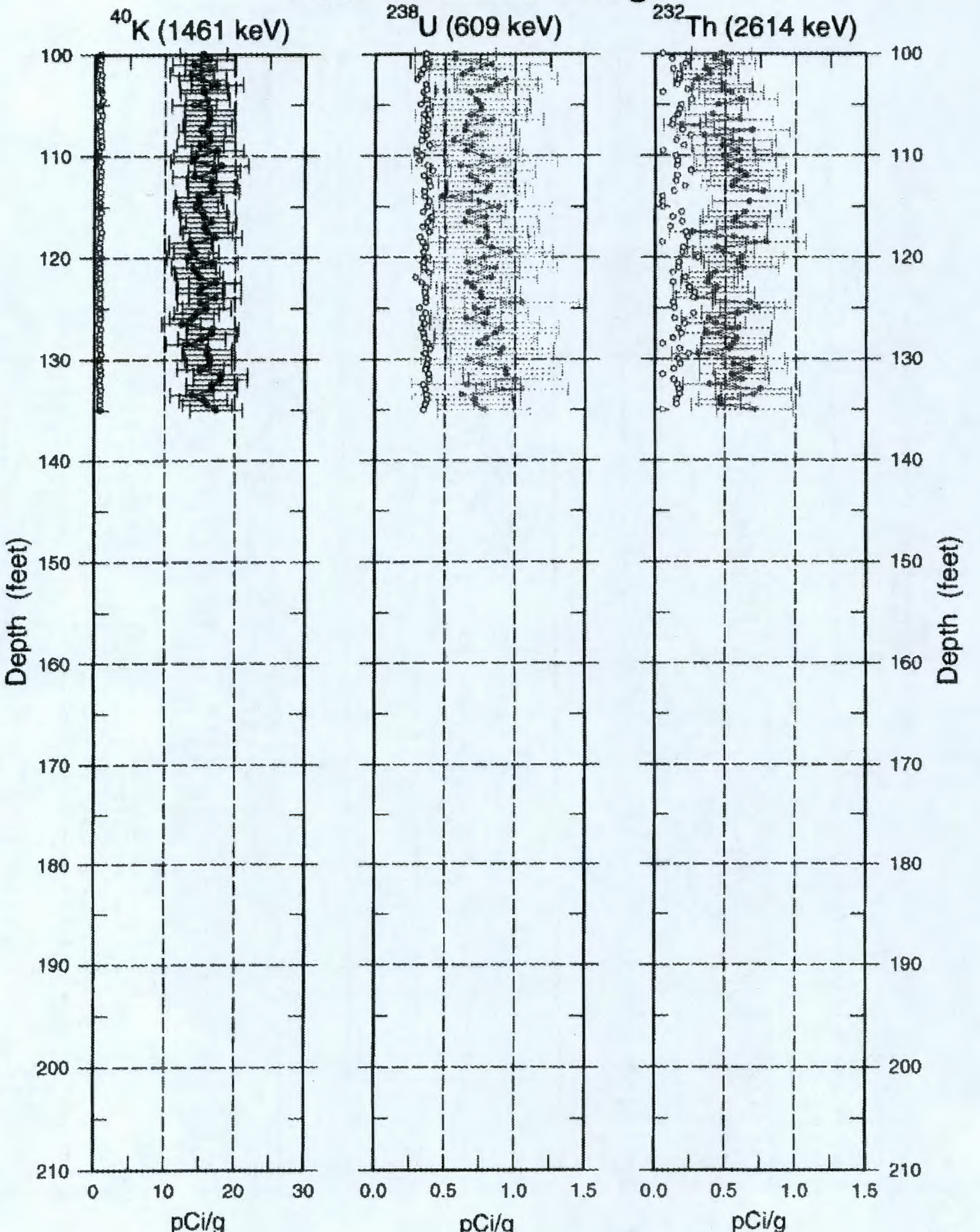
Man-Made Radionuclide Concentrations



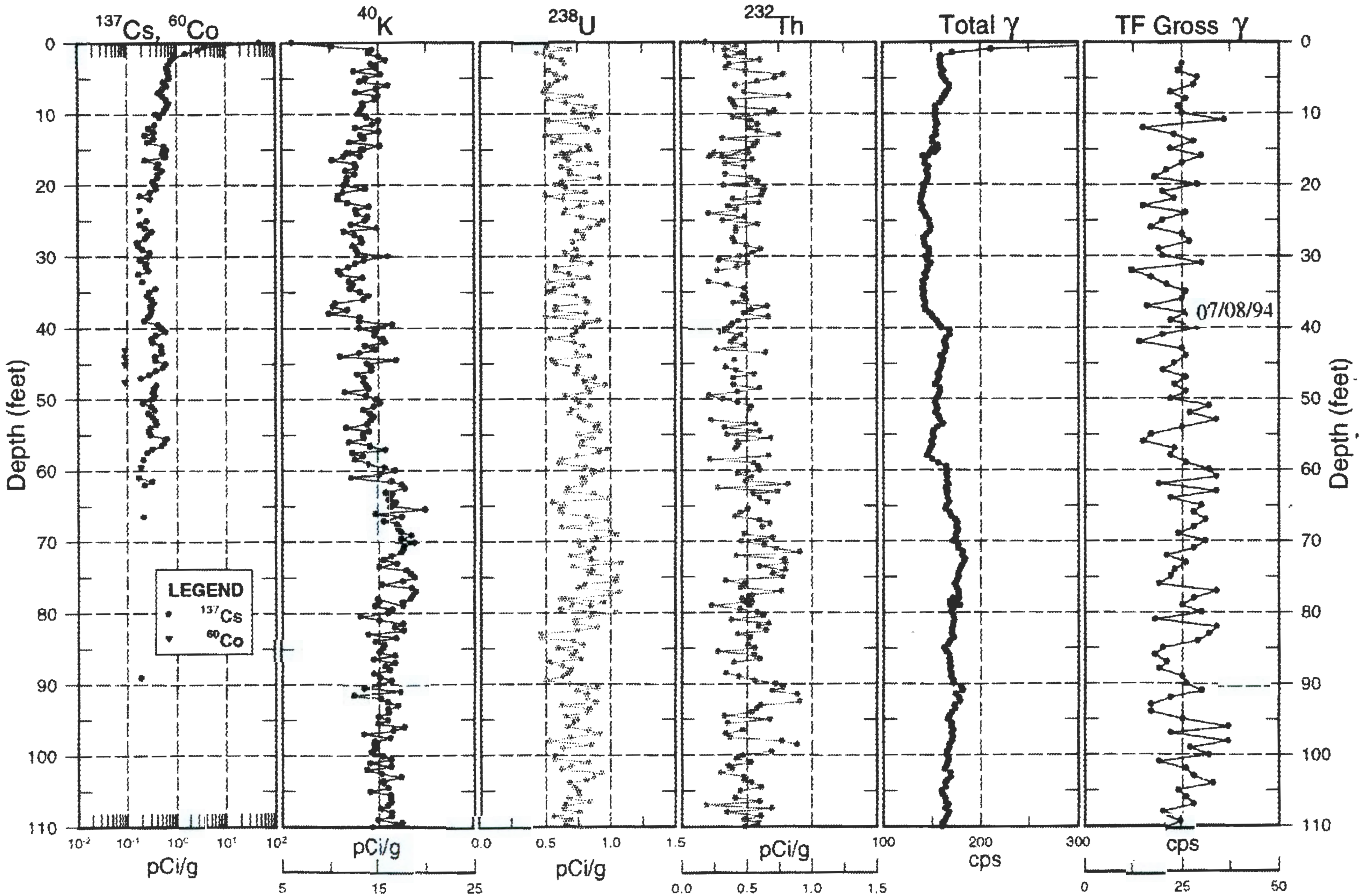
30-04-12
Natural Gamma Logs



30-04-12
Natural Gamma Logs



30-04-12 Combination Plot



30-04-12 Combination Plot