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Tank C-107

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Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-107

October 1997

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U.S. Department of Energy

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October 1997

Prepared for
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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 1997c) and baseline monitoring plan (DOE 1995b). 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.

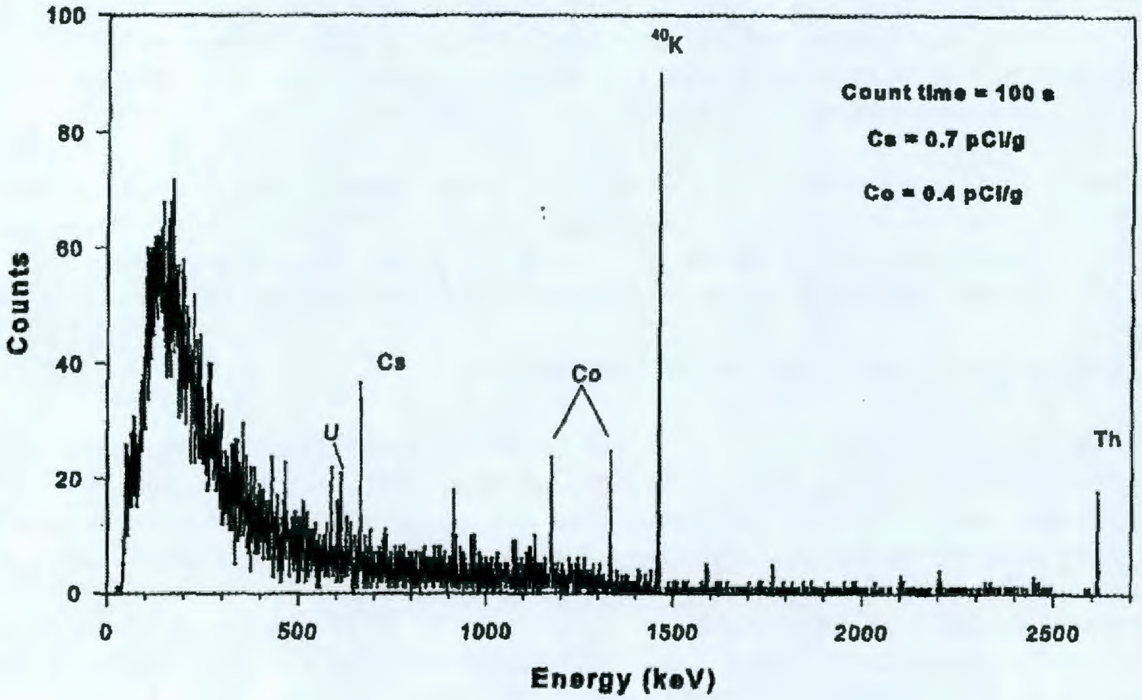

Figure 1. Gamma-Ray Spectrum

Data are acquired in boreholes near the tanks according to methods described in the logging procedures (DOE 1997b). 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 1997a).

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 1997a). 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 1997d) 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 1997a) describes the application of the correction function in the data processing.

2.2 Shape Factor Analysis

Insights into the distribution of the radionuclides identified by the SGLS can be provided by using an analytical method known as shape factor analysis (Wilson 1997). Shape factor analysis takes advantage of 1) the SGLSs ability to record the specific energies of detected gamma rays, and 2) the Compton downscattering caused by the interaction of gamma rays with matter between the gamma-ray source and the detector.

Compton scattering results in higher energy photons being converted to lower energy photons; hence, Compton scattering within and outside of the detector accounts for the low-energy continuum in a pulse height spectrum. Many factors exterior to the detector influence the low-energy portion of the spectrum of gamma rays incident on the detector and thereby affect the low-energy continuum in the pulse height spectrum. Wilson (1997) has shown that variations in gamma-ray source distribution relative to a borehole produce measurable changes in the shapes of the pulse height spectra recorded by logging the boreholes. The spectral shape changes are quantified by ratios of counts from various portions of the pulse height spectrum, and these ratios are used to assess the distribution of the source.

Shape factor analysis can also be used to identify the presence of brehmsstrahlung radiation from the beta-emitting radionuclide ^{90}Sr. Beta particles, emitted from the radioactive decay of ^{90}Sr, interact with the electromagnetic fields within the substances they traverse. The deflection and resulting deceleration of the beta particles produce x-rays, known as brehmsstrahlung radiation, which are detected in the lower energy portion of the gamma-ray spectrum. In instances of high total gamma-ray activity, a preponderance of lower energy gamma radiation may be due to the presence of beta emitters such as ^{90}Sr.

Additional information on shape factor analysis theory is provided in Wilson (1997).

2.2.1 Specific Shape Factors

As stated previously, the ratios of gamma-ray counts from various portions of a spectrum are indicators of gamma-ray source distribution. Three ratios are used in shape factor analysis. These ratios, known as shape factors, are designated CsSF1, CoSF1, and SF2.

- CsSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the counts in the ^{137}Cs peak. This shape factor is useful for evaluating the distribution of the radionuclide ^{137}Cs.

- CoSF1 is the ratio of the total number of counts in the continuum window (60 to 650 keV) to the sum of the counts in the two ^{60}Co peaks (1173 and 1332 keV). This shape factor is useful for evaluating the distribution of the radionuclide ^{60}Co.

- SF2 is the ratio of the total number of counts in the lower energy portion of the continuum window (60 to 350 keV) to the counts in the higher energy portion of the continuum window (350 to 650 keV). This parameter is somewhat sensitive to the radionuclide distribution, but is most applicable to the identification of the beta emitter ^{90}Sr and in distinguishing remote ^{137}Cs or ^{60}Co from ^{90}Sr.

At low concentrations, high uncertainties in the ^{137}Cs and ^{60}Co peak count rates and in the net continuum count rates cause large errors in the calculated values of CsSF1 and CoSF1, respectively. A minimum count rate of 1 cps must be present for the calculated CsSF1 to be meaningful, and a minimum count rate of 2 cps must be present for CoSF1 (Wilson 1997).

The values of CsSF1, CoSF1, and SF2 also become less reliable as the radionuclide concentrations and count rates become very high and the dead time increases. Inaccuracies in the measurement of the spectral regions occur when system dead time increases to above about 20 percent. The effect on shape factors is relatively small for dead times up to 40 percent. For measurements made at dead times below 20 percent, distortion of the spectrum is negligible (Wilson 1997).

2.2.2 Interpretation of Shape Factors

Values of CsSF1, CoSF1, and SF2 that can be expected for radionuclides in various distributions were established from investigations by Wilson (1997). These distributions are: 1) contamination confined to the borehole region, such as when contaminants occur on the borehole casing, 2) contamination uniformly distributed throughout the formation around the borehole, and 3) contamination in the formation but at discrete locations remote from the detector. The expected CsSF1, CoSF1, and SF2 values for various distributions of ^{137}Cs are summarized below.

^{137}Cs or ^{60}Co Source Distribution	Spectral Shape Factor	
	CsSF1 or CoSF1	SF2
Stuck on inside of 6-inch (in.) casing	4.5 - 5.5	2.8
Stuck on outside of 6-in. casing	6.8 - 7.4	2.8
Uniformly distributed in formation	13 - 15	3.5
Discrete source 10 centimeter (cm) radial distance	~ 19	~ 3.8
Discrete source 30 cm radial distance	~ 37	~ 4.2
Discrete source more than 50 cm radially distant	80 - 100	4.4 - 5.0

When CsSF1, CoSF1, and SF2 values exceed those listed, the presence of ^{90}Sr is suggested. However, photons from intense gamma-ray sources remote from the borehole can also produce spectra with high CsSF1 and CoSF1 values, indicating that elevated values of these two shape factors alone are not sufficient for a ^{90}Sr identification. The presence of ^{90}Sr can usually be inferred with confidence when SF2 significantly exceeds the extreme value (about 4.5) for a distant source. The interpretation may be aided by an SF2-SF1 cross plot. If ^{90}Sr is absent, then as the distance between the borehole and the inner edge of a (cylindrically symmetric) ^{137}Cs source increases, the points on the SF2-SF1 cross plot define a "trend line." ^{90}Sr is indicated if the SF2 values are so high that the points on the cross plot lie well above the trend line. However, a ^{90}Sr concentration of about 1,000 pCi/g is necessary to produce a noticeable increase in count rates (DOE 1997a).

2.2.3 Uncertainties of Shape Factor Analysis

The counts resulting from ^{137}Cs and ^{60}Co in the continuum windows are corrected for background by subtracting the counts contributed by the naturally occurring radionuclides ^{40}K, ^{238}U, and ^{232}Th from the continuum windows. Counting statistics for the gamma rays associated with ^{238}U and ^{232}Th are poor for the 100-s counting time typically used by the SGLS in borehole logging; accordingly, there may be a considerable relative statistical uncertainty in the peak intensity that is used to calculate any background correction. To minimize the effects of statistical counting uncertainties in the calculated background corrections, the corrections are calculated at each depth point, then filtered with a Gaussian smoothing function. The correction at a particular depth point is the average over a 5-ft interval that extends 2.5 ft above and 2.5 ft below the point. The other source of experimental uncertainty is systematic uncertainty in the stripping factors. Errors in these constants have been minimized with an heuristic approach, but, in general, the stripping constant errors are the ultimate limitation on the accuracy of the background corrections.

The use of shape factor analysis is currently limited to evaluating the distributions of ^{137}Cs and ^{60}Co and to identifying the presence of ^{90}Sr. At this stage of the method's development, other gamma-ray-emitting radionuclides (i.e., ^{125}Sb, ^{154}Eu, and ^{152}Eu) interfere with shape factor analysis. The number of other radionuclides present in a borehole is a quality indicator. Non-zero values of this indicator may mark intervals of a borehole that are unsuitable for the application of shape factor analysis.

2.3 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-107," 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.

Separate plots showing the results of shape factor analysis of some of the SGLS data are included with each set of borehole plots. The values of CsSF1, CoSF1 (as applicable), SF2, the radionuclide abundance expressed as counts per second, and applicable quality indicators are shown on graphs on these plots. The general expected values for the CsSF1, CoSF1 (as applicable), and SF2 parameters for radionuclides distributed uniformly in the formation or on the outside of the casing are shown on the plots as vertical lines.

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

3.1.2 Geologic and Hydrologic Setting

Excavation for the construction of the C Tank Farm occurred in glaciofluvial sediments of the Hanford formation. These sediments consist primarily of cobbles, pebbles, and coarse to

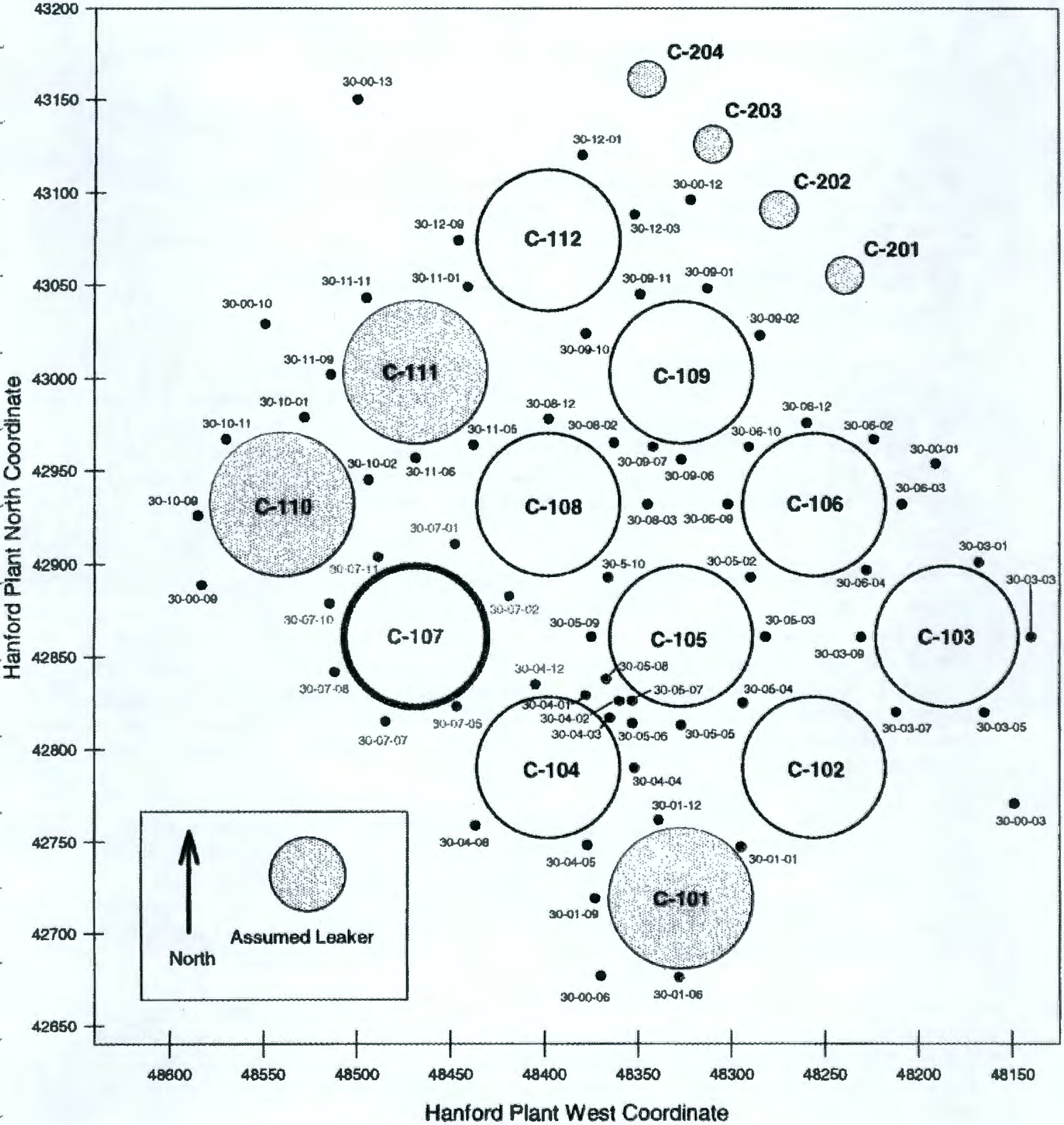

Figure 2. Plan View of Tanks and Boreholes in the C Tank Farm

medium sands with some silts. The excavated sediments were used as backfill around the completed tanks (Price and Fecht 1976).

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

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

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

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

The lower gravel sequence of the Hanford formation is dominated by deposits typical of the gravel-dominated facies. Local intercalated intervals of the sand-dominated facies are also found (DOE 1993). This unit is composed of interbedded sands and gravels with few silt interbeds. Perched water is considered unlikely in this unit. The lower gravel sequence is about 27 ft thick and extends to a depth of approximately 225 ft (Lindsey 1993).

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

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

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

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

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

3.1.3 Tank Contents

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

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

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

3.1.4 Tank Farm Status

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

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

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

3.2 Tank C-107

Tank C-107 was constructed during 1943 and 1944 (Welty 1988). This tank is the first tank in a three-tank cascade series with tanks C-108 and C-109.

Tank C-107 received first-cycle decontamination waste from the second quarter of 1946 until the third quarter of 1948. This tank cascaded waste to tank C-108 from 1946 until 1947, and it received uranium recovery waste from the fourth quarter of 1952 until the third quarter of 1953.

Between 1952 and 1956, the overflow cascade line to tank C-108 was plugged. In the fourth quarter of 1956, the tank was "scavenged" to remove fission products from the tank's supernatant liquid and to reduce the volume of waste in the tank (Brevick et al. 1994a). It is unclear why the tank was not scavenged prior to receiving uranium recovery waste.

The tank received first-cycle decontamination waste from the first quarter of 1957 until the second quarter of 1961 and various other wastes, including Strontium Semiworks waste, from the fourth quarter of 1964 until the second quarter of 1976 (Brevick et al. 1994a).

The tank was removed from service and a salt-well pump was installed in the first quarter of 1976 (Welty 1988; Brevick et al. 1994a). The tank was salt-well pumped from the third quarter of 1976 until the second quarter of 1977 (Brevick et al. 1994a).

The tank was reactivated in August 1977 and received about 29,000 gal of insoluble, strontium-leached sluicing solids (Welty 1988).

Tank C-107 was declared inactive again in 1978, and salt-well pumping to remove the supernatant liquid was completed in July 1979 (Welty 1988). Partial isolation of the tank was completed in December 1982 (Welty 1988), and interim stabilization was completed in September 1985 (Hanlon 1997). The tank is currently classified as "sound" (Hanlon 1997).

Tank C-107 currently contains 237,000 gal of sludge, which includes 24,000 gal of drainable, interstitial liquid. The waste in tank C-107 is classified as dilute-complexed waste (Hanlon 1997). The waste level in the tank is approximately 108 in. above the dished bottom of the tank base and has remained constant since a level adjustment in January 1992 (Brevick et al. 1994b). Hanlon (1997) identifies an ENRAF gauge as the primary method of leak detection.

4.0 Boreholes in the Vicinity of Tank C-107

Eight vadose zone monitoring boreholes surround tank C-107. These boreholes are 30-07-01, 30-07-02, 30-04-12, 30-07-05, 30-07-07, 30-07-08, 30-07-10, and 30-07-11. Figure 2 shows the locations of these boreholes in red.

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

Spectral gamma-ray data were acquired for each borehole in the move/stop/acquire logging mode with a 100-s acquisition time at 0.5-ft depth intervals. The upper 5 ft of borehole 30-07-11 was also logged in real time because of the high dead time encountered. All eight boreholes were logged dry.

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

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

4.1 Borehole 30-07-01

Borehole 30-07-01 is located approximately 12 ft from the northeast side of tank C-107 and was given the Hanford Site designation 299-E27-87. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to provide borehole configuration information. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 100.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 74 ft and intermittently from 75.5 to 87.5 ft. The maximum ^{137}Cs concentration was 3.8 pCi/g at 3 ft. A higher concentration (18.7 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

^{40}K concentrations increase slightly below a depth of about 40 ft (the approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material above this depth to the undisturbed sediments of the Hanford formation below. A zone of low ^{40}K concentrations from 56 to 60 ft probably resulted from the presence of a coarse-grained unit, such as a gravel lense, in this interval.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. Shape-factor analysis produced data for interpretation from the surface to 34 ft, and from 42 to 59 ft. Elsewhere, the ^{137}Cs concentrations were too low to produce valid shape factor data.

The shape-factor analysis indicates that the distribution of ^{137}Cs contamination from the ground surface to about 34 ft varies from remote from the borehole to uniformly distributed in the backfill material around the borehole. The distribution of the contamination is consistent with a surface spill that migrated downward into the backfill material rather than migrating down the borehole casing. The shape-factor analysis also indicates that the ^{137}Cs contamination from 43 to 58 ft is distributed in the formation, rather than being confined to the immediate vicinity of the borehole. This distribution is consistent with a contaminant plume at depth that migrated through the formation, rather than downward along the borehole casing.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 35.5 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole.

The ^{137}Cs contamination detected from about 39 to 69 ft is probably the result of a tank or pipeline leak that migrated into the Hanford formation sediments beneath the C Tank Farm excavation. The origin of this contamination could be any number of tanks and associated pipelines in the C Tank Farm, including tank C-107.

The ^{137}Cs contamination below 70 ft may be distributed in the formation near the borehole or was carried down during borehole drilling operations.

4.2 Borehole 30-07-02

Borehole 30-07-02 is located approximately 12 ft from the northeast side of tank C-107 and was given the Hanford Site designation 299-E27-88. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 99.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 32.5 ft, at 42.5 and 43 ft, and at the bottom of the borehole. The maximum ^{137}Cs concentration was 4.9 pCi/g at 27.5 ft. A higher concentration (41 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

^{40}K concentrations increase below a depth of about 40 ft (the approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material above this depth to the undisturbed sediments of the Hanford formation below. ^{40}K concentrations increase below 60 ft. This concentration increase probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole and a plot of the results is included in Appendix A. Contradictory results were obtained from CsSF1 and SF2 for contamination from the ground surface to about 30 ft. In this interval CsSF1 indicates that the contamination is distributed remotely to uniformly in the formation around the borehole, while SF2 indicates that the contamination is confined to the immediate vicinity of the borehole. The shape factor analysis for ground surface to about 30 ft was deemed to be inconclusive. For the remainder of the borehole, contaminant concentrations were too low to calculate meaningful shape factors.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 32.5 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole. The ^{137}Cs contamination at 42.5 and 43 ft was probably carried down during drilling operations. The ^{137}Cs contamination at the bottom of the borehole may be from particulate matter that fell down into the borehole.

4.3 Borehole 30-04-12

Borehole 30-04-12 is located approximately 27 ft from the southeast side of tank C-107 and is near 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 that 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 and 89 ft and at the bottom of the logged interval. The maximum ^{137}Cs concentration was 3.9 pCi/g at 0.5 ft. A higher ^{137}Cs concentration (48.5 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

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

An increase in the ^{40}K concentrations is observed at 39.5 ft and 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 about this depth. The ^{40}K concentration values increase at about 60 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 60 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 59 ft, corresponding to increases in the ^{40}K concentrations at these depths.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole. However, because ^{137}Cs concentrations are too low to allow meaningful shape factor data to be generated, a plot of the analysis results is not provided for this borehole.

The historical gross gamma log data from January 1975 to July 1994 were reviewed. The most recent historical gross gamma data are presented on the combination plot. No zones of anomalous gamma-ray activity were identified.

The near-surface zone of ^{137}Cs contamination probably resulted from one or more surface spills that migrated into the backfill material around the borehole.

The ^{137}Cs contamination from about 39.5 to 57 ft occurs at the base of the tank farm excavation and may have originated from a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-107, including tank C-107. One possible source of this ^{137}Cs contamination is the cascade-line leak that occurred between tanks C-104 and C-105 (Welty 1988).

The ^{137}Cs contamination from 69.5 to about 83 ft may have been carried down during borehole drilling or may have migrated down the outside of the borehole casing to this depth. It is also possible, but not likely, that the ^{137}Cs contamination is in this depth interval in the vadose zone near the borehole.

The ^{137}Cs contamination at the bottom of the borehole may be from particulate matter that fell down into the borehole.

The ^{60}Co contamination detected between 43 and 47.5 ft may represent the remnant of a plume related to the cascade-line leak that occurred between tanks C-104 and C-105, as described in Welty (1988).

4.4 Borehole 30-07-05

Borehole 30-07-05 is located approximately 3 ft from the southeast side of tank C-107. 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. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not 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 also detected continuously from 49 to 53.5 ft and intermittently from 56 to 77 ft. The maximum measured ^{137}Cs concentration was 0.75 pCi/g at 50.5 ft. A higher ^{137}Cs concentration (19.8 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

The ^{40}K concentration values increase at 40 ft and remain elevated to a depth of 48.5 ft. A sharp decrease in the ^{40}K concentrations occurs at about 50 ft. The ^{40}K concentrations increase at 52 ft and remain elevated with moderate variability from 52 ft to the bottom of the logged interval. 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 increase in the percentage of coarse-grained material in the Hanford formation sediments. The increase in the ^{40}K concentrations at 52 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

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, which corresponds to increases in the ^{40}K and ^{238}U concentrations at these depths.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole. Concentrations of contaminants were too low to allow shape factors to be calculated for this borehole. Therefore, a plot of the analysis results is not provided for this borehole.

The historical gross gamma log data from January 1975 to June 1994 were reviewed, and the most recent data are presented on the combination plot in Appendix A. The earliest recorded historical gross gamma log data (January 1975) indicate that the near-surface ^{137}Cs contamination was present at that time.

The near-surface zone of ^{137}Cs contamination probably resulted from one or more surface spills that migrated into the backfill around the borehole. The ^{137}Cs contamination directly below this zone was probably carried down during borehole drilling.

The zone of elevated ^{137}Cs contamination detected from 49 to 53 ft corresponds with the decrease in ^{40}K concentrations in this zone. The ^{137}Cs contamination in this interval may be the result of a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-107, including tank C-107. One possible source of this ^{137}Cs contamination is the cascade-line leak that occurred between tanks C-104 and C-105, as described in Welty (1988).

The ^{137}Cs contamination detected directly below this zone most likely migrated down the outside of the borehole casing or was carried down during borehole drilling.

4.5 Borehole 30-07-07

Borehole 30-07-07 is located approximately 12 ft from the southwest side of tank C-107 and was given the Hanford Site designation 299-E27-90. This borehole was drilled in October 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 98.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected continuously from the ground surface to 15.5 ft, intermittently from 58.5 to 72 ft at very low concentrations, and at the bottom of the borehole. The maximum ^{137}Cs concentration was 1.5 pCi/g at 11 ft. A higher concentration (3 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

^{40}K concentrations are relatively elevated from 39.5 to 41 ft (the approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material to the undisturbed sediments of the Hanford formation. The elevated ^{40}K and ^{238}U concentrations from 47.5 to about 61 ft and the elevated ^{232}Th concentrations from 50 to about 62 ft are probably caused by an increase in the fraction of fine-grained material in the Hanford formation.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The analysis indicates that the ^{137}Cs contamination from the ground surface to about 13 ft is distributed remotely from the borehole. This distribution is consistent with a surface spill that deposited contamination in the backfill material or on the side of the tank near the borehole but not in the immediate vicinity of the borehole.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 15.5 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole. The ^{137}Cs contamination from 58.5 to 72 ft may be the result of a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-107, including tank C-107. The ^{137}Cs contamination at the bottom of the borehole may be from particulate matter that fell down into the borehole.

4.6 Borehole 30-07-08

Borehole 30-07-08 is located approximately 6 ft from the southwest side of tank C-107 and was given the Hanford Site designation 299-E27-91. This borehole was drilled in October 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 99.0 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 28 ft and at depths of 37.5, 49, 52.5, and 53 ft. The maximum measured ^{137}Cs concentration was 1.1 pCi/g at 11.5 ft. A higher concentration (7.9 pCi/g) was detected at the ground surface; however, this is not an accurate concentration measurement because the source-to-detector geometry at the top of the borehole differs from the source-to-detector geometry used during calibration.

^{40}K concentrations are relatively elevated from 39 to 42 ft (approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material to the undisturbed sediments of the Hanford formation. ^{40}K concentrations are relatively decreased from 42 to about 45 ft, which may represent an increase in the percentage of coarse-grained material, such as gravel, in this interval. The increase in the ^{40}K concentrations at about 45 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The shape-factor analysis indicates that the ^{137}Cs contamination from about 25 to 27 ft is distributed remote to the borehole. The indicated distribution is consistent with subsurface contamination that is not in the immediate vicinity of the borehole. The results of the analysis are inconclusive for the ^{137}Cs contamination from about 11 to 16 ft, because the concentrations are so low.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 28 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole. The ^{137}Cs contamination below 37.5 ft may have been carried down during borehole drilling operations.

4.7 Borehole 30-07-10

Borehole 30-07-10 is located approximately 8 ft from the northwest side of tank C-107 and was given the Hanford Site designation 299-E27-92. This borehole was drilled in September 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used to prepare this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 98.5 ft.

The only man-made radionuclide detected in this borehole was ^{137}Cs. ^{137}Cs contamination was detected almost continuously from the ground surface to 24 ft, from 36 to 37 ft, and at 26, 26.5, and 77.5 ft. The maximum ^{137}Cs concentration was 3 pCi/g at 1 ft.

A thin layer of higher ^{40}K and ^{232}Th concentrations is found at 39.5 ft (approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material to the undisturbed sediments of the Hanford formation. ^{40}K concentrations are relatively decreased from 41.5 to about 45 ft, which may represent an increase in the percentage of coarse-grained material, such as gravel, in this interval. The increase in the ^{40}K concentrations at about 45 ft probably represents the contact between the gravel- and sand-dominated facies of the Hanford formation.

The interval between 20 and 40 ft was relogged as an additional quality check and to demonstrate the repeatability of the radionuclide concentration measurements made by the SGLS. A comparison of the measured ^{137}Cs concentrations and the naturally occurring radionuclides using the data sets provided by the original and repeated logging runs is included in Appendix A. The measurements repeat within two standard deviations (95-percent confidence level), indicating excellent repeatability of the measured gamma-ray spectral peak intensities used to calculate the radionuclide assays.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. Valid shape factor data were generated for the region from the ground surface to about 22 ft. The analysis indicates that the distribution of ^{137}Cs contamination from the ground surface to about 22 ft varies from remote to near the borehole casing. The indicated distribution is consistent with one or more surface spills that migrated down into the backfill material near the borehole.

Historical gross gamma logs from January 1975 through June 1994 were reviewed. No zones of anomalous gamma-ray activity were identified in the logs.

The ^{137}Cs contamination from the ground surface to 26.5 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole. The ^{137}Cs contamination from 36 to 37 ft may have accumulated at the base of the tank farm excavation from a tank or pipeline leak. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-107, including tank C-107.

The ^{137}Cs contamination at 77.5 ft may have been carried down during drilling operations.

4.8 Borehole 30-07-11

Borehole 30-07-11 is located approximately 6 ft from the northwest side of tank C-107 and was given the Hanford Site designation 299-E27-93. This borehole was drilled in July 1974 and completed to a depth of 100 ft with 6-in. casing. A driller's log for this borehole was not available; therefore, information from Chamness and Merz (1993) was used in preparing this report. No information indicated that the borehole was grouted or that the casing was perforated; therefore, it is assumed that the borehole was not grouted or perforated. Total logging depth achieved by the SGLS was 97.5 ft.

The man-made radionuclides ^{137}Cs, ^{60}Co, and ^{154}Eu were detected in this borehole. ^{137}Cs contamination was detected in a high-concentration zone from the ground surface to about 19 ft.

^{137}Cs contamination was also detected at much lower concentrations intermittently from 20.5 to 36 ft, almost continuously from 49 to 74.5 ft, and near the bottom of the borehole at 97.5 ft.

^{60}Co contamination was detected at 4 ft, and ^{154}Eu contamination was detected at 0.5 ft, 1 ft, and 4 ft. The maximum concentrations of these contaminants could not be determined because of the high dead time experienced during logging from 1.5 to 3.5 ft. These radionuclides are probably also present in the very high activity region near the surface, but, because the logging system became saturated in this region, no gamma-ray peaks could be identified in the spectra.

^{40}K concentrations are relatively elevated from 38 to 40 ft (approximate base of the tank farm excavation). This concentration increase probably represents a change from backfill material to the undisturbed sediments of the Hanford formation. KUT concentrations are relatively elevated below about 49 ft. This increase in KUT concentrations may represent the contact between the gravel- and sand-dominated facies of the Hanford formation.

A shape-factor analysis of the distribution of gamma-ray energies was performed for this borehole, and a plot of the analysis results is included in Appendix A. The analysis produced interpretable results from about 8 to 15 ft. The analysis indicates that the ^{137}Cs contamination from about 8 to 14 ft is nearly uniformly distributed in the backfill material around the borehole. The interval of 14 to 15 ft is remote to the borehole. The indicated distribution is consistent with a surface spill that migrated downward into the backfill material around the borehole.

Historical gross gamma logs from January 1975 through June 1994 were reviewed, and a plot of representative logs is included in Appendix A. An interval of anomalously high gamma-ray activity was present in the upper 5 ft of the borehole by February 1984. This anomalously high activity was probably present as early as June 1982, but historical gross gamma logs from June 1982 through November 1983 do not record data from the upper 5 to 6 ft of the borehole. Information about this activity increase was not available.

Additional increases in the gross gamma-ray activity in the upper 5 ft of the borehole were detected in early to middle 1992. An investigation into the cause of these increases was conducted in late 1992 (WHC 1992). The source of the activity increase in 1992 was attributed to salt-well transfer lines that pass close to borehole 30-07-11 at a depth of about 3 ft. The lines had been used immediately before the increase was detected, and flushing of the salt-well transfer line with clean water resulted in an activity decrease in the borehole. It was concluded that the salt-well transfer line was not properly designed, and, therefore, allowed material to remain in the line after a transfer (WHC 1992). The ^{137}Cs, ^{60}Co, and ^{154}Eu contamination from 1 to 4 ft is probably from material remaining within the transfer line.

The ^{137}Cs contamination from the ground surface to 16 ft is probably the result of one or more surface spills that migrated into the backfill material around the borehole and from material contained in the salt-well transfer line near the borehole.

The ^{137}Cs contamination from 16.5 to 37 ft was probably carried down during borehole drilling or migrated down the outside of the borehole casing. The ^{137}Cs contamination from 49 to 74.5 ft may be the result of a tank or pipeline leak or may have been carried down during drilling operations. The source of the leak could be a number of tanks and their associated piping in the vicinity of tank C-107, including tank C-107.

The ^{137}Cs contamination near the bottom of the borehole may be the remnant of a plume that existed at this depth, or the contamination may have migrated down the outside of the borehole casing to this depth.

5.0 Discussion of Results

A plot of the man-made radionuclide concentration profiles for the eight boreholes surrounding tank C-107 is presented in Figure 3. The plot shows ^{137}Cs contamination and a trace amount of ^{60}Co and ^{154}Eu contamination.

The SGLS detected elevated ^{137}Cs concentrations in the upper portions of all eight boreholes. This contamination is probably from surface spills that migrated into the backfill material around the boreholes or contamination that migrated down the outside of the borehole casing. In addition to the ^{137}Cs contamination from surface spills, the SGLS also detected ^{137}Cs, ^{60}Co, and ^{154}Eu contamination associated with a transfer line at about 3 ft near borehole 30-07-11. On the basis of historical information presented in WHC (1992), this contamination is thought to be inside the transfer line. It is possible, however, that the contamination is located in the vadose zone near the transfer line.

^{137}Cs contamination was detected below the base of the tank farm excavation in boreholes 30-07-01, 30-04-12, 30-07-05, 30-07-07, and 30-07-11. These contamination plumes probably originated from several sources including tank and/or pipeline leaks. It may not be possible to positively identify the contaminant sources. The data from this borehole will be correlated with data from boreholes adjacent to other tanks in the C Tank Farm Report (to be published).

The ^{137}Cs contamination near the bottoms of boreholes 30-04-12 and 30-07-11 may be from contamination that migrated down the outside of the borehole casing to this depth. However, it is also possible that the contamination at this depth is in the formation near the borehole.

The ^{60}Co contamination detected between 43 and 47.5 ft in borehole 30-04-12 is thought to be a remnant of a plume related to the cascade-line leak that occurred between tanks C-104 and C-105.

6.0 Conclusions

The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-107 was completed using the SGLS. Data obtained with the SGLS and geologic and historical information indicate that the source of ^{137}Cs contamination around this tank is a combination of surface spills and pipeline and/or tank leaks. The specific sources of the

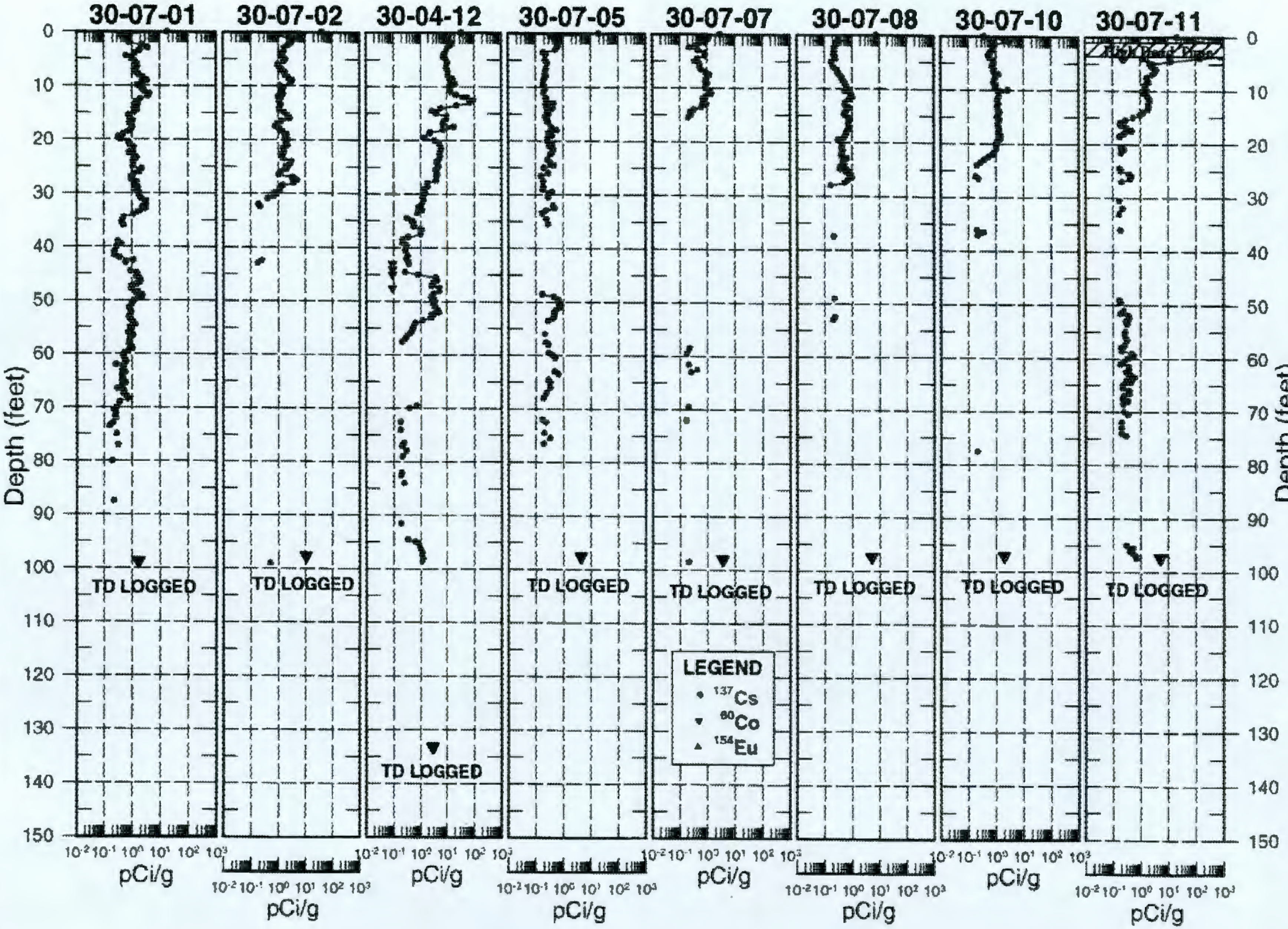

Figure 3. Correlation Plot of ^{137}Cs, ^{60}Co, and ^{154}Eu Concentrations in Boreholes Surrounding Tank C-107

contamination could not be identified. Any of the tanks adjacent to tank C-107, including tank C-107, or the associated piping could be the source of this contamination.

The ^{60}Co, ^{154}Eu, and a large portion of the ^{137}Cs contamination in the upper 5 ft of borehole 30-07-11 appears to be associated with a transfer pipe near this borehole.

7.0 Recommendations

Approximately 24,000 gal of drainable, interstitial liquid remains in tank C-107 (Hanlon 1997). It is recommended that logging of the boreholes surrounding this tank be continued to detect potential future leakage from the tank and associated tank facilities and to monitor the potential spread of contaminant plumes detected during this study. Monitoring of vadose zone boreholes is the only means of leak detection because of the solids in the tank, as noted in Welty (1988). Changes in the contamination profiles would show contaminant migration or additional leakage from this tank.

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Appendix A
Spectral Gamma-Ray Logs for Boreholes in the Vicinity of Tank C-107

Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-01

Borehole Information

Farm :	C	Tank :	C-107	Site Number :	299-E27-87
N-Coord :	42,911	W-Coord :	48,448	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	9/30/74		

Casing Record

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

Borehole Notes:
Borehole 30-07-01 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is assumed 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 :	3/7/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	100.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	48.5	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/10/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	49.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	0.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-07-01

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1   Analysis Date : 8/20/97

Analysis Notes :

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

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

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured almost continuously from the ground surface to 74 ft and intermittently from 75.5 to 87.5 ft.

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole. The K-40 and U-238 concentrations decrease at about 40 ft. Th-232 concentrations are highly variable below about 39 ft. K-40 concentrations decrease from about 56 to 59 ft. K-40 concentrations increase again at 59 ft and remain elevated to the bottom of the logged interval.

Additional information and interpretations of log data are provided in the main body of the Tank Summary Data Reports for tank C-107 and C-108.

Log Plot Notes:

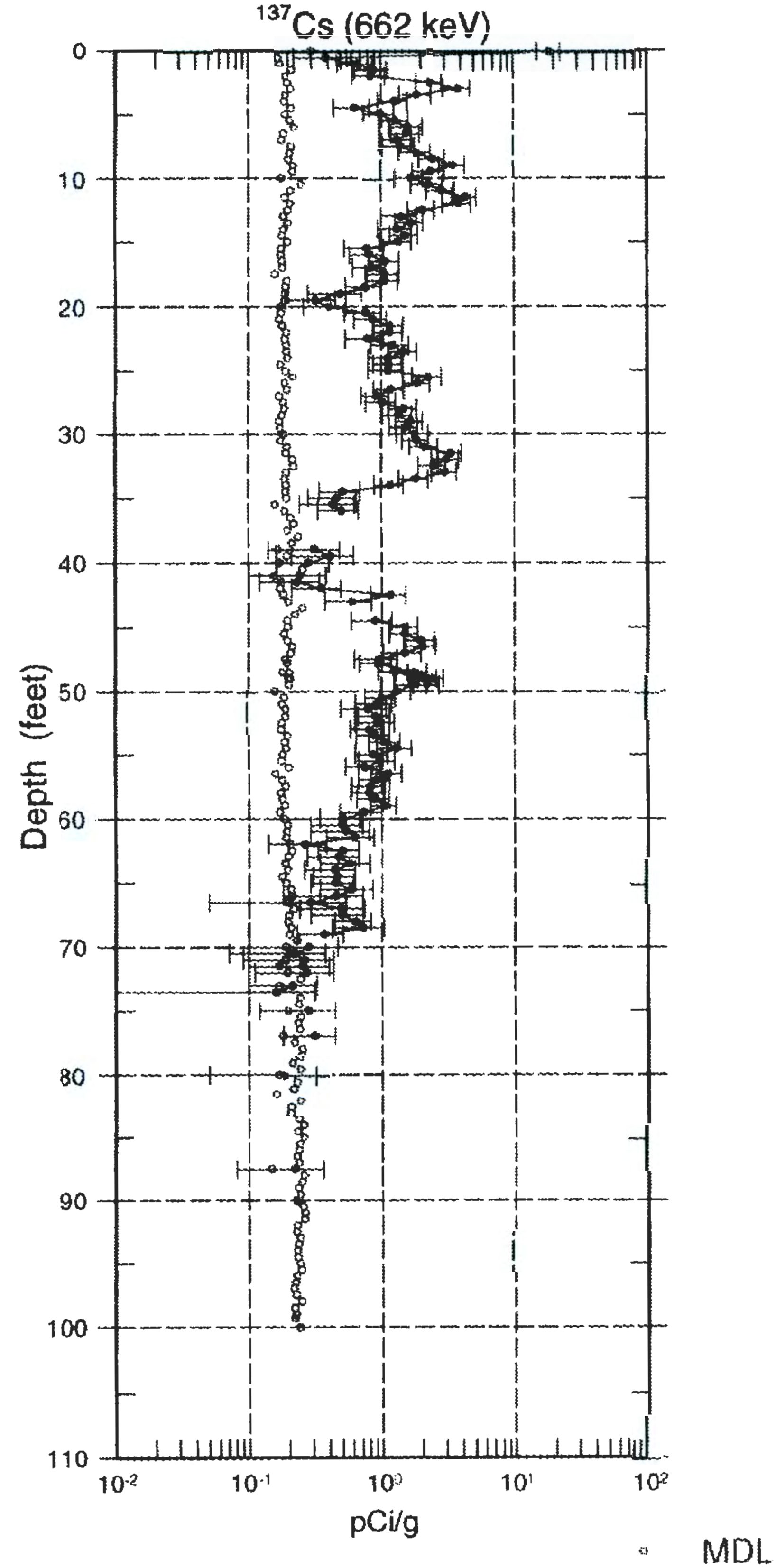
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

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.

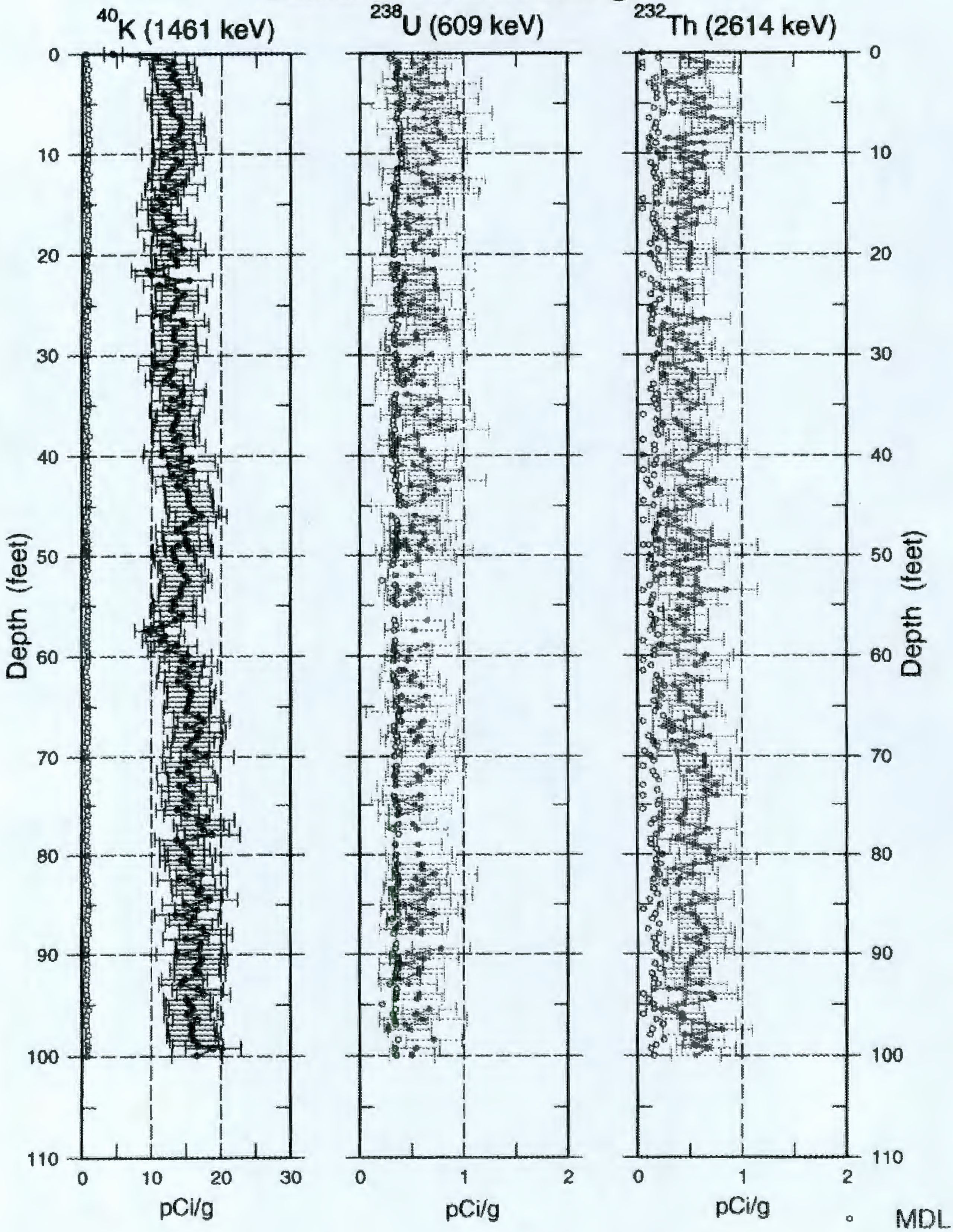
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

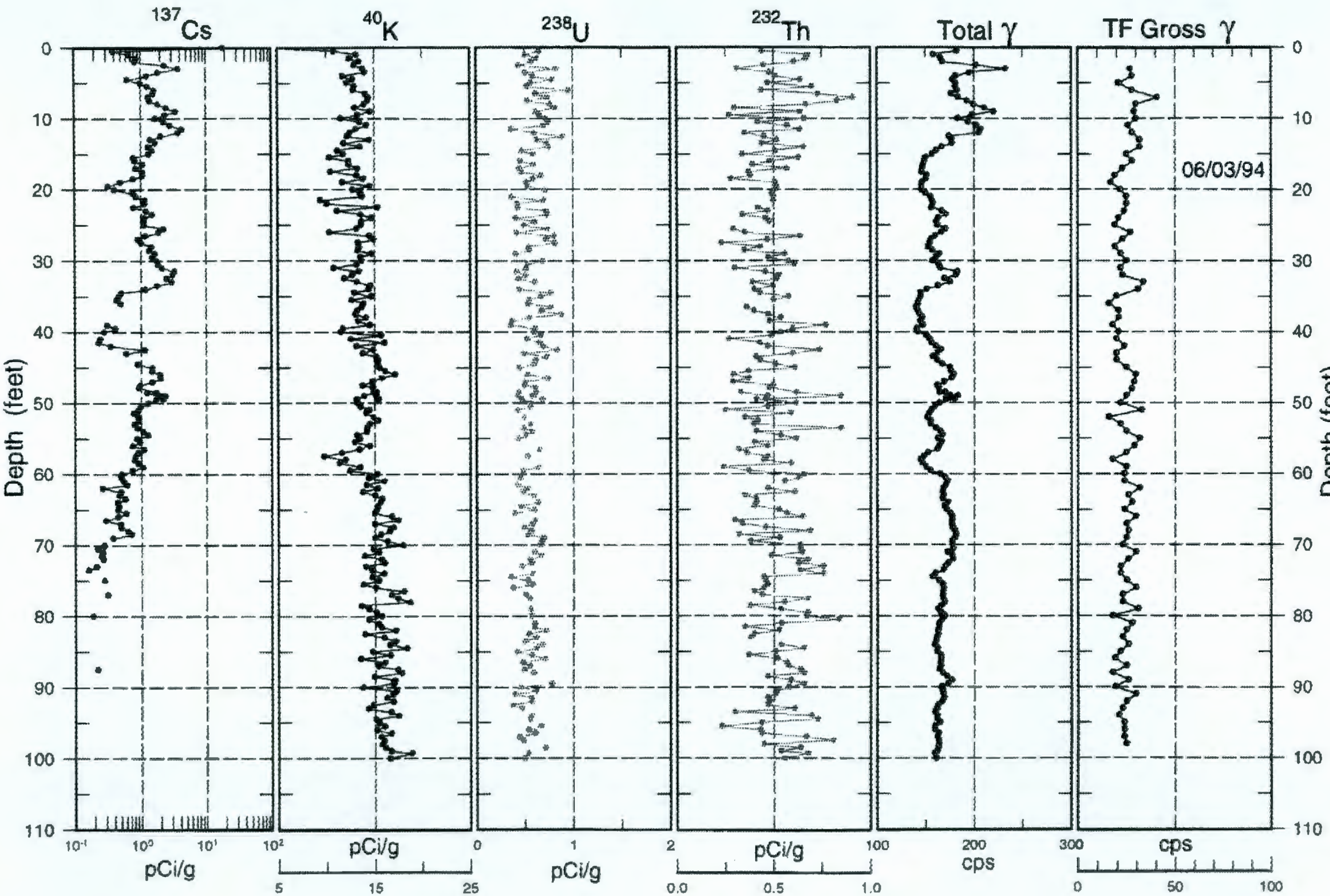
30-07-01
Man-Made Radionuclide Concentrations



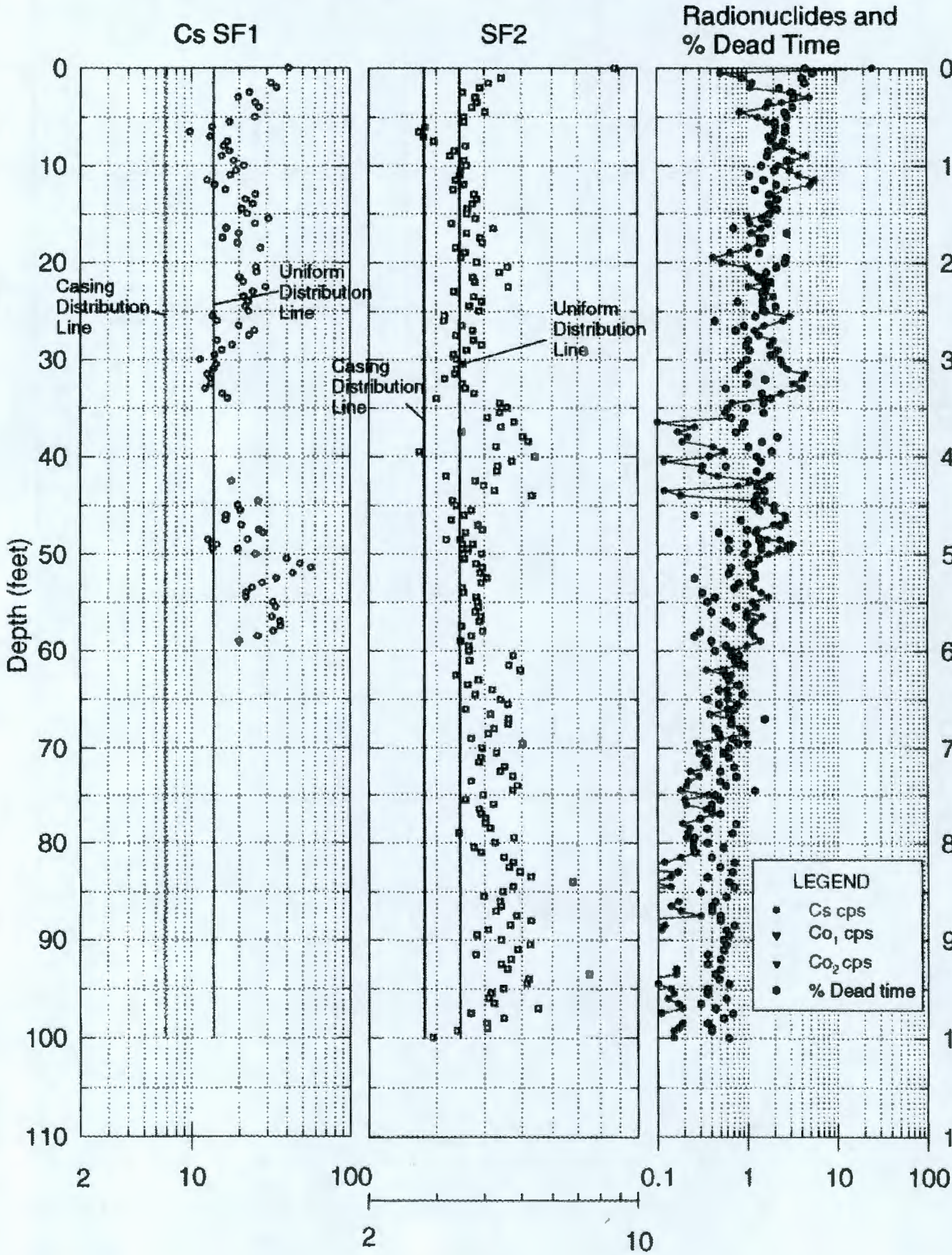
30-07-01
Natural Gamma Logs



30-07-01 Combination Plot



30-07-01
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-02

Borehole Information

Farm :	C	**Tank :**	C-107	**Site Number :**	299-E27-88
N-Coord :	42,883	**W-Coord :**	48,419	**TOC Elevation :**	646.00
Water Level, ft :	None	**Date Drilled :**	9/30/74		

Casing Record

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

Borehole Notes:
Borehole 30-07-02 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System :	1B	**Detector Type :**	HPGe	**Detector Efficiency :**	35.0 %
Calibration Date :	2/97	**Calibration Reference :**	GJO-HAN-14	**Logging Procedure :**	P-GJPO-1783

Log Run Information

Log Run Number :	1	**Log Run Date :**	3/12/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	0.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	28.0	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

Log Run Number :	2	**Log Run Date :**	3/13/97	**Logging Engineer:**	Alan Pearson		
Start Depth, ft.:	27.0	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	99.0	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-02

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 8/20/97

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. There was some gain drift and it was necessary to adjust the established channel-to-energy parameters during processing of log data to maintain proper peak identification.

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

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured almost continuously from the ground surface to 32 ft, at 42.5 and 43 ft, and at the bottom of the logged interval (99 ft).

An analysis of the shape factors associated with applicable segments of the spectra was performed. The shape factors provide insights into the distribution of the Cs-137 contamination and into the nature of zones of elevated total count gamma-ray activity not attributable to gamma-emitting radionuclides.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole. The K-40 concentrations increase at 40 ft and remain elevated to 59 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-108.

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.

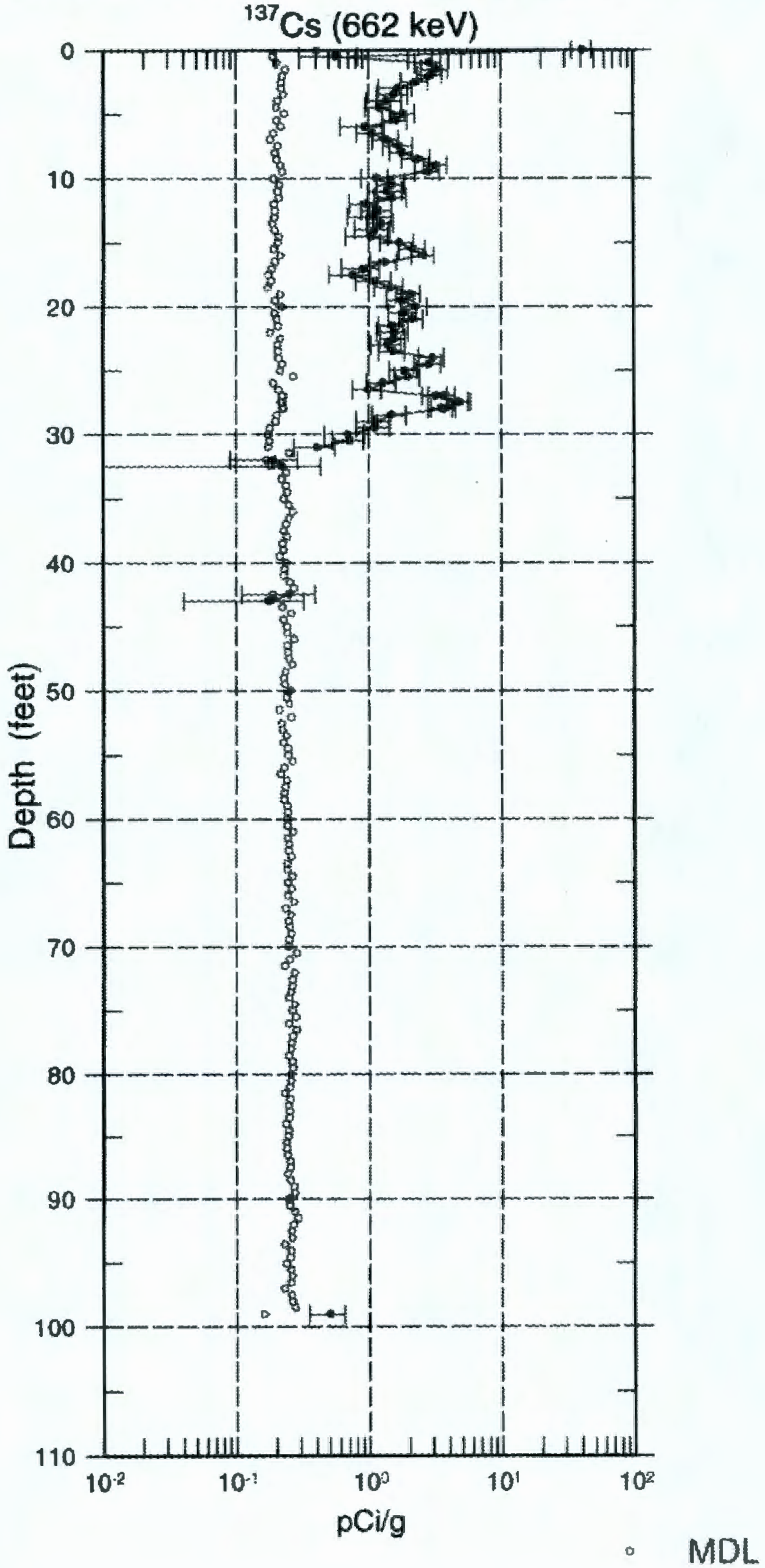
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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.

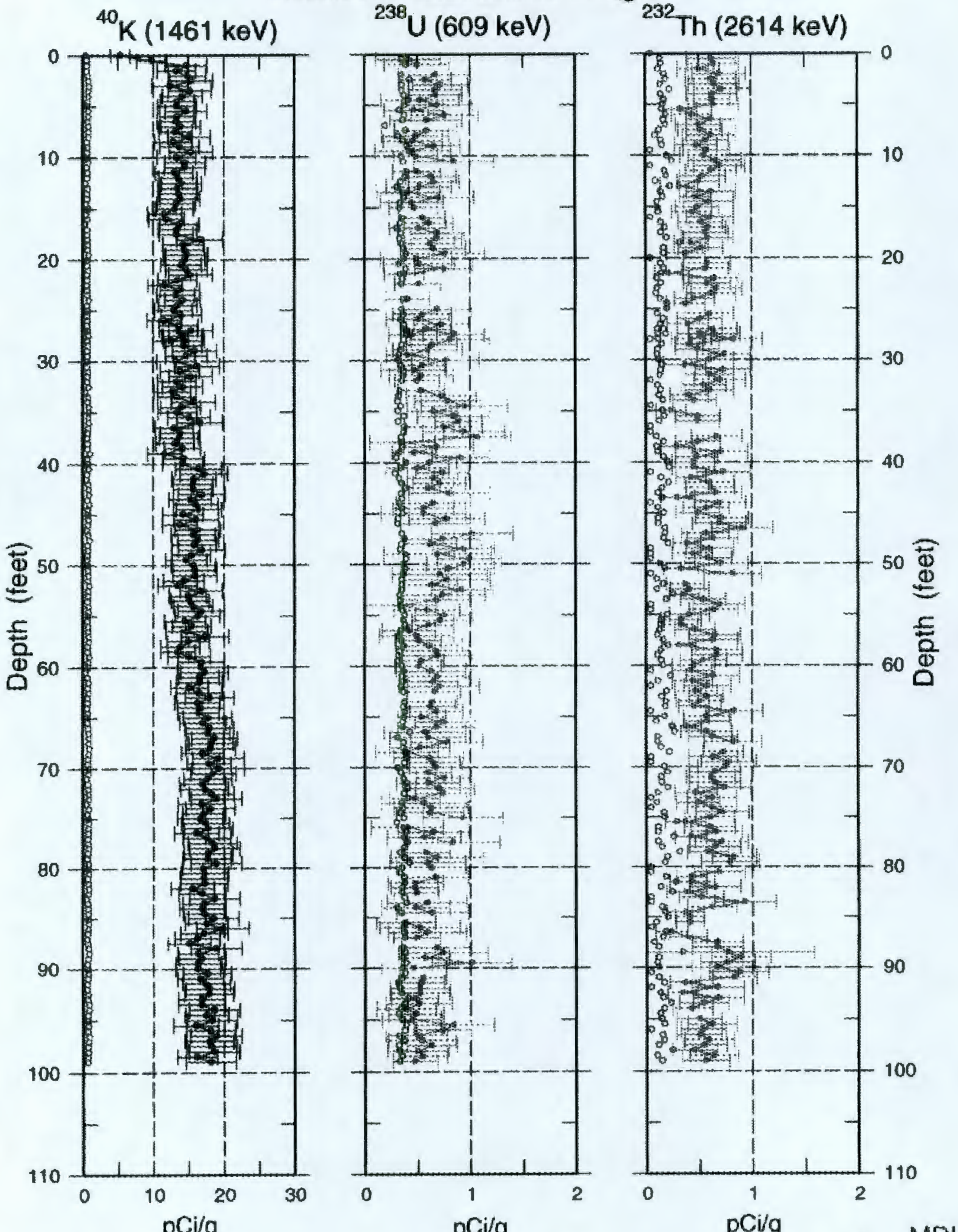
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-02

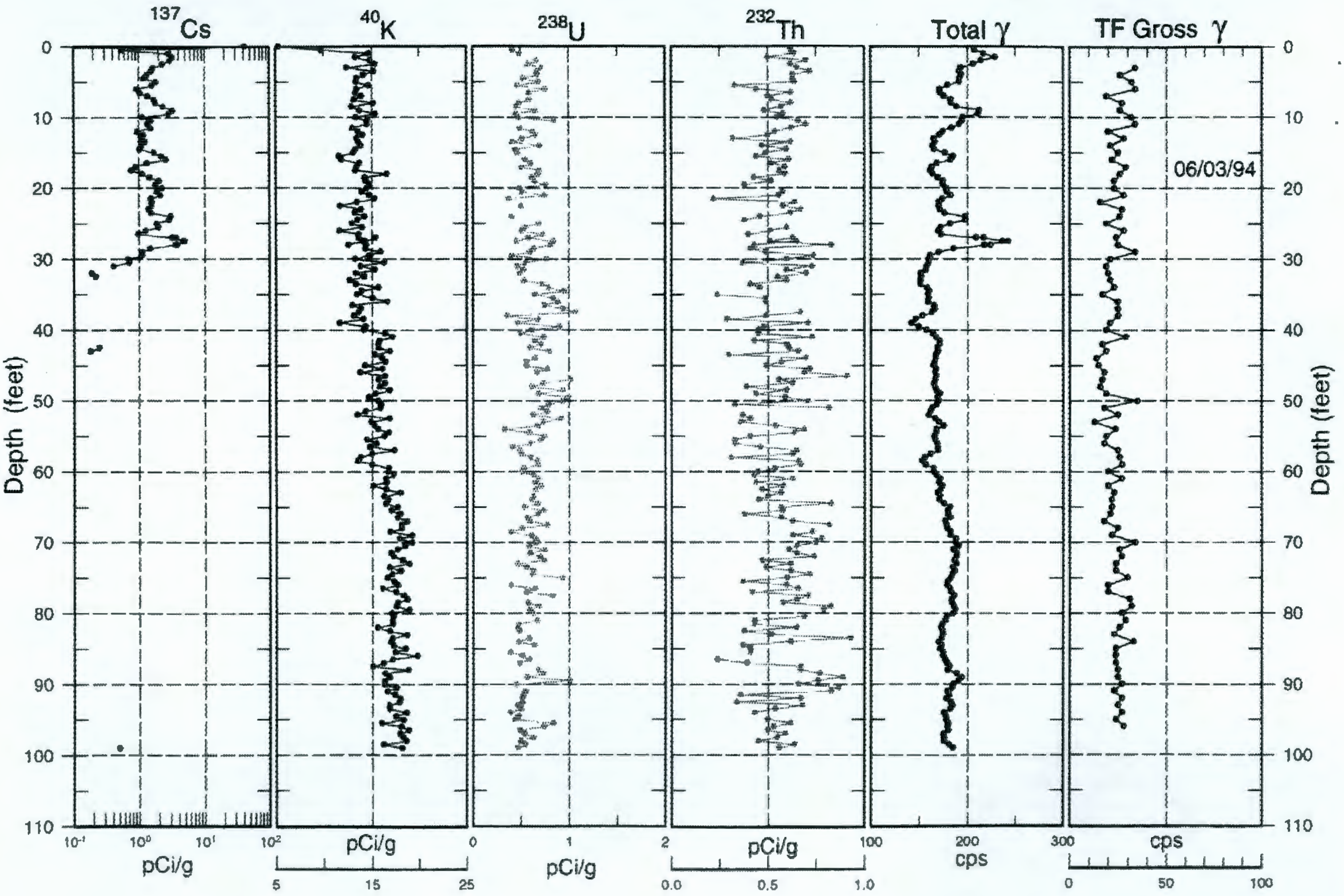
Man-Made Radionuclide Concentrations



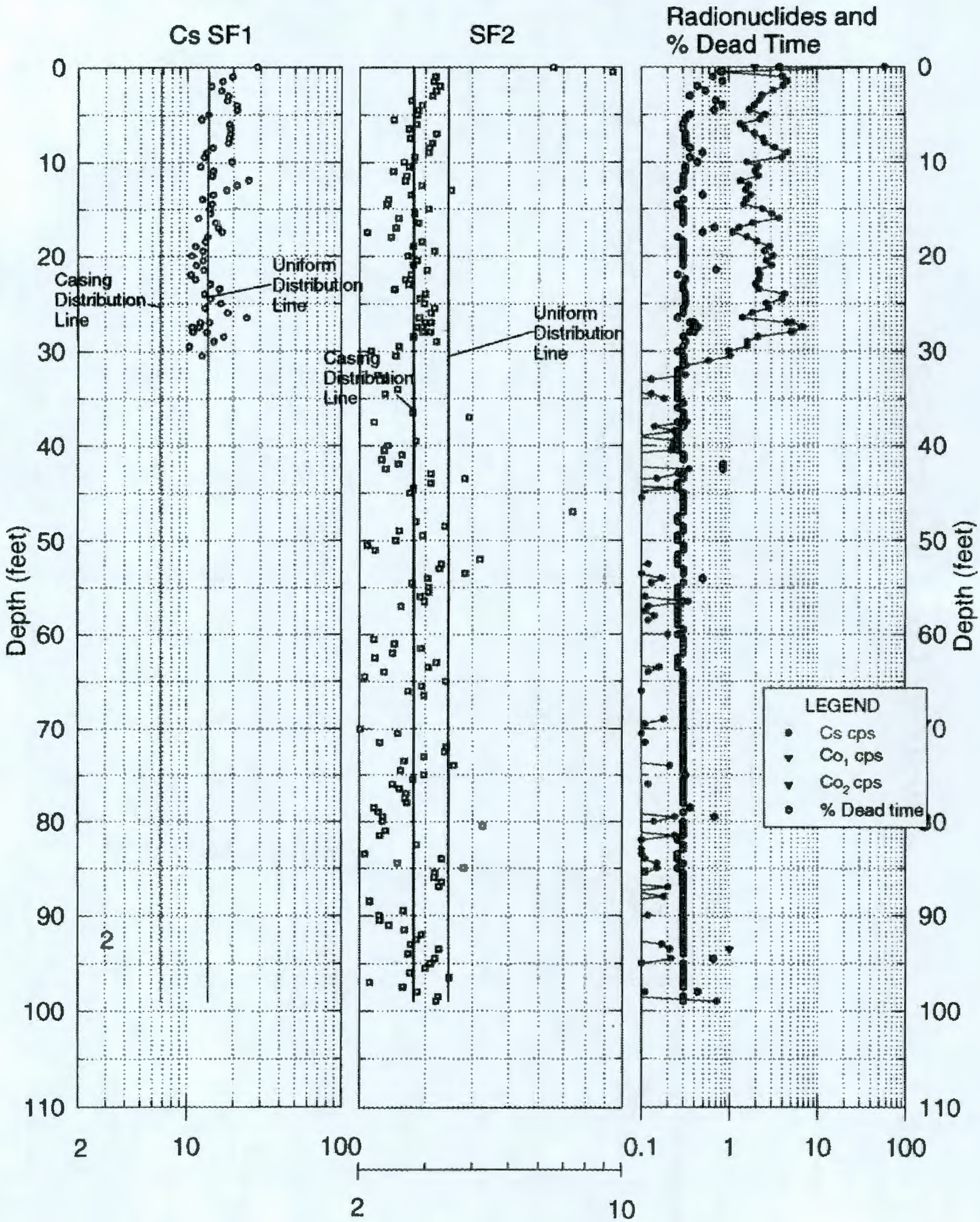
30-07-02
Natural Gamma Logs



30-07-02 Combination Plot



30-07-02
Shape Factor Analysis Logs



Spectral Gamma-Ray Borehole
Log Data Report

Borehole 30-04-12

Log Event A

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. : 0.5	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. : 0.5	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. : 0.5	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.

Shape factor data analysis was performed using the SGLS data from this borehole.

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.

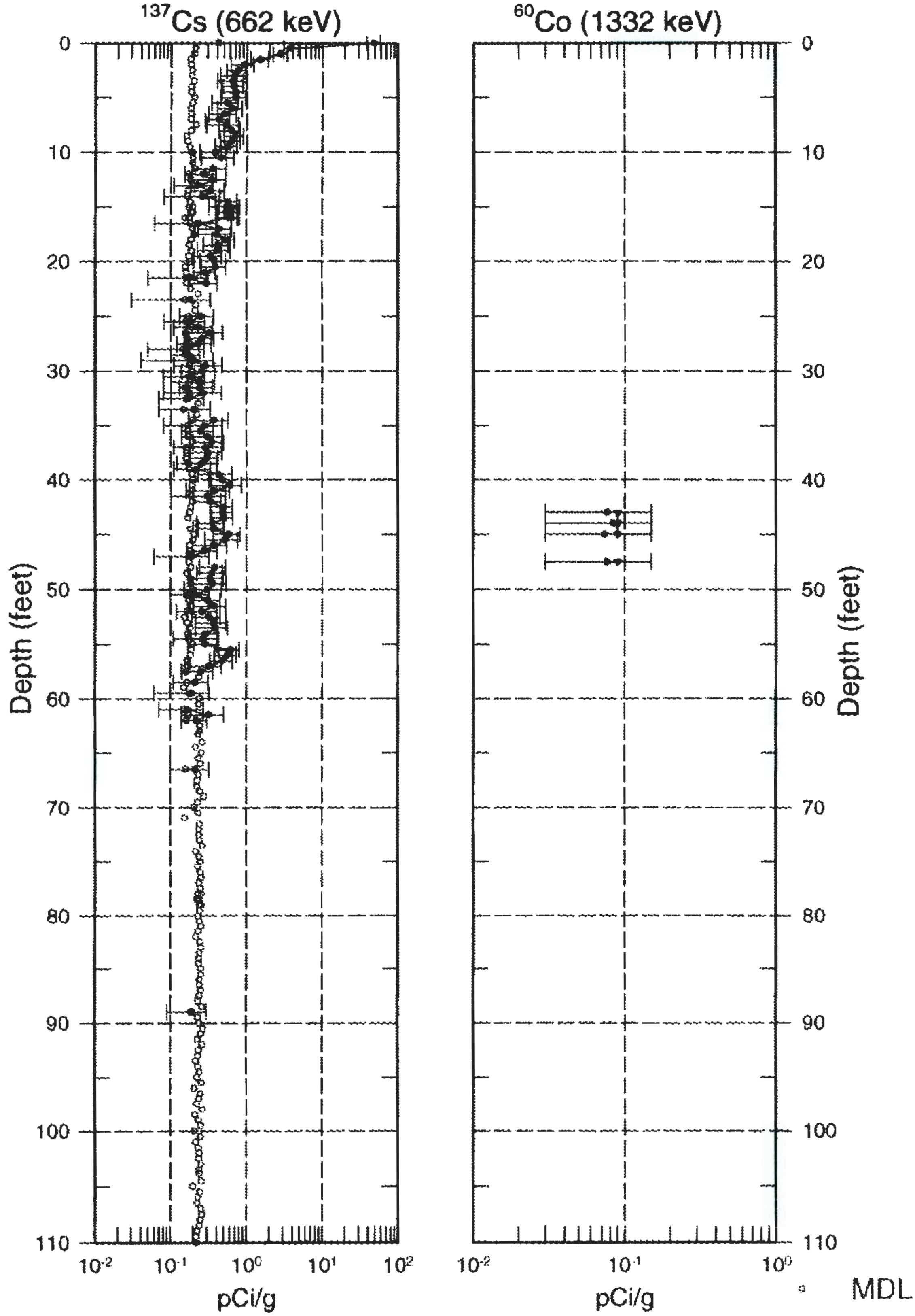
Log Plot Notes:

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.

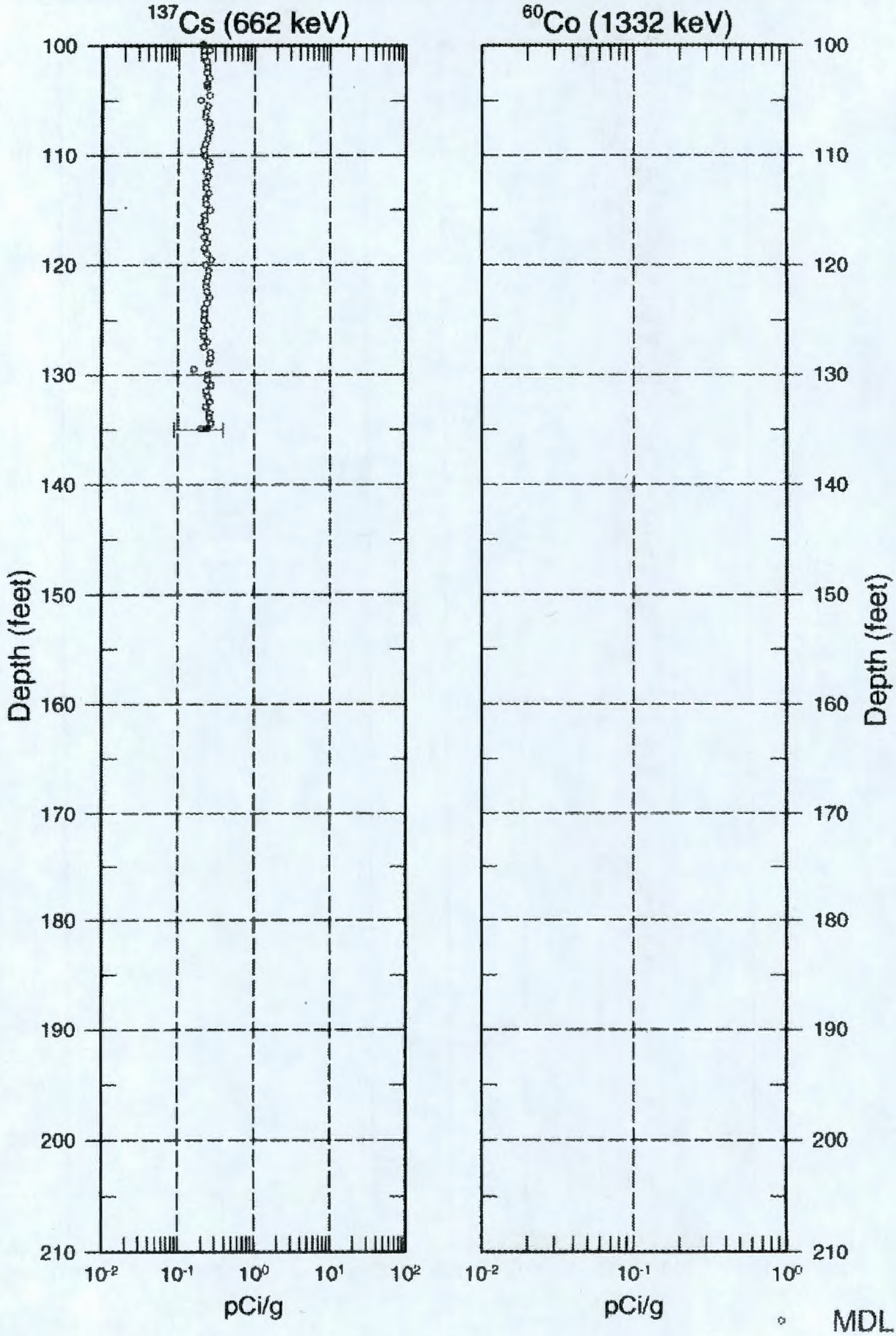
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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.

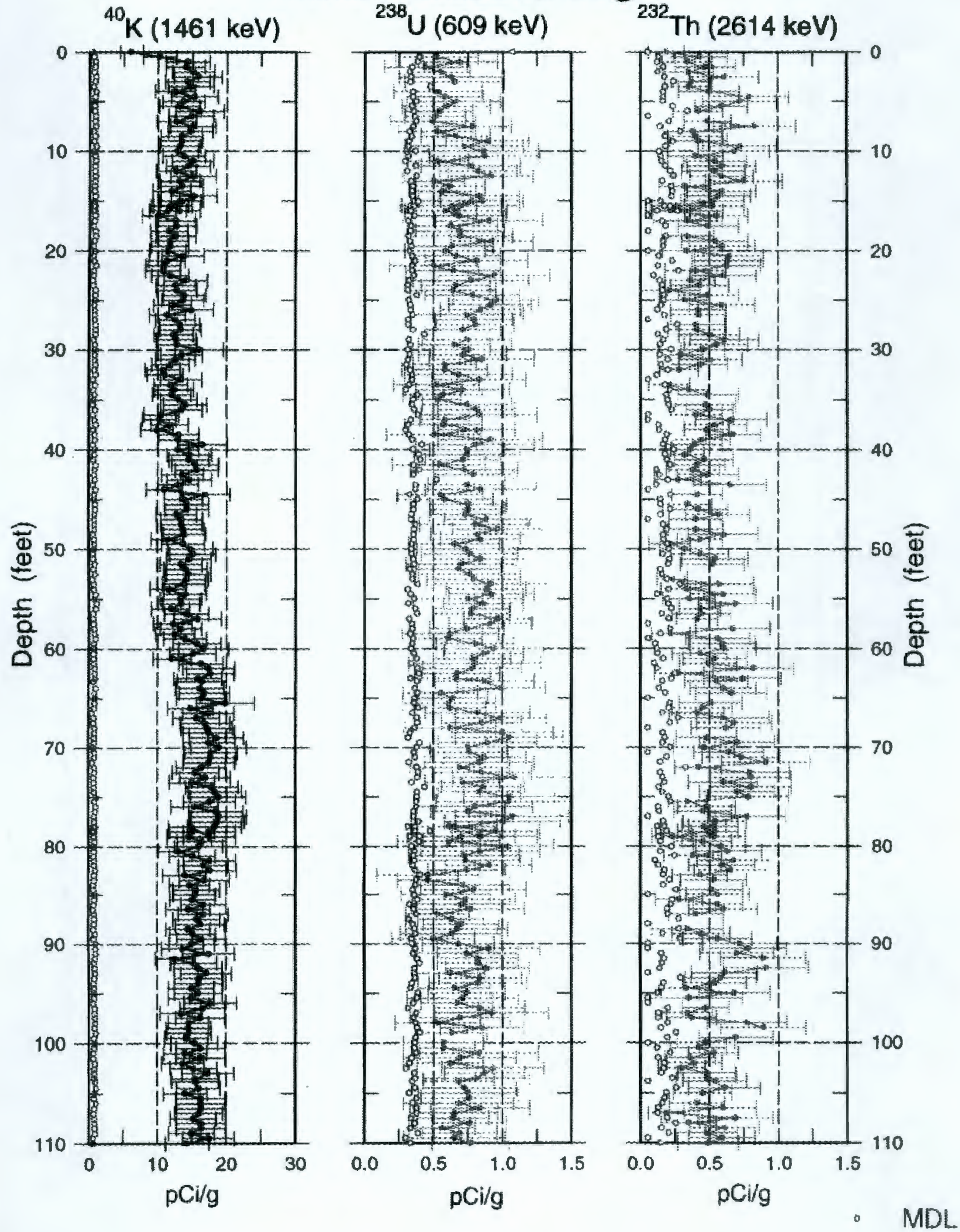
30-04-12
Man-Made Radionuclide Concentrations



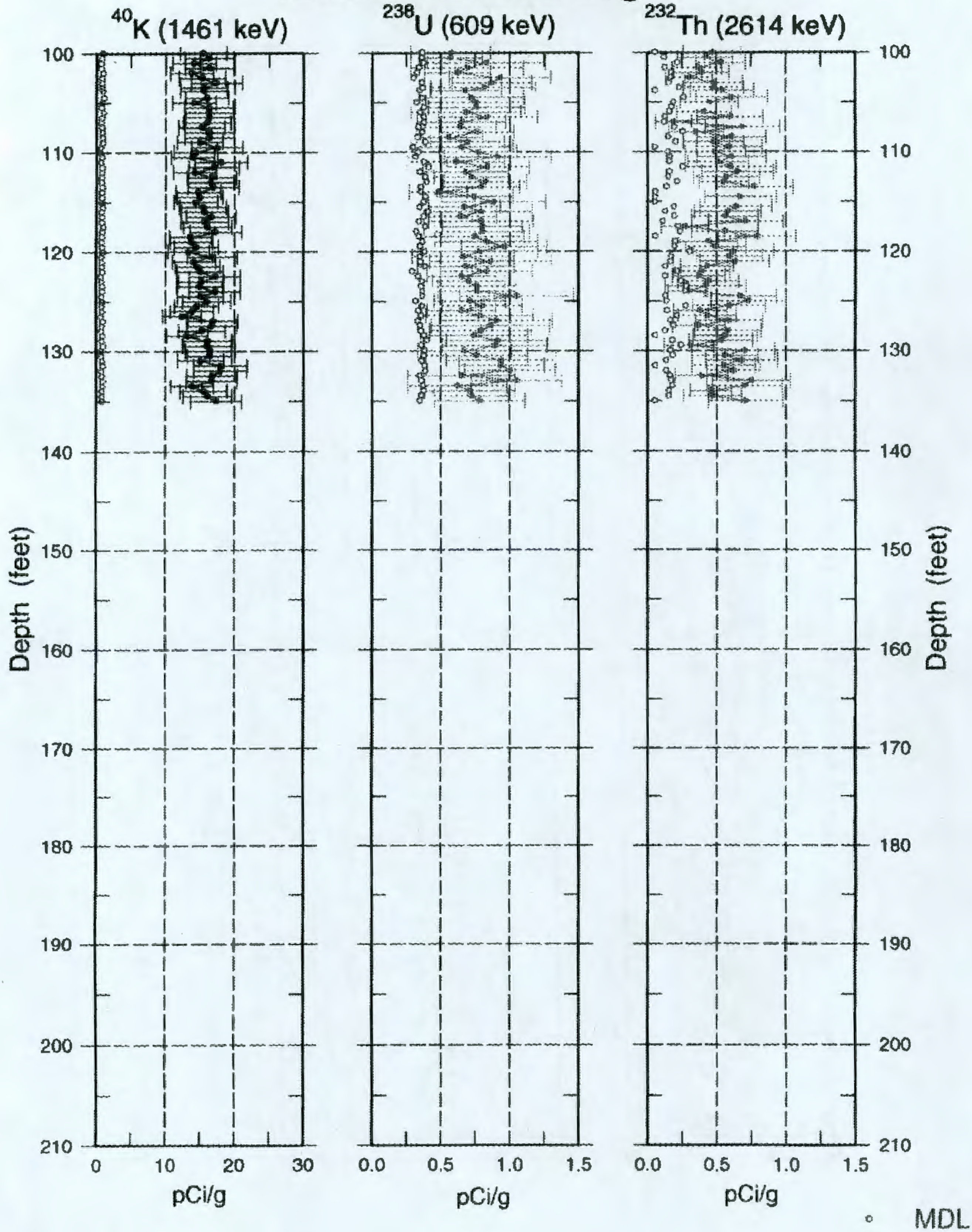
30-04-12
Man-Made Radionuclide Concentrations



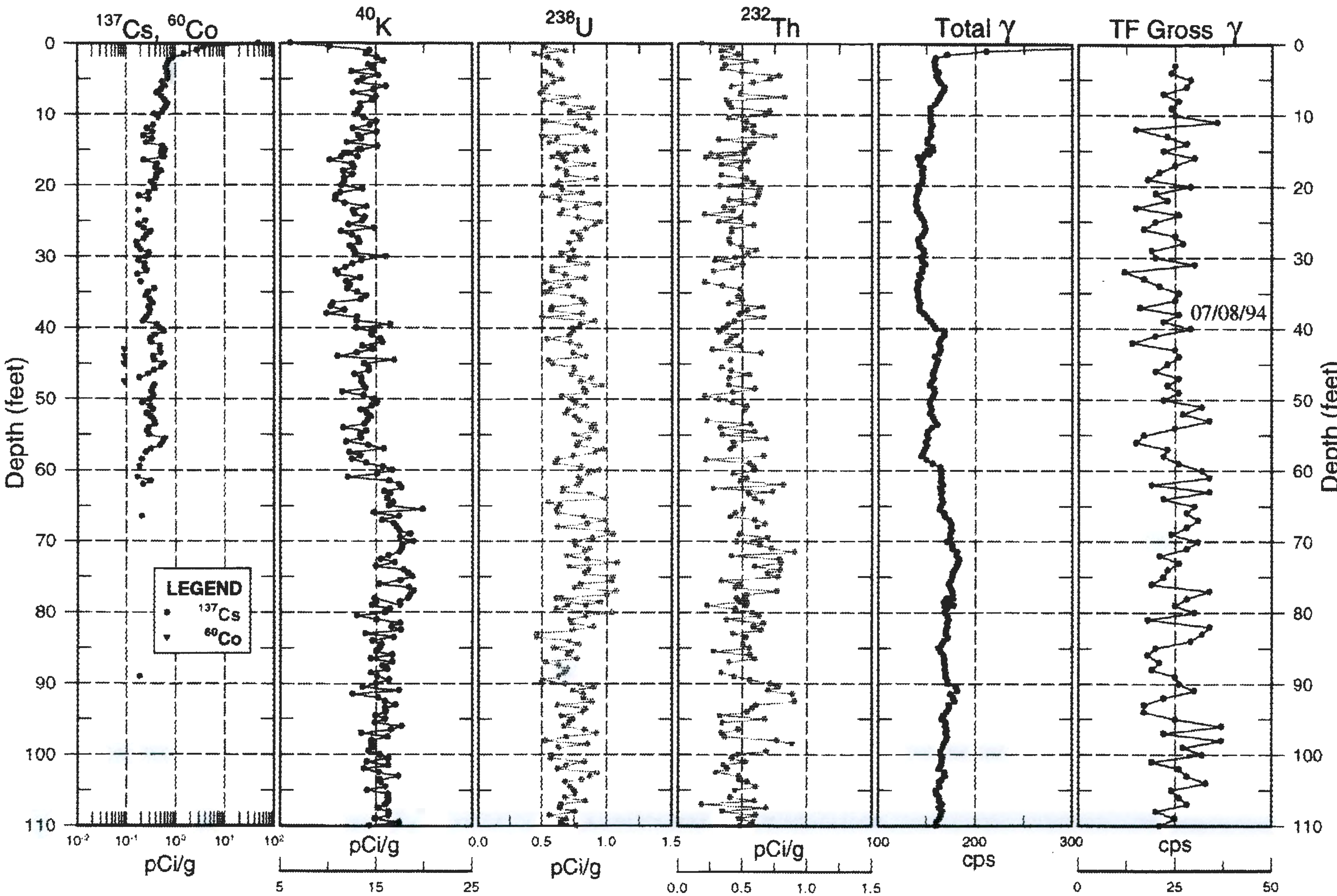
30-04-12
Natural Gamma Logs



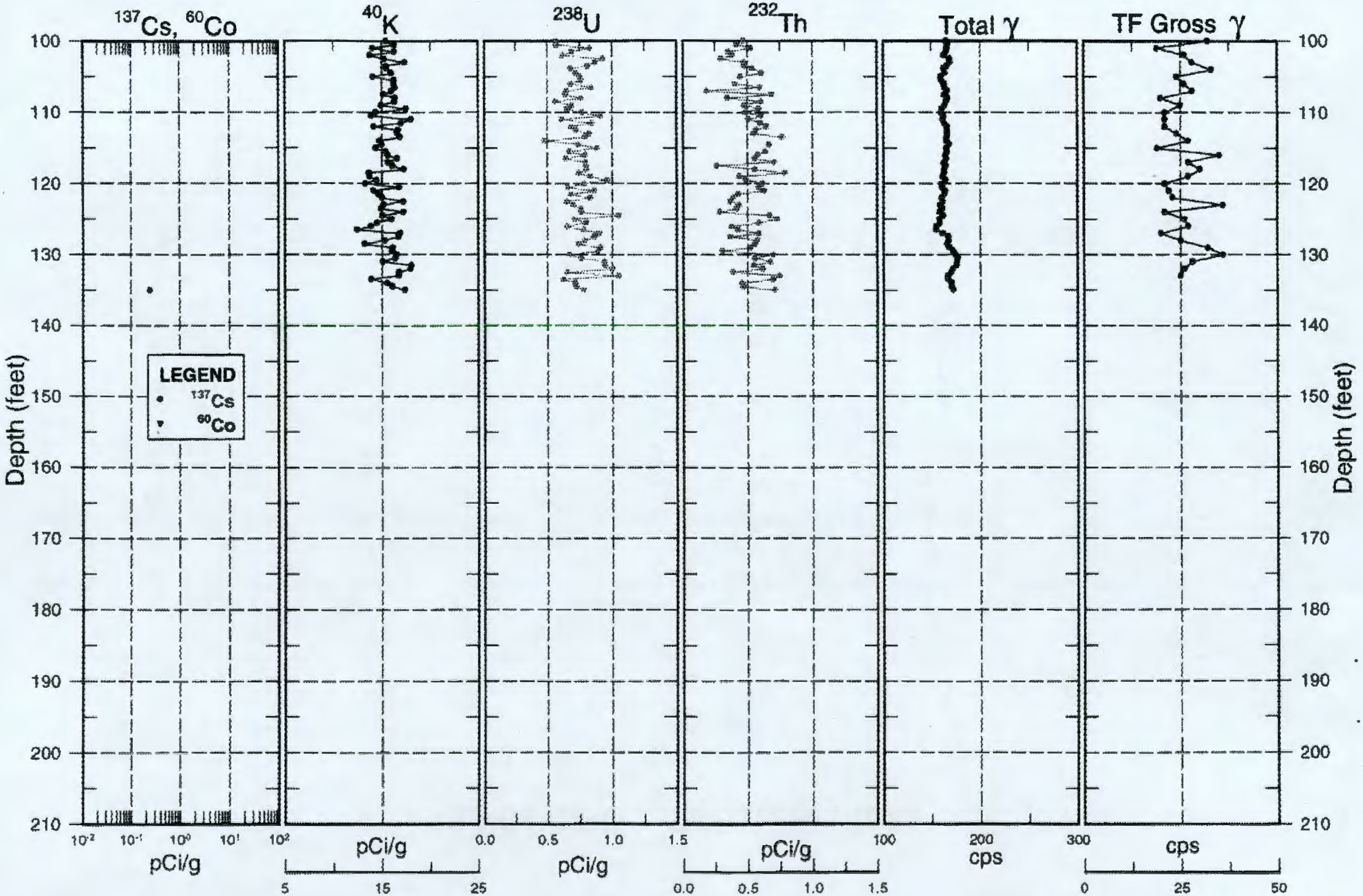
30-04-12
Natural Gamma Logs



30-04-12 Combination Plot



30-04-12 Combination Plot



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. :	0.5	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. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-07-05

Analysis Information

Analyst : E. Larsen

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1   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.

Shape factor data analysis was performed using the SGLS data from this borehole.

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:

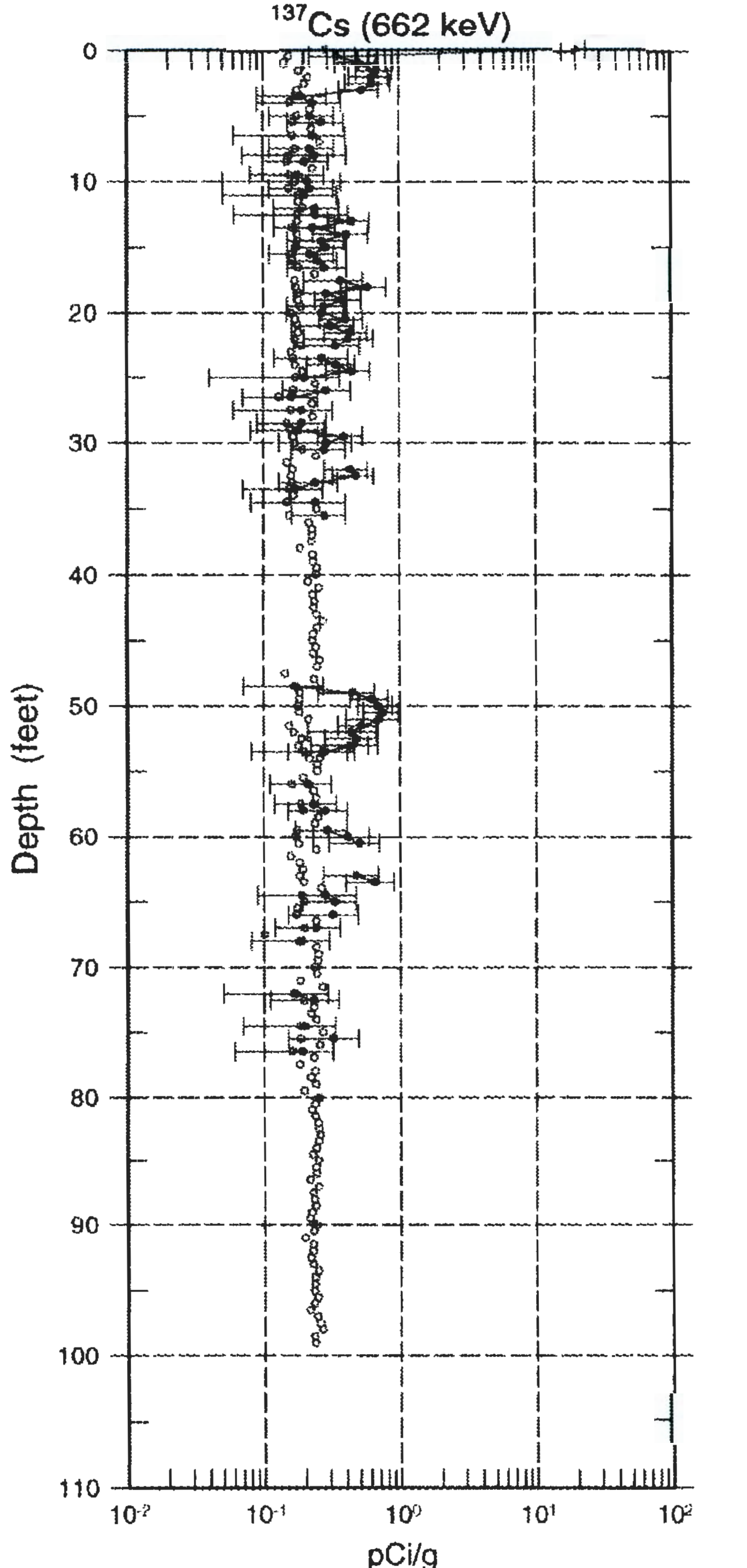
Separate log plots show the man-made and the naturally occurring radionuclides. The natural radionuclides can be used for lithology interpretations. The headings of the plots identify the specific gamma rays used to calculate the concentrations.

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.

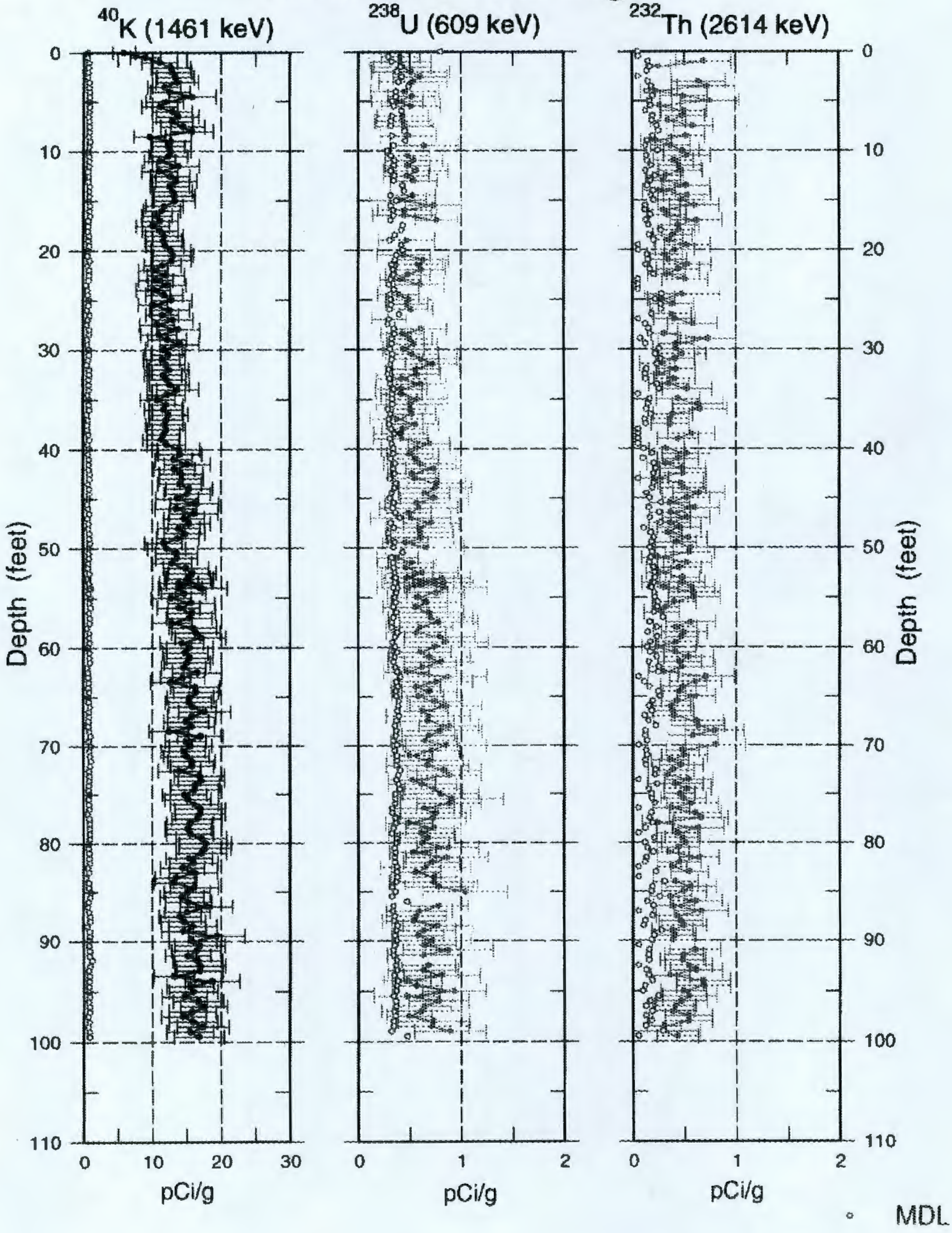
A combination plot includes the man-made and natural radionuclides, the total gamma derived from the spectral data, and the Tank Farms gross gamma log. The gross gamma plot displays the latest available digital data. No attempt has been made to adjust the depths of the gross gamma logs to coincide with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

30-07-05

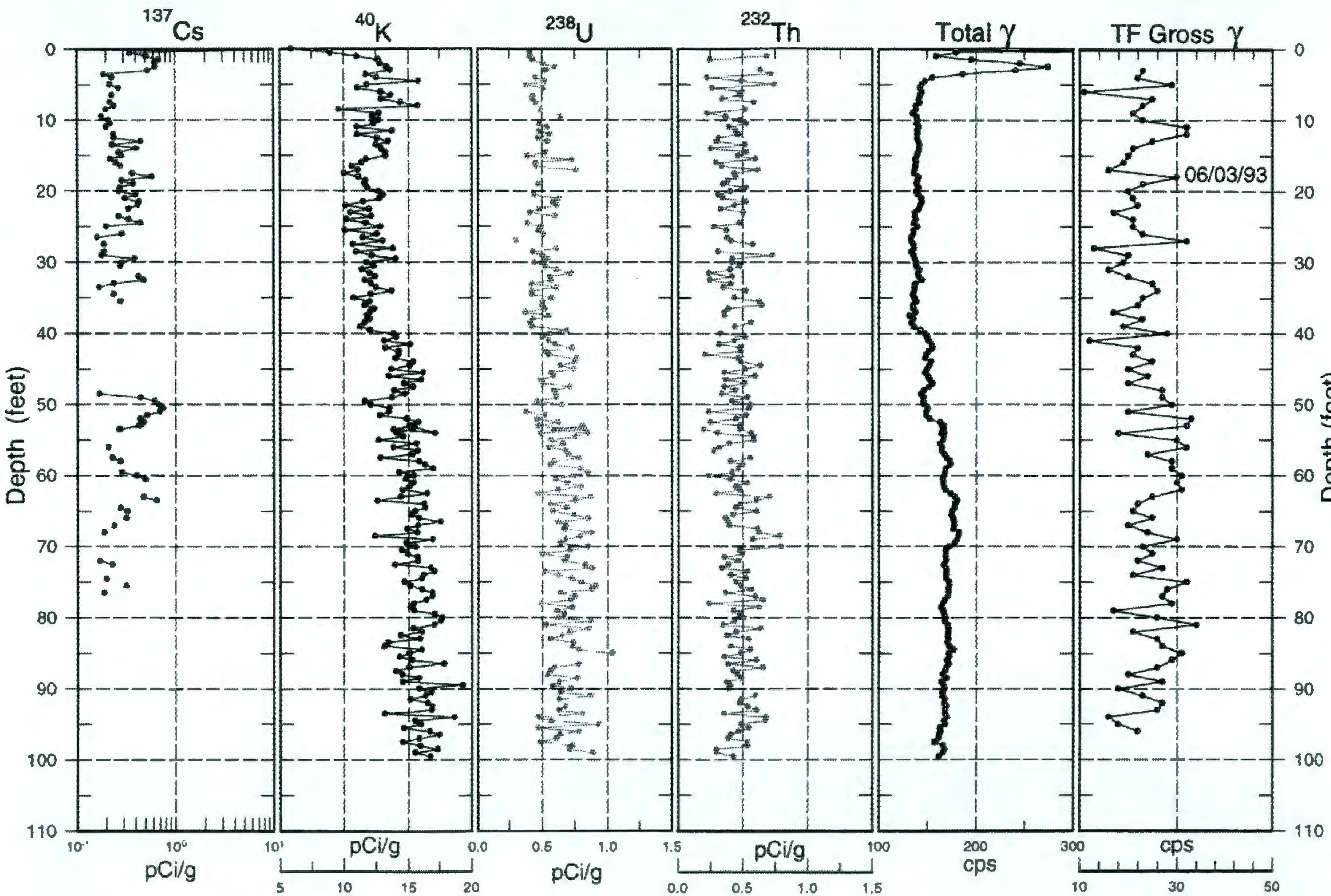
Man-Made Radionuclide Concentrations



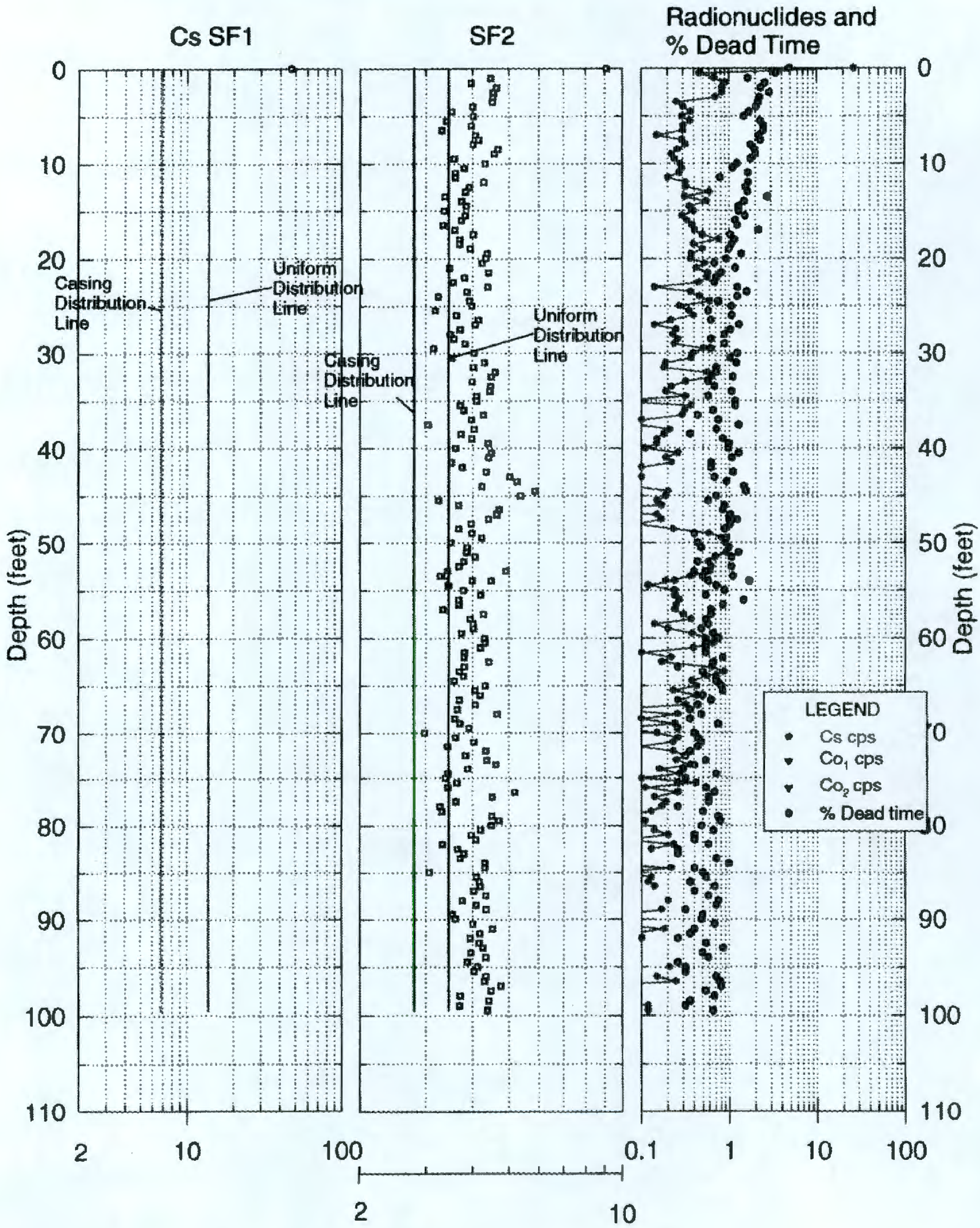
30-07-05
Natural Gamma Logs



30-07-05 Combination Plot



30-07-05
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-07-07

Borehole Information

Farm : C
Tank : C-107
Site Number : 299-E27-90
N-Coord : 42,815
W-Coord : 48,485
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. : 97

Borehole Notes:
Borehole 30-07-07 was drilled in October 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is assumed 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 zero reference is top of the casing and 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 : 3/17/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 98.5
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 60.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 2
Log Run Date : 3/18/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 61.0
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 39.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 3
Log Run Date : 3/18/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 40.0
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 12.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Log Run Number : 4
Log Run Date : 3/19/97
Logging Engineer: Bob Spatz
Start Depth, ft.: 13.0
Counting Time, sec.: 100
L/R : L
Shield : N
Finish Depth, ft. : 0.0
MSA Interval, ft. : 0.5
Log Speed, ft/min.: n/a

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 8/20/97

Analysis Notes :

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

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

The only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured continuously from the ground surface to 15.5 ft, intermittently from 58.5 to 72 ft, and at the bottom of the logged interval (98.5 ft).

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole.

The K-40 concentrations are relatively elevated from 39.5 to 41 ft. K-40 and U-238 concentrations are elevated from 47.5 to about 61 ft. Th-232 concentrations are elevated from 50 to about 62 ft and are highly variable over the depth of the borehole.

Shape factor data analysis was performed using the SGLS data from this borehole.

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

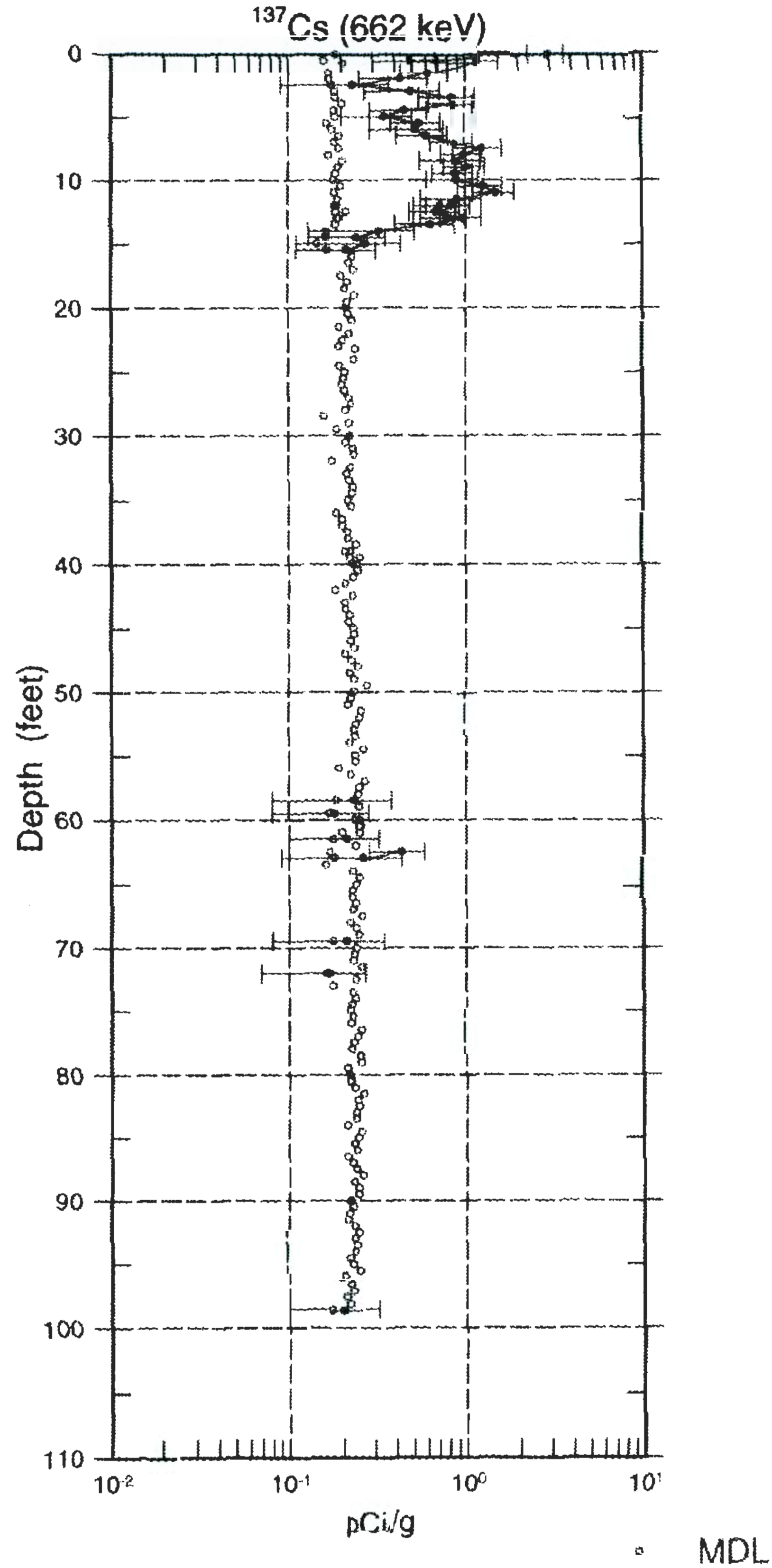
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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.

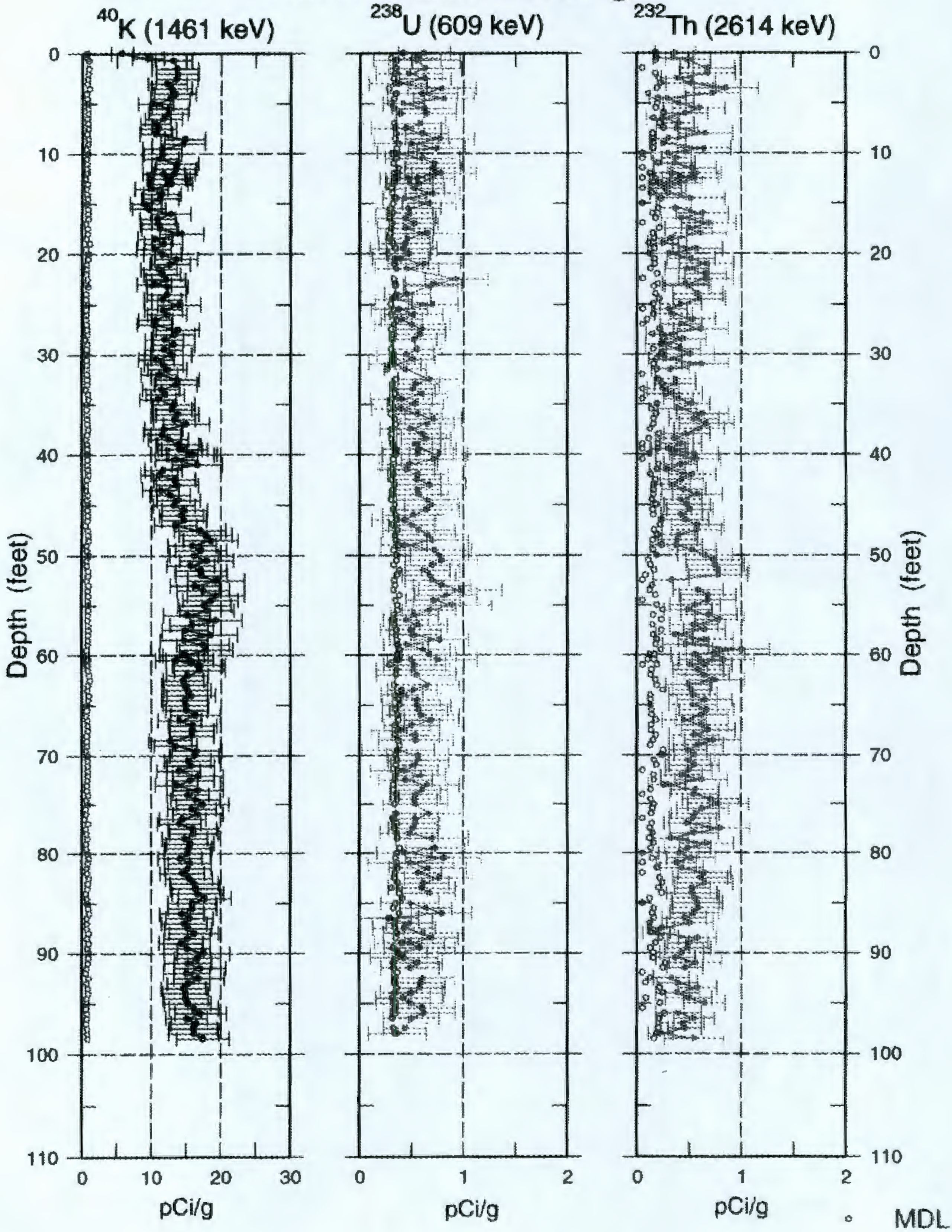
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-07

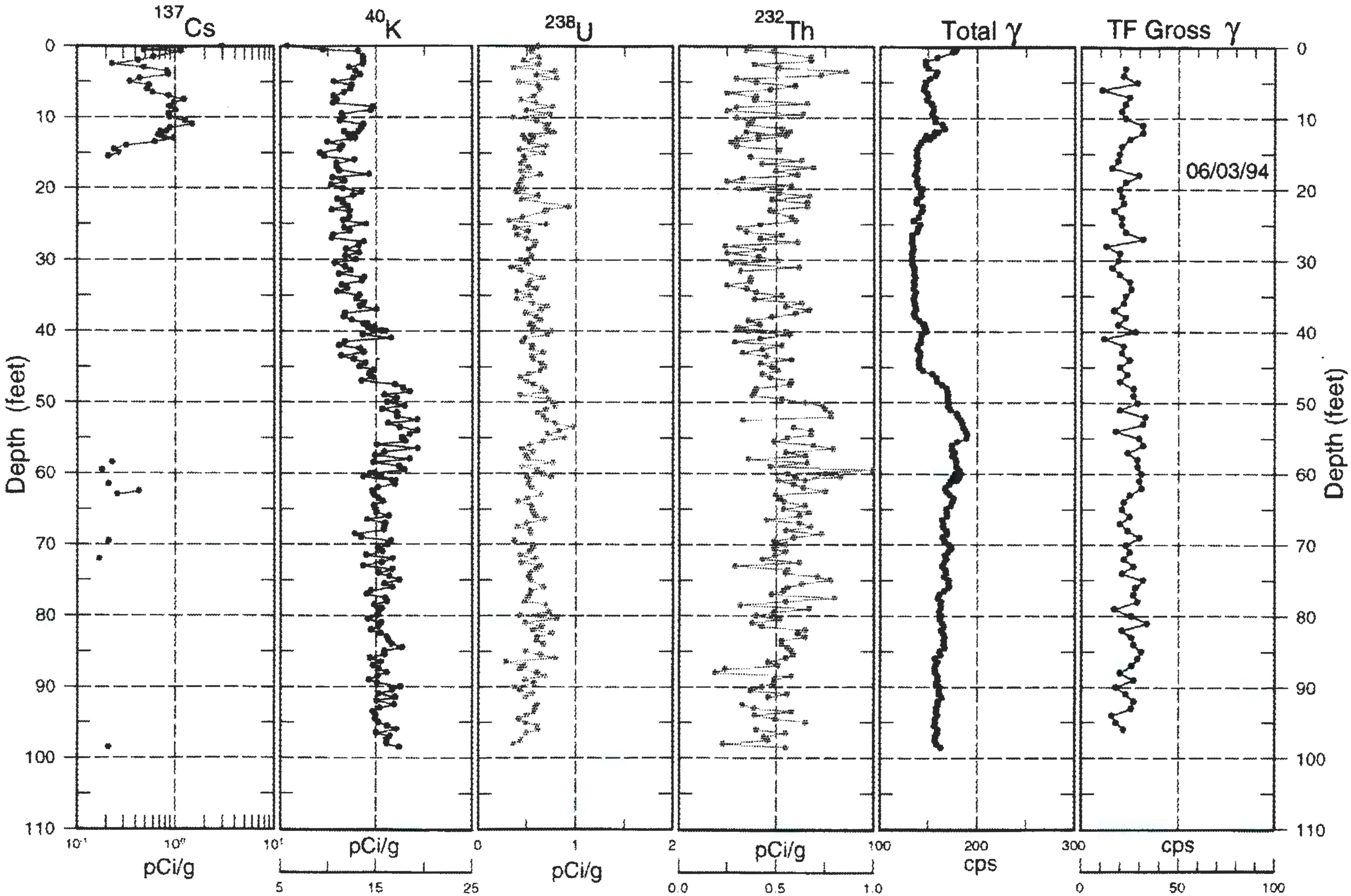
Man-Made Radionuclide Concentrations



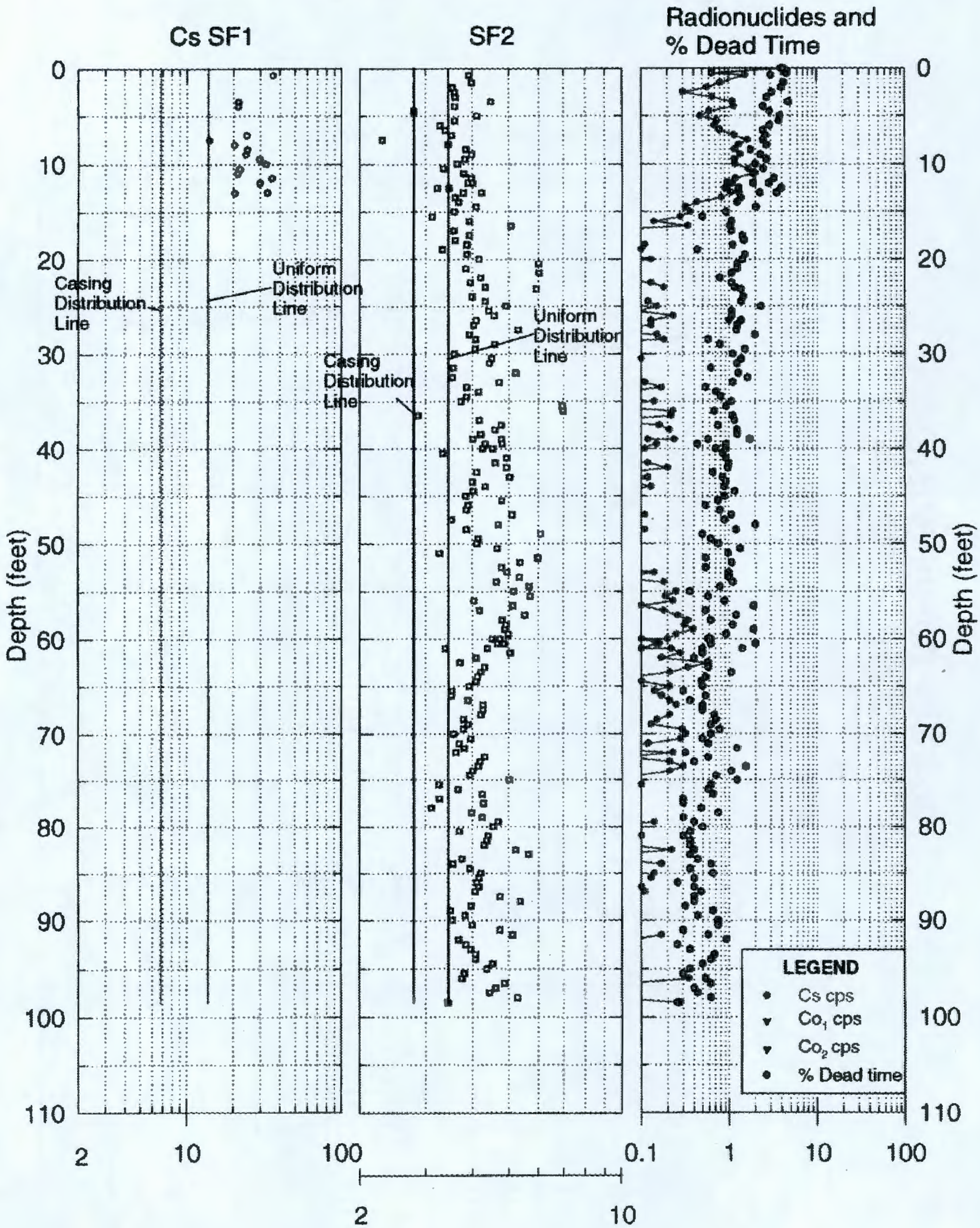
30-07-07
Natural Gamma Logs



30-07-07 Combination Plot



30-07-07
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-07-08

Borehole Information

Farm :	C	Tank :	C-107	Site Number :	299-E27-91
N-Coord :	42,842	W-Coord :	48,512	TOC Elevation :	646.00
Water Level, ft :	None	Date Drilled :	10/31/74		

Casing Record

Type :	Steel-welded	Thickness, in. :	0.280	ID, in. :	6
Top Depth, ft. :	0	Bottom Depth, ft. :	97		

Borehole Notes:

This borehole was drilled in October 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 :	3/13/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	26.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/14/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	99.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	60.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/14/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	61.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	41.5	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Event A

Borehole 30-07-08

Log Run Number :	4	**Log Run Date :**	3/17/97	**Logging Engineer:**	Bob Spatz		
Start Depth, ft.:	42.5	**Counting Time, sec.:**	100	**L/R :**	L	**Shield :**	N
Finish Depth, ft. :	25.0	**MSA Interval, ft. :**	0.5	**Log Speed, ft/min.:**	n/a		

Analysis Information

Analyst :	D.L. Parker		
Data Processing Reference :	MAC-VZCP 1.7.9, Rev. 1	Analysis Date :	8/20/97

Analysis Notes :

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

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

The only man-made radionuclide detected in this borehole was Cs-137. Cs-137 contamination was measured almost continuously from the ground surface to 28 ft and at depths of 37.5, 49, 52.5, and 53 ft.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole. The K-40 concentrations are slightly elevated from about 39 to 42 ft and decreased from about 42 to 45 ft. K-40 concentrations increase below 45 ft.

Shape factor data analysis was performed using the SGLS data from this borehole.

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

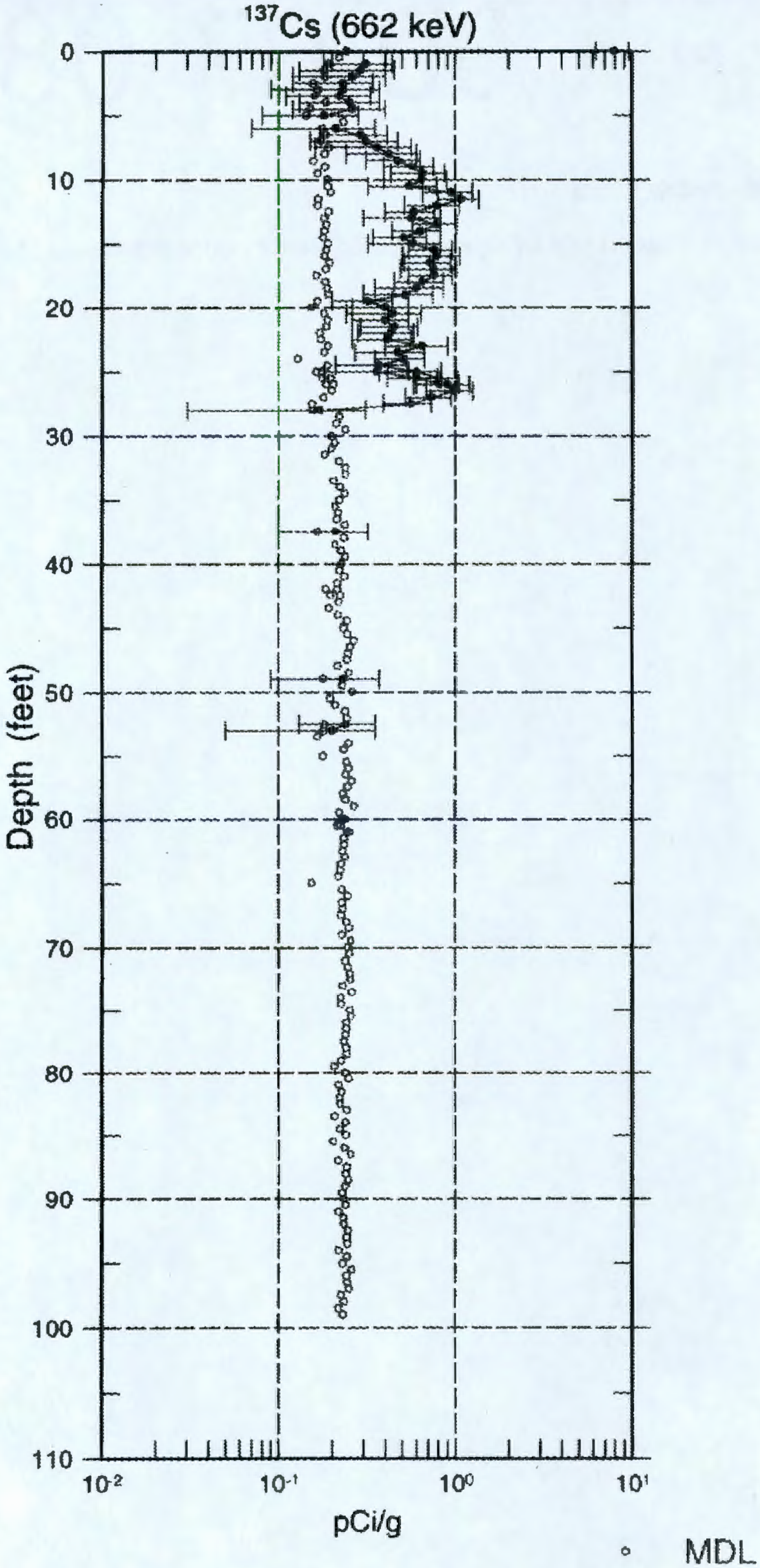
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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.

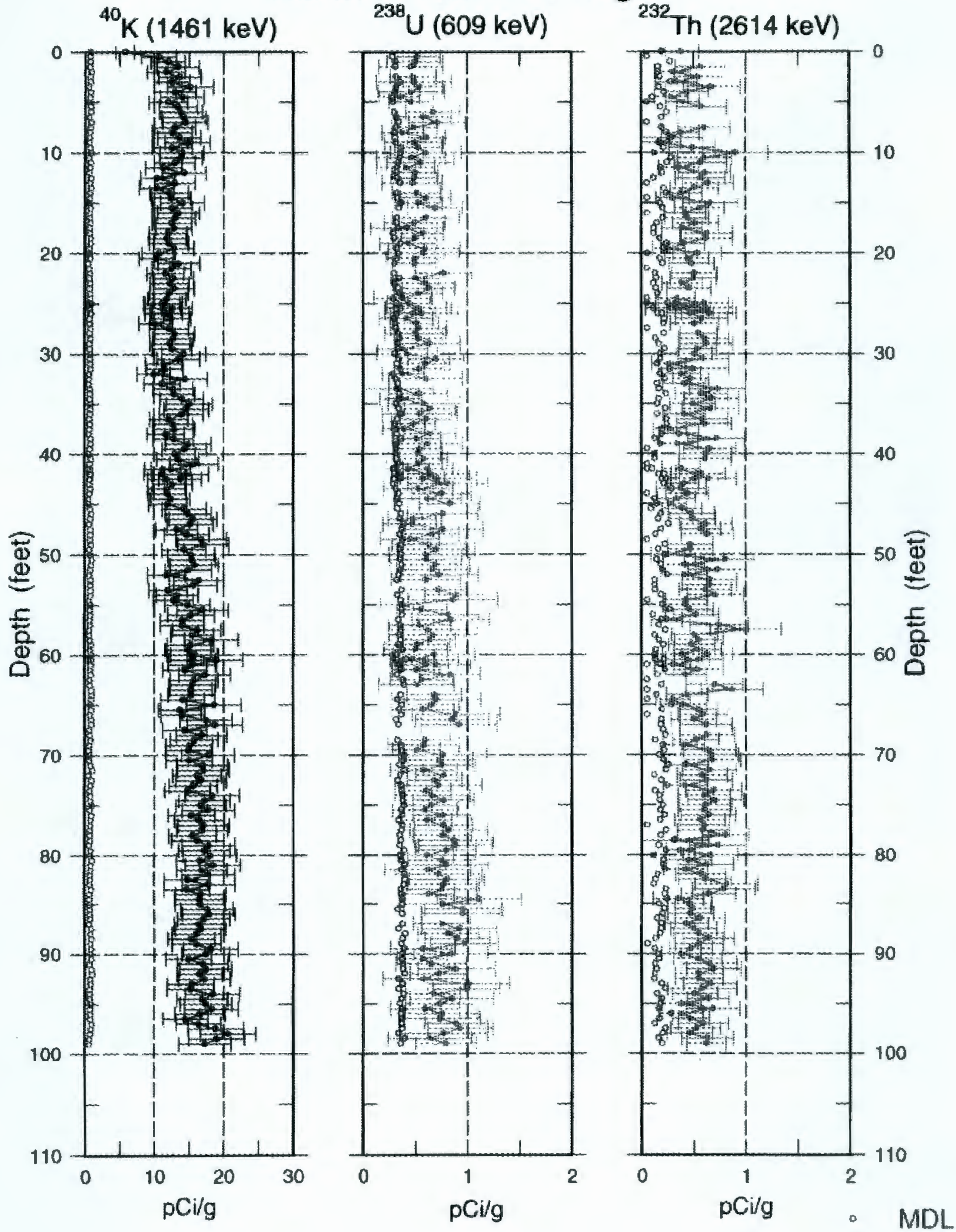
A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

30-07-08

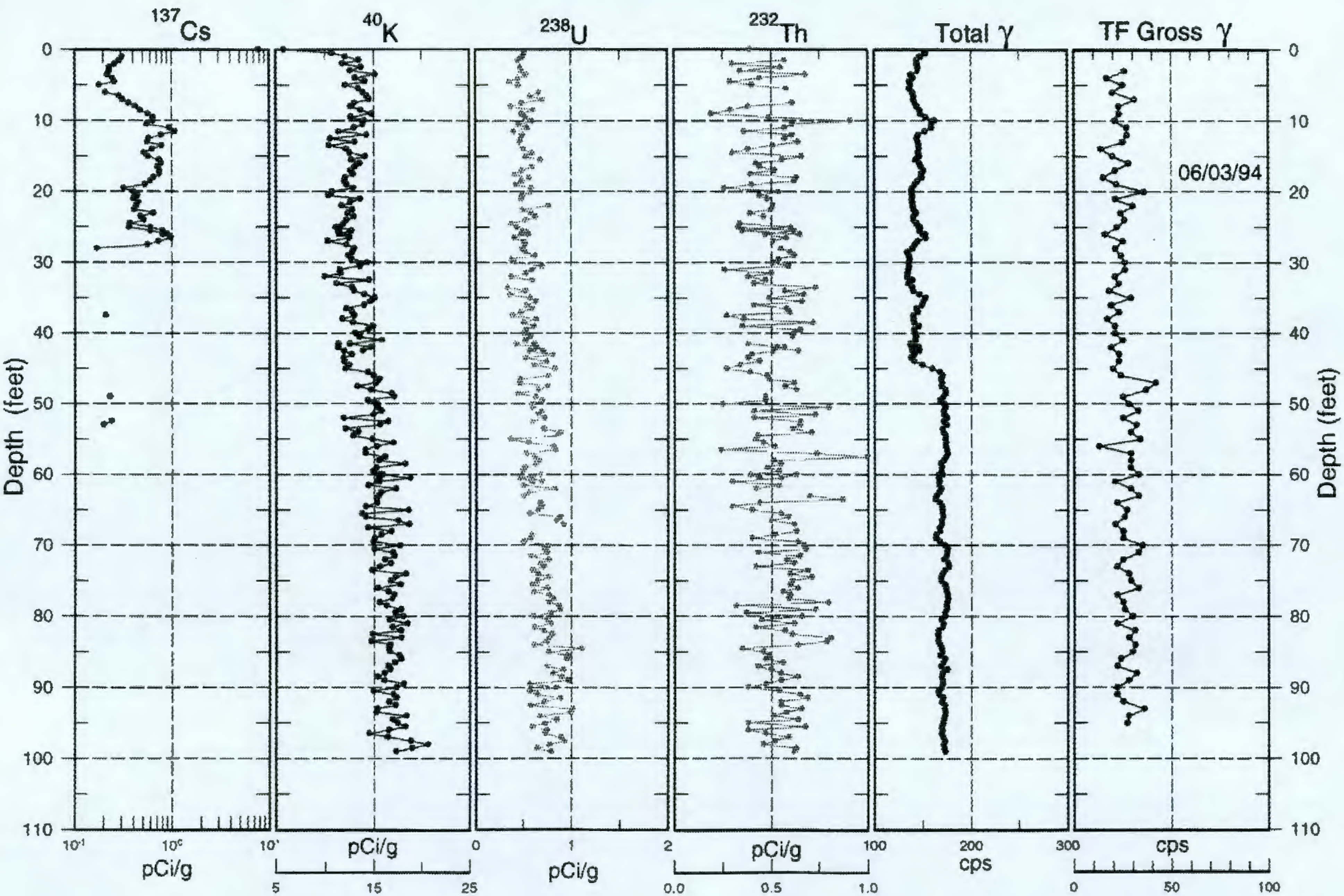
Man-Made Radionuclide Concentrations



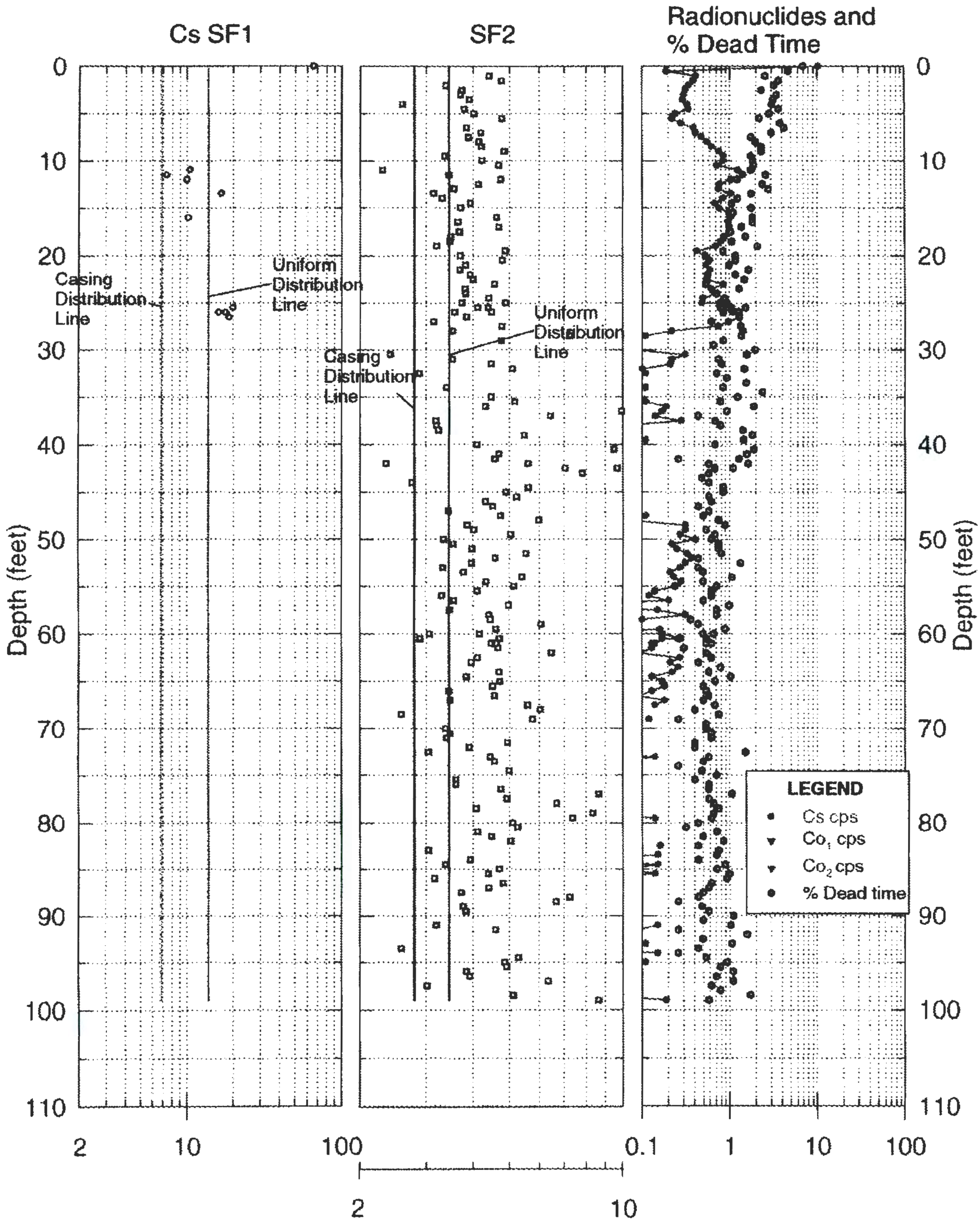
30-07-08
Natural Gamma Logs



30-07-08 Combination Plot



30-07-08
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole Log Data Report

Log Event A

Borehole 30-07-10

Borehole Information

Farm : C	**Tank :** C-107	**Site Number :** 299-E27-92
N-Coord : 42,879	**W-Coord :** 48,515	**TOC Elevation :** 646.00
Water Level, ft : None	**Date Drilled :** 9/30/74	

Casing Record

Type : Steel-welded	**Thickness :** 0.280	**ID, in. :** 6
Top Depth, ft. : 0	**Bottom Depth, ft. :** 97	

Borehole Notes:
Borehole 30-07-10 was drilled in September 1974 to a depth of 100 ft with 6-in. casing. The casing thickness is presumed to be 0.280 in., on the basis of the published thickness for schedule-40, 6-in. steel tubing. No information concerning grouting or perforations was available; therefore, it is assumed that the borehole was not grouted or perforated. The top of the casing, which is the zero reference for the SGLS, is even with the ground surface.

Equipment Information

Logging System : 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 :** 3/12/97	**Logging Engineer:** Bob Spatz
Start Depth, ft.: 98.5	**Counting Time, sec.:** 100	**L/R :** L **Shield :** N
Finish Depth, ft. : 31.5	**MSA Interval, ft. :** 0.5	**Log Speed, ft/min.:** n/a

Log Run Number : 2	**Log Run Date :** 3/13/97	**Logging Engineer:** Bob Spatz
Start Depth, ft.: 32.5	**Counting Time, sec.:** 100	**L/R :** L **Shield :** N
Finish Depth, ft. : 0.0	**MSA Interval, ft. :** 0.5	**Log Speed, ft/min.:** n/a

Log Run Number : 3	**Log Run Date :** 3/13/97	**Logging Engineer:** Bob Spatz
Start Depth, ft.: 40.0	**Counting Time, sec.:** 100	**L/R :** L **Shield :** N
Finish Depth, ft. : 20.0	**MSA Interval, ft. :** 0.5	**Log Speed, ft/min.:** n/a

Borehole 30-07-10

Log Event A

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1   Analysis Date : 8/20/97

Analysis Notes :

This borehole was logged by the SGLS in three log runs. One of the log runs was a relog of a previously logged section to provide an additional quality check. 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 only man-made radionuclide detected in this borehole was Cs-137. The presence of Cs-137 was measured continuously from the ground surface to 24 ft, 26 to 26.5 ft, 36 to 37 ft, and at 77.5 ft.

The U-238 concentration data are absent along several short intervals throughout the length of the borehole.

The K-40 and Th-232 concentrations increase at about 39.5 ft. K-40 concentrations are decreased from 42 to about 45 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Shape factor data analysis was performed using the SGLS data from this borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-110.

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.

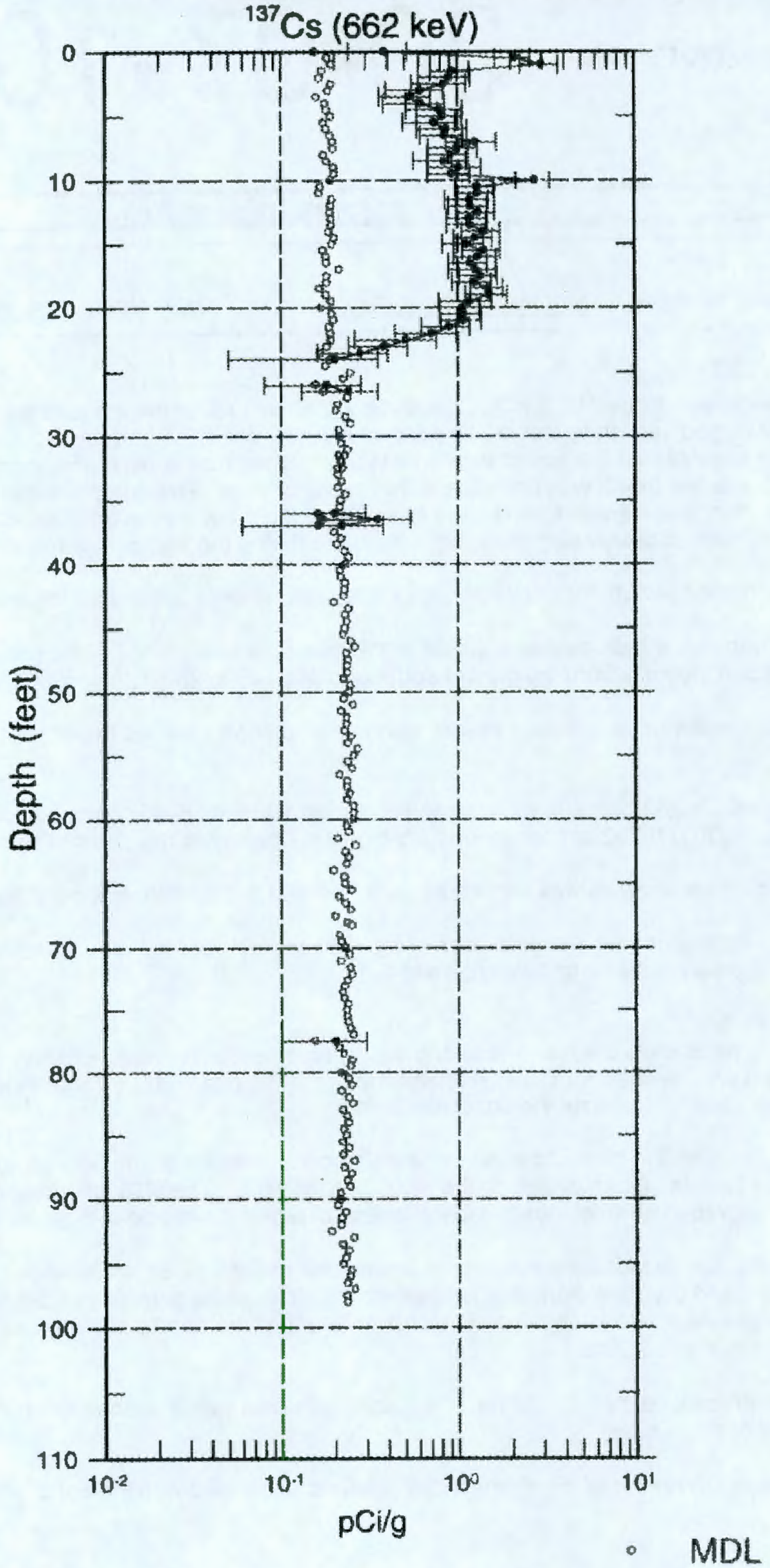
Uncertainty bars on the plots show the statistical uncertainties for the measurements as 95-percent confidence intervals. Open circles on the plots give the MDL. The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

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.

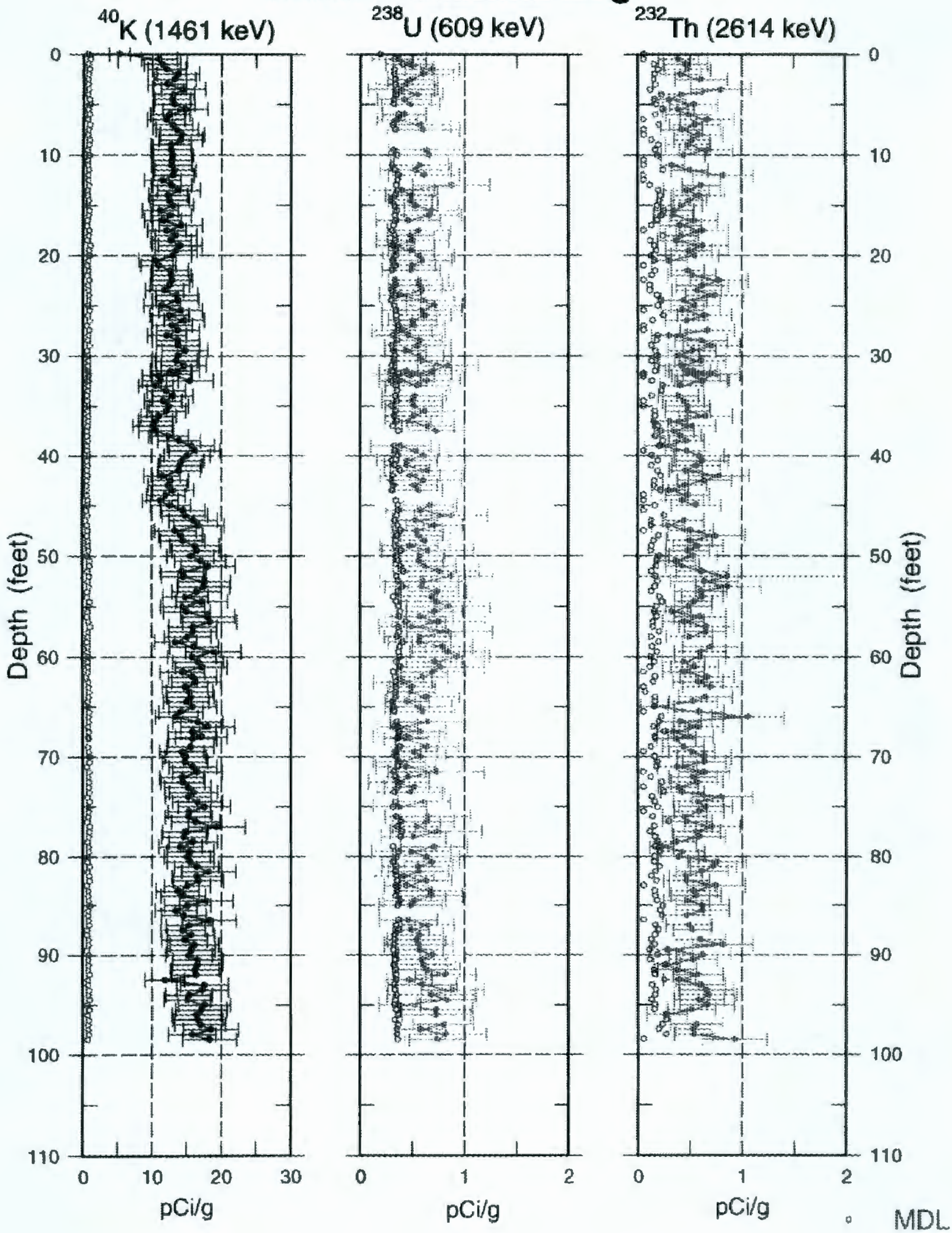
A rerun plot presents data from the rerun log along with data from the original run to show the repeatability of the results.

A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

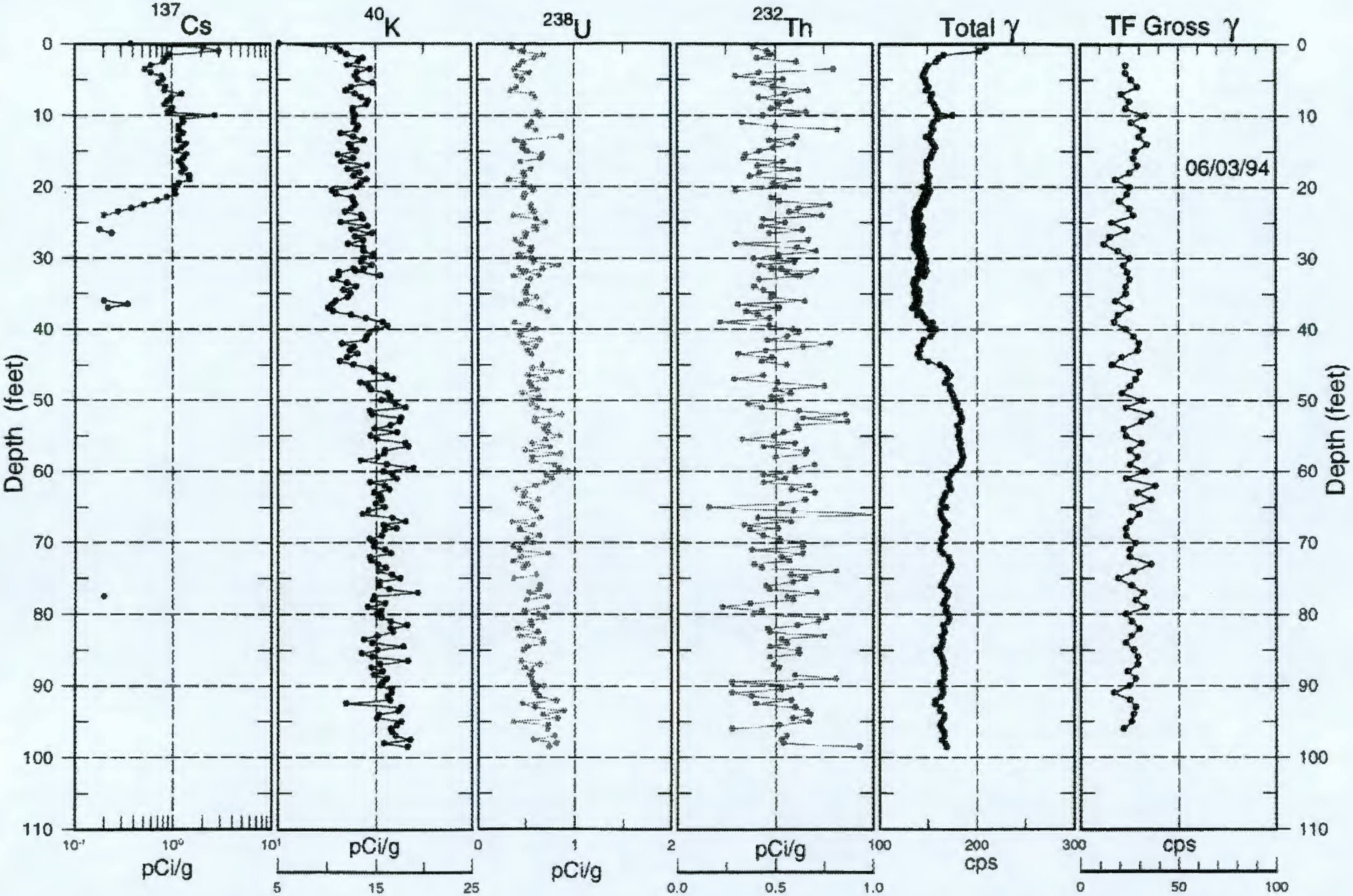
30-07-10
Man-Made Radionuclide Concentrations



30-07-10
Natural Gamma Logs

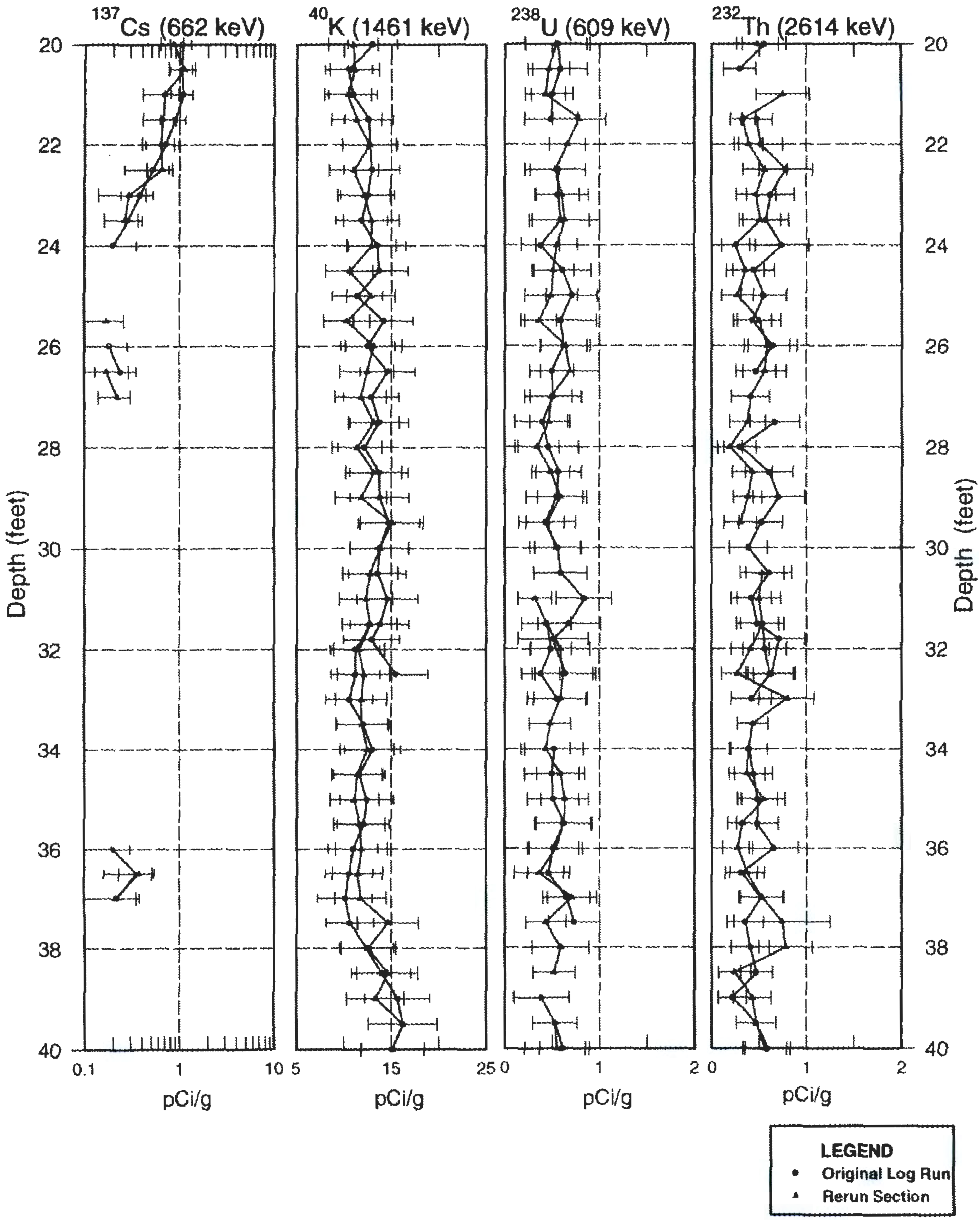


30-07-10 Combination Plot

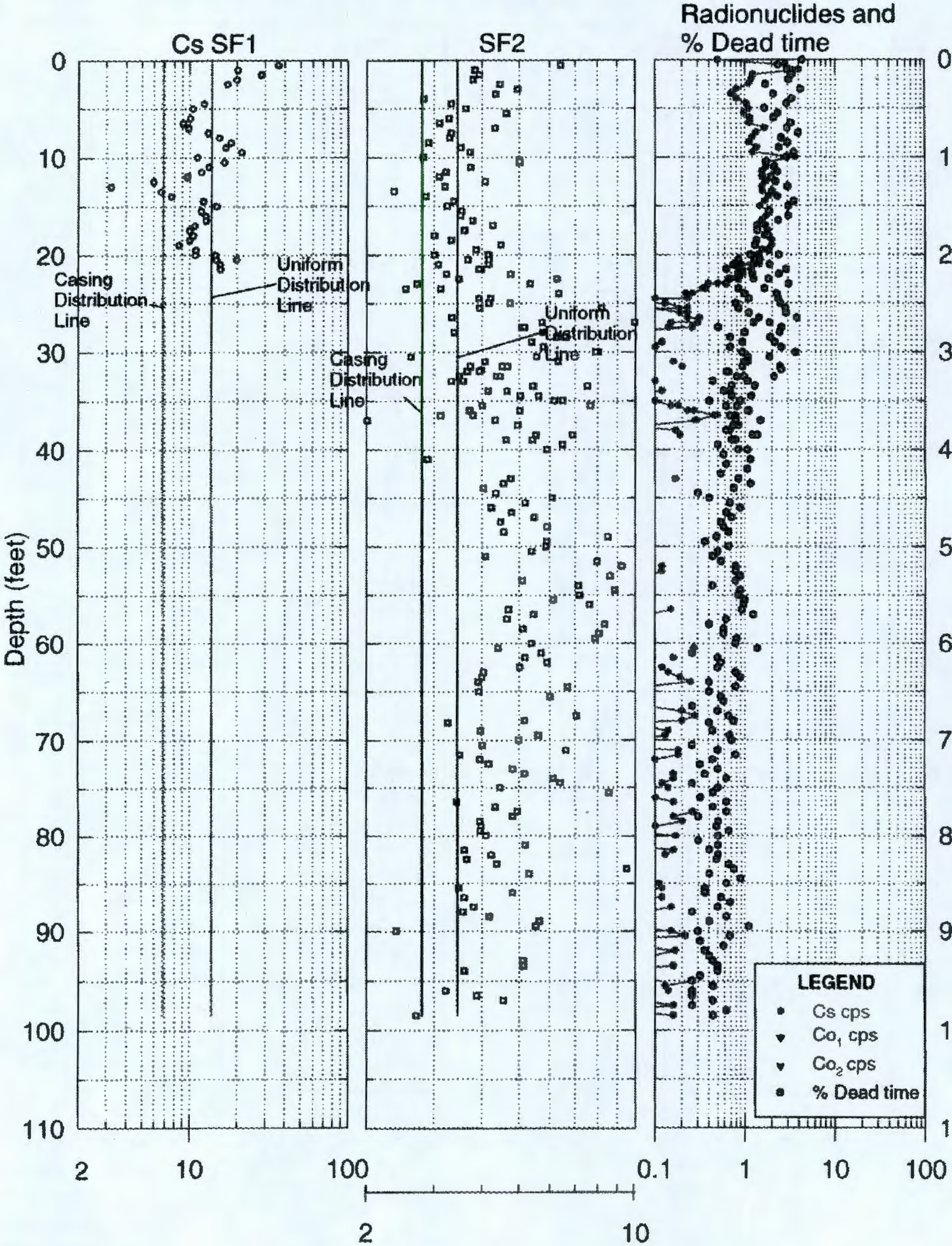


30-07-10

Rerun Section of the Man-Made and Natural Gamma Logs



30-07-10
Shape Factor Analysis Logs



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Spectral Gamma-Ray Borehole
Log Data Report

Log Event A

Borehole 30-07-11

Borehole Information

Farm :	C	Tank :	C-107	Site Number :	299-E27-93
N-Coord :	42,904	W-Coord :	48,489	TOC Elevation :	646.59
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. :	97		

Borehole Notes:
Borehole 30-07-11 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 approximately 6 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 :	3/10/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	0.0	Counting Time, sec.:	100	L/R :	R	Shield :	N
Finish Depth, ft. :	5.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	2	Log Run Date :	3/11/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	97.5	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	19.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Log Run Number :	3	Log Run Date :	3/12/97	Logging Engineer:	Bob Spatz		
Start Depth, ft.:	20.0	Counting Time, sec.:	100	L/R :	L	Shield :	N
Finish Depth, ft. :	4.0	MSA Interval, ft. :	0.5	Log Speed, ft/min.:	n/a		

Analysis Information

Analyst : D.L. Parker

Data Processing Reference : MAC-VZCP 1.7.9, Rev. 1 Analysis Date : 8/20/97

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.

The upper 5 ft of the borehole were logged in real time because of high dead time during the first log run. Accurate radionuclide concentrations could not be measured in the interval from 1.5 to 3.5 ft because the dead time exceeded 81 percent.

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

The man-made radionuclides detected in this borehole were Cs-137, Co-60, and Eu-154. The presence of Cs-137 was measured almost continuously from the ground surface to 19 ft, intermittently from 20.5 to 36 ft, intermittently from 49 to 74.5 ft, and near the bottom of the logged interval (97.5 ft). Co-60 contamination was detected at 4 ft. Eu-154 concentrations were detected at 0.5, 1, and 4 ft.

The U-238 and Th-232 concentration data are absent along several short intervals throughout the length of the borehole.

The K-40 concentrations are relatively elevated from 38 to 40 ft. KUT concentrations are elevated below about 49 ft. Th-232 concentrations are highly variable over the depth of the borehole.

Shape factor data analysis was performed using the SGLS data from this borehole.

Additional information and interpretations of log data are included in the main body of the Tank Summary Data Reports for tanks C-107 and C-110.

Log Plot Notes:

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

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

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

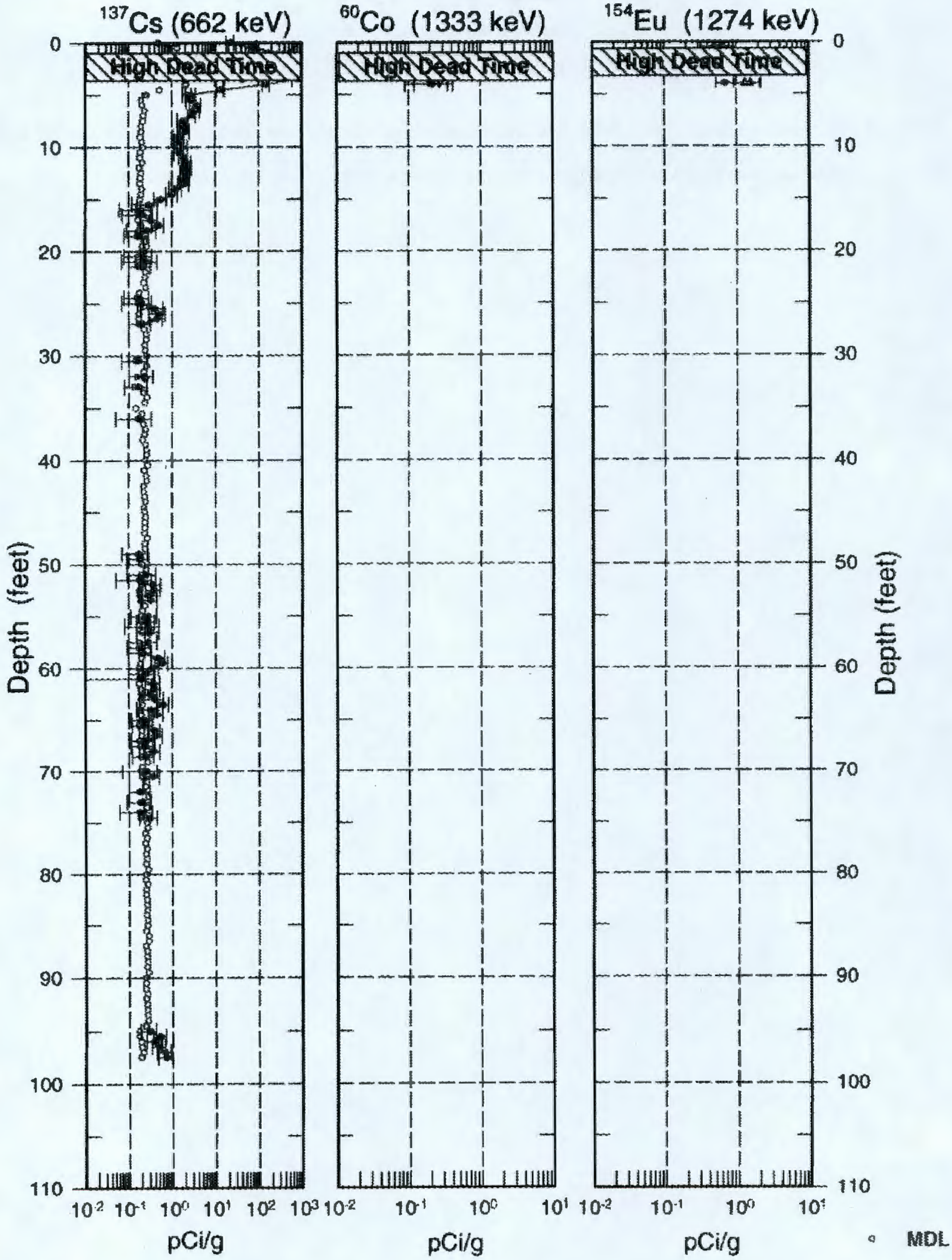
Borehole # 30-07-11

A plot showing the results of the shape factor analysis is included with the set of plots for this borehole.

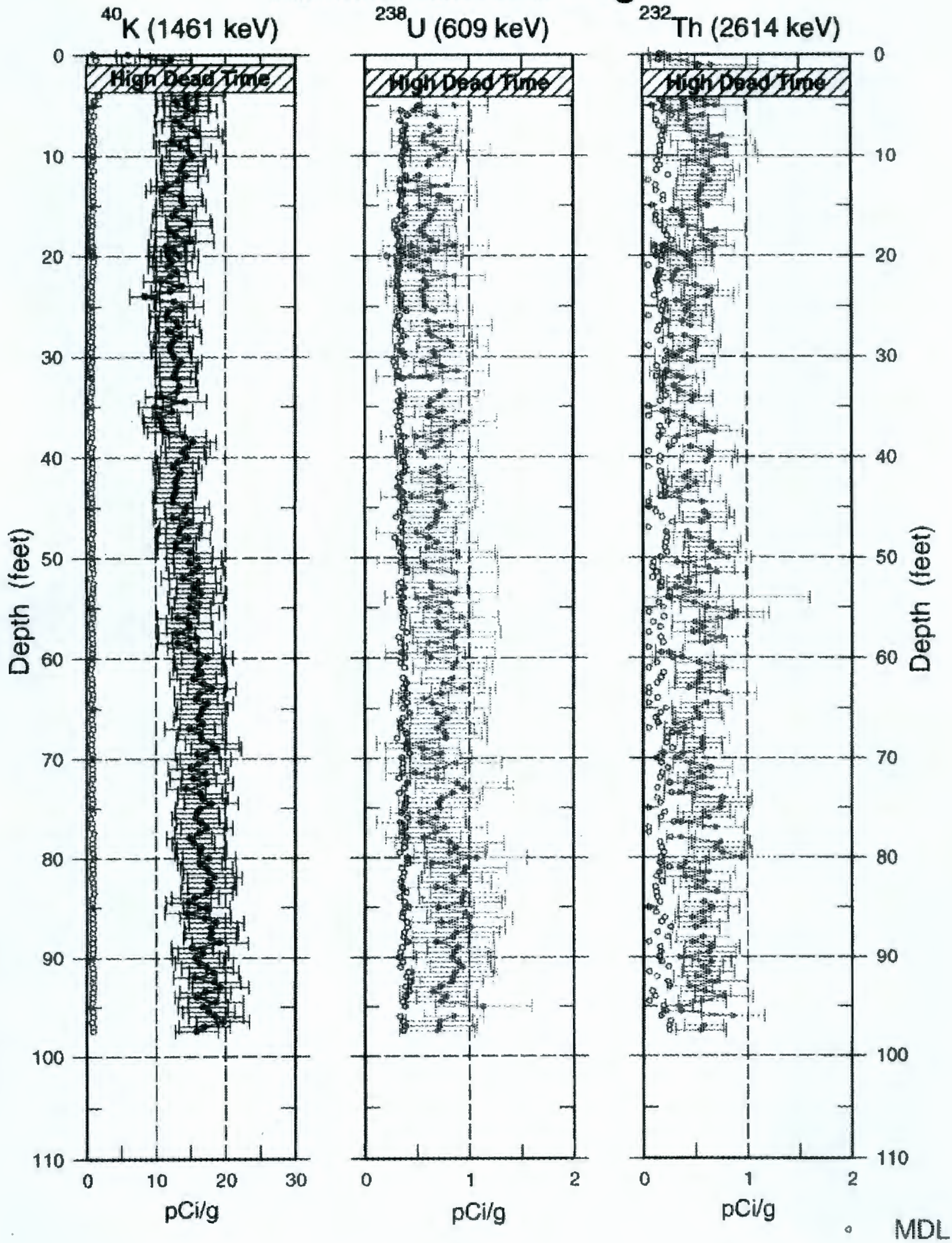
A plot of representative historical gross gamma-ray logs from 1979 to 1993 is included.

30-07-11

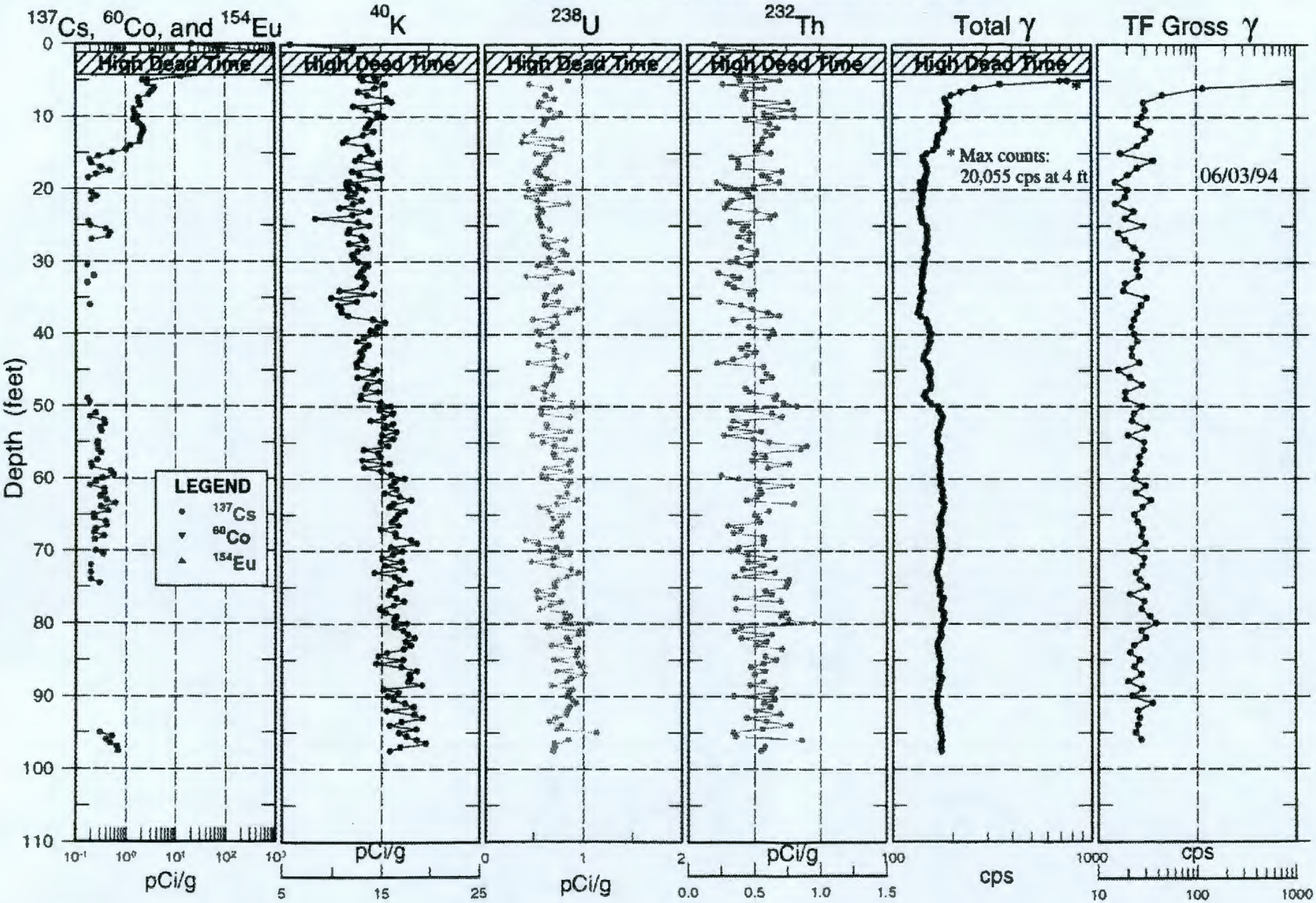
Man-Made Radionuclide Concentrations



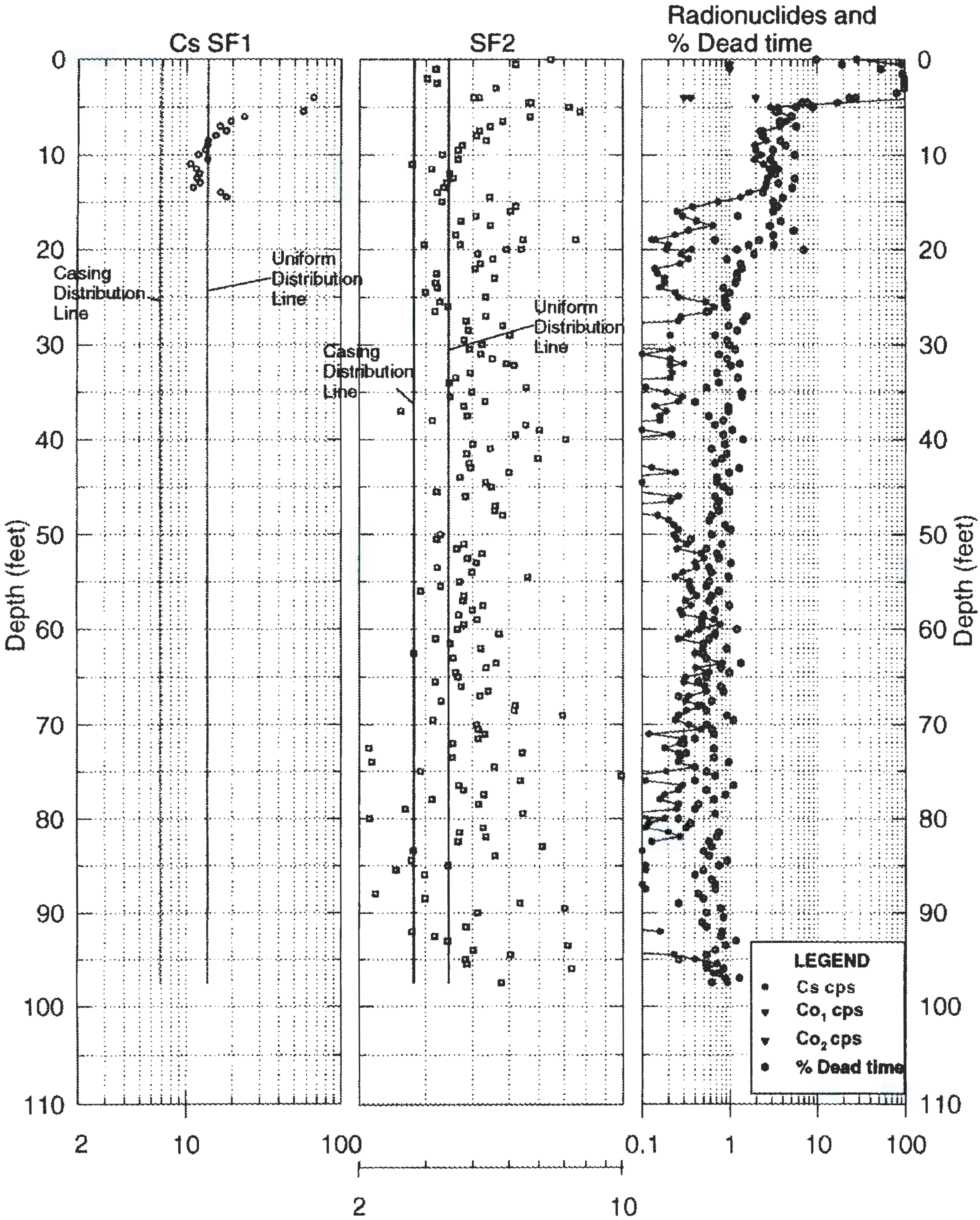
30-07-11
Natural Gamma Logs



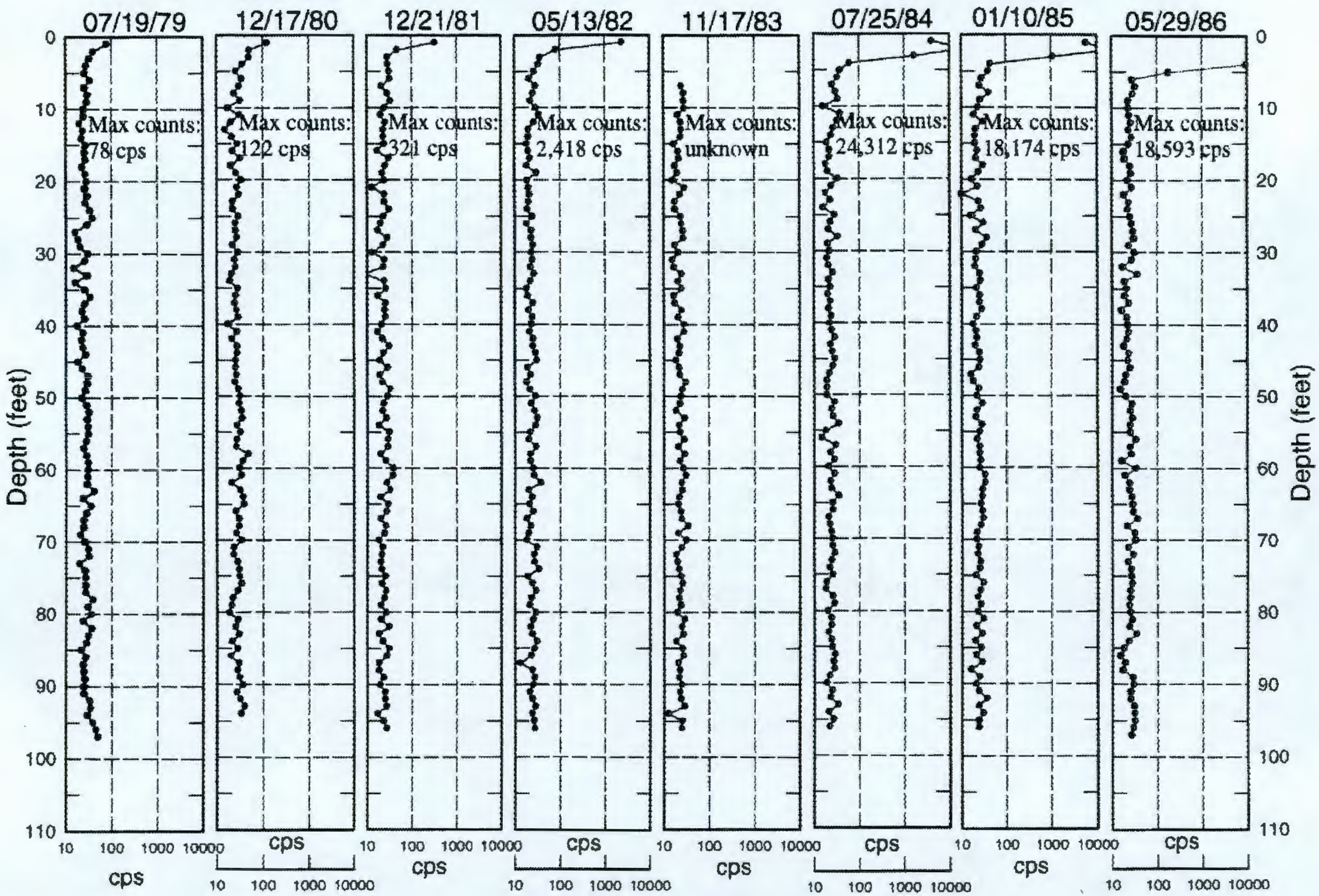
30-07-11 Combination Plot



30-07-11
Shape Factor Analysis Logs



Historical Gross Gamma Logs for Borehole 30-07-11



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GJ-HAN-90
Tank C-108

Vadose Zone Characterization Project at the Hanford Tank Farms

Tank Summary Data Report for Tank C-108

October 1997

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U.S. Department of Energy

GRAND JUNCTION OFFICE

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