SMALL DIAMETER GEOPHYSICAL LOGGING IN THE 241-B TANK FARM

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Abstract: The report gives the gamma logging results for 9 small diamater probe holes and neutron moisture results for probe hole in 241-B Tank Farm.

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Small Diameter Geophysical Logging In the 241-B Tank Farm

by

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April 2007

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1.0 INTRODUCTION

Pacific Northwest Geophysics (PNG) and Three Rivers Scientific provided small diameter (slim hole) logging in support of field activities at the 241-B Tank Farm to investigate the extent of subsurface contamination around Diversion boxes. Logging surveys were conducted with a neutron-neutron moisture probe and two gamma detectors (i.e. NaI [scintillation] gross gamma and a Geiger Mueller tube [GM]). The surveys assisted in identifying zones of interest for sample collection and laboratory analysis. Spectral gamma measurements were acquired in one probe hole to identify the dominant gamma emitting radionuclide. This report includes the survey results for 9 probe holes installed at the investigation site (see Appendix A).

The objective of the gamma survey logs was to identify depth interval(s) with elevated gamma activity (i.e. equivalent Cs-137 concentrations greater than 10 pCi/g). Rapid scan gamma surveys (4 ft/minute) satisfy the Cs-137 detection threshold and the results are reported as gross gamma logs in pCi/g of equivalent Cs-137.

The NaI gross gamma and GM gross gamma detectors were calibrated for the probe-hole conditions present at the investigation site. The calibration unit of equivalent Ra-226 (pCi/g) is used for background levels of the natural radionuclides. The calibration unit of equivalent Cs-137 (pCi/g) is used for elevated levels of gamma activity (see section 3.0).

The neutron moisture detector measures the distribution of hydrogen (moisture) in the subsurface soils. Detector calibration is discussed in section 0. Moisture surveys were acquired in four probe holes (C5163, C5165, C5177, and C5179). The moisture content ranged from 5 to over 20 percent volume fraction moisture (%vf).

The gamma activity exceeded 90 pCi/g of equivalent Cs-137 in three probe holes (C5163, C5167, and C5169). The maximum activity was 477,000 pCi/g of Eq.Cs-137 in probe hole C5163. Spectral measurements acquired in this probe hole (C5163) identified Eu-154 as the dominant gamma emitting radionuclide below 20-ft. Detector saturation (gamma-ray pile-up) prevented radionuclide identification in the high activity zone. A representative spectrum is plotted with the survey results in Appendix A. A brief discussion is included in the appendix that shows how to relate the concentration of Eu-154 to the calibration for equivalent Cs-137.

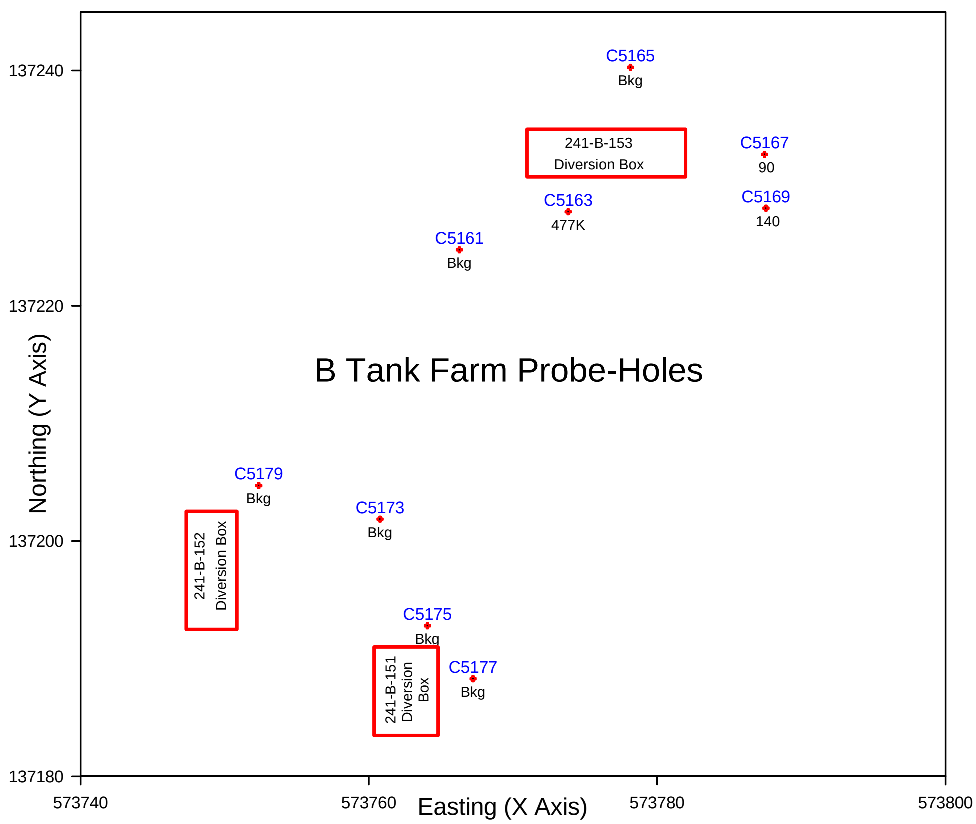
Low sensitivity gross gamma surveys, using a Green GM detector, were acquired in eight probe holes. The high gamma activity in probe hole C5163 saturated the high sensitivity scintillation (NaI) detector. The gamma activity of the other probe holes was below the minimum detection threshold of the Green GM detector.

2.0 SURVEY RESULTS

Log surveys were recorded from the bottom of the probe hole (maximum survey depth) to the ground surface. Zero depth reference is at ground surface. A repeat measurement was acquired daily in at least one probe hole to verify instrument repeatability. The main log and repeat intervals are presented on the same plot. The computed results of the main and repeat intervals were reviewed and the results agree within the uncertainty of the measurement counting statistics.

The survey results for each probe hole are presented as a depth versus concentration plot in Appendix A. The plots are in numeric order of the probe holes (C5161 – C5179). Appendix A also contains a summary table of each probe hole, detectors used, probe hole depth, depth of maximum gamma activity and maximum concentration (Eq Cs-137 in pCi/g). A graphic view of the probe-hole locations and maximum activity is shown in Figure 1.

Figure 1. Summary B Push Hole Locations and Maximum Activity



3.0 GEOPHYSICAL LOGGING SYSTEM

The small-diameter logging system deployed to the investigation site is portable (i.e. mounted on a wagon) and is powered by the on-site generator (120v AC). The logging system includes a laptop computer to monitor encoder depth positions (logging cable), control the winch motor, and record detector responses. The NaI and GM detectors contain their own signal processing/counting hardware and each respond directly to communication commands from the laptop computer. The down-hole digital-processing of detected signal pulses enhances stability, simplifies system setup, and improves calibration.

3.1 GROSS GAMMA CALIBRATION AND SURVEYS

The gross gamma scintillation detector is a sodium-iodide (NaI) crystal. The NaI crystal (1-in. long) is hydroscopic and is enclosed in a hermetically sealed can (1-in. diameter) to maintain its integrity. Other components of the gamma detector are the high-voltage supply, photo-multiplier tube, pre-amp, and multi-channel analyzer. The settings of the detector components are fixed (i.e. set up during assembly, prior to calibration) and are not adjustable by the field-logging engineer. The detector gain and lower threshold are set to record gamma ray activity with energies between 100 and 3000 keV. By comparison, the highest gamma ray from naturally occurring radionuclides is from thorium-232 and it occurs at 2614 keV. Coleman lantern mantles containing thorium-232 are used as a field verifier at the beginning and ending of each day's logging activities to check detector resolution (integrity) and energy calibration (amplifier gain).

The NaI detector is calibrated in Gross gamma borehole calibration models located at the U.S.-DOE Hanford site near Richland, Washington. Calibration was performed in the two most appropriate (lowest concentration) gross gamma calibration zones (SBA and SBU). The calibration method accounts for the attenuation effect of the steel casing in the probe-holes. Since the attenuation varies with gamma ray energy, a section of the steel drill tubing (4-ft long and 0.375-in. thick) was installed over the detector during calibration measurements to acquire spectra that properly represents logging conditions. The calibration data are summarized in Table 1. The calibration units are pCi/g of equivalent Radium-226 (eRa-226) (Steele & George, 1986). See Figure 2 for the calibration certificate.

Table 1. Gross Gamma Calibration Data

Calibration Model	Concentration eRa-226 (pCi/g)	Gross Gamma Response[1] (cps)	Dead-Time Corrected Gross Gamma Count-Rate[2] (cps)
SBA	61.2	459.1	460.8
SBU	185	1327.0	1341.5

1-Count rates are mean of 10 sample measurements at 100-sec each.

2-NaI Detector system dead time is 8.15 microsecond

The NaI gamma surveys were logged at 4 ft/minute. A spectrum of 256 channels was collected each 0.5 feet from the bottom of the probe-hole to the surface. The spectra were recorded in Ortec PHA “-.chn” format with one spectra per file. Detector count rates were dead-time corrected and the gamma survey data was processed as gross gamma response to determine the concentration of equivalent Radium-226 (eRa-226) in pCi/g.

The dead time correction is a nonparalysable relationship (Knoll, 1979) and described by the following equation:

$$C_t = \frac{C_{obs}}{1 - \varepsilon \cdot C_{obs}}$$

where C_t is the true or dead time corrected count rate in c/s, C_{obs} is the observed count rate in c/s, and ε is the dead time factor of 8.25μs (Randall & Price, 2006).

The NaI gross gamma detector was also calibrated for eCs-137 (pCi/g). The calibration for eCs-137 was to identify high concentration zones that must be avoided for sample collection (i.e. RWP limiting condition of 100,000 DPM). Calibration for eCs-137 was performed in Hanford vadose well 299-W10-72 (a standard identified by Stoller Corporations’ logging group). The Cs-137 in the well is stable, except for the 30 year half life decay of the radio-isotope. Also, distribution of Cs-137 ranges from less than 1 pCi/g to 40,000 pCi/g along the depth of the well. The concentrations of Cs-137were established by two HPGe detectors (70% and High Rate tools). Casing in the well is 0.288-in thick. A section of steel tubing 0.115-in thick was installed over the detector for calibration (total thickness 0.403-in. The conversion factor from detector count rate (cps) to eCs-137 is 0.373 (pCi/g per cps) for casing thickness of 0.40-in. See Figure 3 for the calibration certificate.

The NaI gamma detector upper limit for identifying samples that will not exceed the RWP with the HPT survey instruments is estimated as follows:

Given:

a. The background activity 50 CPM = 500 DPM with the HPT survey meter (in a zone with no contamination at the surface).

b. The RWP limit is 100,000 DPM = 10,000 CPM with the HPT survey meter (200 times above background of 50 CPM).

c. The background activity is 25 cps with the 1x1-inch NaI Gamma detector in the 0.37-inch thick steel probe-hole casing.

Therefore: The suggested limit on the NaI gamma detector for avoiding samples that exceed 100,000 DPM is 25 * 200 = 5000 cps (dead time corrected) or 4800 cps (observed) count rate (conservative upper limit). Using the eCs-137 conversion factor (0.373 pCi/g per cps) this translates to about 1900 pCi/g of Cs-137.

Figure 2. Gross Gamma Calibration Certificate (Equivalent Radium-226)

Certificate of Calibration
SD-GR.NaI.1
October 6, 2006

Data were taken at the Hanford KUT models on October 6, 2006. SD-GR.NaI.1 is the designated Scintillator tool. Two models were used for the gross gamma calibration (SBU and SBA). Ten spectra were recorded for each model in order to perform statistical analysis. The observed deviations were seen to be near the theoretically predicted variation, refer to the file CalEqRa.xls.

This calibration is required for the Direct Push logging, and funded by subcontract 013661.

The instrument was covered with 0.37 inch wall-thickness probe-tubing.

The coefficient analysis is determined by the algorithm described in the document WHC-SD-EN-TI-293, Rev. 0. The gross gamma calibration for equivalent ^{226}Ra in pCi/g is a regression function and is generally defined by:

$$\mathbf{Ra = a*GR + b}$$

Where Ra is the Eq. ^{226}Ra in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficients of a & b are the fit coefficients. A more physical relationship constrains the intercept (b) to a zero value. This computation yields improved response extrapolated to low concentrations of K, U, and Th (clean zones). The coefficients were determined to be:

$$\mathbf{a = .139\ Eq.^{226}Ra\ pCi/g\ /\ (c/s)}$$
$$\mathbf{b \equiv 0}$$

Digital files condensed as Cal_SD-GR-02_2006-v0.zip. This compressed file contains:

- Calibration raw data
- MathCad data analysis files
- Spreadsheet data formatting

The undersigned certifies that the data archived in the file "Cal_SD-GR-02_2006-v0.zip" were collected and evaluated in accordance with procedures WHC-SD-EN-TI-293, "Procedures for Calibrating Scintillation Gamma-Ray Well Logging Tools Using Hanford Formation Models" and that the above stated calibration coefficients are correct and applicable for the tool SD-GR.NaI.1 effective October 6, 2006.

Signature: Date: October 10, 2006
Russel Randall PhD

Company: Three Rivers Scientific

Figure 3. Gross Gamma Calibration Certificate (Equivalent Cesium-137)

Certificate of Calibration
SDGR-4N4-NaI1
July 7, 2005

Data were taken at the Hanford well 299-W10-72 located in the 216-T-7 Crib. SDGR-4N4-NaI1 is the designated scintillator tool. A repeat interval from 40 to 124 feet were recorded in order to perform statistical analysis. The observed deviations were seen to be reasonable for the instrument response.

The instrument was covered with 0.115 inch wall-thickness probe-tubing and the casing thickness in the well is 0.288 inches, for a total wall thickness of 0.40 inch.

The calibration for EqCs-137 for the instrument SDGR-4N4-Nai1 is described in "Gamma Surveys of Single Shell Tank Laterals for A and SX Tank Farm", CH2M Hill Hanford Group, RPP-RPT-27605 Rev.0. The gross gamma calibration for equivalent ^{137}Cs in pCi/g is a regression function and is generally defined by:

$$\mathbf{Cs = \alpha * GR}$$

Where Cs is the Eq. ^{137}Cs in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficient α is the fit coefficient. The deadtime correction is a non-paralyzable relationship, thus the following full relationship

$$Cs = \frac{\alpha \cdot GR}{1 - \varepsilon \cdot GR}$$

where ε is the system deadtime. The least square fit results in the following values for α and ε:

α=0.373 Eq ^{137}Cs pCi/g/(c/s)
ε=8.25 μs

The analysis was performed by the undersigned in accordance with DTS procedures and certifies that the above stated calibration coefficients are correct and applicable for tool SDGR-4N4-NaI1, effective July 7, 2005.

Signature: Russel Randall PhD | Date: July 2005

Company: Three Rivers Scientific

Figure 4. Green GM Calibration Certificate (Equivalent Cesium-137)

Certificate of Calibration
SDGR-GrGM
June 28, 2005

Data were taken at the Hanford well 299-W10-72 located in the 216-T-7 Crib. SDGR-GrGM is the designated Green GM tool. A repeat interval from 40 to 126 feet were recorded in order to perform statistical analysis. The observed deviations were seen to be reasonable for the instrument response.

The instrument was covered with 0.115 inch wall-thickness probe-tubing and the casing thickness in the well is 0.288 inches, for a total wall thickness of 0.40 inch.

The calibration for EqCs-137 for the instrument SDGR-GrGM is described in "Gamma Surveys of Single Shell Tank Laterals for A and SX Tank Farm", CH2M Hill Hanford Group, RPP-RPT-27605 Rev.0, The gross gamma calibration for equivalent ^{137}Cs in pCi/g is a regression function and is generally defined by:

Cs = α*GR

Where Cs is the Eq. ^{137}Cs in pCi/g, and GR is the observed gross gamma count rate (c/s), dead time corrected. The coefficient α is the fit coefficient. The deadtime correction is a non-paralyzable relationship, thus the following full relationship

$$Cs = \frac{\alpha \cdot GR}{1 - \varepsilon \cdot GR}$$

where ε is the system deadtime. The least square fit results in the following values for α and ε:

α=1324 Eq ^{137}Cs pCi/g/(c/s)
ε=160 μs

The analysis was performed by the undersigned in accordance with DTS procedures and certifies that the above stated calibration coefficients are correct and applicable for tool SDGR-GrGM, effective June 28, 2005.

Signature: Russel Randall PhD Date: July 2005

Company: Three Rivers Scientific

3.2 GEIGER MUELLER (GM) CALIBRATION AND SURVEYS

The Green GM detector has substantially lower sensitivity than the NaI detector and is designed to measure high gamma ray flux. The GM detector was calibrated for Cesium-137 in the Cesium Calibration Well (299-W10-72 located in the 216-T-7 Crib). The concentration of ^{137}Cs was assigned from high-resolution gamma measurements collected by Stoller at 1-foot increments along the well depth. The Stoller instruments were calibrated at the Hanford borehole calibration facility, which is traceable to NIST standards.

The calibration for Eq ^{137}Cs assumes that all of the gammas are due to the presence of ^{137}Cs. The GM detector data were depth shifted to match the HPGe log data. Very good agreement between the raw count rate and Cs-137 activity indicated a low dead time correction, of approximately 0.5%. The calibration coefficient of the Green GM for Eq ^{137}Cs is 1324 (pCi/g) per (c/s). The dead-time of the GM detectors (160 uSec) was computed from calibration measurements. (Randall & Price, 2006). See Figure 4 for the calibration certificate.

3.3 NEUTRON-MOISTURE CALIBRATION AND SURVEYS

The neutron-moisture sonde combines the PNG-owned thermal-neutron detector and a DOE-owned sealed neutron source (50 mCi AmBe). The DOE-owned neutron source was used because it was already on the Hanford site and was managed by the DOE radiation management program. The neutron source is an integral component of a neutron-moisture detector, manufactured by Campbell Pacific Nuclear. The neutron source is identified by the tool serial number (H38092506).

The integrity of the sealed neutron source was always maintained when it was used in calibration activities and in probe hole logging activities. Source integrity was achieved by inserting the PNG owned neutron detector module into the housing containing the sealed neutron source.

Calibration was performed in six borehole calibration models (Meisner & Randall, 1995). Three models have 6-in. hole-size and three models have 8-in hole-size. The moisture content of each model in a set of three borehole models is different (5, 12, or 20 percent by volume). The detector count rate in each of the six borehole calibration models is summarized in Table 2. The calibration certificate is shown in Figure 5.

Table 2. Moisture Calibration Data

Moisture Content Percent – volume fraction	6-inch Models* (cps)	8-inch Models* (cps)
5% vf	209.62	165.97
12% vf	310.18	234.20
20% vf	391.93	285.25

*Count rates are mean of 10 sample measurements at 60-sec each.

The probe-hole size for this project was 2.5-inch. Therefore, the moisture calibration was extrapolated to the correct hole-size. The moisture calibration certificate for 2.5-in hole-size is shown in Figure 6.

The probe hole survey was collected at 2 ft/minute or slower. Processing of the moisture survey data requires that the borehole survey data be normalized to the thickness of the steel casing present in the calibration models (0.325-in). Given that the probe hole casing thickness is 0.38-in, a correction factor of 1.055 is required to increase (normalize) the observed detector count rate to the conditions of the calibration model (Meisner, et al. 1996).

Figure 5. Moisture Calibration Certificate, Hole Size: 6-in. and 8-in.

Certificate of Calibration for
Instrument SD-Moist 506-1 on
January 8, 2007

Data were taken in the Moisture models on January 8, 2007 for SD-Moist506-1 neutron-neutron moisture tool. The neutron source from DOE moisture tool # H38092506 was used with the passive neutron detector probe from PNG.

Six models were used for moisture calibration, 3 for 6”casing and 3 for 8” casing. Repeated spectra were recorded for each model in order to perform statistical analysis. The observed statistical variation agreed with the theoretically predicted variation, refer to the file “Source Calibration.xls” for this analysis.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

$$V = a \cdot CR^{a}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s).

6” casing	8” casing
a = .00003941	a = .00001195
α = 2.198	α = 2.532

The undersigned certifies that the data archived in data file “SD-Moist506_2007.zip” were collected and evaluated in accordance with procedures WHC-SD-EN-TI-306, “Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration” and that the above stated calibration coefficients are correct and applicable for tool SD-Moist506-1, effective Jan 8, 2007.

Signature: Date:

Russel Randall, PhD February 22, 2007
Three Rivers Scientific

Figure 6. Moisture Calibration Certificate, Hole Size 2.5-in.

Moisture Calibration Extrapolation to 2.5 Inch Borehole
Instrument SD-Moist506-1
Jan 8, 2007

Moisture calibration was performed in the Hanford physical models. These standards have 6 and 8 inch ID casings. The Tank Farm Direct Push borehole is cased with a 2.5 inch OD iron casing. The calibration for the moisture response is a function of borehole diameter.

The coefficient generation is determined by the algorithm described in the document WHC-SD-EN-TI-306, Rev. 0. The regression function used is a power law form and defined by:

$$V = a \cdot CR^{a}$$

Where V is the formation moisture content in volume fraction water in vf units. One vf unit is 1% by volume water. The coefficients a and α are fit coefficients, and CR is the deadtime corrected observed total count rate, (c/s). A linear extrapolation was applied to determine the 2.5 inch borehole diameter.

2.5" borehole
a = .00008086
α = 1.94

The undersigned certifies that the analysis files are archived in the file "SD-Moist506_2007.zip" was evaluated in accordance with DFS procedures and that the above stated calibration coefficients are correct and applicable for tool SD-Moist506-1, effective Jan 8, 2007.

Signature: Date:

Russel Randall, PhD February 22, 2007
Three Rivers Scientific

4.0 CONCLUSION

Scintillation Gross Gamma, Spectral Gamma, Geiger-Mueller, and Neutron-Moisture survey logs were collected in 9 probe holes installed around diversion boxes in the 241-B Tank Farm. All probe holes were pushed to their target depth between 35 or 65 feet.

The rapid-scan gamma surveys of the probe holes can be summarized as follows:

- The highest detected gamma activity was in borehole C5163, (greater than 470,000 pCi/g of eCs-137).
- Spectral measurements taken in probe-hole C5163 identified Eu-154 as the dominant gamma emitting radionuclide, below the high activity zones. (Eu-154 is recognized by presence of several photo peaks: 1275, 873, 723, and two close peaks at 996 & 1005 keV).
- Two probe holes (C5167, C5169) contain elevated gamma activity near 20-ft depth. The concentrations are less than 200 pCi/g eCs-137.
- Six probe holes (C5161, C5165, C5173, C5175, C5177, and C5179) showed only background activity from the natural radionuclides.

5.0 REFERENCES

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APPENDIX A: GAMMA AND MOISTURE SURVEY RESULTS

Gross Gamma and Moisture Survey Plots follow for the 9 probe holes installed in the 241-B Tank Farm. The gross gamma survey data were dead-time corrected and the results are converted to two calibration units

(1) Eq Ra-226 for natural radionuclides (**black line**). Hanford sediments have concentrations less than 5 pCi/g eRa-226. The plot scale for eRa-226 is 0-25 pCi/g (black scale)

(2) Eq Cs-137 for contamination zones (**red line**) is shown for concentrations greater than 4 pCi/g of eq. Cs-137. The plot scale for eCs-137 (red line) is displayed as linear (0 to 250 pCi/g) or logarithmic scale (10^0 to 10^8, i.e., eight orders of magnitude)

The **Green GM** is displayed as a **green dotted line** with the logarithmic eCs-137 (pCi/g) scale (see Probe Hole C5163).

NaI spectra measurements were taken below the highest gamma activity in probe-hole C5163. Eu-154 was identified as the dominant gamma emitting radionuclide. The five highest intensity gamma rays of Eu-154 (723, 873, 995, 1005 and, 1275 keV) are generally seen in the spectra plots.

The gross gamma measurements are processed and reported as though the radionuclide were Cs-137, even though spectra measurements have identified that Eu-154 is dominant radionuclide in portions of the probe hole. No calibration factor is available for equivalent Eu-154.

The concentration of Eu-154 will be less than the computed concentration for Eq Cs-137. A simple explanation follows to help clarify this statement.

- First, the decay activity of the two radionuclides is different [i.e. energy of gamma ray(s), number of gamma rays during decay, and intensity of gamma rays (number of gamma ray photons per 100 decays)].
- The Gamma activity for Cs-137 is simple [i.e. one gamma ray (662 keV) with intensity of 84% (number of 662 keV gamma ray photons per 100 decays)].
- Eu-154 has over 50 gamma rays. Twelve gamma rays are emitted with intensities greater than 1% and energies greater than 100 keV. The sum of the intensities is 155% for these twelve gamma rays.
- Thus the gamma activity for Eu-154 is higher than the gamma activity for Cs-137, which means that the concentration and detection threshold for Eu-154 is lower than Cs-137.

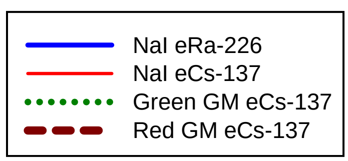
The neutron-neutron moisture survey data are shown as **Blue dashed line**. The moisture plot scale is 0-25 (%vf).

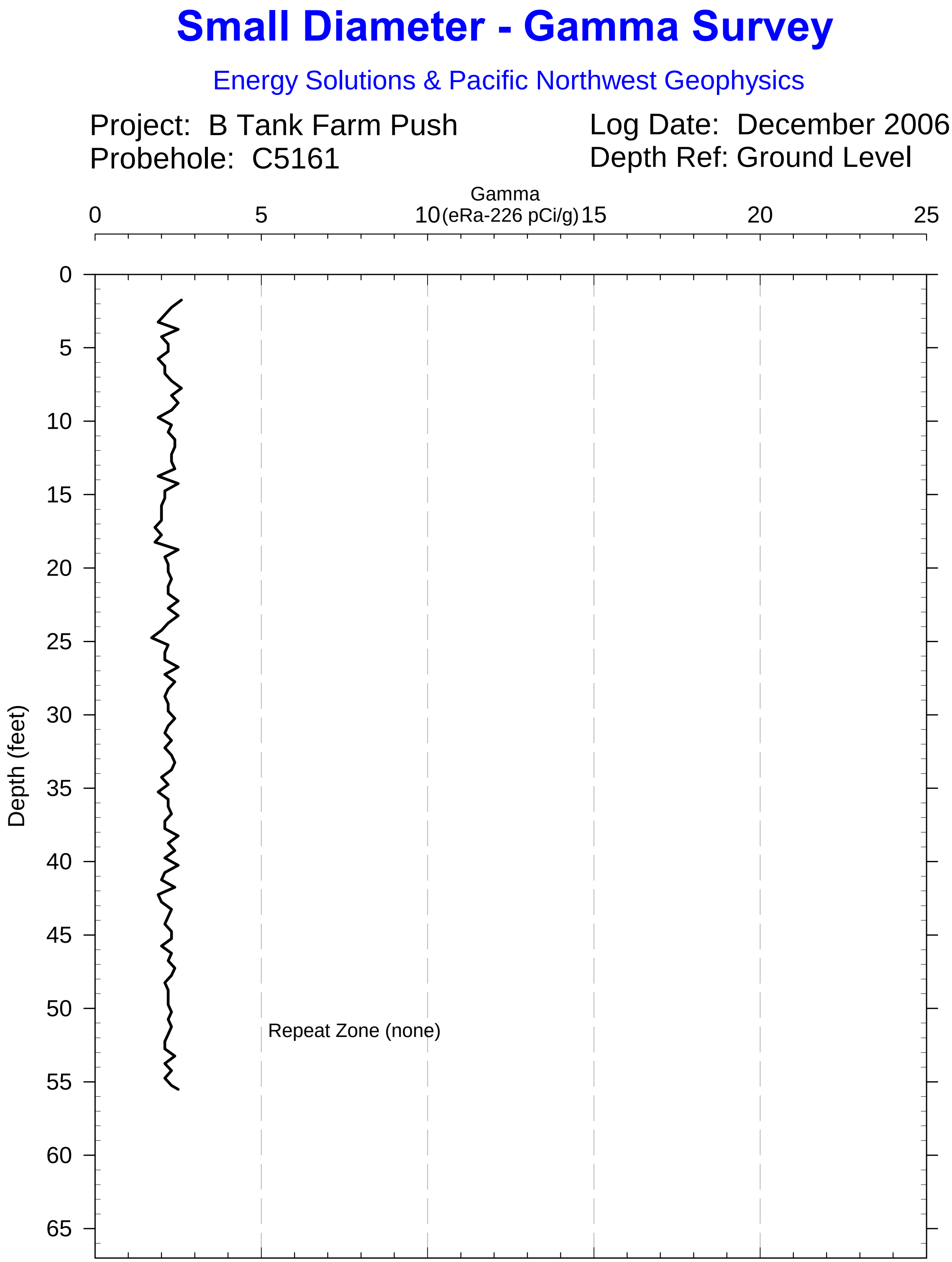
The plot legend is shown in Figure 7.

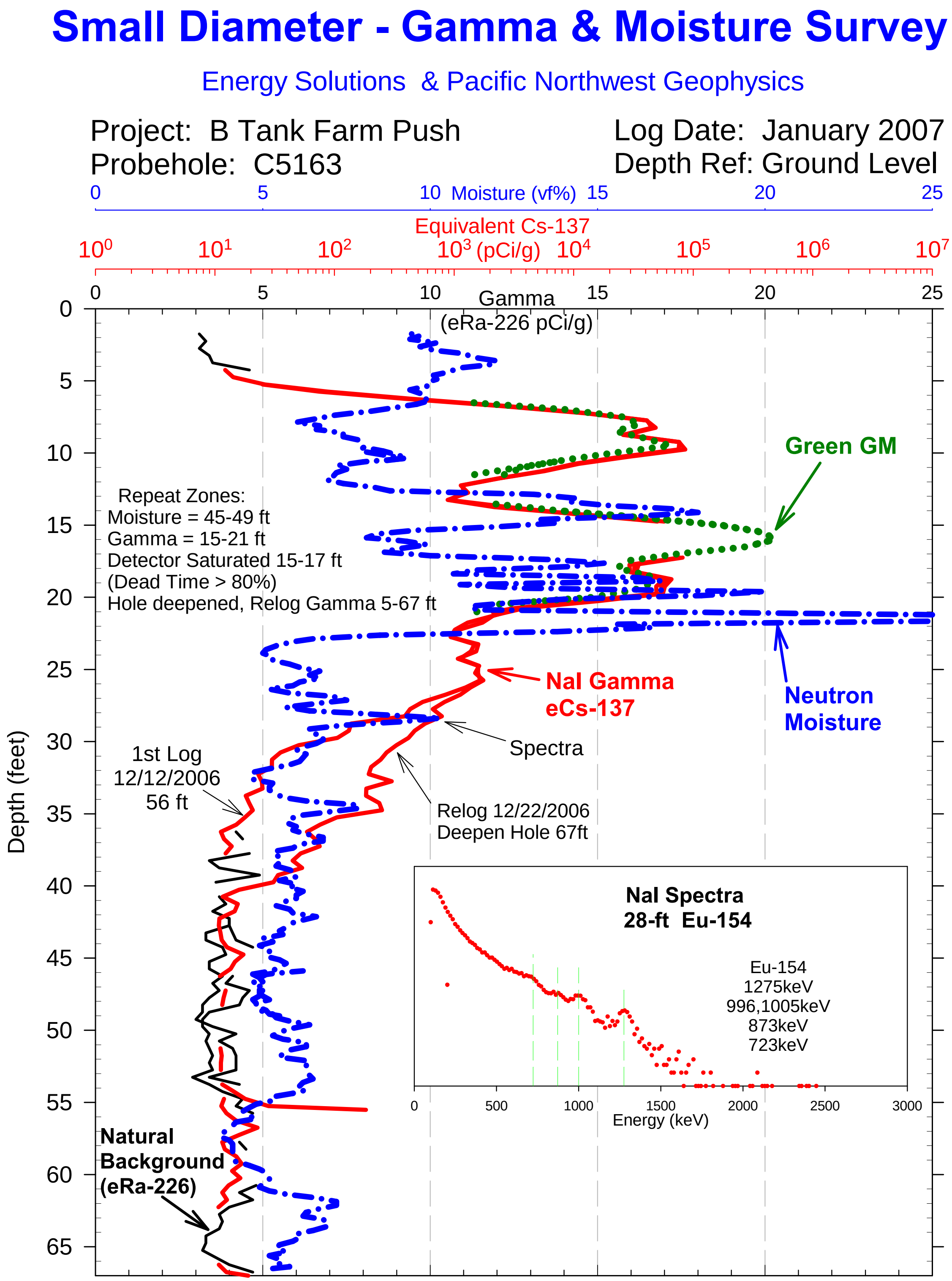
Table 3. Probe Hole Survey Summary

Hole	Gross Gamma	Spectral Gamma	Neutron Moisture	Hole Depth (ft)	Depth Max Gamma Activity	Max eCs-137 (pCi/g)	Comment
C5161	**X**			56 ft	Natural	Background	
C5163	**X**	**Spectra**	**Moisture**	55.5 ft	16 ft	477,000	Spectra 17-38 ft Deepen hole to 66.5ft
C5165	**X**		**Moisture**	56 ft	Natural	Background	
C5167	**X**			55 ft	20 ft	90	
C5169	**X**			56 ft	20 ft	140	
C5173	**X**			36 ft	Natural	Background	
C5175	**X**			36 ft	Natural	Background	
C5177	**X**		**Moisture**	36 ft	Natural	Background	
C5179	**X**		**Moisture**	36 ft	Natural	Background	

Figure 7. Plot Legend




Small Diameter - Gamma Survey
Energy Solutions & Pacific Northwest Geophysics
Project: B Tank Farm Push
Probehole: C5161
Log Date: December 2006
Depth Ref: Ground Level
Gamma
(eRa-226 pCi/g)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone (none)

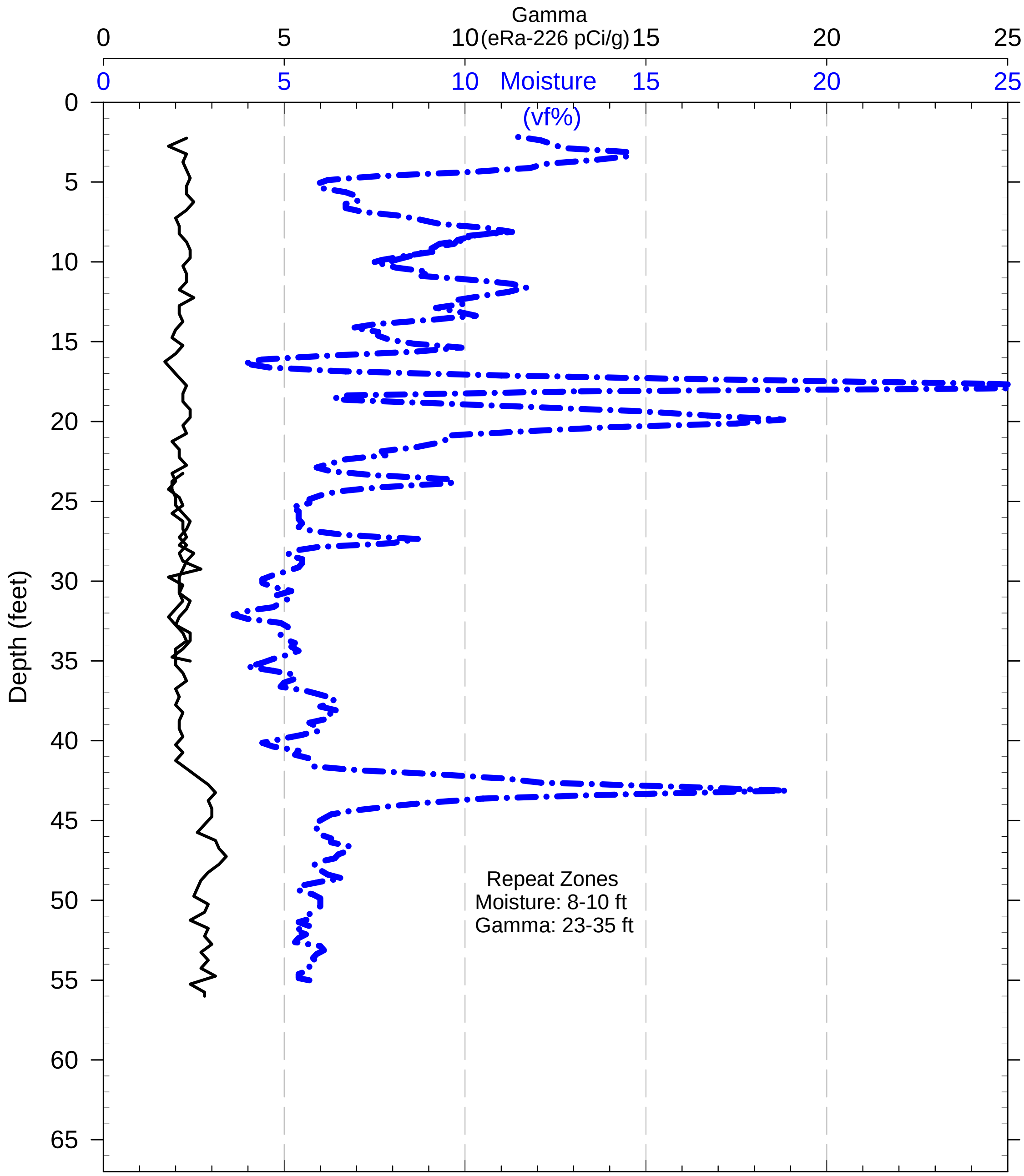

Small Diameter - Gamma & Moisture Survey
Energy Solutions & Pacific Northwest Geophysics
Project: B Tank Farm Push
Probehole: C5163
Log Date: January 2007
Depth Ref: Ground Level
Moisture (vf%)
Equivalent Cs-137 (pCi/g)
Gamma (eRa-226 pCi/g)
Depth (feet)
Repeat Zones:
Moisture = 45-49 ft
Gamma = 15-21 ft
Detector Saturated 15-17 ft
(Dead Time > 80%)
Hole deepened, Relog Gamma 5-67 ft
Green GM
NaI Gamma eCs-137
Neutron Moisture
Spectra
1st Log 12/12/2006 56 ft
Relog 12/22/2006 Deepen Hole 67ft
Natural Background (eRa-226)
NaI Spectra
28-ft Eu-154
Eu-154
1275keV
996,1005keV
873keV
723keV
Energy (keV)

Small Diameter - Gamma & Moisture Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push
Probehole: C5165

Log Date: January 2007
Depth Ref: Ground Level

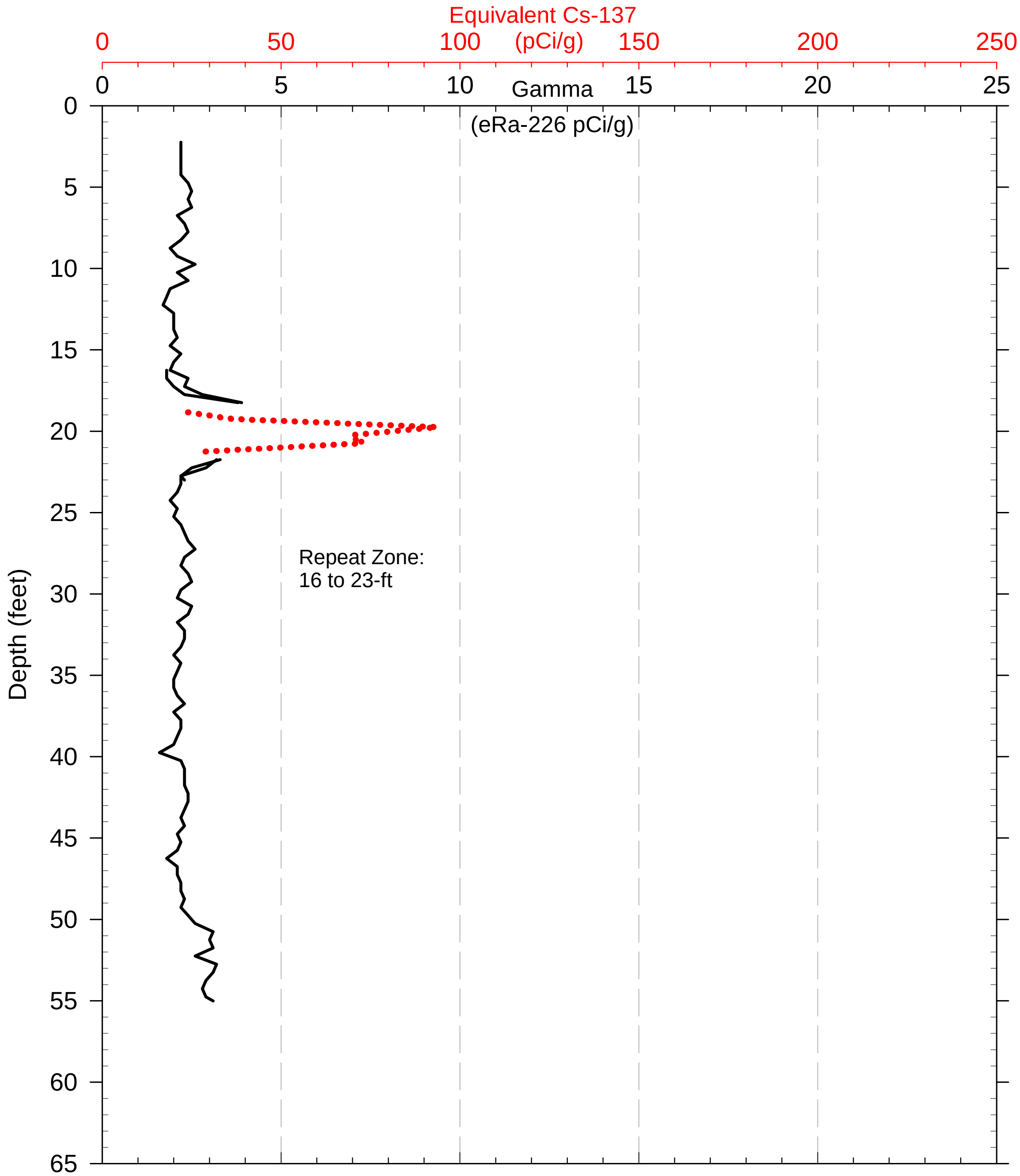


Small Diameter - Gamma Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push
Probehole: C5167

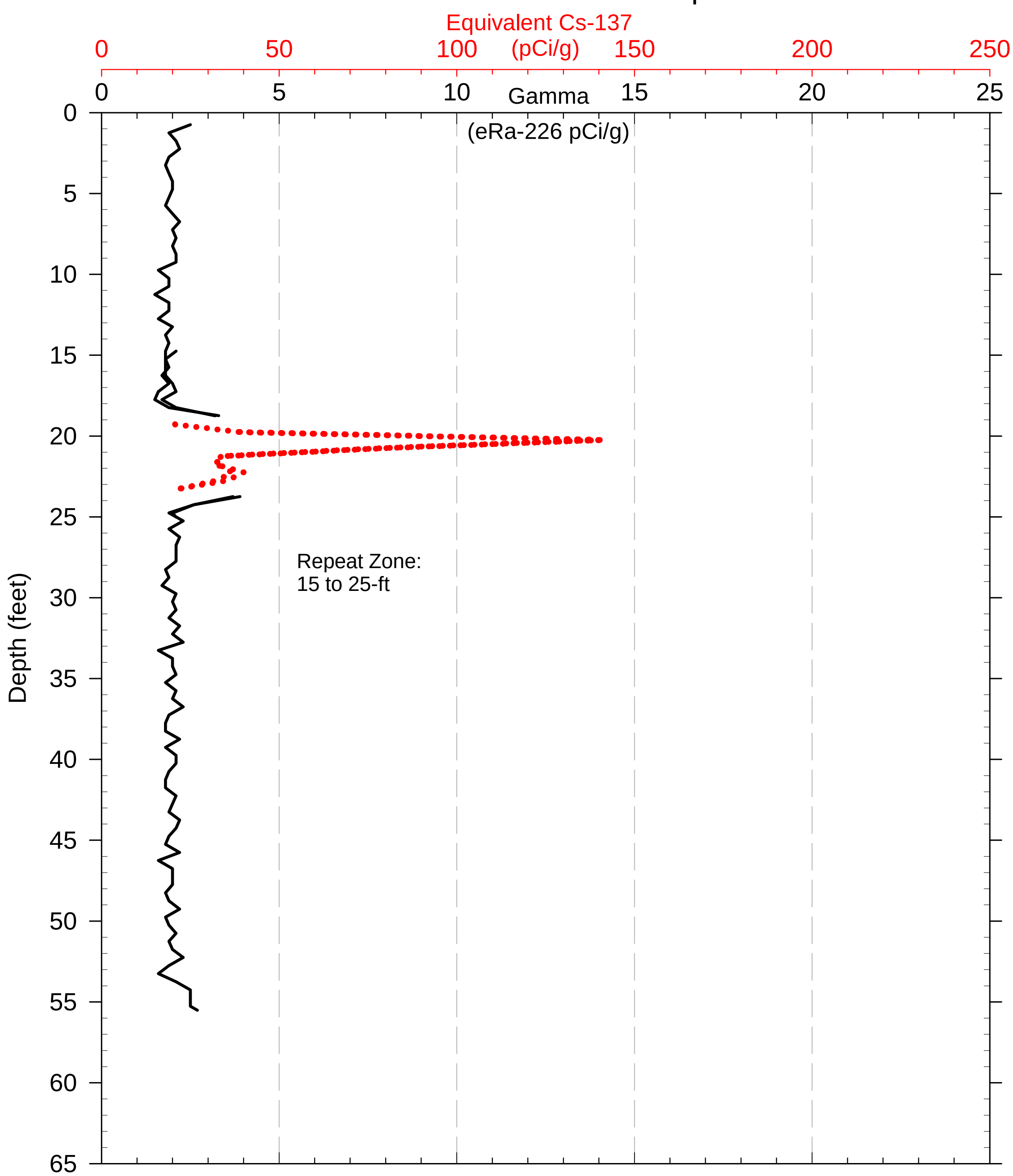
Log Date: January 2007
Depth Ref: Ground Level



Small Diameter - Gamma Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push | Log Date: December 2006
Probehole: C5169 | Depth Ref: Ground Level

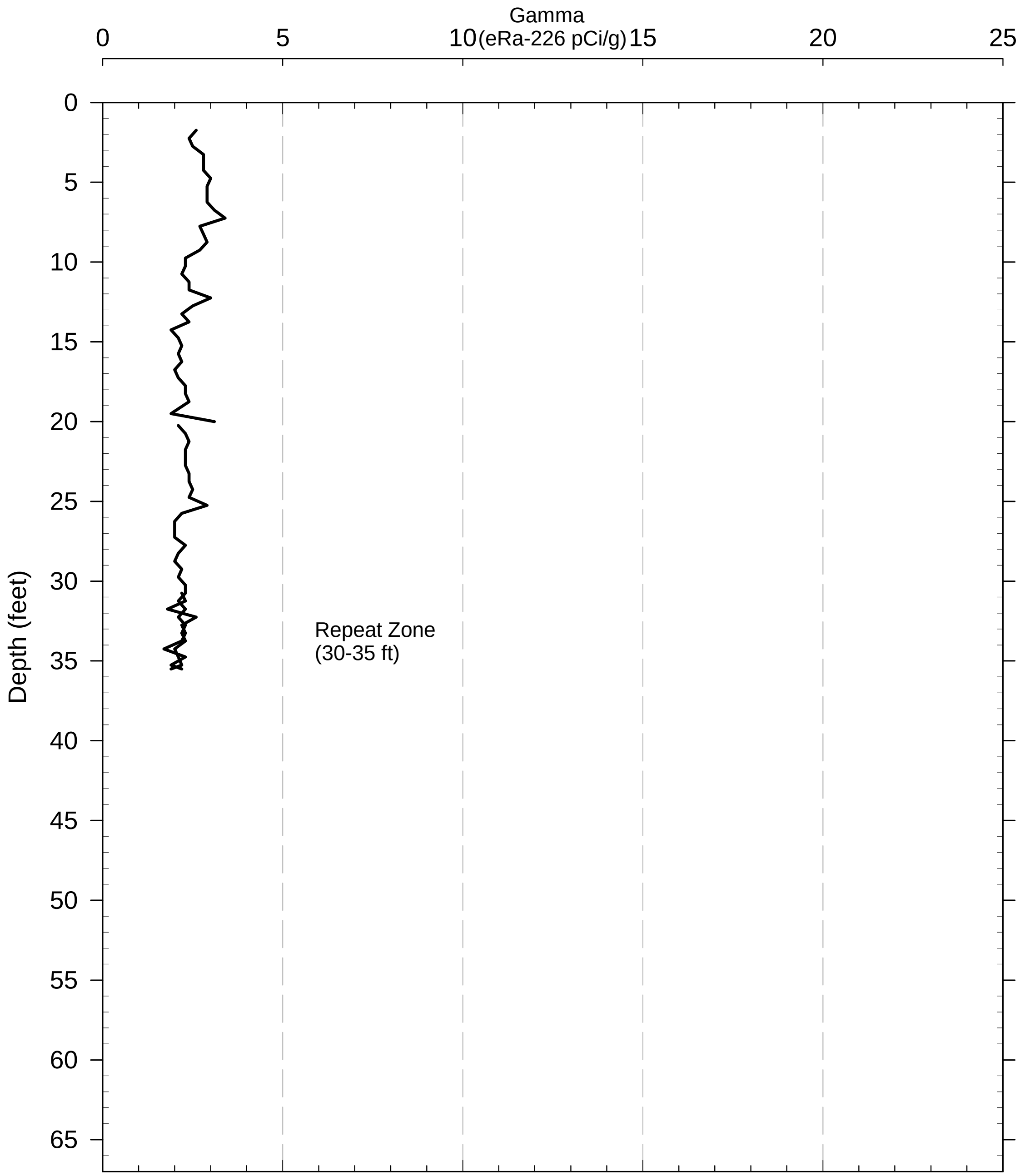


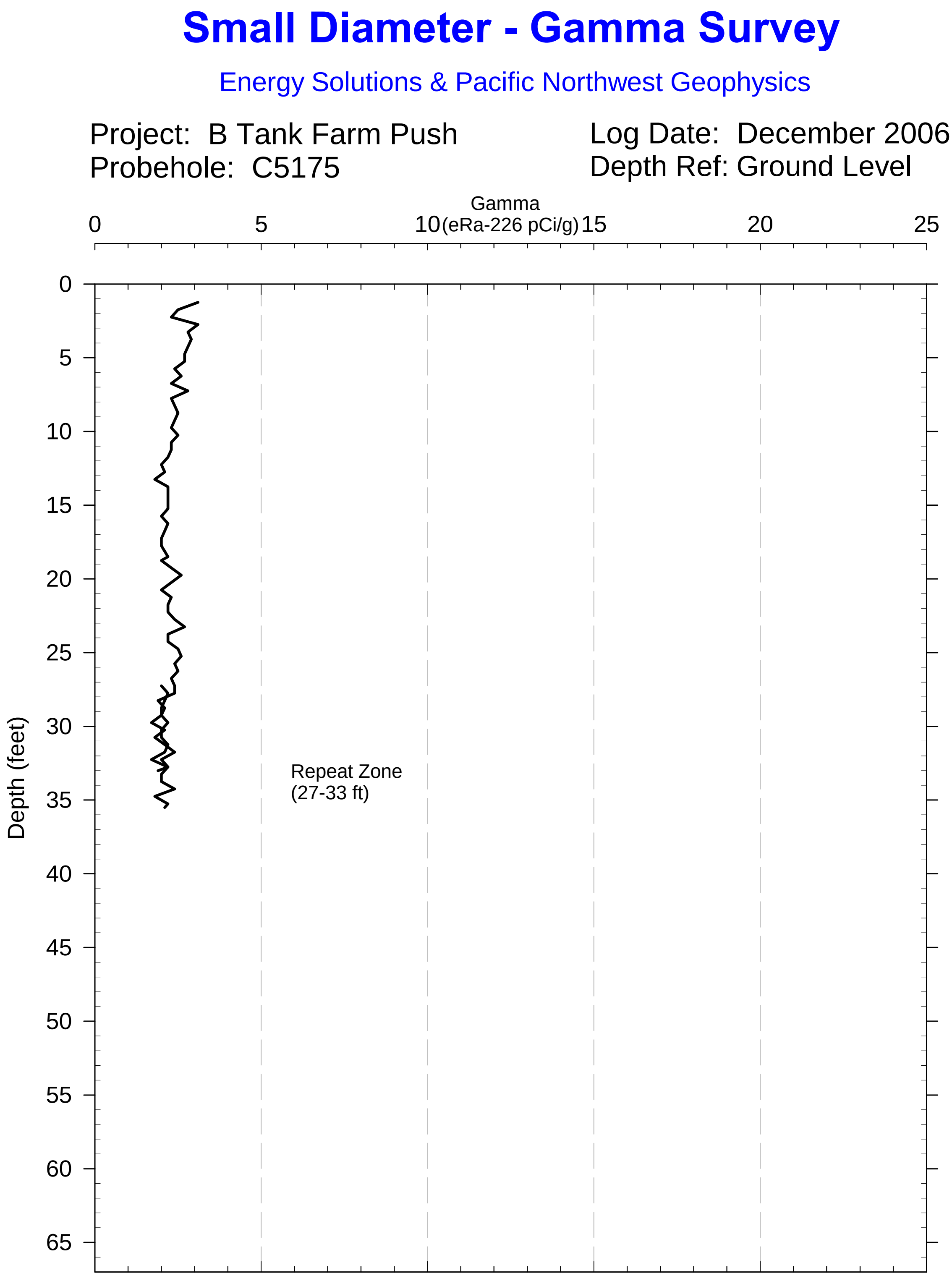
Small Diameter - Gamma Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push
Probehole: C5173

Log Date: December 2006
Depth Ref: Ground Level



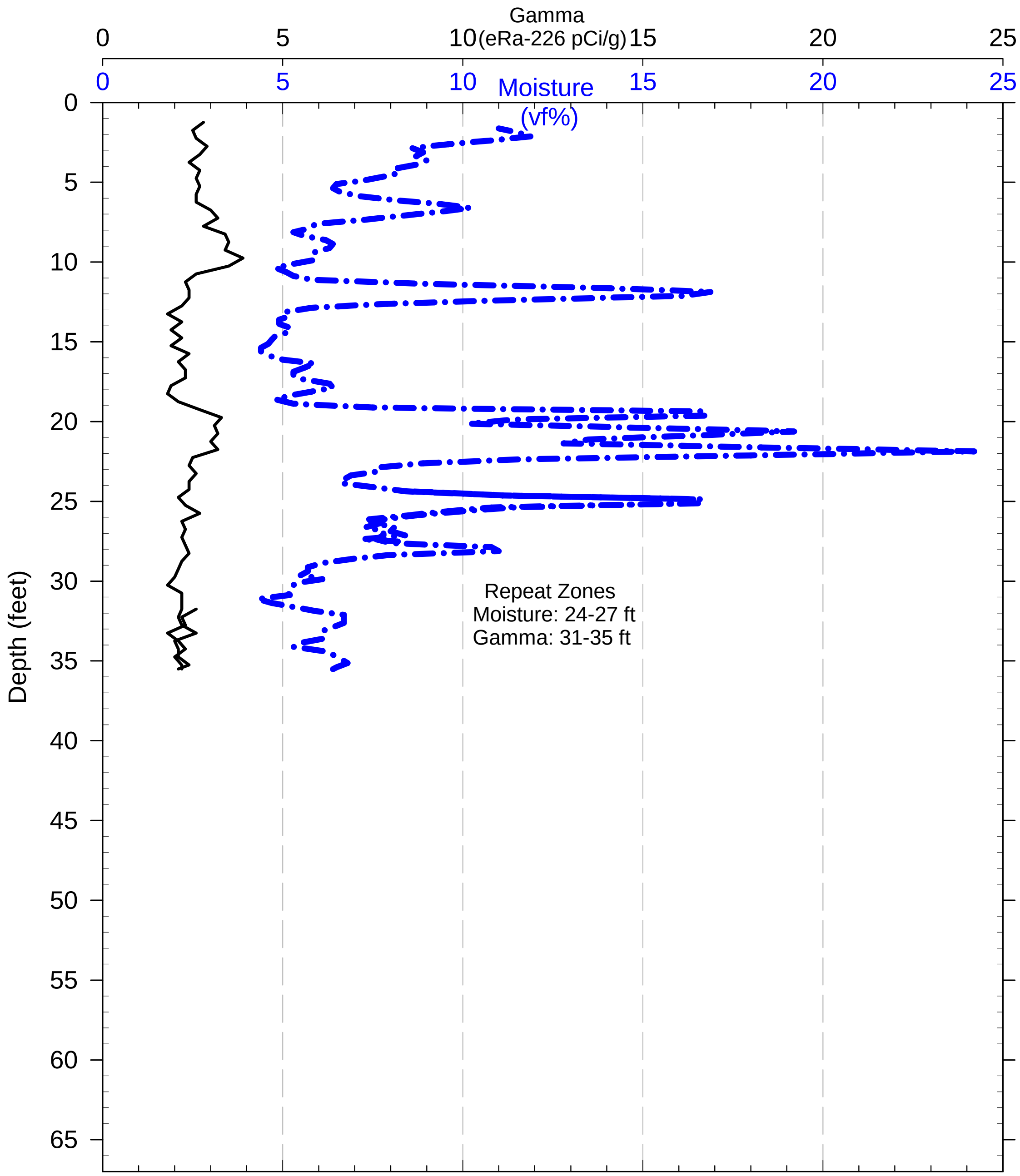

Small Diameter - Gamma Survey
Energy Solutions & Pacific Northwest Geophysics
Project: B Tank Farm Push
Probehole: C5175
Log Date: December 2006
Depth Ref: Ground Level
Gamma
(eRa-226 pCi/g)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone
(27-33 ft)

Small Diameter - Gamma & Moisture Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push
Probehole: C5177

Log Date: January 2007
Depth Ref: Ground Level



Small Diameter - Gamma & Moisture Survey

Energy Solutions & Pacific Northwest Geophysics

Project: B Tank Farm Push
Probehole: C5179

Log Date: January 2007
Depth Ref: Ground Level