RPP 34644, Rev. 0

SMALL DIAMETER GEOPHYSICAL LOGGING AT THE 241-C-152 DIVERSION BOX

Russ Randall, PhD and Randall Price
CH2M Hill Hanford Group, Inc.
Richland, WA 99352
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Abstract: The report gives the gamma and neutron moisture logging results for 20 probe holes in 241-C Tank Farm near diversion box 241-C-152.

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Small Diameter Geophysical Logging At the 241-C-152 Diversion Box

by

Russ Randall, PhD and Randall Price

to

Duratek Technical Services
345 Hills Street
Richland, Washington 99354

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Pacific Northwest Geophysics
4200 W 19th Avenue
Kennewick, Washington 99338

Three Rivers Scientific
3740 Grant Court
West Richland, Washington 99353

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1.0 INTRODUCTION

To investigate the extent of subsurface contamination at the 241-C-152 Diversion Box, Pacific Northwest Geophysics (PNG) and Three Rivers Scientific provided small diameter (slim hole) logging in support of field activities. Logging surveys were conducted with three detectors: neutron-moisture (moisture gauge), gross gamma, and spectral gamma. The surveys assisted in identifying zones of interest for sample collection and laboratory analysis. This report includes the results of these surveys for the 20 probe holes installed around the investigation site.

Moisture surveys measure the distribution of moisture in the subsurface soils. Previous drilling and sampling programs have shown that contamination from liquid waste is more likely to be present in zones with high moisture content than in zones of low moisture content. The moisture content ranged from less than 5 to over 20 percent volume fraction moisture.

The main gamma-ray emitting constituent of the liquid waste that leaked from the 241-C-152 Diversion Box is Cesium-137. The objective of the gamma survey logs is to identify the presence of Cs-137 at concentrations greater than 10 pCi/g and to highlight high concentration zones that must be avoided for sample collections (RWP limiting condition of 100,000 DPM). Rapid scan gamma surveys (4 ft/minute) satisfy the Cs-137 detection threshold and the results are reported as gross gamma logs.

Through selected intervals in two probe holes, spectral gamma ray surveys were collected to identify the concentrations of the naturally occurring radionuclides.

Each logging unit (moisture, gross gamma, and spectral gamma) was calibrated for the probe hole conditions present at the investigation site (see section 0).

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 daily repeat measurement was acquired 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 plot in Appendix A. The plots are in numeric order of the probe holes (C4401 - C4447). Appendix A also contains a table that summarizes for each probe hole, the survey date, detector, maximum/minimum survey depth, and repeat intervals. Cesium-137 was not detected in any probe hole.

Unfortunately, the rapid scan gamma detector exhibited intermittent noise in the spectra on a few of the probe hole surveys. These data values were masked out in the final presentation and were replaced by an appropriate comment. Repeat logs in the holes were useful to confirm the background radioactive component of the formation. Repeat logs are presented with the main log runs, both agree within counting statistics, and confirm background activity of the subsurface formation.

3.0 GEOPHYSICAL LOGGING SYSTEM

Three small-diameter logging units were deployed to the investigation site. The logging systems were portable units (i.e. mounted on a wagon) powered by a 120v AC electrical cord connected to the on-site generator. A laptop computer allocated to each logging unit was used to monitor encoder depth positions, control the winch motor, and record detector responses.

The moisture and gross gamma (NaI) detectors are more advanced than the older spectral gamma (BGO) system. The older BGO sonde transmits each detector response as an analog (voltage) pulse through the logging cable to the up-hole amplifier and multi-channel-analyzer (MCA).

The more advanced moisture and NaI gamma detectors are connected to their own multi-channel analyzers that are installed in the small diameter logging sonde. Detector responses are converted to digital format within the logging tool, which significantly improves system stability. These two detectors are interchangeable between the two winch units because digital detector responses are not influenced by up-hole logging equipment (winch motor, depth encoder, etc.).

3.1 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 (H38068291).

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 1. The calibration certificate is shown in Figure 1.

The probe holes size for this project was 2.51-inch. Therefore, the moisture calibration was extrapolated to the correct hole-size. The moisture calibration certificate for 2.51-in hole-size is shown in Figure 2.

Table 1. Moisture Calibration Data

Moisture Content Percent – volume fraction	6-inch Models* (cps)	8-inch Models* (cps)
5% vf	96.2	75.7
12% vf	142.7	106.5
20% vf	179.0	129.7

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

The probe hole survey was collected at 1 ft/minute. 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 0.37-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).

3.2 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).

Figure 1. Moisture Calibration Certificate, Hole Size: 6-in. and 8-in.

Certificate of Calibration for Instrument SD-Moist291-2
June 6, 2005

On June 6, 2005 data were taken in the Moisture models for the SD-Moist291-2 neutron-neutron moisture tool. The neutron source from DOE moisture tool # H38068291 was used with the passive neutron detector probe from PNG. This calibration is required for the Direct Push logging, and it is funded by subcontract 013661.

Six models were used for moisture calibration, three for 6-in. casing and three for 8-in. 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 Stats-moist.xls for this analysis).

The coefficient generation is determined by the algorithm described in WHC-SD-EN-TI-306, *Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration*, Rev. 0. The regression function used is a power law form and defined by:

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

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 = .0002069	a = .00008067
α = 2.210	α = 2.550

The undersigned certifies that the data archived in data file "SD-Moist291_2005.zip" were collected and evaluated in accordance with WHC-SD-EN-TI-306 and that the above stated calibration coefficients are correct and applicable for tool SD-Moist291-2, effective June 6, 2005.

Signature: Date:

Russel Randall, PhD July 1, 2005
Three Rivers Scientific

Figure 2. Moisture Calibration Certificate, Hole Size 2.51-in.

Moisture Calibration Extrapolation to 2.51 Inch Borehole
Instrument SD-Moist291-2
June 6, 2005

Moisture calibration was performed in the Hanford physical models. These standards have 6-in. and 8-in. inside diameter (ID) casings. The Tank Farm Direct Push borehole is cased with a 2.51-in. outside diameter (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 WHC-SD-EN-TI-306, *Radionuclide Logging System In Situ Vadose Zone Moisture Measurement Calibration*, Rev. 0. The regression function used is a power law form and defined by:

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

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 2.51 inch borehole diameter.

2.51" borehole
a = .000343
α = 1.951

The undersigned certifies that the analysis files are archived in the file "SD-Moist291_2005.zip" which was evaluated in accordance with DTS procedures and that the above stated calibration coefficients are correct and applicable for tool SD-Moist291-2, effective June 6, 2005.

Signature: Date:

Russel Randall, PhD July 12, 2005
Three Rivers Scientific

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 detector was covered with a 4-ft long section of the probe/drill tubing (0.37-inch thick). The calibration data are summarized in Table 2. The calibration units are pCi/g of equivalent Radium-226 (eRa-226). See Figure 3 for the calibration certificate.

Table 2. 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	476.0	477.8
SBU	186	1396.6	1412.7

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 8.15μs (Randall & Price, 2005).

Also, the NaI gross gamma detector was calibrated for eCs-137 (pCi/g) in addition to the primary calibration for eRa-226. 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 well 299-W10-72 (a new standard proposed by Stoller Corporations' logging group). The distribution of Cs-137 varied along the depth of the well, therefore, the concentrations were established by two HPGe detectors (the 70% tool and the High Rate tool). The conversion factor from detector count rate (cps) to eCs-137 is 0.373 (pCi/g per cps) for casing thickness 0.40-in.

Figure 3. Gross Gamma Calibration Certificate

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

Data were taken at the Hanford KUT models on July 7, 2005. SDGR-4N4-NaI1 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, for this analysis, refer to the compressed files: Gross.xls.

This calibration is required for the Direct Push logging, and it is 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 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:

$$\mathbf{a = .131 \ \ Eq.^{226}Ra \ pCi/g \ / \ (c/s)}$$
$$\mathbf{b \equiv 0}$$

Digital files condensed as Cal_SD-GR-02_2005-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_2005-v0.zip" were collected and evaluated in accordance with 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 SDGR-4N4-NaI1 effective July 7, 2005.

Signature: Russel Randall PhD　　　　Date: July 8, 2005

Company: Three Rivers Scientific

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.

3.3 SPECTRAL GAMMA CALIBRATION AND SURVEYS

Calibration of the BGO logging system was performed in the four spectral gamma borehole calibration models located at the U.S.-DOE Hanford Site near Richland, Washington and according to Hanford Site procedures for scintillation type spectral gamma ray borehole detectors (Randall & Stromswold, 1995). The four calibration models contain elevated concentrations of the naturally occurring radionuclides (potassium, uranium or radium in secular equilibrium with uranium, and thorium, aka KUT). The radionuclide concentrations are traceable to NIST standards, (Steele & George, 1986). Table 3 lists the radionuclide concentration in each of the gamma calibration models. The uncertainty is quoted at the 2-sigma (95%) confidence level.

Table 3. Hanford Calibration Model Values for KUT

Model	^{40}K Concentration (pCi/g)	^{226}Ra Concentration (pCi/g)	^{232}Th Concentration (pCi/g)
SBK	53.50 ± 1.67	1.16 ± 0.11	0.11 ± 0.02
SBU	10.72 ± 0.84	190.52 ± 5.81	0.66 ± 0.06
SBT	10.63 ± 1.34	10.02 ± 0.48	58.11 ± 1.44
SBM	41.78 ± 1.84	125.79 ± 4.00	39.12 ± 1.07

Calibration was performed with a section of the steel drill tubing (4-ft long) 0.37-in. thick (2.5-in. OD) installed over detector (4-in. long) during calibration measurements. Calibration with the casing installed over the detector is more rigorous than calibration with open hole and applying casing correction to the probe hole survey to correct for the presence of casing. See Figure 4 for the spectral gamma Calibration Certificate.

During logging the gamma peak at 1461 keV from potassium (K-40) is almost always present as the dominant peak in each spectra and is used to monitor for spectra gain changes. During data processing the spectra gain is adjusted to track the reference gamma peak.

Borehole survey spectra (200 seconds each) were measured each 0.5 feet between the selected depth intervals in two probe holes (C4409 and C4417) in move-stop-acquire logging mode and the results are presented in Appendix B.

Figure 4. Spectral Gamma Calibration Certificate

Certificate of Calibration
SDGR.02
July 7, 2005

Data were taken at the Hanford KUT models on July 7, 2005. SDGR.02 is the designated Scintillator tool. Four models were used for Spectral KUT calibration. Ten spectra were recorded for each model in order to perform statistical analysis. The observed statistical deviations were seen to be within the theoretically predicted variation, for this analysis, refer to the compressed file: AveOut.XLS. The instrument was covered with 0.37 inch wall thickness probe tubing.

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

The algorithm described in WHC-SD-EN-TI-293, Rev. 0, determines the coefficient analysis. Three energy windows are used for each potassium, uranium and thorium (K U & T), and these are:

K: 1320-1575 keV **U: 1650-2390 keV** **T: 2475-2765 keV**

The concentration for each of the three elements is a linear combination of the count rates in the three windows. The resulting coefficients for each of the three elements are:

Concentration-K =	**3.472*K**	**-2.916*U**	**2.146*T**
Concentration-U =	**-0.0086*K**	**1.071*U**	**-1.931*T**
Concentration-T =	**-0.00099*K**	**-0.035*U**	**1.433*T**

Where K U & T are the count rates (c/s) in the listed energy windows and the resulting concentration values are in pCi/g.

Digital files condensed as Cal_SD-GR-02_2005-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_2005-v0.zip" were collected and evaluated in accordance with 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 SDGR.02 effective July 7, 2005.

Signature: Russel Randall, PhD Date: September 8, 2005

4.0 CONCLUSION

Neutron-Moisture and Passive Gross Gamma survey logs were collected in 20 probe holes installed around the 241-C-152 Diversion Box. All probe holes were pushed to their target depth, none were aborted because of refusal to advance. Nine of the probe holes were pushed to approximately 30 feet in depth, the remaining eleven holes were pushed to approximately 60 feet in depth.

The moisture surveys identified several zones typically above 30 feet with moisture content greater then 10 %vf, many were very thin zones with moisture content greater than 20 %vf. The moisture content below 30 feet is typically less than 8 %vf, except for one zone in C4431 at 37-ft that approaches 9 %vf.

The rapid-scan gamma surveys encountered only background activity from the natural radionuclides. No surveys encountered Cs-137 or any other anthropogenic radionuclide at concentrations approaching the targeted minimum detection threshold of 10 pCi/g.

Spectral gamma surveys were acquired in selected depth intervals in two probe holes (C4409 and C4417). The survey depth interval was selected to span a transition in the gamma response and moisture content. Changes in concentration of potassium and thorium were measured with each survey. Unfortunately, the variations in concentration of uranium in the formation are less than the precision of the logging measurement.

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APPENDIX A: MOISTURE AND GROSS GAMMA SURVEYS

Moisture and Gross Gamma Survey Plots follow for the 20 probe holes installed around the 241-C-152 Diversion Box. The gamma survey results are plotted with the scale of 0-25 pCi/g for some probe holes and the scale is 1-26 pCi/g for other probe holes. The scale was changed (adjusted) to prevent confusion from overlap with moisture results.

Table 4. Probe Hole Survey Summary

Probe Hole	Log Date	Detector	Max Depth (ft)	Min Depth (ft)	Repeat Zone(s) (ft)	Comment
C4401	11/1/2004	BGO Gamma	60	0		
C4401	11/1/2004	Moisture	60	0		
C4403	7/7/2005	Moisture	58.6	0		
C4403	7/14/2005	Gross Gamma	58.7	1	38-35	
C4405	7/7/2005	Moisture	30.4	0		Depth increment 0.5 ft
C4405	7/11/2005	Moisture	30.2	0.25		Depth increment 0.25 ft
C4405	7/14/2005	Gross Gamma	31	1	14-11	
C4407	7/12/2005	Moisture	59.2	0.25		
C4407	7/14/2005	Gross Gamma	58.7	1	13-9	
C4409	7/12/2005	Gross Gamma	30.7	1		
C4409	7/12/2005	Moisture	30.7	0.25	26-22	
C4409	7/25/2005	Spectral Gamma	30	21	23.5-25	
C4411	7/14/2005	Gross Gamma	66	1	26-20	
C4411	7/15/2005	Moisture	66.2	1	15-9	
C4413	7/15/2005	Gross Gamma	30.4	0.5	16-8	
C4413	7/15/2005	Moisture	30.5	1	16-11	
C4415	7/15/2005	Gross Gamma	58.3	1	32-28	
C4415	7/19/2005	Moisture	58.1	1	17-13	
C4417	7/15/2005	Gross Gamma	58	1	20-14	
C4417	7/19/2005	Moisture	58.6	1	19-14	
C4417	7/26/2005	Spectral Gamma	20	14	16.5-15.5	
C4419	7/19/2005	Gross Gamma	57.5	1	35-30	

Table 4. Probe Hole Survey Summary

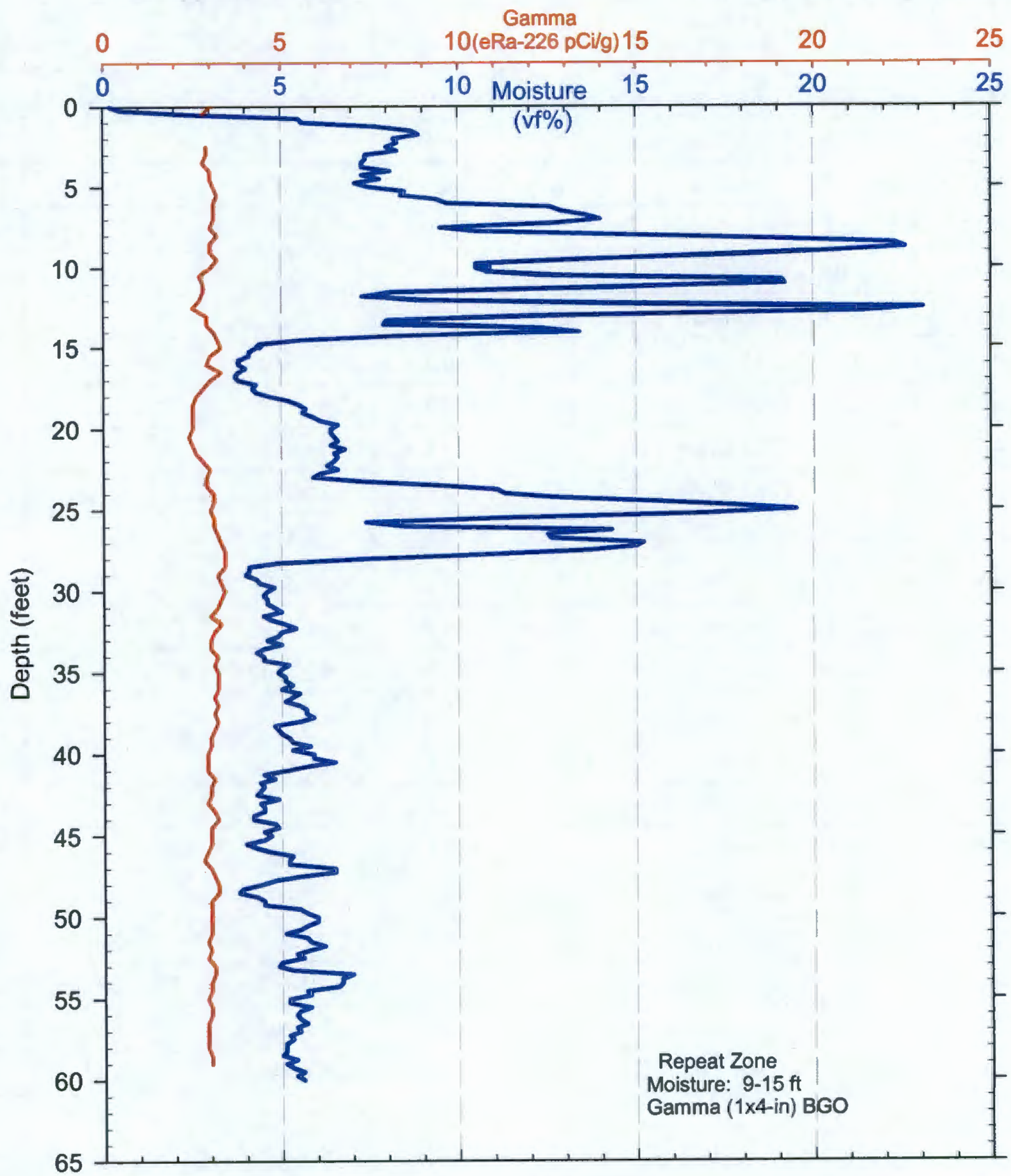
Probe Hole	Log Date	Detector	Max Depth (ft)	Min Depth (ft)	Repeat Zone(s) (ft)	Comment
C4419	7/21/2005	Moisture	57.5	1	19-14	
C4421	7/19/2005	Gross Gamma	58.1	1	22-18, 25-12	
C4421	7/21/2005	Moisture	58	15		
C4421	7/22/2005	Moisture	21	0	9-5.5	Complete Survey (next day)
C4425	8/18/2005	Gross Gamma	30	0.5	10.5-7	
C4425	8/19/2005	Moisture	30	0.5	8.5-5.5	
C4427	8/24/2005	Gross Gamma	32	0.5		Intermittent Noise
C4427	8/29/2005	Gross Gamma	32	0.5	32-22	Intermittent Noise
C4427	8/25/2005	Moisture	32	0.5		
C4429	8/16/2005	Moisture	58	0.5	5.5-3.5	
C4429	8/17/2005	Gross Gamma	58	0.5		
C4431	8/25/2005	Moisture	59	0.5	8.5-4	
C4431	8/29/2005	Gross Gamma	59	0.5	26-20	
C4433	8/16/2005	Moisture	31	0.5	13.5-11	
C4433	8/18/2005	Gross Gamma	32	0.5	18.5-14	
C4435	8/18/2005	Gross Gamma	32	0.5	19.5-14	
C4435	8/19/2005	Moisture	32	0.5	14.25-10.75	
C4437	8/17/2005	Moisture	59	9.5		
C4437	8/19/2005	Moisture	13.25	0.5		
C4437	8/18/2005	Gross Gamma	59	0.5	18.5-12	
C4439	8/17/2005	Moisture	32	0.5	19-16	
C4439	8/18/2005	Gross Gamma	32	0.5	20-10	
C4447	8/24/2005	Gross Gamma	27	0.5	27-1, 27-1, 27-1	Intermittent Noise
C4447	8/24/2005	Gross Gamma	23	0.5	23-0.5	Intermittent Noise
C4447	8/29/2005	Gross Gamma	27	0.5	15-5, 20-0.5	
C4447	8/25/2005	Moisture	27	0.5	11-5	

Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4401

Log Date: Nov 2004
Depth Ref: Ground Level

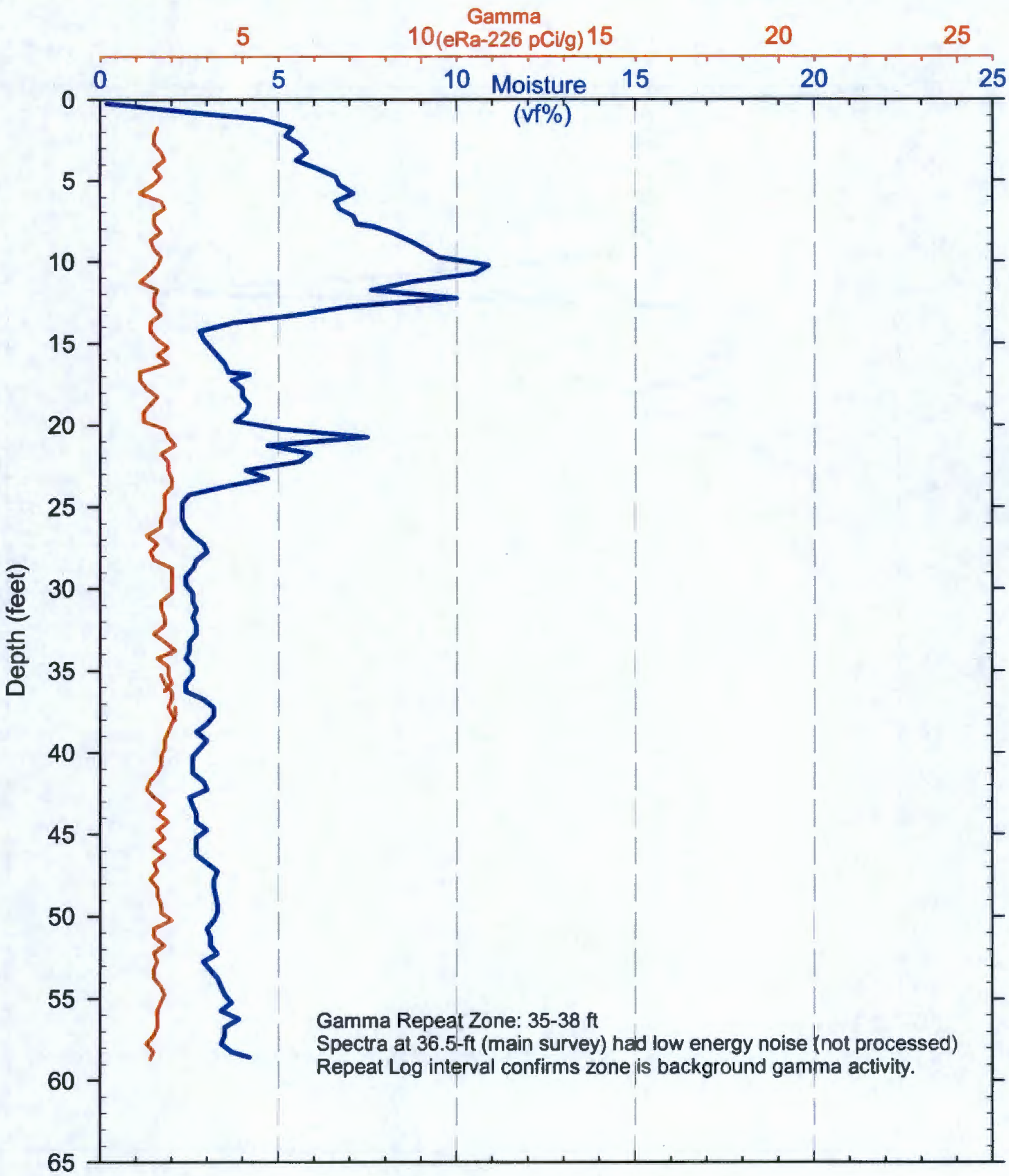


Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4403

Log Date : July 2005
Depth Ref: Ground Level

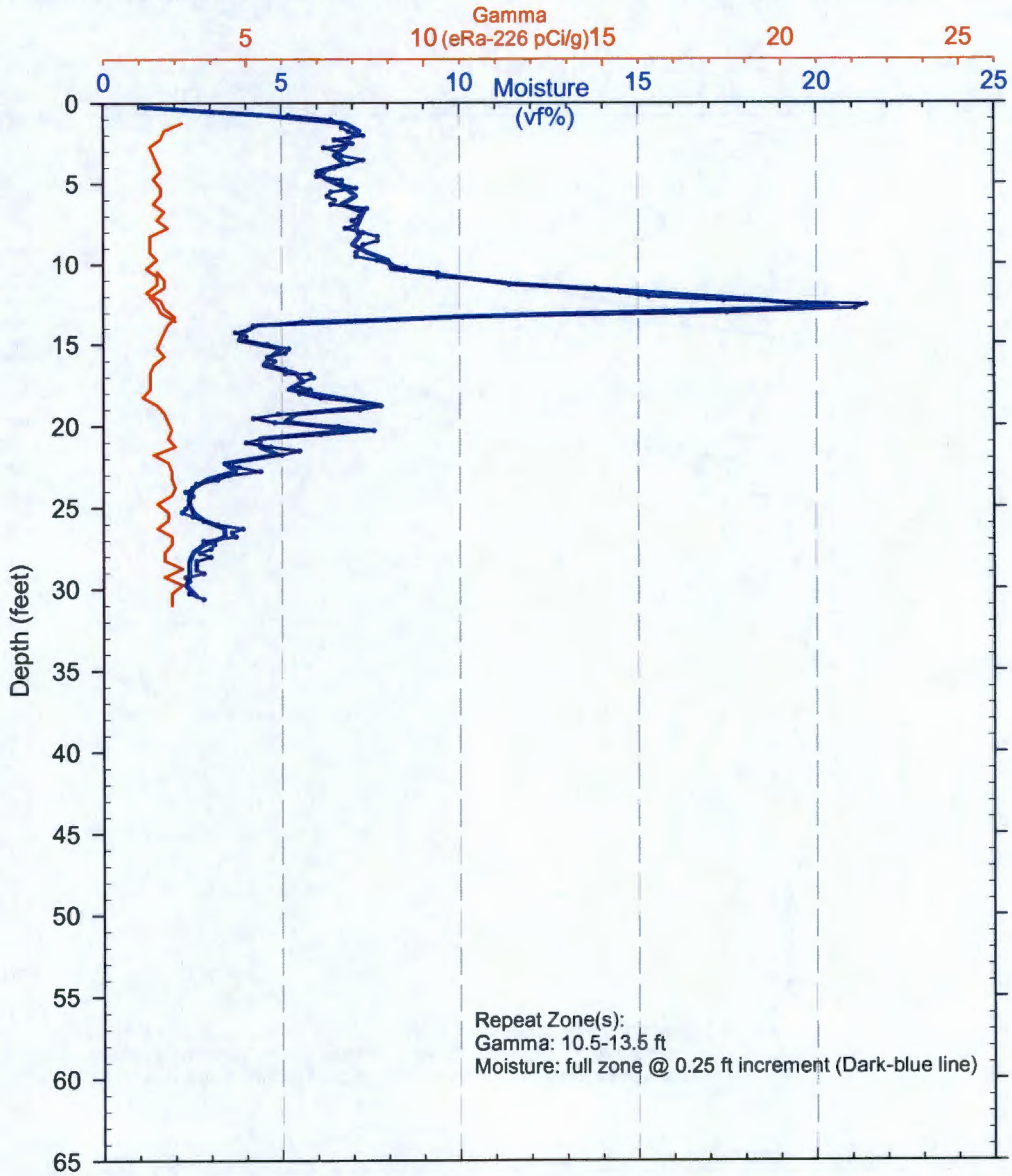


Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4405

Log Date : July 2005
Depth Ref: Ground Level

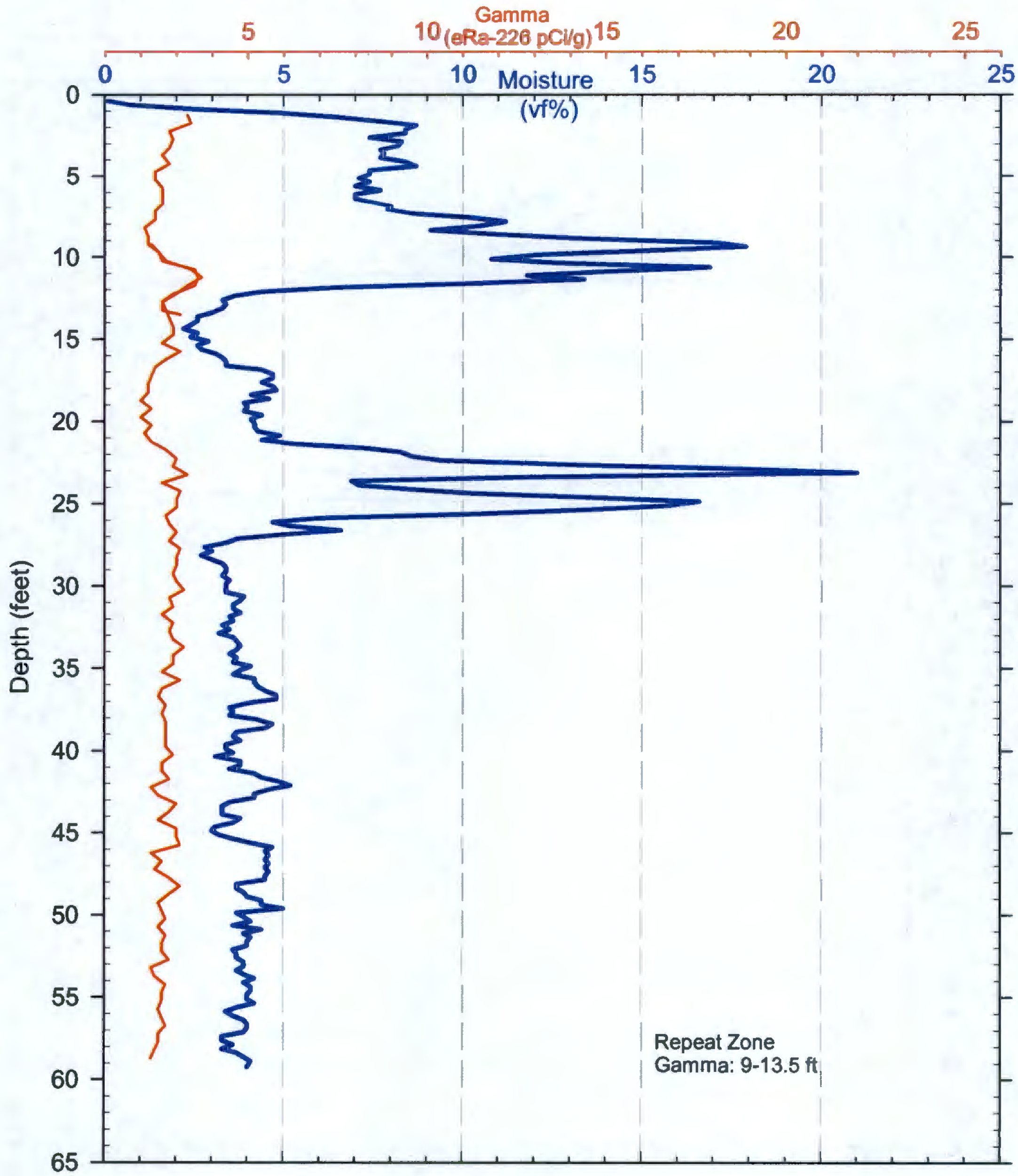


Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4407

Log Date : July 2005
Depth Ref: Ground Level

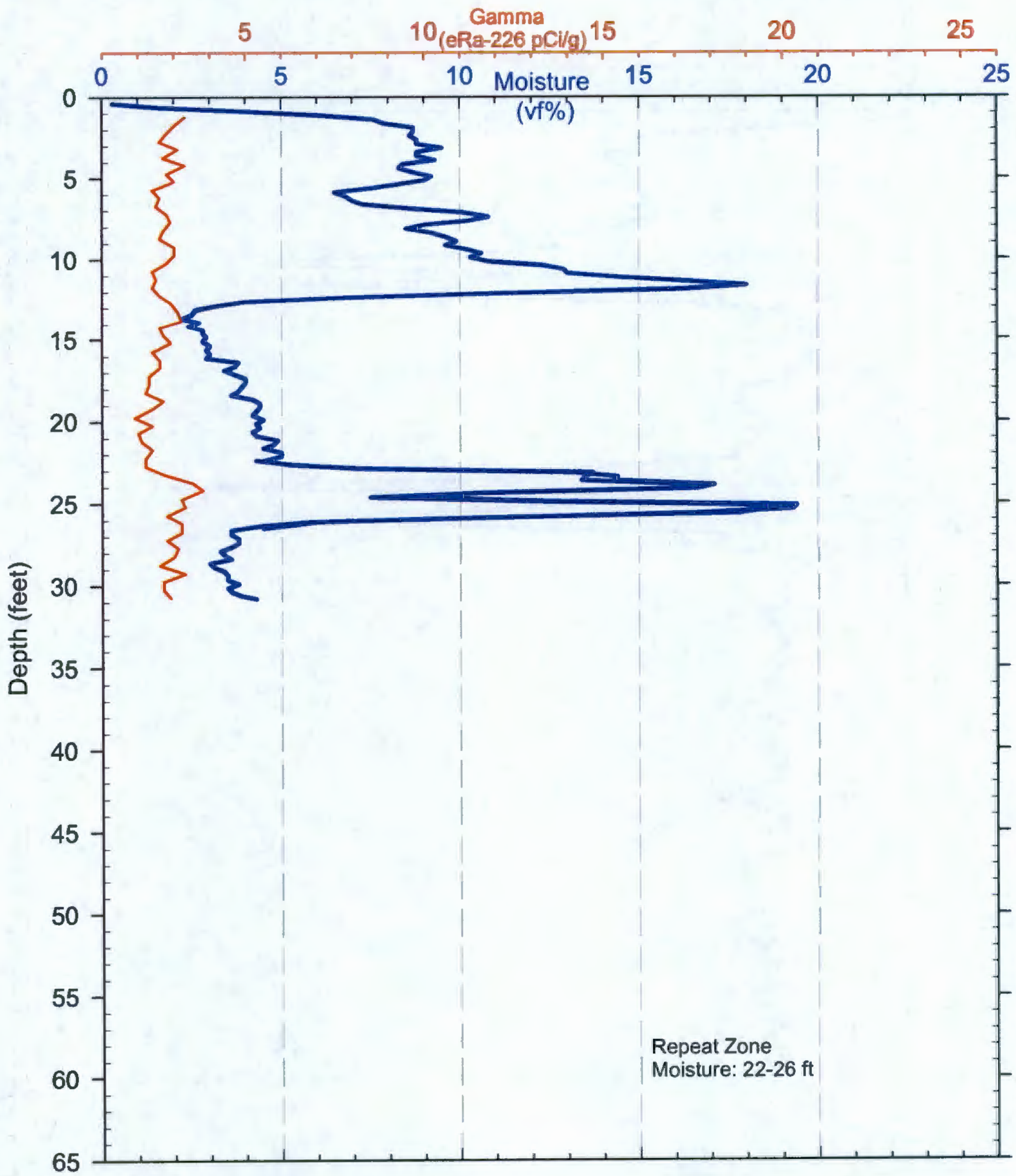


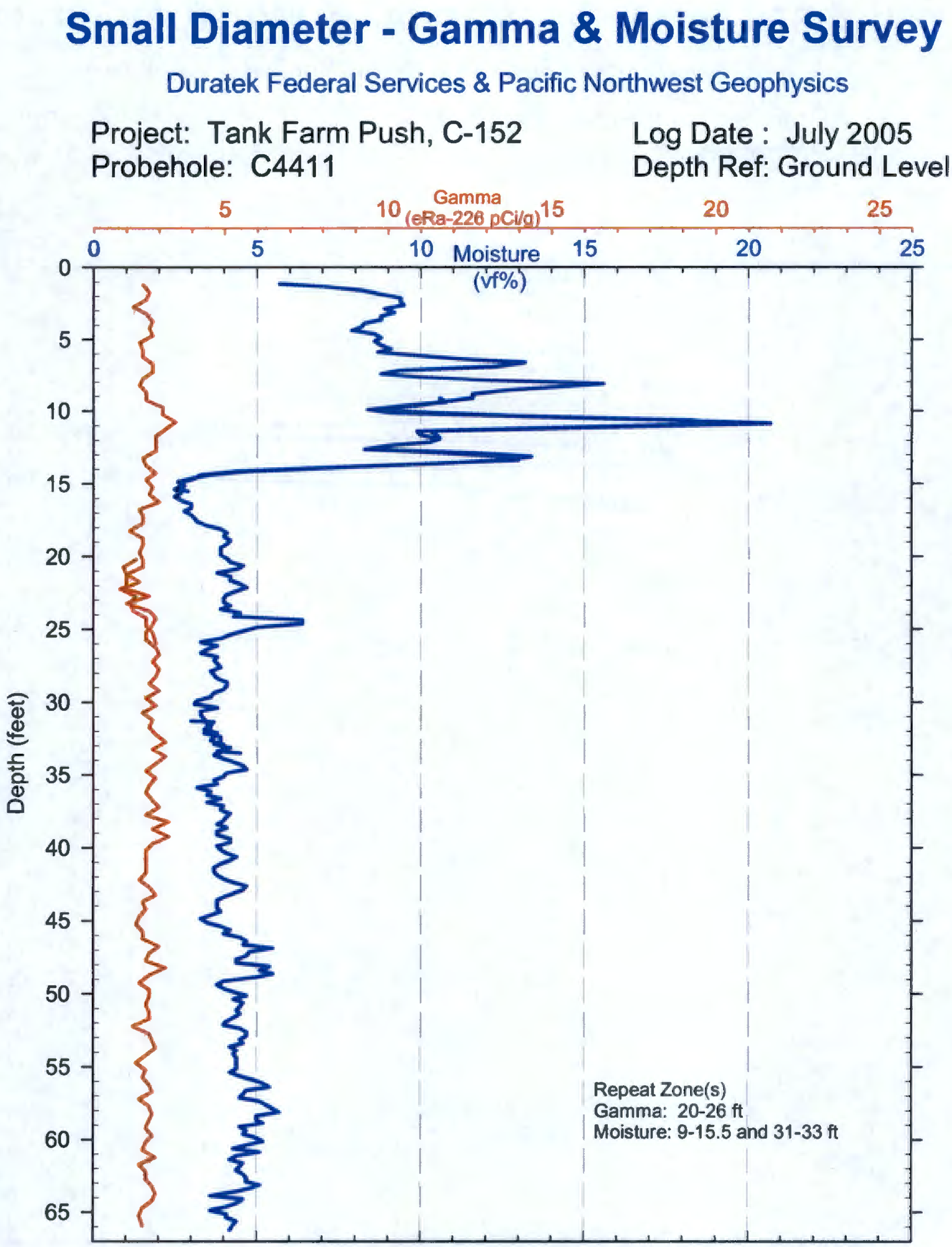
Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4409

Log Date : July 2005
Depth Ref: Ground Level



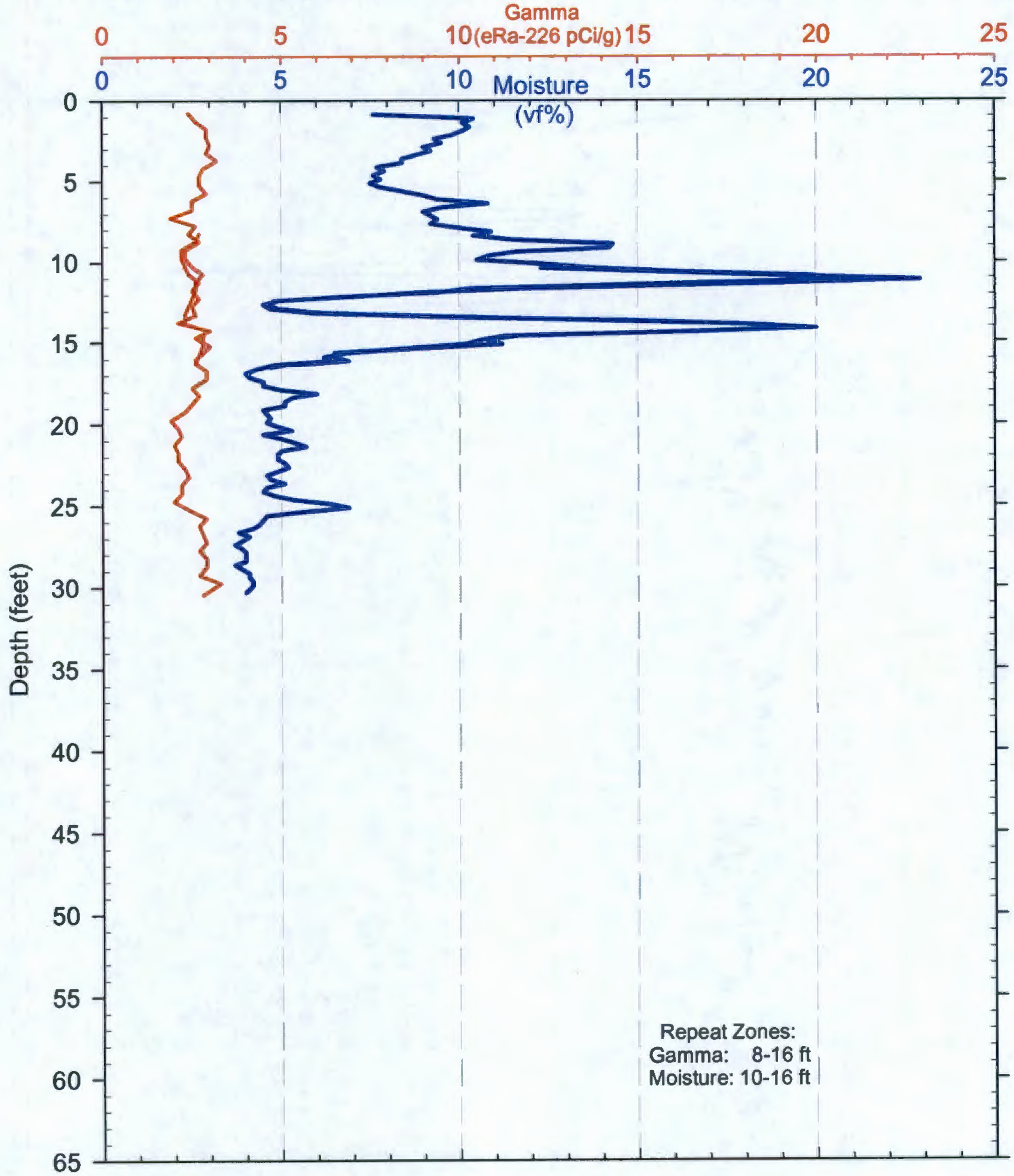

Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4411
Log Date : July 2005
Depth Ref: Ground Level
Gamma (eRa-226 pCi/g)
5
10
15
20
25
Moisture (vf%)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone(s)
Gamma: 20-26 ft
Moisture: 9-15.5 and 31-33 ft

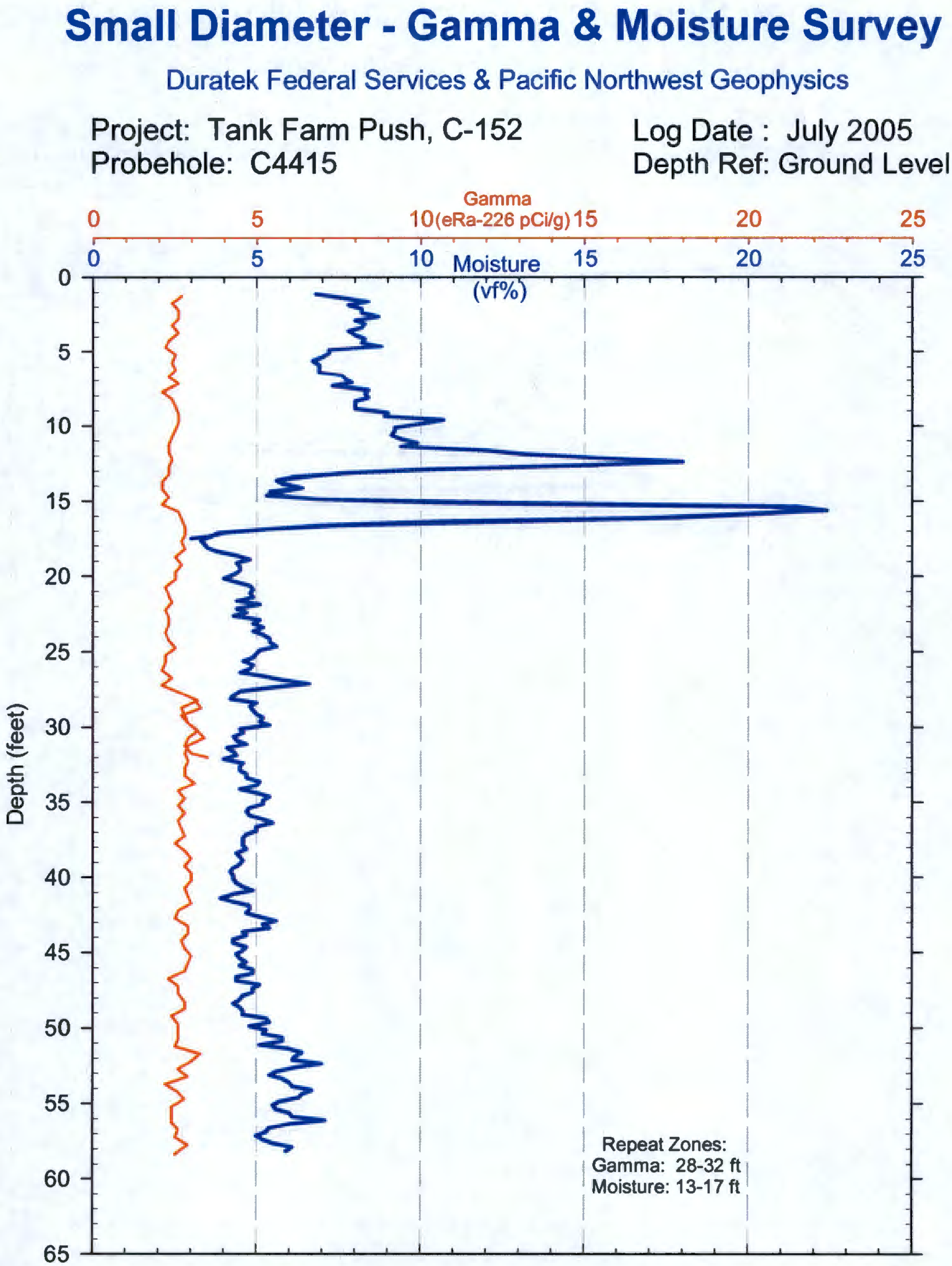
Small Diameter - Gamma & Moisture Survey

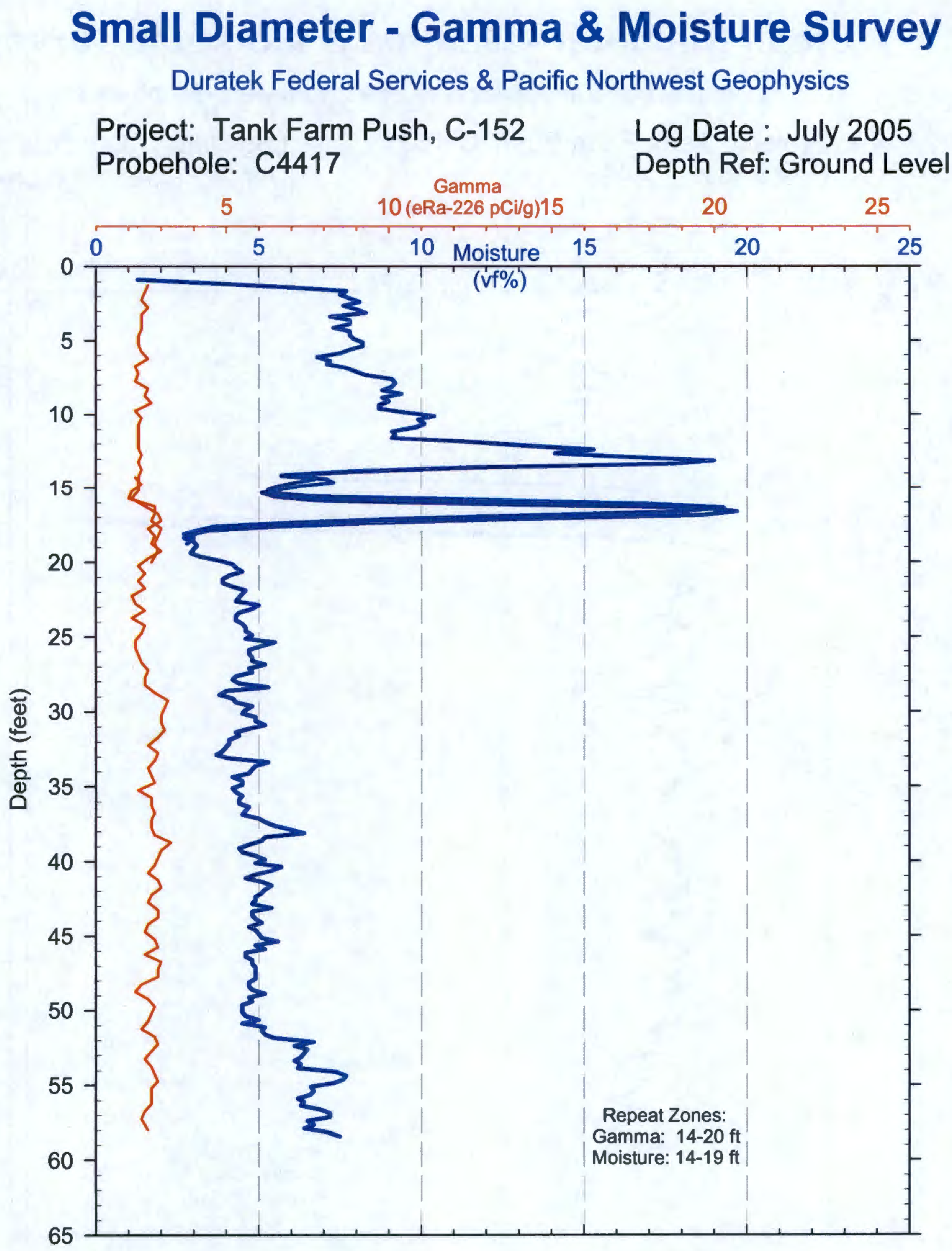
Duratek Federal Services & Pacific Northwest Geophysics

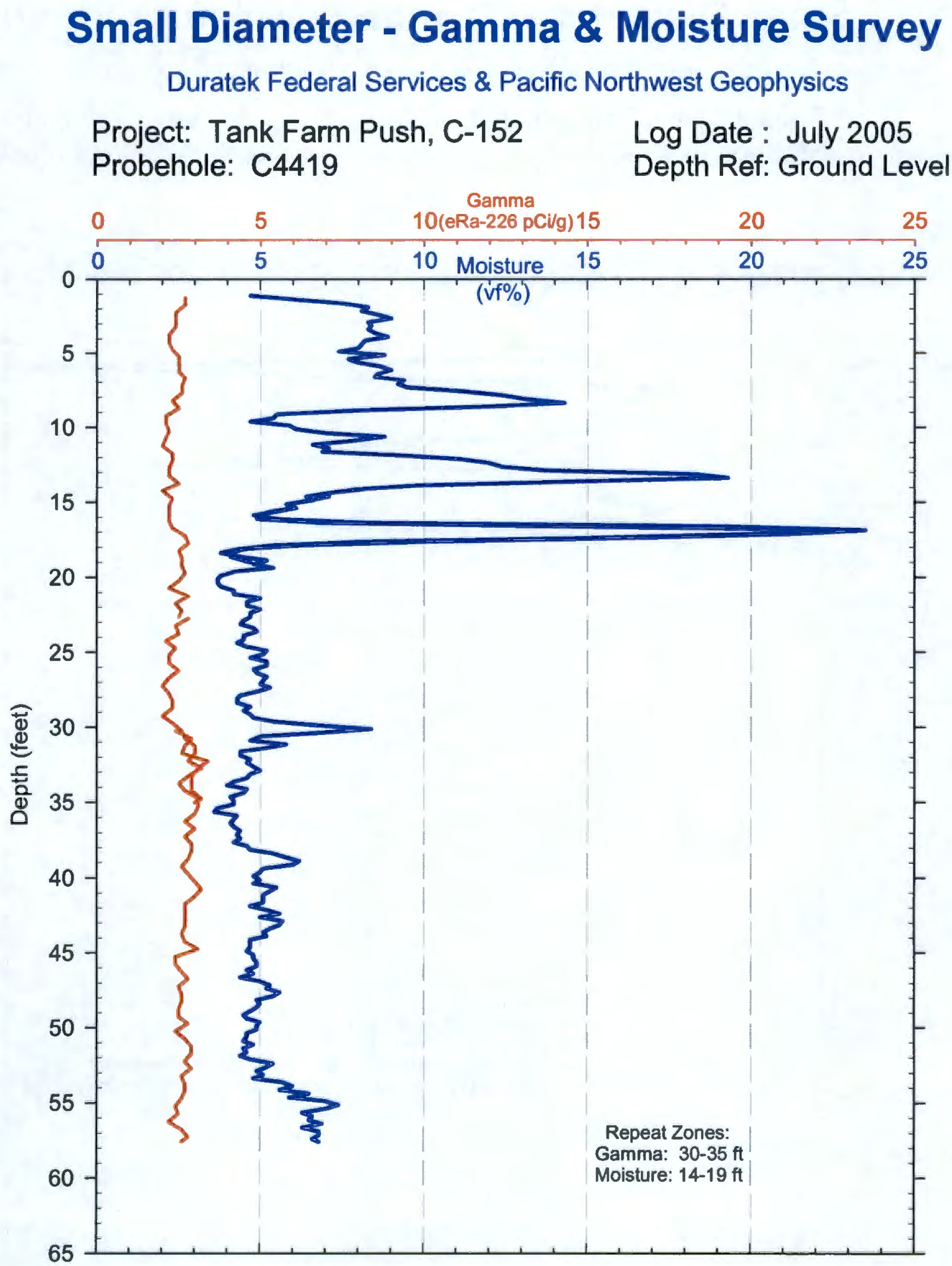
Project: Tank Farm Push, C-152
Probehole: C4413

Log Date : July 2005
Depth Ref: Ground Level




Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4415
Log Date : July 2005
Depth Ref: Ground Level
Gamma
(eRa-226 pCi/g)
0
5
10
15
20
25
Moisture
(vf%)
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zones:
Gamma: 28-32 ft
Moisture: 13-17 ft


Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4417
Log Date : July 2005
Depth Ref: Ground Level
Gamma
5
10 (eRa-226 pCi/g) 15
20
25
0
5
10
Moisture (vf%)
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zones:
Gamma: 14-20 ft
Moisture: 14-19 ft



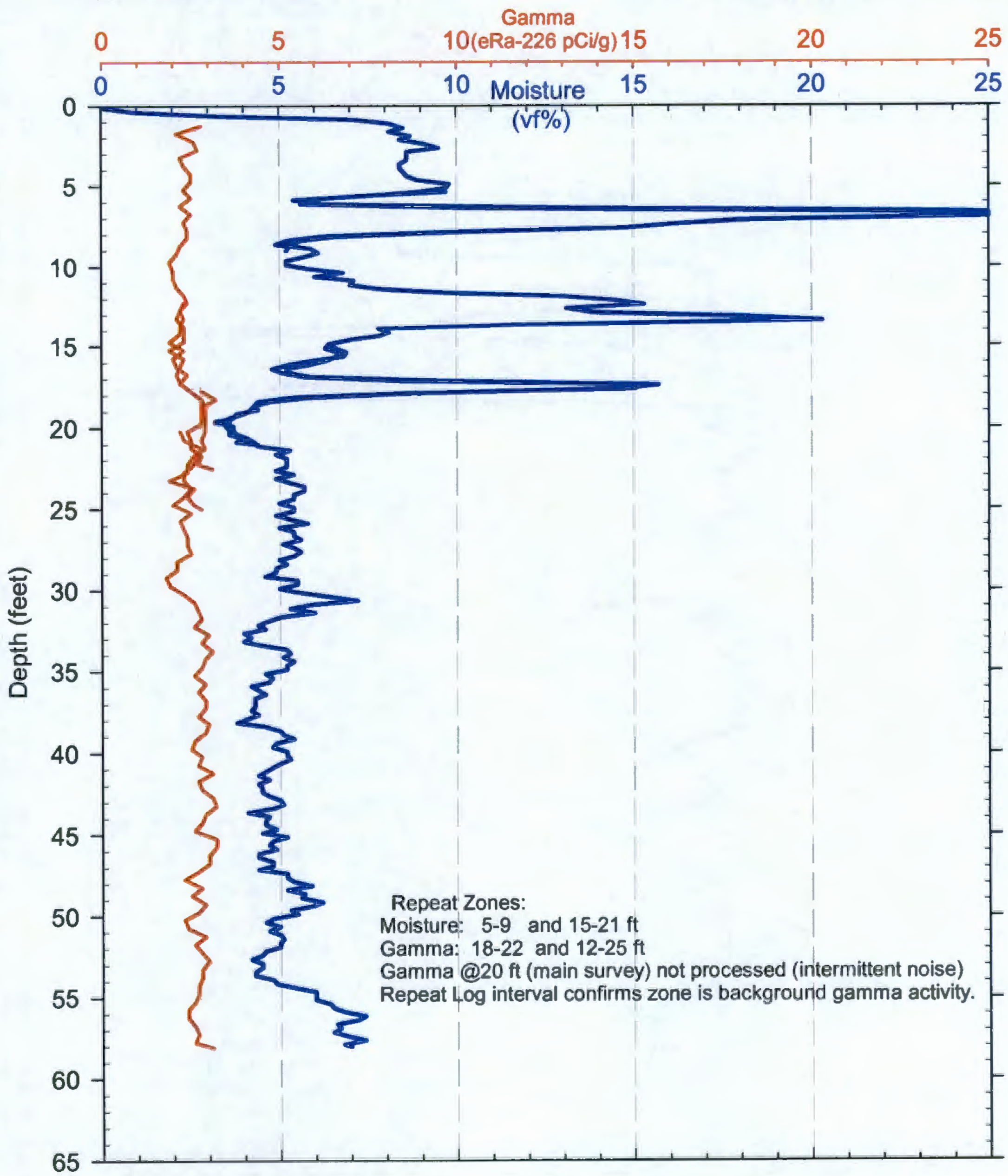
Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4419
Log Date : July 2005
Depth Ref: Ground Level
Gamma
(eRa-226 pCi/g)
0
5
10
15
20
25
Moisture
(vf%)
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zones:
Gamma: 30-35 ft
Moisture: 14-19 ft

Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4421

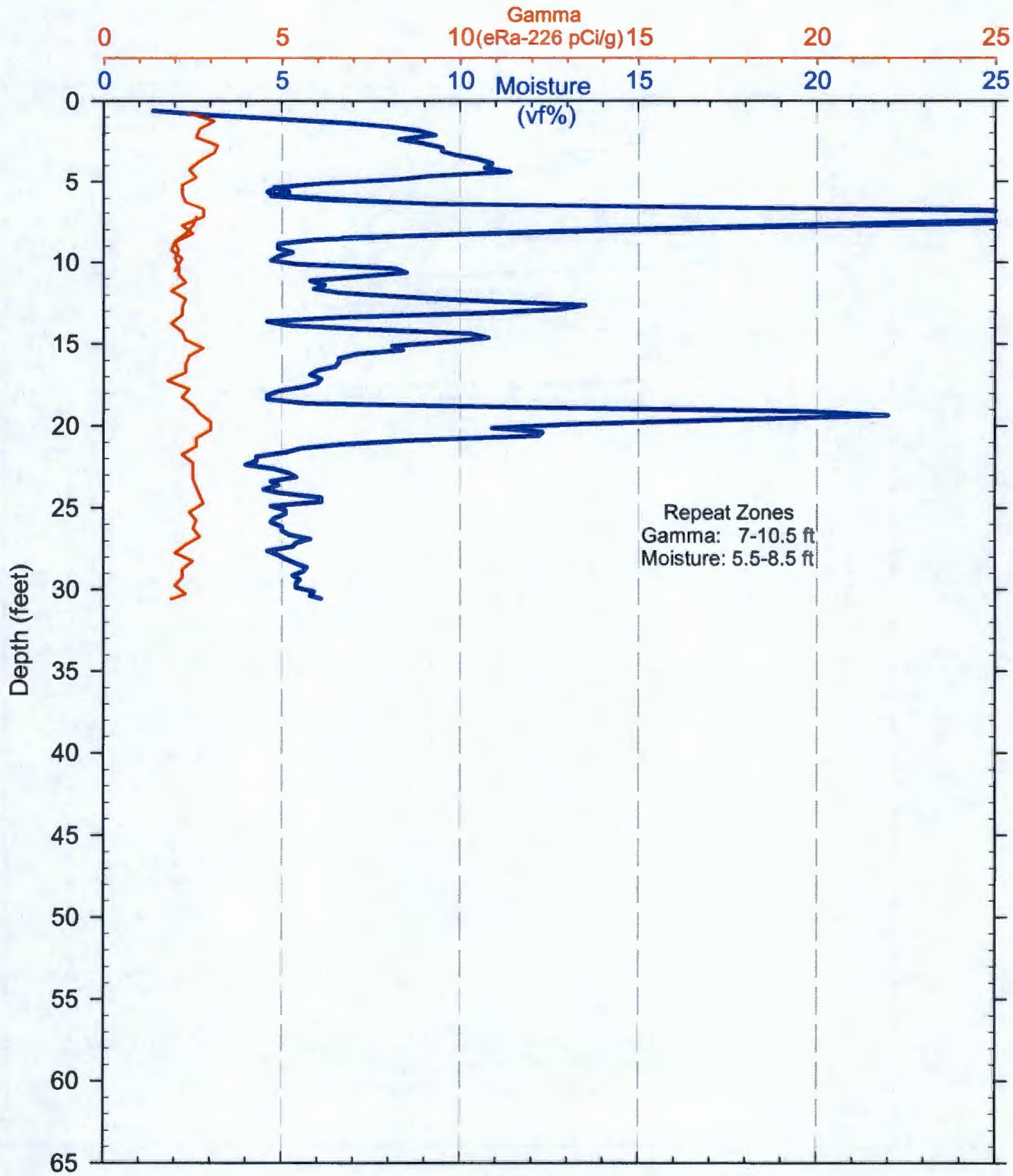
Log Date : July 2005
Depth Ref: Ground Level



Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152 Log Date: August 2005
Probehole: C4425 Depth Ref: Ground Level

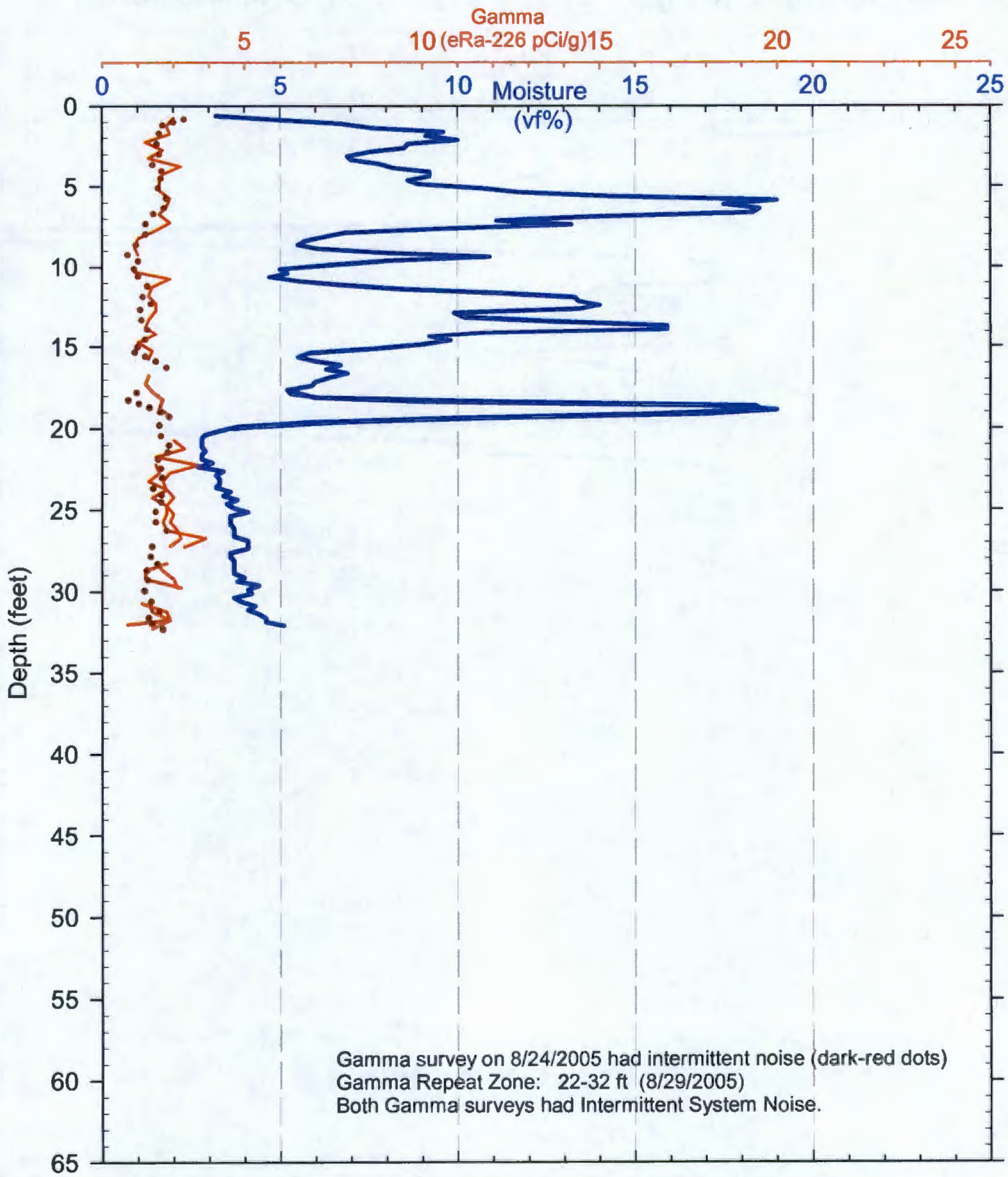


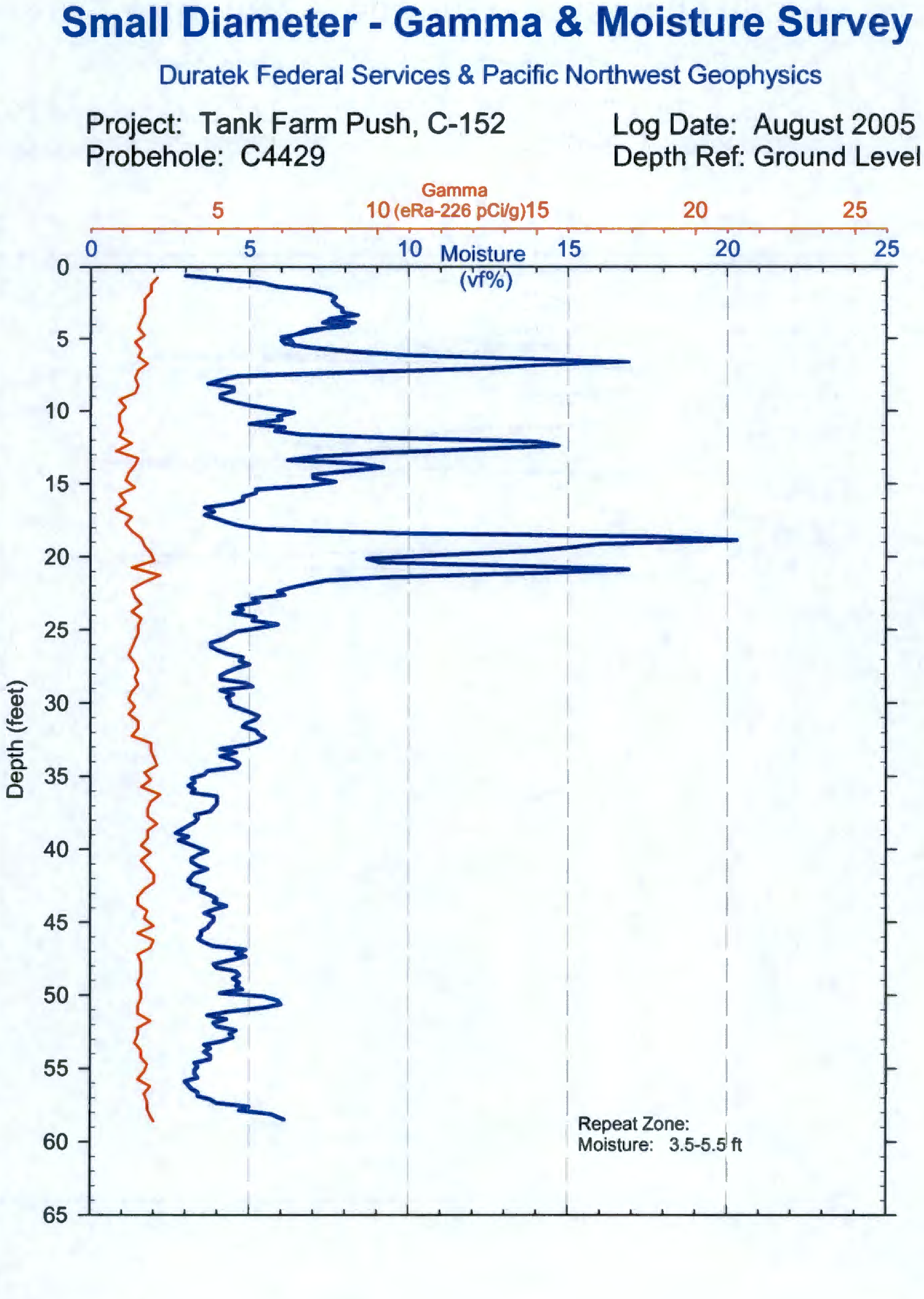
Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

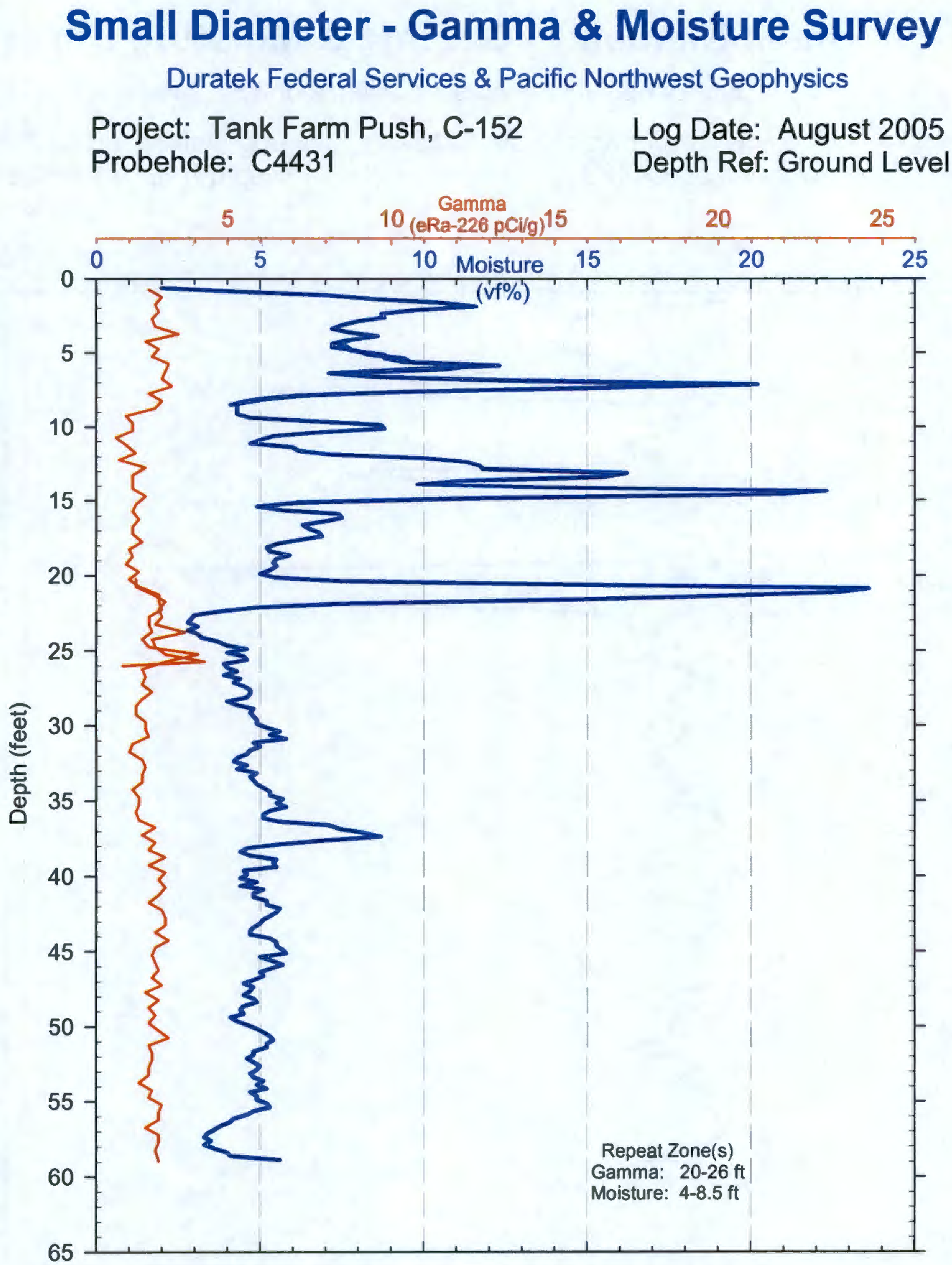
Project: Tank Farm Push, C-152
Probehole: C4427

Log Date: August 2005
Depth Ref: Ground Level





Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4429
Log Date: August 2005
Depth Ref: Ground Level
Gamma
10 (eRa-226 pCi/g)15
5
20
25
Moisture
(vf%)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone:
Moisture: 3.5-5.5 ft

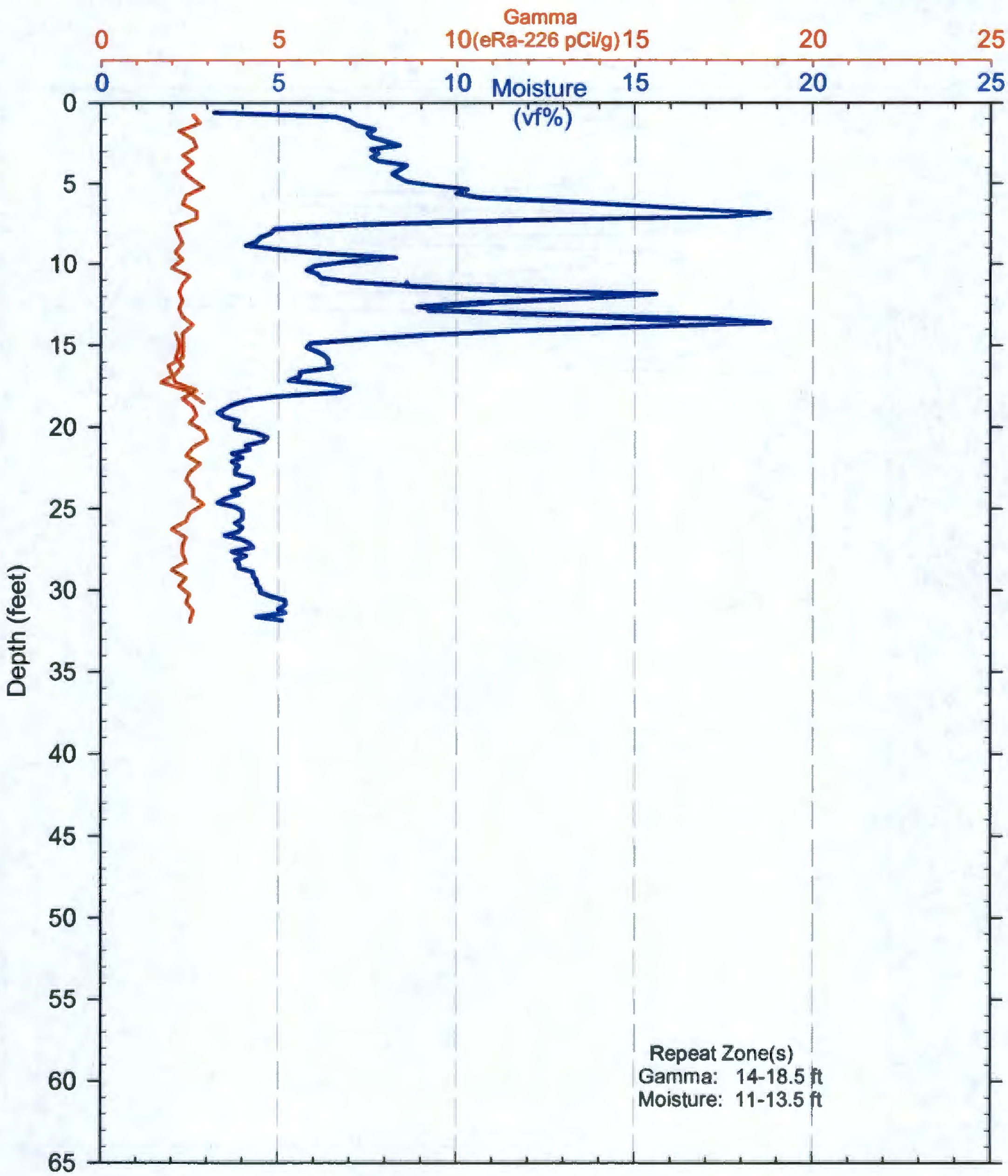

Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4431
Log Date: August 2005
Depth Ref: Ground Level
Gamma (eRa-226 pCi/g)
5
10
15
20
25
Moisture (vf%)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone(s)
Gamma: 20-26 ft
Moisture: 4-8.5 ft

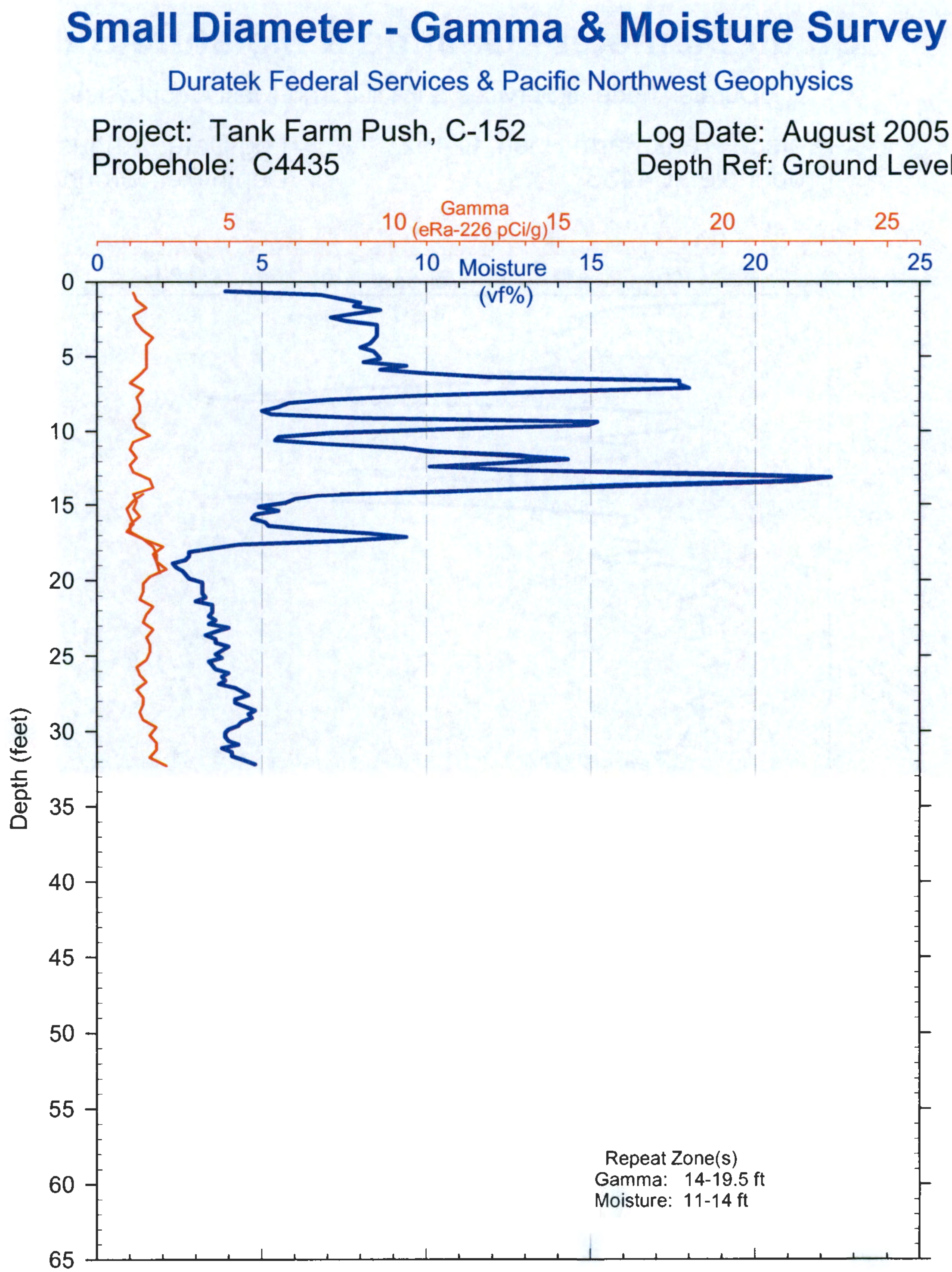
Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4433

Log Date: August 2005
Depth Ref: Ground Level



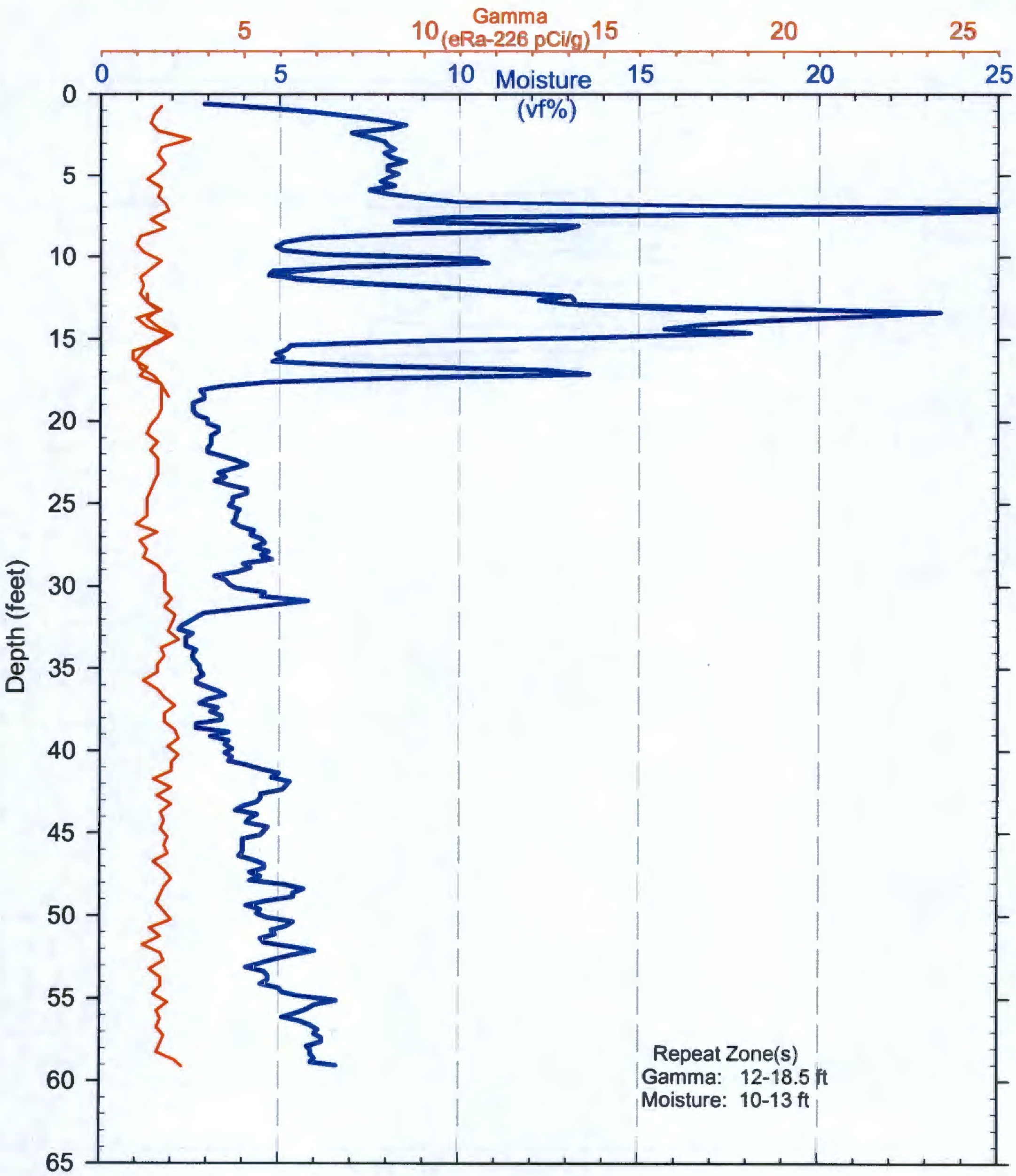

Small Diameter - Gamma & Moisture Survey
Duratek Federal Services & Pacific Northwest Geophysics
Project: Tank Farm Push, C-152
Probehole: C4435
Log Date: August 2005
Depth Ref: Ground Level
Gamma (eRa-226 pCi/g)
5
10
15
20
25
Moisture (vf%)
0
5
10
15
20
25
Depth (feet)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Repeat Zone(s)
Gamma: 14-19.5 ft
Moisture: 11-14 ft

Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4437

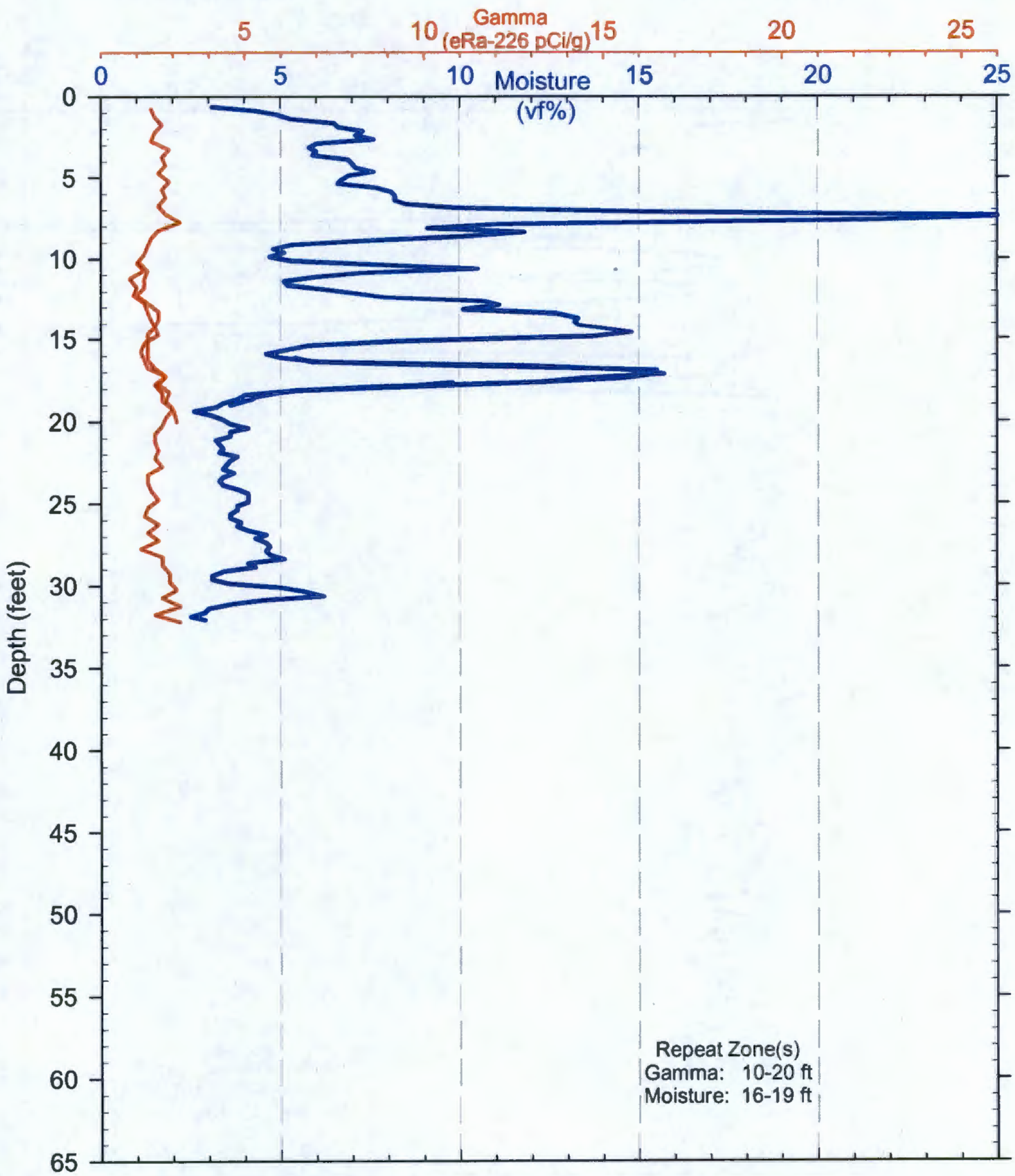
Log Date: August 2005
Depth Ref: Ground Level



Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152 Log Date: August 2005
Probehole: C4439 Depth Ref: Ground Level

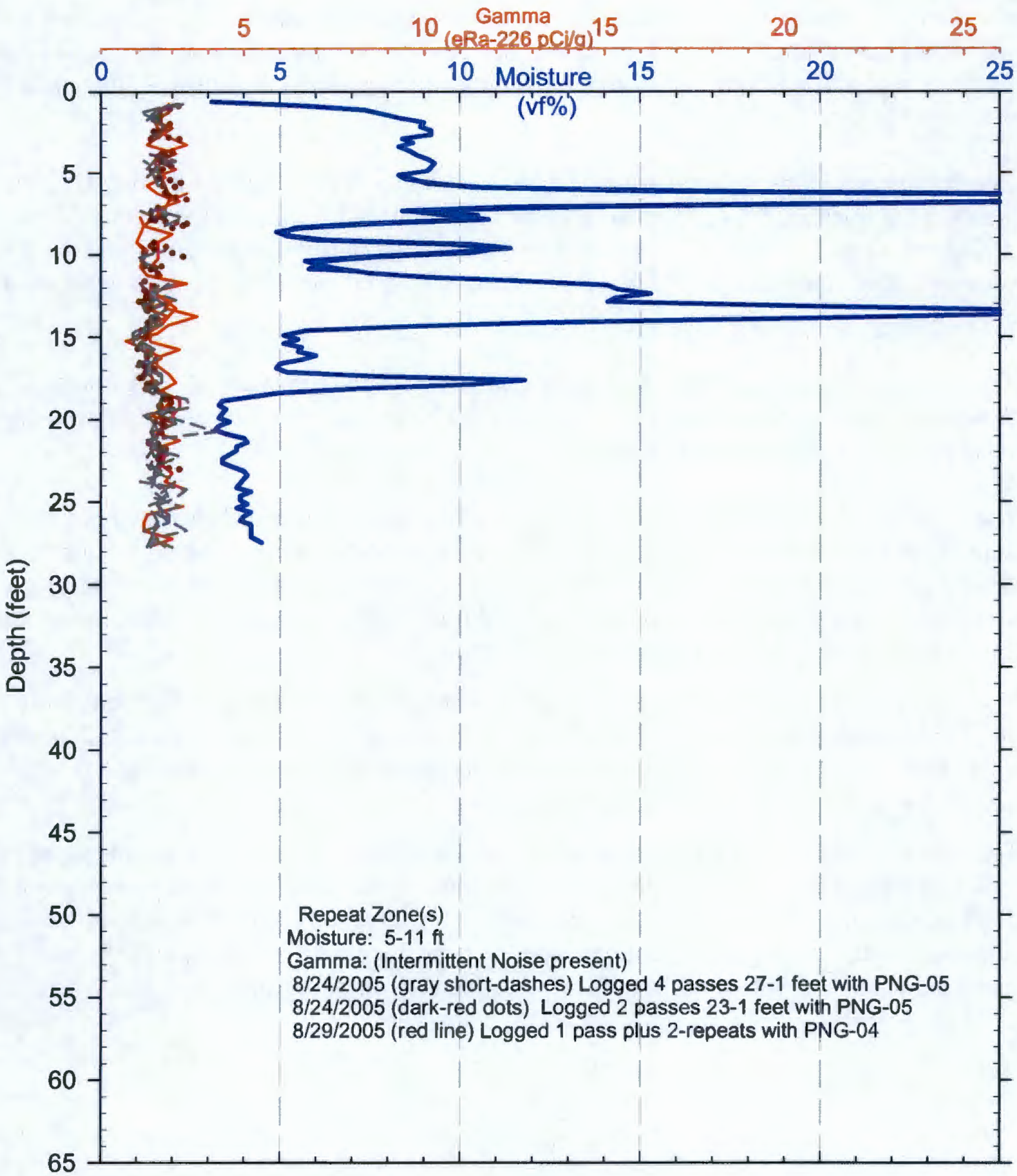


Small Diameter - Gamma & Moisture Survey

Duratek Federal Services & Pacific Northwest Geophysics

Project: Tank Farm Push, C-152
Probehole: C4447

Log Date: August 2005
Depth Ref: Ground Level



APPENDIX B: SPECTRAL GAMMA SURVEY RESULTS

Spectral Gamma surveys were collected in two probe holes. The survey interval in each probe hole (C4409:21-30 ft and C4417:14-20 ft) was selected based on a transition from lower to higher activity identified in the gross gamma survey and significant moisture content changes (from low to high) within the interval.

The spectral gamma survey data were processed to quantify the concentrations of KUT (the three natural radionuclides) and are presented graphically below. These log responses are typical of spectral gamma surveys from other detector types (i.e. high purity germanium) that are collected with comparable counting times. If better precision is desired then longer counting times are required.

The Gross Gamma response for both surveys clearly shows the transition in the gamma activity of the subsurface formation materials. Review of the KUT log responses with the gross gamma response reveals some interesting points.

- The potassium values show a relatively smooth response (confirming the good precision) with small incremental change between successive depth locations. The potassium distribution follows the general trend of the gross gamma response, however detail differences are quickly observed. This general trend indicates that a significant percentage of the gross gamma response is generated from potassium.
- The relatively high concentrations of potassium (range from 12 to 20 pCi/g) contribute to the good measurement precision. The concentration of uranium and thorium are both much lower (less than 1 pCi/g) and the computed concentrations have lower precision (high uncertainty) as a percentage of the concentration.
- The thorium values show lower precision as indicated by large incremental change between values at successive depth locations and by the noticeable difference in values between the main survey and repeat spectra measurements. The general trend of thorium compares relatively well with the gross gamma response, which indicates that a percentage of the gross gamma response is generated from the low concentration of thorium.

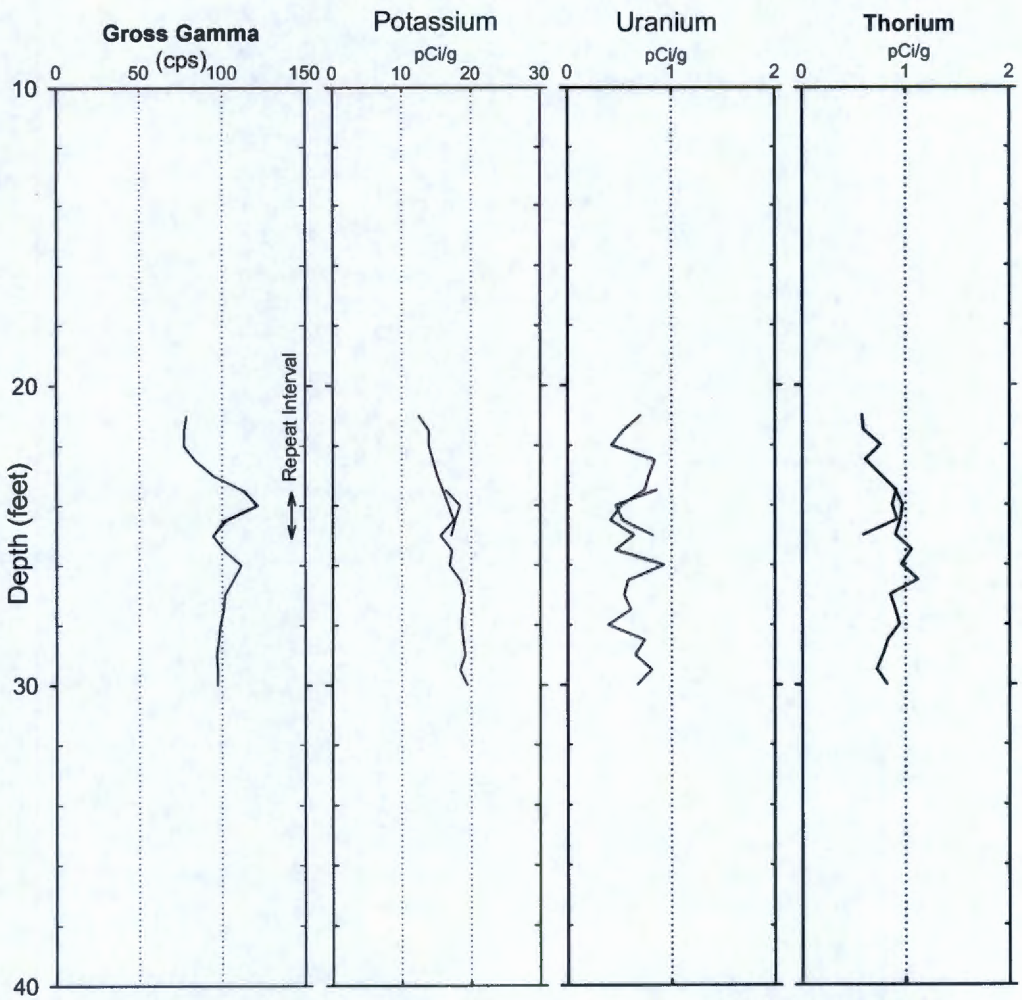
- The uranium values show the lowest precision of the three radionuclides. This is indicated by (1) large difference between the main and repeat survey measurements, (2) very large incremental changes between the sample depths, (3) no noticeable change in the apparent uranium concentration, within the survey interval, which also confirms the large measurement uncertainties, (4) the large uncertainty in uranium concentration is masking the minor concentration changes that may be present in the subsurface formation materials, and (5) the lack of noticeable change in uranium concentration within the survey interval, which means that the computed uranium content can not be used to construct a computed gross gamma response.

Small Diameter Logging Service
BGO Scintillator Survey

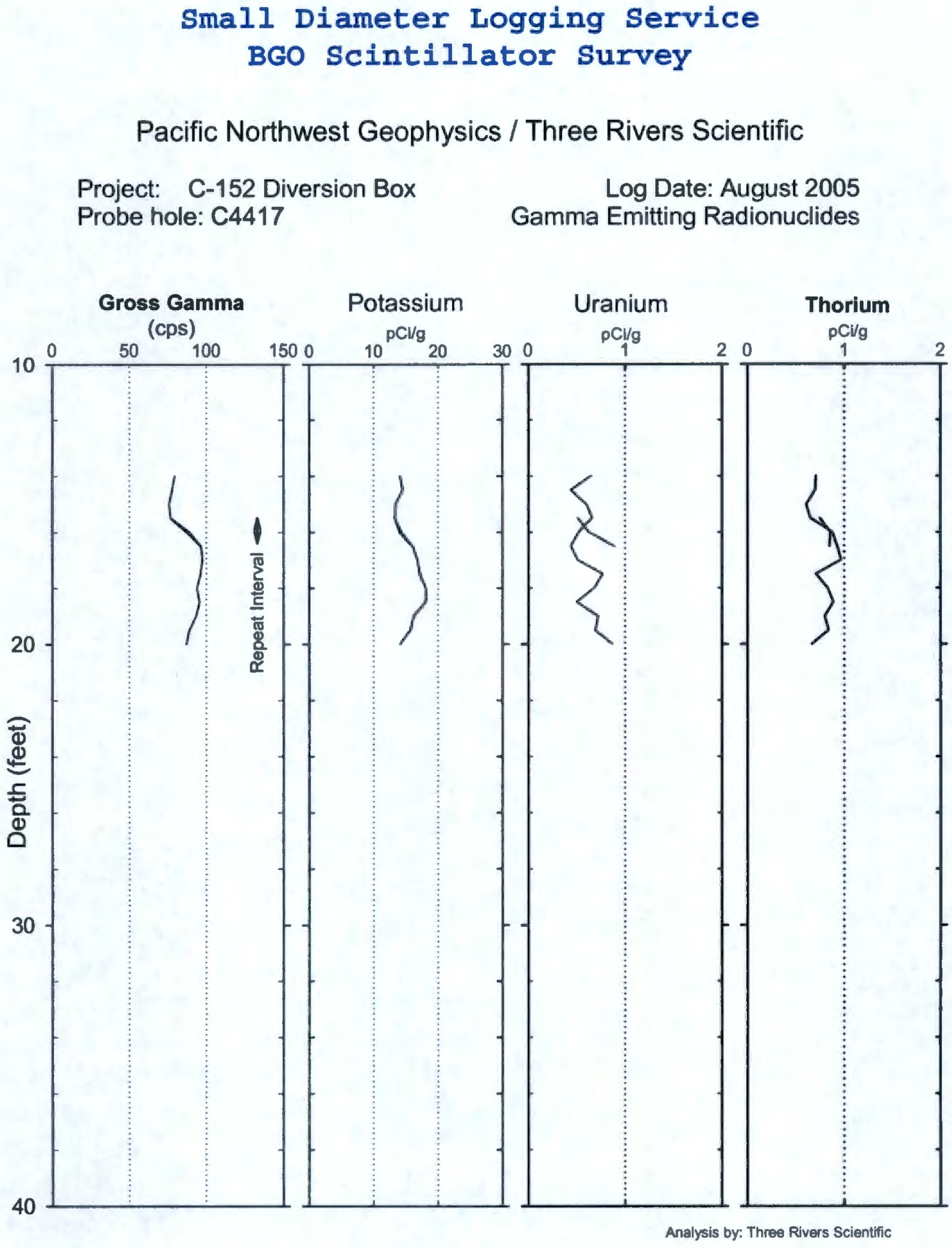
Pacific Northwest Geophysics / Three Rivers Scientific

Project: C-152 Diversion Box
Probe hole: C4409

Log Date: August 2005
Gamma Emitting Radionuclides



Analysis by: Three Rivers Scientific



Small Diameter Logging Service
BGO Scintillator Survey
Pacific Northwest Geophysics / Three Rivers Scientific
Project: C-152 Diversion Box
Probe hole: C4417
Log Date: August 2005
Gamma Emitting Radionuclides
Gross Gamma
(cps)
0
50
100
150
Potassium
pCi/g
0
10
20
30
Uranium
pCi/g
0
1
2
Thorium
pCi/g
0
1
2
10
20
30
40
Depth (feet)
Repeat Interval
Analysis by: Three Rivers Scientific