PNNL-13198

Borehole Data Package for the 216-S-10 Pond and Ditch Well 299-W26-13

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1.0 Introduction

One new Resource Conservation and Recovery Act (RCRA) groundwater monitoring well was installed at the 216-S-10 pond and ditch during November and December 1999 in fulfillment of Tri-Party Agreement (Ecology 1996) milestone M-24-42. The well is 299-W26-13 and is located at the northeast corner to the 216-S-10 pond, southwest of 200 West Area. The well is a new downgradient well in the monitoring network. Figure 1 shows the locations of all wells in the 216-S-10 pond and ditch monitoring network.

The new well was constructed to the specifications and requirements described in Washington Administrative Code (WAC) 173-160 and WAC 173-303, the groundwater monitoring plan for the 216-S-10 pond and ditch (Airhart et al. 1990), and the description of work for well drilling and installation.[1] During drilling and construction of well 299-W26-13, sampling and analysis activities were done to support remedial action, closure decisions at treatment, storage and disposal facilities, and to confirm preliminary site conceptual models developed in the 200-CS-1 Work Plan (DOE/RL 1999).

This document compiles information on the drilling and construction, well development, pump installation, and sediment and groundwater testing applicable to well 299-W26-13. Appendix A contains the Well Summary Sheet (as-built diagram), the Well Construction Summary Report, and the geologist's log. Appendix B contains results of field and laboratory determinations of physical and chemical properties of sediment samples. Appendix C contains borehole geophysical logs. Additional documentation concerning well construction is on file with Bechtel Hanford, Inc., Richland, Washington.

English units are used in this report to describe drilling and well completion activities because that is the system of units used by drillers to measure and report depths and well construction details. Conversion to metric is made by multiplying feet by 0.3048 to obtain meters or multiplying inches by 2.54 to obtain centimeters.

2.0 Well 299-W26-13

2.1 Drilling and Sampling

Well 299-W26-13 was drilled with a cable tool drill rig and drive barrel between 0 and 52 ft, 90.7 and 152 ft, and 170 to 240.7 ft below ground surface (bgs). Air rotary was used to drill between 52 and

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1 Letter from R. M. Smith, Pacific Northwest National Laboratory, Richland, Washington, to G. C. Henckel, Bechtel Hanford, Inc., dated May 26, 1999, "Description of Work for Drilling of CY 1999 RCRA Groundwater Monitoring Wells."

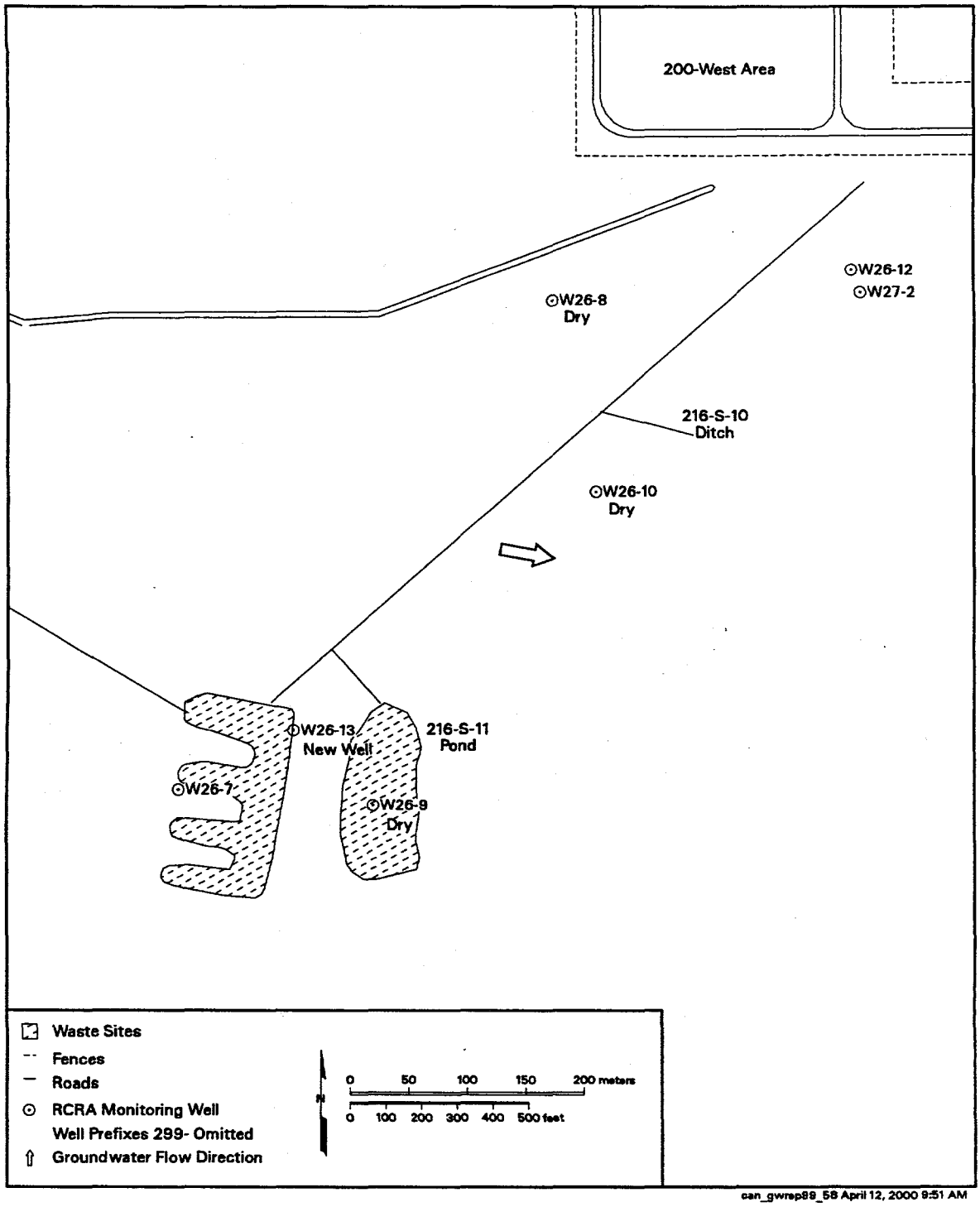

Figure 1. Map of 216-S-10 Pond and Ditch and Locations of Wells in the Groundwater Monitoring Network

90.7 ft and between 152 and 170 ft bgs. Temporary 11 ¾-in.-outside-diameter, carbon steel casing was placed from 0 to 36.3 ft bgs and temporary 8 5/8-in.-outside-diameter, carbon steel casing was used between 0 and total depth (240.7 ft bgs).

Grab samples of sediment for geologic description and archive were collected at approximately 5 ft intervals from 40 ft to total depth. Also, nine 2-ft-long spoon samples were collected for chemical and/or physical properties analyses. Section 3.0 describes the details of sampling and analysis of vadose zone sediments in support of the 200-CS-1 Operable Unit. The results of laboratory analyses are in Appendix B.

Sediments encountered during drilling were predominantly silty to slightly silty sand with minor sand and gravelly sandy silt of the Hanford formation from the surface to about 110 ft bgs; Plio-Pliestocene sandy silt and calcareous sandy silt and silty sand from about 110 to 139 ft bgs; and gravelly sand and sandy gravel of the Ringold Formation from 139 to 240 ft bgs (total depth). A geologist's log is included in Appendix A. The groundwater monitoring plan for the 216-S-10 pond and ditch (Airhart et al. 1990) describes the hydrogeology of the 216-S-10 pond and ditch area.

The borehole and drill cuttings were monitored regularly for organic vapors and radionuclide contaminants. No man-made contamination was noted. The well was geophysically logged using high resolution, spectral gamma-ray and neutron-neutron moisture instrumentation. No man-made radionuclides were detected. The geophysical logs are in Appendix C.

2.2 Well Completion

The permanent casing and screen were installed in well 299-W26-13 in December 1999. A 4-in.-inner-diameter, stainless steel, continuous wire-wrap (0.01-in. slot) screen was set from 237.3 to 202.2 ft bgs. The permanent casing is 4-in.-inside-diameter, stainless steel from 202.2 ft bgs to 2.9 ft above ground surface. The bottom of the screen has a 4-in. PVC end cap to facilitate later deepening of the well if necessary.

The filter pack is 20 to 40 mesh silica sand from 237.3 to 190.7 ft bgs. The annular seal is bentonite crumbles from 190.7 to 10.3 ft bgs and Portland cement from 10.3 ft to the surface. A 4 ft by 4 ft by 6 in. concrete pad was placed around the well at the surface. A protective casing with locking cap, four protective steel posts, and a brass marker stamped with the well number were set into the concrete. The Well Construction Summary Report and the Well Summary Sheet (as-built) are included in Appendix A.

The vertical and horizontal coordinates of the well were surveyed in March 2000. The horizontal position of the well was determined by Global Positioning System observations referenced to horizontal control stations established by Rogers Surveying, Inc., Richland, Washington. The coordinates are Washington Coordinate System, South Zone, NAD83(91) datum. Vertical datum is NAVD 1988 and is based on existing bench marks established by the U.S. Corps of Engineers. Survey data are included in Table 1. The static water level was 200.05 ft bgs on December 13, 1999.

Table 1. Survey Data for Well 299-W26-13 at the 216-S-10 Pond and Ditch

Well Name	Easting m (ft)	Northing m (ft)	Elevation m (ft)	
299-W26-13	566,424.387 (1,858,342.122)	133,293.598 (437,313.635)		Center of Casing
			199.815 (655.559)	"X" on Casing
	566,424.589 (1,858,342.784)	133,293.974 (437,314.869)	199.037 (653.007)	Brass Cap

2.3 Well Development and Pump Installation

Well 299-W26-13 was developed in December 1999. A temporary, submersible pump was used to remove approximately 9,850 gal of formation water from the well at an initial rate of 18 gal/min and a final rate of 11 gal/min. The pump intake was at 227.9 ft bgs. The approximate drawdown was 12 ft and the final turbidity was 11.5 NTU.

A dedicated Hydrostar sampling pump was installed in well 299-W26-13 in January 2000. The sampling pump intake is at about 205 ft bgs or about 5 ft below the water table.

3.0 Vadose Zone Sampling and Analysis

3.1 Sampling

This section describes the collection and analysis of vadose zone samples from well 299-W26-13 in support of the 200-CS-1 Operable Unit.

3.1.1 Field Screening

Soil samples were screened in the field prior to sample collection for indications of contamination and to assist with the determination of sample points during drilling. Samples were screened for volatile organic contamination, beta-gamma activity, and alpha activity. Radiological screening was performed by radiation control technicians with an E-600 ratemeter using a SHP380-A/B scintillation probe. Beta-gamma activities during drilling were at or below background (200 to 300 counts per minute) for all sampled intervals. However, a zone of natural occurring radiation was encountered at approximately 197 ft bgs. Radiological field screening indicated a reading of 1,400 cpm of beta-gamma activity. A sample of the material (sample number RCF6872) was sent to the Radiological Counting Facility for analysis. The results indicated that the activity was associated with naturally occurring short-lived

daughter products of uranium-238 and thorium-232. Volatile organic screening was performed with a photoionization detector. No volatile organics were detected during drilling.

3.1.2 Borehole Sampling

Soil samples were collected for analysis of chemical and radiological constituents and for determination of physical properties. The chemical and radiological analyses were done to assess the nature and vertical extent of chemical and radiological contamination. Analyzed constituents included volatile organic and semi-volatile organic compounds, including polychlorinated biphenyls (PCBs), inorganics (metals), total petroleum hydrocarbons, anions, and radionuclides. Physical properties analyses were done to provide input parameters for flow and transport models. Sample collection was guided by the sample schedule in DOE/RL 1999, Appendix B, Tables B.3 to B.5. Samples were analyzed selectively for the following physical properties: field bulk density (using the Bechtel Hanford, Inc. procedure EIP 3.9, Determination of Field Bulk Density Using a Split-spoon Sampler), particle size distribution (by the method ASTM D422), and moisture content (by the method ASTM D2216).

All soil samples were collected with a split-spoon sampler according to BHI-EE-01, Procedure 4.0, "Soil and Sediment Sampling."[1] A total of 10 soil samples were collected from the borehole including 3 quality control samples. The sample locations with respect to ground surface are shown in Figure 2. All analytical results are in Appendix B.

3.1.3 Geophysical Logging

Spectral gamma-ray and neutron-neutron geophysical surveys were conducted in borehole 299-W26-13. Logging was performed between December 9 and 10, 1999. The spectral gamma-ray and neutron-neutron tools were used to determine the concentration of individual man-made and naturally occurring gamma-emitting radionuclides and the volume fraction of moisture (volume of water/volume total) in the soil column. The spectral gamma-ray tool was run from ground surface to a depth of 240.5 ft bgs. Data were collected in four log runs within the temporary, 11- and 8-in.-diameter casings. Two of these log runs were repeat sections to assess repeatability of measurements. Measurements were made at a move-stop-acquire mode and at a rate of 100 seconds per 0.5 ft.

The moisture tool was run from the bottom of the 11-in.-diameter casing to groundwater (36.3 ft to ~200.5 ft). Data were collected in two log runs that include a repeat section. Moisture data were acquired at a continuous logging speed of 1.0 ft per minute. Ground surface to 36.3 ft was not logged with the moisture tool because it is not calibrated for an 11-in. casing. A detailed report of logging operation is provided in Appendix C. The report describes calibration requirements, data processing, and log plots.

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1 Bechtel Hanford, Inc., Richland, Washington.

299-W26-13

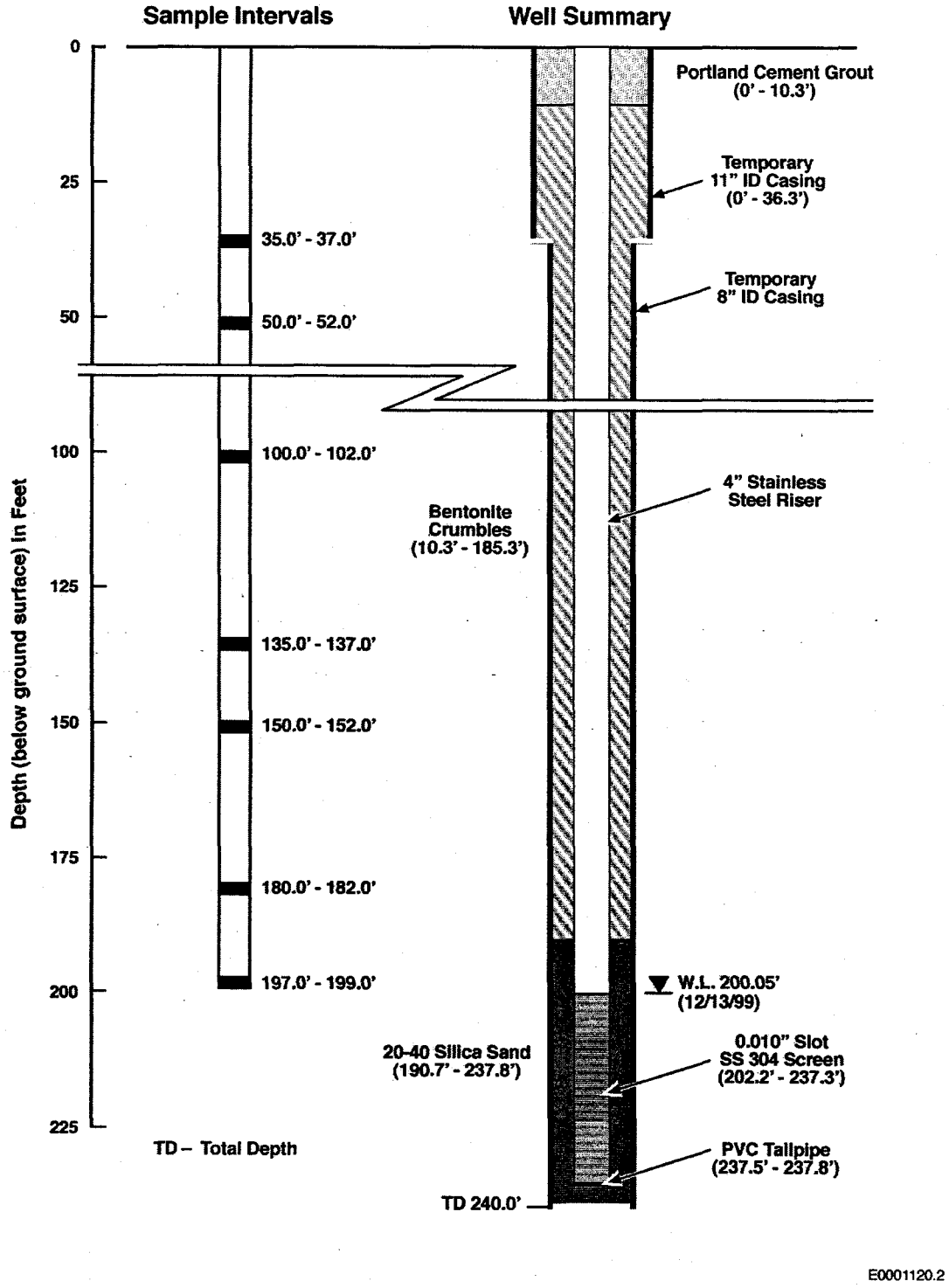


Figure 2. Well Summary and Sampled Vadose Zone Intervals

3.2 Results

Results from the soil sampling and analyses phase of the 299-W26-13 borehole are described in this section. The section includes a discussion of chemical and radiological analyses, physical property testing, geophysical logging data, and quality control.

3.2.1 Chemical Analyses

Samples for chemical analyses were sent to an offsite laboratory. All of the analytical results are provided in Tables B.1 through B.7 of Appendix B.

Metal analyses were conducted on all samples and the results are provided in Table B.1. Silver was the only metal not detected in any sample. Arsenic, barium, beryllium, cadmium, total chromium, copper, mercury, nickel, lead, vanadium, and zinc were detected in most of the samples. The concentrations of these metals are generally near or below the Hanford Site background concentrations (DOE/RL 1995). Cadmium and selenium were detected in four samples from 135 to 199 ft bgs with maximum concentrations of 0.5 mg/kg and 1.9 mg/kg, respectively. Hexavalent chromium was detected only in the 197 to 199 ft bgs interval (directly above the water table) at a concentration of 0.97 mg/kg. Hexavalent chromium is present in the aquifer at this location, and its occurrence in the deepest sample may represent residual contamination in the vadose zone as the aquifer drops.

No polychlorinated biphenyls or diesel range organic compounds were found in any of the samples (Table B.2 and Table B.3, respectively).

Analyses for the anions ammonia, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, and sulfide were conducted for the majority of samples and are presented in Table B.4. Cyanide, fluoride, and nitrite were not detected in any sample. The concentrations of the remaining anions were generally less than 5 mg/kg with a maximum concentration of 12.4 mg/kg for sulfate.

Analyses for semivolatile organic compounds were conducted on all samples with the exception of the 135 to 137 ft bgs interval. The only contaminant detected was bis (2-ethylhexyl) phthalate with concentrations ranging from 24 to 230 μg/kg (Table B.5). Bis (2-ethylhexly) phthalate is a common laboratory contaminant and was also detected in the quality control blank for the detected maximum value. No other semivolatile organic compounds were detected in any of the samples.

Analyses for volatile organic compounds were conducted on all samples with the exception of the 135 to 137 ft bgs interval. Three target volatile organic contaminants including acetone, 2-butanone, and methylene chloride were detected (Table B.6). Of these, acetone, and methylene chloride were also detected in the quality control blanks and are likely the result of laboratory cross-contamination. 2-butanone was detected once at a concentration of 12 μg/kg. No other volatile organic compounds were detected in any of the samples.

The laboratory reported a limited number of volatile and semivolatile tentatively identified compounds. No compounds of significant concern were identified as tentatively identified compounds.

3.2.2 Radiological Analyses

Samples for radiological analyses were sent to an offsite laboratory. All of the results for the radionuclide analyses are provided in Appendix B.

Analyses for both man-made and naturally occurring radionuclides were conducted on all radiological samples. The man-made radionuclides strontium-90, nickel-63, and plutonium-239/240 were each detected once at concentrations of 1.57 pCi/g, 2.46 pCi/g, and 0.117 pCi/g, respectively (Table B.7). The nickel-63 and strontium-90 were detected in the duplicate sample at the 50 to 52 ft bgs interval and the plutonium-239/240 was detected in the 99.5 to 101.5 ft bgs interval. No other man-made radionuclides were detected.

The concentration of total uranium was determined for each sample and ranged from 0.46 to 2.14 μg/g (Table B.7). Isotopic analysis for uranium-234, uranium-235, and uranium–238 was conducted for two samples that contained total uranium concentrations above the background level. The concentrations of isotopic uranium compounds detected were less than 0.5 pCi/g.

The concentrations of uranium-238 are generally consistent with those of total uranium (when converted to activity units of pCi/g). The presence of uranium-238 daughter products thorium-230 and radium-226 throughout the vadose zone indicates that the majority of the uranium-238 present is a result of natural rather than nuclear waste disposal processes. Other naturally occurring radionuclides (potassium-40 and thorium-232 plus decay products thorium-228, radium-228, and radium-224) were also detected throughout the vadose zone.

3.2.3 Physical Properties

Samples for determination of pH, particle size distribution, and gravimetric moisture content were sent to an offsite laboratory. Bulk density was calculated for three samples based on field measurements. All of the results are provided in Appendix B.

The field pH measurements ranged from 8.61 to 8.85 (Table B.8). The laboratory pH measurements ranged from 8.1 to 9.1 (Table B.4). The gravimetric moisture content ranged from 2.5 to 11.6%; and bulk density ranged from 1.48 to 2.07 g/cm^3 (Table B.8). Volumetric moisture was also calculated by multiplying the bulk density with the moisture content and dividing by the density of water. Calculated volumetric moisture content ranged from 4.9 to 24.1 (Table B.8). Particle size distribution data are provided in Appendix B.

3.2.4 Geophysical Logging

No man-made radionuclides were detected in borehole 299-W26-13. Plots of naturally occurring radionuclides indicate there are several distinct activity changes at depths of about 50, 102, 133, 195 and 237 ft. Major changes correlate to stratigraphic features and with the moisture log data. Potassium-40 activities typically ranged between 5 and 21 pCi/g; however, a maximum of 34 pCi/g was detected at a

depth of 237 ft. Uranium-238 and thorium-232 activities ranged between 0.5 to 1.8 pCi/g and 0.3 to 1.5 pCi/g, respectively. Background values of potassium-40, uranium-238, and thorium 232 are 16.1, 1.1 and 1.32 pCi/g, respectively (DOE/RL 1996).

Volumetric moisture content ranged between 2 and 15% throughout the logged interval. The maximum value was measured at a depth of 134 ft and correlates to the top of a carbonate-rich zone (caliche). The most obvious features on the moisture plot are the fluctuating values between depths of 90 and 130 ft. These depths correlate to a zone of sand with 1 to 2 in. thick beds of silt to slightly silty sand. Peaks of high moisture are indicative of the finer grained material within the sand.

3.2.5 Quality Control Samples

Quality control samples were collected to evaluate the cross-contamination and laboratory performance. One trip blank and equipment rinsate blank was collected during the field activities.

The trip blank was analyzed only for volatile organics for which no contaminants were detected. The equipment blank was analyzed for volatile and semivolatile organic compounds, anions (except cyanide), metals (excluding hexavalent chromium and mercury), pH, gross alpha and gross beta. One semivolatile compound, di-n-butylphthalate, was detected at an estimated concentration of 1 μg/L. Barium and zinc were also in the equipment blank at concentrations of 1.1 μg/L. No other contaminants were detected.

Comparison of the analytical results for the sample and the field duplicate were acceptable (relative percent difference values within 35%) for most chemical and radiological constituents.

4.0 References

Airhart, S. P., J. V. Borghese, and S. Dudziak. 1990. *Interim-Status Ground-Water Monitoring Plan for the 216-S-10 Pond and Ditch.* WHC-SD-EN-AP-018, Westinghouse Hanford Company, Richland, Washington.

DOE/RL. 1995. *Hanford Site Background: Part 1, Soil Background for Inorganics.* DOE/RL-92-24, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL. 1996. *Hanford Site Background: Part 2, Soil Background for Radionuclides.* DOE/RL-96-12, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE/RL. 1999. *200-CS-1 Operable Unit RI/FS Work Plan and RCRA TSD Unit Sampling Plan.* DOE/RL-99-44, Draft B, U.S. Department of Energy, Richland, Washington.

Ecology - Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1996. *Hanford Federal Facility Agreement and Consent Order.* Document No. 89-10, Rev. 4 (The Tri-Party Agreement), Ecology, Olympia, Washington.

RCRA - Resource Conservation and Recovery Act. 1976. Public Law 94-580, as amended, 90 Stat. 2795, 42 USC 6901 et seq.

WAC 173-160, Washington Administrative Code. *Minimum Standards for Construction and Maintenance of Wells.* Olympia, Washington.

WAC 173-303, Washington Administrative Code. *Dangerous Waste Regulations.* Olympia, Washington.

Appendix A

Well Construction and Completion Documentation

WELL SUMMARY SHEET

Page 1 of 1

Date: 14 Dec 99

Well ID:	B8817	Well Name:	299-W26-13
Location:	216-S-10 Pond	Project:	200-CS-1/RCRA
Prepared By:	T.A. Lee	Date: 14 Dec 99	Reviewed By: DCWeekes	Date: 12/29/99
Signature:	[signature]	Signature:	[signature]

CONSTRUCTION DATA

Description

SS 304 Riser Pipe, 4½" OD, 4" ID, from +2.9 to 202.2 ft. bgs.

Temporary casings: 11¾" carbon steel 0'-36.3'
8⅜" carbon steel 0'-240.0'

Portland cement from 0' to 10.3'

Bentonite crumbles from 10.3 to 185.2 ft bgs

Bentonite holeplug from 185.2 to 190.7 ft bgs.

20-40 Colorado Silica Sand from 190.7 to 237.8 ft bgs.

W.L. = 200.1' bgs, 13 Dec 99, 0800 hrs

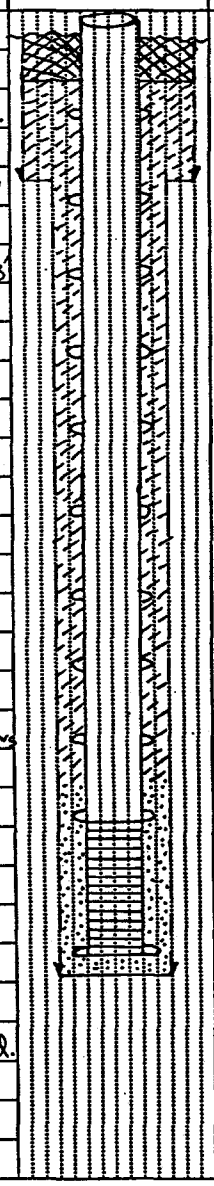
SS 304 Screen, 4½" OD, 4" ID, 0.010" slot, from 202.2 to 237.3 ft bgs.

PVC Schedule 40 tail pipe from 237.3 to 237.8 ft bgs.

All depths in ft. below ground.

All Temporary casings removed.

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description
0		0.0'-7.5' Slightly Silty SAND
		7.5'-12.0' Gravelly SAND
		12.0'-22.0' Silty SAND
		22.0'-36.5' SAND
		36.5'-47.0' Silty SAND
50		47.0'-51.0' Gravelly Sandy SILT
		51.0'-110.0' Silty SAND
100		110.0'-134.0' Sandy SILT
		134.0'-139.0' CALICHE ZONE
150		139.0'-148.0' Silty Sandy GRAVEL
		148.0'-234.0' Sandy GRAVEL
200		Water level = 200.05' (12/13/99)
		234.0'-237.0' SAND
		237.0'-240.7' Sandy GRAVEL
250		T.D. = 240.7' bgs.

BHI-EE-189 (12/97)

WELL CONSTRUCTION SUMMARY REPORT

Finish Date: 12/21/99

Page 1 of 1

Specification No.: 0200X-SP-V0002	Rev. No.: 0	Well Name: 299-W26-13	Temp. Well No.: B8817
ECNs: NA		Approximate Location: 216-S-10 Pond	
Project: RCRA Resource Protection Well		Other Companies: CHI	
Drilling Company: RSI		Geologist(s): B. Raidl, T. Lee	
Driller: Mac			

TEMPORARY CASING AND DRILL DEPTH

*Size/Grade/Lbs. Per Ft.	Interval	Shoe O.D./I.D.
11 3/4" Carbon Steel	0' - 36.3'	11 3/4"/11"
8 3/8" Carbon Steel	0' - 240.0'	8 3/8"/8"
	-	
	-	
	-	

*Indicate Welded (W) - Flush Joint (FJ) Coupled (C) & Thread Design

DRILLING METHOD/HOLE DIAMETER

Auger:	Diameter From		to
Cable Tool:	Diameter From	0'	to 52'
Air Rotary:	Diameter From	52'	to 90.7'
A.R. w/Sonic:	Diameter From		to
Cable tool	Diameter From	90.7'	to 152'
Air Rotary	Diameter From	152'	to 170
Cable tool	Diameter From	170'	to 240.7'

Drilling Fluid: Air

Total Drilled Depth: 240.7'	Hole Dia @ TD: 8 3/8"	Total Amt. Of Water Added During Drilling: —	
Well Straightness Test Results: N/A		Static Water Level: 200.05'	Date: 12-13-99

GEOPHYSICAL LOGGING

Sondes (type)	Interval	Date	Sondes (type)	Interval	Date
gamma/neutron moisture	36.3 - 240.7	12-10-99		-	
	-			-	
	-			-	

COMPLETED WELL

Size/Wt./Material	Depth	Thread	Slot Size	Type	Interval Annual Seal/Filter Pack	Volume	Mesh Size
6"ID Tailpipe ~~SS 304~~	237.8 - 237.3	F480	NA	Colorado Silica Sand	190.7 - 237.3	20 sks	20-40
6"ID Screen SS 304	202.2 - 237.3	F480	0.010	Bentonite Crumbles	10.3 - 185.2		
6"ID Riser SS 304	+2.9 - 202.2	F480	NA	Bentonite hole plug	185.2 - 190.7	2 sks.	
	-			Portland cement	0 - 10.3		
	-				-		

OTHER ACTIVITIES

Aquifer Test: Final Well Development	Date: 12/16-12/20/99	Well Abandoned:	Yes:	No:	Date:
Description: Well developed by pumping. Final rate was 11 gpm with ~12 ft of drawdown.		Description:			

WELL SURVEY DATA

Date:	Protective Casing Elevation:
Washington State Plane Coordinates:	Brass Cap Elevation:

COMMENTS/REMARKS

Reported By: T.A. Lee		Reviewed By: J Davidson	
Title: geologist	Date: 12-13-99	Title: Sr Engineer	Date: 18 Jan 00
Signature: [signature]		Signature: [signature]	

BHI-EE-181 (12/97)

BOREHOLE LOG

Page 1 of 9
Date: 18 NOV 1999

Well ID: B BB17 | Well Name: 299-W26-13 | Location: 216-S-10 Pond

Project: 200-CS-1/RCRA | Reference Measuring Point: Ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
0				0.0 - 1.5' FILL : Imported angular	Cable tool. Using
				gravel mixed into sand for drilling	drive barrel inside
				pad. Max. size 4"	11 3/4 CS temp casing
				1.5' - 7.5 ft SLIGHTLY SILTY SAND ; (mS). fine to med,	
				very slight moist, approximately 90-95%	
5				sand, 10% fines (silt); no cohesiveness.	
				well sorted, sub ang. grayish brn 10YR 5/2	
				7.5-12 (gS) Gravelly Sand; fine to coarse	
				w/trace very fine pebbles; 75% basaltic	
				sand which is f-med and 25% qtz and	
10				felsic frags. which are med-crse, dry, trace silt	
				subang-subrd., dark gray 2.5Y N4	
				12-19 ft Slightly Silty Sand (m)S; Fine-	
				to med sand, well sorted, 95% sand,	
				5% silt (fines, non cohesive], subang to	
15				subrounded, sl. moist, max size = crse	19 NOV 99
				sand, non reactive, lt olive brn 2.5Y 5/4	
				19-22 ft SILTY SAND mS ; Fine to	
				med sand, well sorted, sl. moist w/10-15%	
				fines (non cohesive), lenses of silt and fine	
20				sand react. w/HCl, subrd - subang. max size	
				3-4 in, rounded grav. lt brngray 2.5Y 6/2	
				22 - 36.5 ft SAND (s); fine to medium	
				sand, well sorted, sl. moist, subrd - subang,	
				very clean, max size = crse sand. olive brn	
25				2.5Y 4/3	

Reported By: RF Raidl | Reviewed By: DC Weekes

Title: Geologist | Title: Geologist

Signature: RF Raidl | Date: 18 NOV 9 | Signature: DC Weekes | Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date: 19 Nov 1999

Well ID: B8817 | Well Name: 299-W26-13 | Location: 216-S-10 Pond

Project: 200-CS-1/RCRA | Reference Measuring Point: Ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
30					
35	Split Tube	100%		36.5-41 ft SLIGHTLY SILTY SAND (m) S 90% fine-med sand, subrd to subang, well sorted, max particle size crse sand, ~10% noncohesive fines (prob. silt), mod reaction to HCl, sl. moist, Grayish brn 2.5Y 5/2	35-37: SPT sampler 4"
40	Archive (Grab)			41-44 ft SILTY SAND (mS). 75% fine-med sand, subrd to subang, well sorted, max particle size = 1/4 in, sl. cohesive, mod reac to HCl, vsl. moist, 25% fines	
45	Archive (Grab)			44-47 ft SILTY SANDY GRAVEL msG 60% fine-crse pebbles, max particle size 3-4 in., 30% f-crse sand, 10% sl. cohesive fine, poorly sorted, dry, mod HCl reaction gray 10YR 6/1	
50	Archive (Grab) Split Tube	264 blows / 2.5 ft 100% rec		47-51 GRAVELLY SANDY SILT (gsM) 70% dry, powdery, noncohesive silt, 20% f-crse sand, 10% ang grav to 4 in, mostly 1-2 in. dry, gray 10YR 6/1	Ash?
55	Archive (Grab)			51-85 ft sl. silty sand (m) S 95% f-med sand, subangular to subrded, very well sorted, max particle size = 1/2 inch, v sl. moist, sl reaction to HCl; 10% non cohesive fines olive brn 2.5Y 4/3	

Reported By: RF Raidl | Reviewed By: DCWeekes

Title: Geologist | Title: Geologist

Signature: RF Raidl | Date: 22 NOV 99 | Signature: DC Weekes | Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Page 2 of 7
Date: 22 NOV 1999

Well ID: B8817 | Well Name: 299-W26-13 | Location: 216-S-10 Pond

Project: 200-CS-1/RCRA | Reference Measuring Point: Ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
60	Archive (grab)			Slightly silty Sand (n)S	
				described above	
65	Archive (grab)				
70	Archive (Grab)				
75	Archive (Grab)				
80	Archive (Grab)				
				85-92 SAND w/ silty Intervals (mS)	
85	Archive (grab)			95% f-med sand except for thin	
				1-2" thick silt, or sandy silt beds,	
				subrd to subang, well sorted, max particle	
				size 1/4", dry, sl-mod HCl reac.	
				silty intervals are approx 50%	

Reported By: RF Raidl | Reviewed By: DCWeekes

Title: Geologist | Title: Geologist

Signature: RF Raidl | Date: 22 NOV 1999 | Signature: DCWeekes | Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date:

Well ID: B8817	Well Name: 299-W26-13	Location: 216-S-10 Pond	
Project: 200-CS-1/RCRA		Reference Measuring Point: Ground Surface	

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
90	Archive (grab)			f-med sand > 50% non cohesive	
				fines Grayish brn 2.5Y 5/2	
				92 ft-98 ft Silty Sand mS	
				65% f-med sand, subang-subrd, sl moist,	
				max particle size = v.crse sand, 35% non	Start 23 NOV 99
95	Archive (grab)			cohesive to sl. cohesive fines, sl-mod	
				HCl reaction. light brn 7.5YR 6/3	
				98 ft - 104 SLIGHTLY SILTY SAND	
	Archive			(m)S. 90% f-med sand, subang-subrd,	
100	split spoon (chem)	100% rec 175 blows		sl. moist, max particle size = v. crse sand,	
				10% non cohesive fines, sl HCl reac.	
				light brn 7.5YR 6/3	
				104 - 110 ft SANDY SILT / SILTY SAND	
				INTERBEDS; grades in and out between	
105	Archive (grab)			silt dominated and fine sand dominated;	
				locally more indurated where silt dominated	
				massive. Sandy silt is 60-70% silt (fines)	
				and 30% f-sand; silty sand is opposite	
				in grain size distrib; sl HCL reac., sl. moist	
110	Archive (grab)			lt. brn 7.5YR 6/3.	
				110 - 134.0 Sandy SILT (SM), 90% - 95%	
				sl cohesive fines, indurated, sl. moist	
				locally w/ fine sand, max particle size	
				- med sand, mod HCl reaction, yellowish brn	
115	Archive (grab)			10YR 5/6, iron staining at the base	

Reported By: RF Raidl		Reviewed By: DC Weekes	
Title: Geologist		Title: Geologist	
Signature: RF Raidl	Date: 23 NOV 1999	Signature: DC Weekes	Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date:

Well ID: B8817	Well Name: 299-W26-13	Location: 216-S-10 Pond	
Project: 200-CS-1/RCRA		Reference Measuring Point: Ground Surface	

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
120	Archive (grab)			134 ft - 139 ft - CALICHE ZONE - sandy silt / silty sand (SM/MS), calcareous, 80-85% fines, 15% v f-f sand, <5% occassional gravel, strong HCL RXn, white 10YR 8/1 to yellowish brown 10YR 5/6 gravel increasing toward base. ~~139ft~~	
125	Archive (grab)				start 29 Nov 99
130	Archive (grab)				
	Archive (grab)				Caliche at 134'-139'
135	split spoon (chem/geo)	100% Rec. ~175 blows			start 30 Nov 99
				139ft 148 - SILTY SANDY GRAVEL (msG) 80% basaltic gravel 20% felsic, subrounded - subang; fine-med grained sand, well-sorted; silt non-cohesive; mod RXN to HCL; dark yellowish brown 10YR 4/4 interbedded zones of ~~inte~~ iron stained, hard matrix, very cohesive	
140	Archive (grab)				
145	Archive (grab)				start 1 Dec 99

Reported By: T.A. Lee		Reviewed By: DCWeekes	
Title: geologist		Title: Geologist	
Signature: [signature]	Date: 30 Nov 99	Signature: [signature]	Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date:

Well ID: B8817	Well Name: 299- W26- 73	Location: 216- S- 10 Pond	
Project: 200-CS-1 / RCRA		Reference Measuring Point: Ground Surface	

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
150	Archive (grab) split spoon (chem/Rad)	100% Rec w 100 blows		148ft - 157 ft. ~~GRAVELLY~~ SAND (gS) 80% Sand, 10% gravel, Sand 90% qtz and 10% other (felsic/basalt), fine to coarse, sub rnd - sub ang, slightly moist, trace silt; no RXN to HCL, light yellowish brown 10YR 6/4	end cable tool begin air rotary
155	Archive (grab)				
				157 ft 170 ft - GRAVELLY SAND (gS) 80% Sand and 20% gravel, sand is 80% qtz and 20% other (felsic/basalt), fine to coarse, sub rnd - sub ang; gravel is predominately basalt, sub rnd - sub ang; slightly moist; trace silt; no RXN to HCL; dark yellowish brown 10YR 4/4	
160	Archive (grab)				
165	Archive (grab)				
170	Archive (grab)			170 ft - 179 ft - SANDY GRAVEL (sG) 50% Sand and 50% gravel, sand is 80% felsic and 20% other, fr sub rnd - sub angular, csc - vcsc; gravel is predominately basalt, sub rounded; trace silt; no RXN to HCL; dark yellowish brown 10YR 4/6, trace cobble	end air rotary begin cable tool begin 2 Dec 99
175	Archive (grab)				

Reported By: T. A. Lee		Reviewed By: DCWeekes	
Title: Geologist		Title: Geologist	
Signature: Timothy A Lee	Date: 2 Dec 99	Signature: DCWeekes	Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date:

Well ID: B8817	Well Name: 299-W26-13	Location: 216-S-10 Pond
Project: 200-CS-1/RCRA		Reference Measuring Point: ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCL	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
180	Archive (grab)			179 ft - 195 ft - SILTY SANDY	
	Split spoon (chem/RAD)	100% Rec ~100 blows		GRAVEL (mSG) - 40% gravel,	
				40% sand, 20% silt; gravel is	
				subrnd basalt (50%) and granitics (50%).	start 3 Dec 99
				sand is 60% basalt and 40% other,	
185	Archive (grab)			cse - vcse, angular - subang; trace	
				cobbles; weak Rxn to HCL; dark	
				yellowish brown 10YR 4/6. DRY.	
190	Archive (grab)				start 6 Dec 99
195	Archive (grab)			195 ft - 203 ft - SANDY GRAVEL	
				(sG) - Sand (60%) and Gravel (40%).	
	Split spoon (chem/RAD/phys prop)	100% Rec ~90 blows		Gravel is rounded, predominately	start 7 Dec 99
				granitics; Sand is granitics (70%)	
				and other (30%), fine to cse,	water at 199.5 ft
200	Archive (grab)	collect save sample		subang - subrnd; weak Rxn to HCL;	end cable tool
				light grey 5YR 7/1. Wet at 199.5 ft.	start 8 Dec 99
				(NOTE: At 199.4 ft (at bottom of	begin air rotary
				split spoon sample), RCT detected	
				RAD in soil (~900 dpm above back	
205	Archive (grab)			ground). It was determined to be	
				naturally occurring thorium)	

Reported By: T. A. Lee		Reviewed By: DC Weekes	
Title: geologist		Title: Geologist	
Signature: [signature]	Date: 6 Dec 99	Signature: [signature]	Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Date:

Well ID: B8817	Well Name: 299-W26-13	Location: 216-S-10 Pond
Project: 200-CS-1/RCRA		Reference Measuring Point: ground surface

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
210	Archive (grab)			203 ft – 234 ft – SANDY GRAVEL	
				(SG) Gravel (50%) and Sand (50%);	
				Gravel is rounded, predominately granitics (70%)	
				and other (30%); sand is predominately	
				granitics (80%); fine to cse; sub	
215	Archive (grab)			rounded; weak RxN to HCL;	end air rotary
	split spoon (grab-prep)	75% rec w/ 50 blows		light yellowish brown 10YR 6/4	drive split spoon
				very wet.	begin air rotary
220	Archive (grab)				
	grab (waste designation)				
225	Archive (grab)				
230	Archive (grab)				
	split spoon (sieve)	100% rec w/ 50 blows			end air rotary
					begin cable tool
				234 ft – 237 ft – Sand (S),	
235	Archive (grab)			predominately granitics (85%) and	Start 10 Dec 99
				other; fn – md, subang – subrnd,	
				weak Rxn to HCL; very wet;	
				light gray 5YR 7/1	

Reported By: T.A. Lee		Reviewed By: DC Weekes	
Title: geologist		Title: Geologist	
Signature: [signature]	Date: 8 Dec 99	Signature: DC Weekes	Date: 12/28/99

BHI-EE-183 (12/97)

BOREHOLE LOG

Page 1 of 1

Date:

Well ID: B8817	Well Name: 299-W26-13	Location: 216-S-10 Pond	
Project: 200-CS-1 / RCRA		Reference Measuring Point: ground Surface	

Depth (Ft.)	Sample Type No.	Sample Blows Recovery	Graphic Log	Sample Description: Group Name, Grain Size Distribution, Soil Classification, Color, Moisture Content, Sorting, Angularity, Mineralogy, Max Particle Size, Reaction to HCl	Comments: Depth of Casing, Drilling Method, Method of Driving Sampling Tool, Sampler Size, Water Level
240	Archive (grab)			237 ft - 240.7 ft - SANDY GRAVEL (SG) - Sand (60%) and gravel (40%), gravel is rounded, predominately granitics; trace cobbles; sand is granitics (70%) and other (basalt = 20%), cse, sub ang - sub rnd, weak Rxn to HCL; wet; light gray 5YR 7/1.	TD = 240.7 ft

Reported By: T. A. Lee		Reviewed By: DC Weekes	
Title: geologist		Title: Geologist	
Signature: Tracy Ann	Date: 8 Dec 99	Signature: DC Weekes	Date: 12/28/99

BHI-EE-183 (12/97)

Appendix B

Sediment Samples Physical and Chemical Properties Data

Appendix B

Sediment Samples Physical and Chemical Properties Data

This appendix includes the results of laboratory testing for chemical and physical properties of sediment samples collected during drilling of well 299-W26-13. The analytical methods and the results are discussed in Section 3.0 of this report.

Table B.1. Results of Analyses for Metals in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Silver 7429-90-5 mg/kg	Arsenic 7440-38-2 mg/kg	Barium 7440-39-3 mg/kg	Beryllium 7440-41-7 mg/kg	Cadmium 7440-43-9 mg/kg	Total Chromium 7440-47-3 mg/kg	Copper 7440-50-8 mg/kg	Mercury 7439-97-6 mg/kg	Nickel 7440-02-0 mg/kg	Lead 7439-92-1 mg/kg
35-37	B0X099	11/19/99		0.09 U	3	97.4	0.34	0.04 U	9.4	12.6	0.02 U	10.2	4.2
(Dup)	B0X0B0	11/19/99		0.08 U	3.1	87	0.28	0.04 U	7.9	11.3	0.02 U	9.3	3.9
(Split)	B0X0X4	11/19/99		0.09 U	2.5	45.1	0.30 B	0.03 U	8.9	12.6	--	9.3	3.3
50-52	B0X0B1	11/22/99		0.06 U	2.4	67.2	0.2	0.03 U	12.1	12.1	0.02 U	10.6	10.3
(Dup)	B0X0B2	11/22/99		0.06 U	2.6	52.4	0.2	0.03 U	11.9	10.6	0.02	10	7.2
99.5-101.5	B0X0B3	11/23/99		0.07 U	5.3	85.1	0.35	0.04 U	15.9	13.9	0.02	14	7.3
135-137	B0X0B4	11/30/99		0.07 U	4	95.7	0.3	0.23	7	12.1	--	9.4	3.2
150-152	B0X0B5	12/01/99		0.07 U	3.3	82	0.45	0.28	12.5	18.9	0.02 U	12.3	4.5
180-182	B0X0B6	12/02/99		0.07 U	2.2	124	0.43	0.5	15.5	18	0.02 U	14.7	3.3
197-199	B0X0B7	12/07/99		0.07 U	2.8	70.2	0.2	0.17	39	15.4	0.02 U	25.2	5.2

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Selenium 7782-49-2 mg/kg	Vandium 7440-62-2 mg/kg	Zinc 7440-62-2 mg/kg	Hexavalent Chromium 7440-47-3 mg/kg
35-37	B0X099	11/19/99		0.45 U	63.7	42.7	0.45 U
(Dup)	B0X0B0	11/19/99		0.42 U	53.9	36.5	0.43 U
(Split)	B0X0X4	11/19/99		0.78	56.8	38.3	0.10 U
50-52	B0X0B1	11/22/99		0.30 U	41.9	31.8	0.41 U
(Dup)	B0X0B2	11/22/99		0.29 U	37.4	29.5	0.41 U
99.5-101.5	B0X0B3	11/23/99		0.38 U	36.9	42.8	0.44 U
135-137	B0X0B4	11/30/99		0.85	58.6	32.2	0.44 U
150-152	B0X0B5	12/01/99		1.9	87.5	49.6	0.47 U
180-182	B0X0B6	12/02/99		2	87.1	52.5	0.42 U
197-199	B0X0B7	12/07/99		1.1	25.4	201	0.97

-- = Not analyzed.
U = Analyzed for but not detected. Value reported is the quantitation limit.
B = The analyte was detected in the associated QC blank and in the sample.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.2. Results of Analyses for Polychlorinated Biphenyls in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Aroclor 1016 674-1 µg/kg	Aroclor 1221 11104-28-2 µg/kg	Aroclor 1232 11141-16-5 µg/kg	Aroclor 1242 53469-21-9 µg/kg	Aroclor 1248 12672-29-6 µg/kg	Aroclor 1254 11097-69-1 µg/kg	Aroclor 1260 11096-82-5 µg/kg
35-37	B0X099	11/19/99		49 U	99 U	49 U	49 U	49 U	49 U	49 U
(Dup)	B0X0B0	11/19/99		36 U	72 U	36 U	36 U	36 U	36 U	36 U
(Split)	B0X0X4	11/19/99		--	--	--	--	--	--	--
50-52	B0X0B1	11/22/99		34 U	68 U	34 U	34 U	34 U	34 U	34 U
(Dup)	B0X0B2	11/22/99		34 U	69 U	34 U	34 U	34 U	34 U	34 U
99.5-101.5	B0X0B3	11/23/99		33 U	67 U	33 U	33 U	33 U	33 U	33 U
135-137	B0X0B4	11/30/99		--	--	--	--	--	--	--
150-152	B0X0B5	12/01/99		39 U	78 U	39 U	39 U	39 U	39 U	39 U
180-182	B0X0B6	12/02/99		35 U	71 U	35 U	35 U	35 U	35 U	35 U
197-199	B0X0B7	12/07/99		34 U	68 U	34 U	34 U	34 U	34 U	34 U

-- = Not analyzed.
U = Analyzed for but not detected. Value reported is the quantitation limit.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.3. Results of Analyses for Diesel Range Organic Components in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Diesel Range Organics DRO mg/kg
35-37	B0X099	11/19/99		4.5 U
(Dup)	B0X0B0	11/19/99		4.3 U
(Split)	B0X0X4	11/19/99		--
50-52	B0X0B1	11/22/99		4.1 U
(Dup)	B0X0B2	11/22/99		4.1 U
99.5-101.5	B0X0B3	11/23/99		4.4 U
135-137	B0X0B4	11/30/99		--
150-152	B0X0B5	12/01/99		4.7 U
180-182	B0X0B6	12/02/99		4.2 U
197-199	B0X0B7	12/07/99		4.1 U

-- = Not analyzed.
U = Analyzed for but not detected. Value reported is the quantitation limit.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.4. Results of Analyses for Anions in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Chloride mg/kg	Fluoride mg/kg	Nitrite N02-N mg/kg	Nitrate N03-N mg/kg	Cyanide 57-12-5 mg/kg	Phosphate mg/kg	Sulfate 14808-79-8 mg/kg	Nitrate-Nitrite N02+N03-N mg/kg	Ammonia as Nitrogen NH3-N mg/kg	Sulfide mg/kg	pH -
35-37	B0X099	11/19/99		1.4 U	2.8 U	1.4 U	5.4	0.56 U	1.5	3.4	1.1	1.4 U	4.3	8.7
(Dup)	B0X0B0	11/19/99		2.3	2.7 U	1.4 U	4	0.54 U	1.4 U	3	0.73	1.3 U	4.1	8.7
(Split)	B0X0X4	11/19/99		2.0 U	1.0 U	0.2 U	0.98	--	5.0 U	5.73	0.5 U	--	--	8.88
50-52	B0X0B1	11/22/99		1.9	2.6 U	1.3 U	1.5	0.51 U	1.3 U	7.5	0.29	1.3 U	2.0 U	9.1
(Dup)	B0X0B2	11/22/99		2	2.6 U	1.3 U	1.3	0.52 U	1.3 U	9	0.31	1.7	2.2 U	9
99.5-101.5	B0X0B3	11/23/99		1.7	2.8 U	1.4 U	1.4 U	0.55 U	1.4 U	2.6	0.27	1.4	4.3	8.8
135-137	B0X0B4	11/30/99		1.5	2.7 U	1.4 U	1.6	--	1.4 U	7.7	--	--	--	8.7
150-152	B0X0B5	12/01/99		1.7	2.9 U	1.5 U	2.3	0.58 U	1.5 U	2.4	0.64	1.4	4.3	8.5
180-182	B0X0B6	12/02/99		2	2.7 U	1.3 U	1.3 U	0.53 U	2.6	12.4	0.22 U	1.3 U	8.3	8.1
197-199	B0X0B7	12/07/99		2.5	2.6 U	1.3 U	1.3 U	0.51 U	1.4	8.2	0.22 U	1.3 U	4	8.6

-- = Not analyzed.
U = Analyzed for but not detected. Value reported is the quantitation limit.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.5. Results of Analyses for Semi-Volatile Organic Compounds in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078		CAS Units	Bis (2-ethylhexyl) phthalate
	HEIS Number	Sample Date		
35-37	B0X099	11/19/99		370 U
(Dup)	B0X0B0	11/19/99		370 U
(Split)	B0X0X4	11/19/99		--
50-52	B0X0B1	11/22/99		24 J
(Dup)	B0X0B2	11/22/99		27 J
99.5-101.5	B0X0B3	11/23/99		370 U
135-137	B0X0B4	11/30/99		--
150-152	B0X0B5	12/01/99		570 U
180-182	B0X0B6	12/02/99		260 J
197-199	B0X0B7	12/07/99		230 JB

-- = Not analyzed.
J = Value reported is an estimate.
B = The analyte was detected in the associated QC blank and in the sample.
U = Analyzed for but not detected. Value reported is the quantitation limit.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.6. Results of Analyses for Volatile Organic Compounds in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B99-078		CAS Units	Acetone 67-64-1 µg/kg	2-Butanone 78-93-3 µg/kg	Methylene Chloride 75-09-2 µg/kg
	HEIS Number	Sample Date				
35-37	B0X099	11/19/99		11 U	11 U	8 B
(Dup)	B0X0B0	11/19/99		6 J	11 U	10 B
(Split)	B0X0X4	11/19/99		--	--	--
50-52	B0X0B1	11/22/99		30	10 U	6 B
(Dup)	B0X0B2	11/22/99		22	11 U	7 B
99.5-101.5	B0X0B3	11/23/99		33	12	19 B
135-137	B0X0B4	11/30/99		--	--	--
150-152	B0X0B5	12/01/99		22 B	12 U	15 B
180-182	B0X0B6	12/02/99		6 JB	11 U	4 JB
197-199	B0X0B7	12/07/99		5 J	11 U	20 B

-- = Not analyzed.
J = Value reported is an estimate.
B = The analyte was detected in the associated QC blank and in the sample.
U = Analyzed for but not detected. Value reported is the quantitation limit.
SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.7. Results of Analyses for Radionuclides in Soil Samples from Well 299-W26-13

Sample Interval (ft bgs)	SAF B00-006 HEIS Number	Sample Date	CAS Units	Tritium 10028-17-8 pCi/g	Technetium 9914133-76-7 pCi/g	Neptunium 237 13994-20-2 pCi/g	Total Uranium 7440-61-1 µg/g	Plutonium 238 13981-16-3 pCi/g	Plutonium 239/240 PU-239/240 pCi/g	Nickel 63 13981-37-8 pCi/g	Americium 241 14596-10-2 pCi/g	Total Strontium SR-RAD pCi/g	Thorium 228 14274-82-9 pCi/g	Thorium 230 14269-63-7 pCi/g	Thorium 232 TH-232 pCi/g
35-37	B0X099	11/19/99		--	--	--	0.460 J	0.033 U	0.014 U	--	0.004 U	-0.057 U	0.87	--	0.536
(Dup)	B0X0B0	11/19/99		--	--	--	2.14	0.036 U	0.009 U	--	0.025 U	-0.052 U	0.637	--	0.829
(Split)	B0X0X4	11/19/99		--	--	--	0.614 J	0.00226	0 U	--	0.0094 U	0.0264 U	--	--	--
50-52	B0X0B1	11/22/99		0.064 U	-0.062 U	0.030 U	1.94	0.026 U	0.015 U	0.758 U	0.028 U	-0.015 U	0.475 J	1.06	0.387 J
(Dup)	B0X0B2	11/22/99		0.040 U	-0.144 U	0.028 U	0.804 J	0 U	0.016 U	2.46 J	0.029 U	1.57	0.564 J	0.432	0.344
99.5-101.5	B0X0B3	11/23/99		0.038 U	-0.132 U	0.013 U	0.772 J	0.005 U	0.117 J	2.14 U	0.020 U	-0.065 U	0.580 J	0.812 J	0.534 J
135-137	B0X0B4	11/30/99		--	--	--	0.806 J	-0.006 U	0.006 U		0.019 U	-0.068 U	0.623	--	0.606
150-152	B0X0B5	12/01/99		-0.046 U	0.118 U	0.004 U	0.589 J	-0.014 U	0.021 U	1.4 U	0.024 U	-0.027 U	0.484 J	0.436 J	0.390 J
180-182	B0X0B6	12/02/99		-0.001 U	0.114 U	0.008 U	0.782 J	0.004 U	0.012 U	-0.088 U	0.007 U	-0.023 U	0.484 J	0.738 J	0.387 J
197-199	B0X0B7	12/07/99		0.012 U	-0.049 U	-0.016 U	0.377 J	-0.007 U	0.007 U	1.41 U	0.033 U	-0.133 U	0.516 J	0.243 J	0.531 J

Sample Interval (ft bgs)	SAF B99-078 HEIS Number	Sample Date	CAS Units	Potassium 40 13966-00-2 pCi/g	Cobalt 60 10198-40-0 pCi/g	Cesium 137 10045-97-3 pCi/g	Europium 152 14683-23-9 pCi/g	Europium 154 15585-10-1 pCi/g	Europium 155 14391-16-3 pCi/g	Radium 226 13982-63-3 pCi/g	Radium 228 15262-20-1 pCi/g	Uranium 233/234 U-233/234 pCi/g	Uranium 235 15117-96-1 pCi/g	Uranium 238 U-238 pCi/g	Gross Alpha 12587-46-1 pCi/g	Gross Beta 12587-47-2 pCi/g
35-37	B0X099	11/19/99		13.7	0.12 U	0.084 U	0.18 U	0.29 U	0.11 U	0.589	0.536	--	0.19 U	11 U	3.93 J	12.8 J
(Dup)	B0X0B0	11/19/99		12.4	0.071 U	0.062 U	0.16 U	0.24 U	0.16 U	0.396	0.829	0.407 J	0.055 U	0.434 J	7.2 J	14.4 J
(Split)	B0X0X4	11/19/99		--	0.0155 U	0.0326 U	0.023 U	0.0839 U	0.0376 U	--	0.834	--	--	--	10.6	22.1
50-52	B0X0B1	11/22/99		12.9	0.059 U	0.047 U	0.12 U	0.17 U	0.12 U	0.428	0.566	0.452 J	0.022 J	0.381 J	5.61 J	19.8
(Dup)	B0X0B2	11/22/99		12.5	0.048 U	0.043 U	0.11 U	0.15 U	0.089 U	0.362	0.492	--	0.15 U	5.4 U	7.62 J	21.9
99.5-101.5	B0X0B3	11/23/99		13.1	0.030 U	0.029 U	0.070 U	0.10 U	0.067 U	0.564	0.907	--	0.10 U	3.8 U	9.15 J	16.8
135-137	B0X0B4	11/30/99		9.14	0.092 U	0.075 U	0.20 U	0.26 U	0.19 U	0.533	0.606	--	0.26 U	8.7 U	10.7	40.3
150-152	B0X0B5	12/01/99		10.7	0.014 U	0.12 U	0.29 U	0.34 U	0.28 U	0.311	0.667	--	0.36 U	15 U	3.02 J	24.0 B
180-182	B0X0B6	12/02/99		8.51	0.29 U	0.22 U	0.41 U	0.91 U	0.30 U	0.515	1.2 U	--	0.49 U	27 U	9.03 J	8.18 J
197-199	B0X0B7	12/07/99		13.9	0.13 U	0.098 U	0.21 U	0.39 U	0.13 U	0.344	0.523	--	0.21 U	14 U	6.58 J	33.1 B

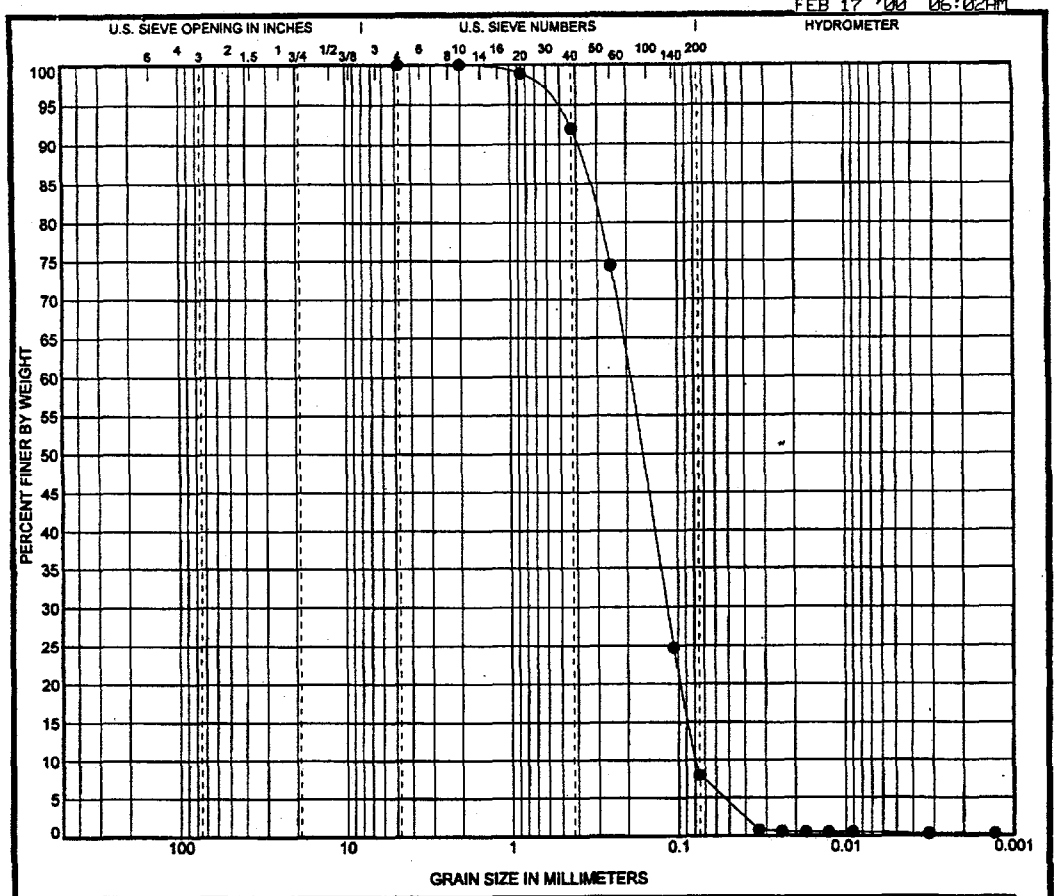
-- = Not analyzed.
U = Analyzed for but not detected above the minimum detectables activity in the sample. The value reported as the result.
B = The analyte was detected in the associated QC blank and in the sample.
J = Concentration is estimated.

SAF = Sample Authorization Form.
CAS = Chemical Abstract Service registry number.
Dup = Duplicate.
Split = Duplicate sample for quality control purposes.

Table B.8. Soil Physical Properties for Three Samples from Well 299-W26-13

Sample Interval							
Top (ft bgs)	**Bottom (ft bgs)**	**HIES umber**	**Field pH**	**Moisture Content (wt. %)[a]**	**Calculated Volumetric Moisture (vol. %)**	**Calculated Dry Bulk Density (g/cm^3)**	**Particle Size Analysis**
35	37	B0X0C0	8.61	6.5	9.64	1.48	Yes
135	137	B0X0C1	8.80	11.6	24.1	2.07	Yes
197	199	B0X0C2	8.85	2.5	4.9	1.96	Yes

(a) Water content reported on a gravimetric basis: (mass of water/mass of dry soil x 100).
HEIS = Hanford Environmental Information System



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 9912001-001	0.0					0.89	2.49
BOXOCO							

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 9912001-001	0.0	4.75	0.195	0.116	0.078	0.0	92.0	7.7	0.4

US GRAIN SIZE BECHTEL.GPJ US LAB.GDT 2/17/00

Logo

Maxim Technologies, Inc.
1908 Innerbelt Business Center Drive
St. Louis, Missouri 63114
Telephone: 314-426-0880
Fax: 314-426-4212

GRAIN SIZE DISTRIBUTION

Project: Chris Cearlock
Location:
Number: 9905093

Final Data
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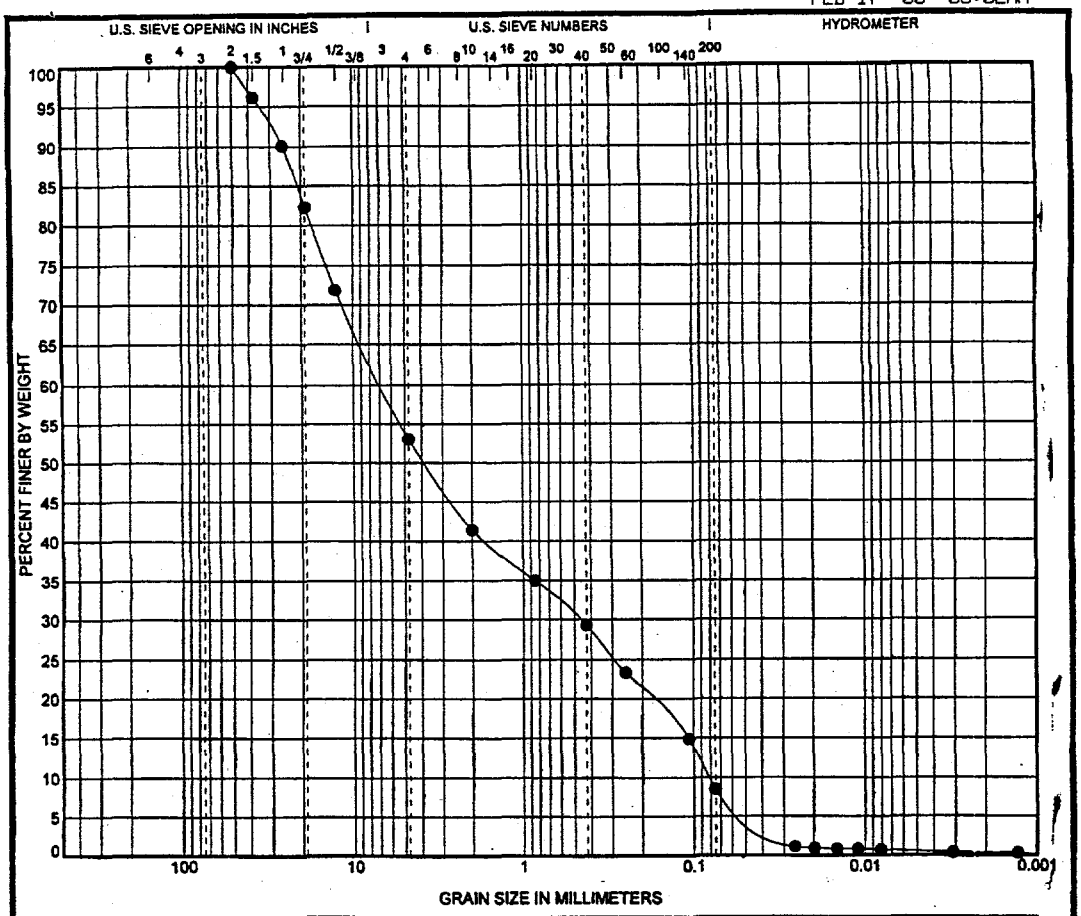
Figure B.1. Particle Size Distribution for the 35 to 37 ft Interval in Well 299-W26-13



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 9912003-001	0.0					0.39	84.02
BOX0C1							

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 9912003-001	0.0	50	6.827	0.465	0.081	46.9	44.5	8.0	0.5

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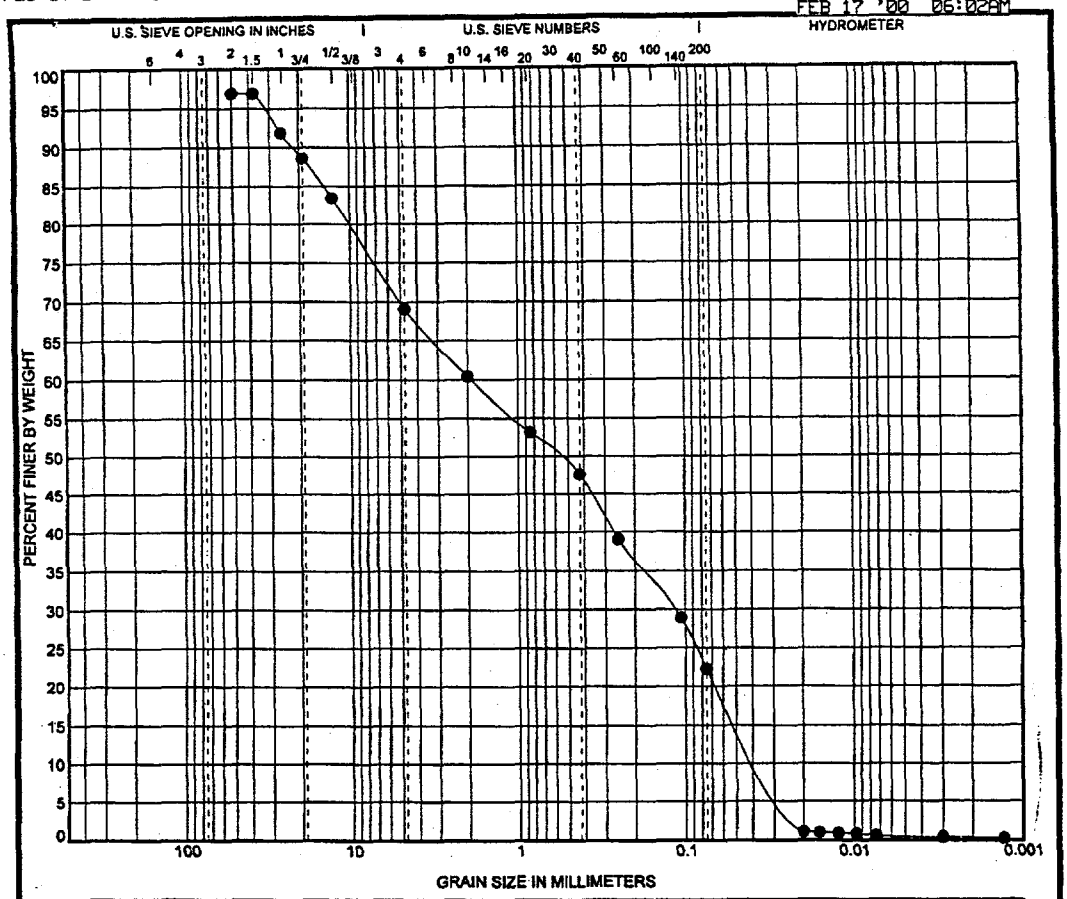
Figure B.2. Particle Size Distribution for Interval 135 to 137 ft in Well 299-W26-13



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 9912004-001	0.0					0.20	54.64
BOXOC2							

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 9912004-001	0.0	50	1.904	0.116	0.035	27.7	46.9	21.8	0.5

US GRAIN SIZE BECHTEL.GPJ US LAB.GDT 2/17/00

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TOTAL P.05

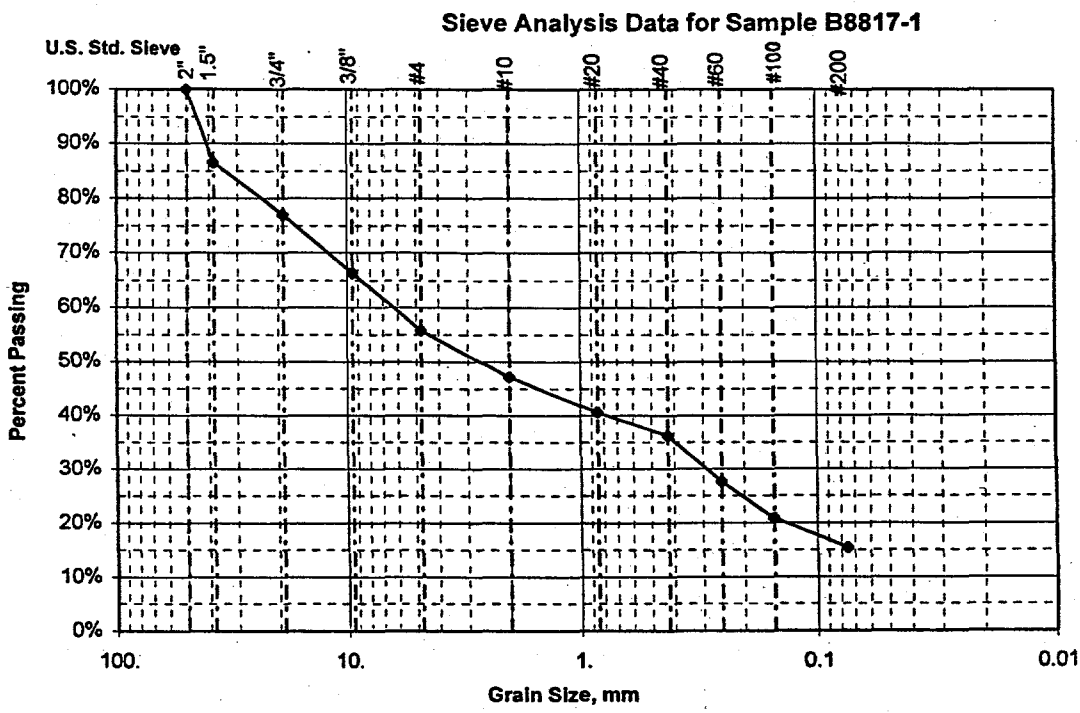
Figure B.3. Particle Size Distribution for the 197 to 199 ft Interval in Well 299-W26-13

CH2M Hill Hanford, Inc.

SIEVE ANALYSIS

WELL NAME	299-W26-13	DEPTH	199.5'-200.5'	SAMPLE#	B8817-1	WELL ID#	B8817
TESTED BY	JMF	CONTACT	Dave Weekes	PHONE	372-9582	DATE	12/28/1999

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT(g)	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
703.50	2"	0.0	0.0	100.0	50.00	
	1.5"	94.5	13.4	86.6	38.10	
	3/4"	161.4	22.9	77.1	19.00	
	3/8"	236.9	33.7	66.3	9.50	
	#4	310.9	44.2	55.8	4.75	
	#10	371.6	52.8	47.2	2.00	
	#20	418.0	59.4	40.6	0.85	
	#40	449.0	63.8	36.2	0.43	
	#60	509.8	72.5	27.5	0.25	
	#100	556.5	79.1	20.9	0.150	
	#200	595.4	84.6	15.4	0.075	



Comments: Silty Sandy Gravel

All data are accurately and completely recorded.

Checked By: [signature] Date: 12/29/99

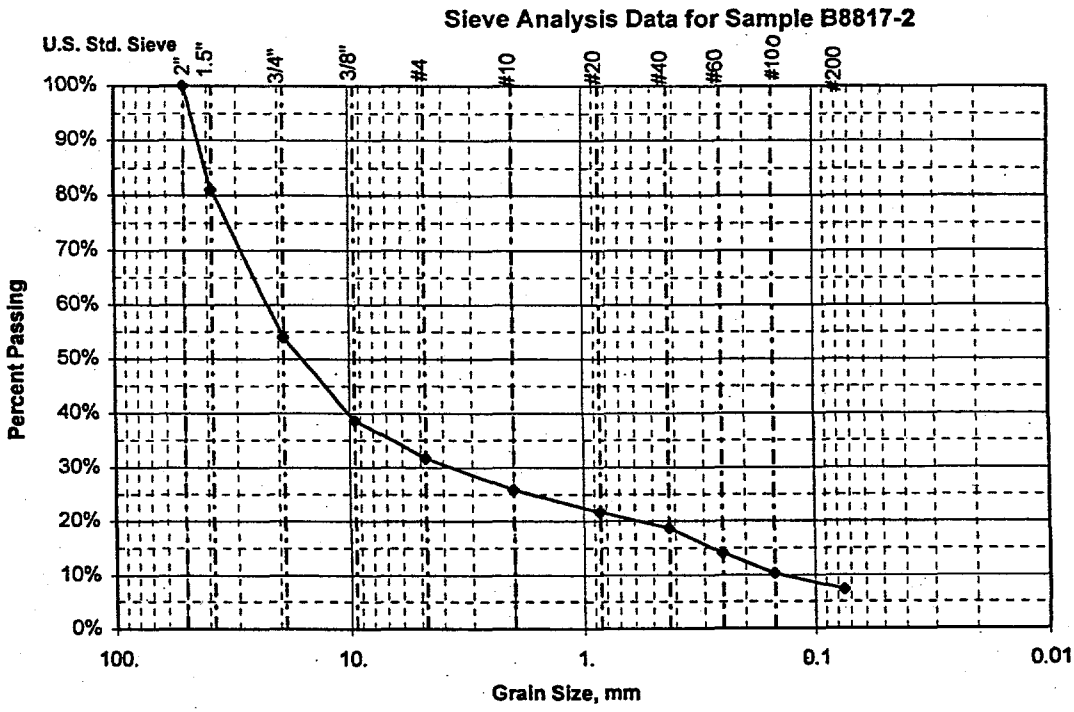
Figure B.4. Particle Size Distribution for the 199.5 to 200.5 ft Interval in Well 299-W26-13

CH2M Hill Hanford, Inc.

SIEVE ANALYSIS

WELL NAME	299-W26-13	DEPTH	216'-217'	SAMPLE#	B8817-2	WELL ID#	B8817
TESTED BY	JMF	CONTACT	Dave Weekes	PHONE	372-9582	DATE	12/28/1999

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT(g)	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
956.70	2"	0.0	0.0	100.0	50.00	
	1.5"	182.2	19.0	81.0	38.10	
	3/4"	440.0	46.0	54.0	19.00	
	3/8"	587.1	61.4	38.6	9.50	
	#4	653.2	68.3	31.7	4.75	
	#10	710.1	74.2	25.8	2.00	
	#20	749.2	78.3	21.7	0.85	
	#40	778.2	81.3	18.7	0.43	
	#60	822.6	86.0	14.0	0.25	
	#100	858.2	89.7	10.3	0.150	
	#200	887.9	92.8	7.2	0.075	



Comments: Sandy Gravel

All data are accurately and completely recorded.

Checked By: DC Weekes Date: 12/29/99

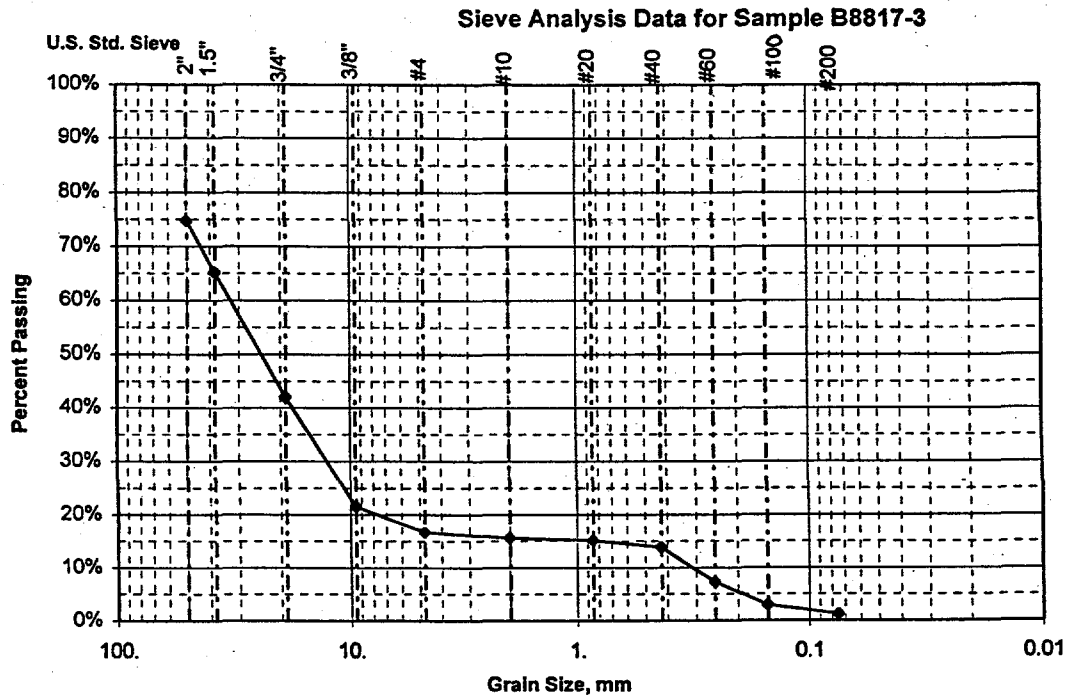
Figure B.5. Particle Size Distribution for the 216 to 217 ft Interval in Well 299-W26-13

CH2M Hill Hanford, Inc.

SIEVE ANALYSIS

WELL NAME	299-W26-13	DEPTH	231'-233'	SAMPLE#	B8817-3	WELL ID#	B8817
TESTED BY	JMF	CONTACT	Dave Weekes	PHONE	372-9582	DATE	12/28/1999

SAMPLE WT (g)	SIEVE SIZE IN.	CUMULATIVE WEIGHT(g)	% WEIGHT RETAINED	% PASSING	Grain Size (mm)	COMMENTS
1209.60	2"	306.1	25.3	74.7	50.00	
	1.5"	420.7	34.8	65.2	38.10	
	3/4"	701.0	58.0	42.0	19.00	
	3/8"	949.6	78.5	21.5	9.50	
	#4	1008.2	83.3	16.7	4.75	
	#10	1021.3	84.4	15.6	2.00	
	#20	1026.9	84.9	15.1	0.85	
	#40	1042.6	86.2	13.8	0.43	
	#60	1121.9	92.7	7.3	0.25	
	#100	1174.2	97.1	2.9	0.150	
	#200	1194.8	98.8	1.2	0.075	



Comments: Gravel

All data are accurately and completely recorded.

Checked By: DC Weekes Date: 12/29/99

Figure B.6. Particle Size Distribution for the 231 to 233 ft Interval in Well 299-W26-13

Appendix C

Borehole Geophysical Logs

Appendix C

Borehole Geophysical Logs

This appendix contains the borehole geophysical logs obtained from borehole 299-W26-13. The gamma-ray log was run and analyzed by MACTEC-ERS, Inc. The neutron-neutron moisture log was run and analyzed by Waste Management Federal Services, Inc. Included with the logs are Log Header sheets and Log Analysis Summary Reports.

Spectral Gamma-Ray Borehole Log Data Report

Borehole 299-W26-13

Borehole Information

Farm : NA	Tank : NA	Site Number : B8817
N-Coord :	W-Coord :	TOC Elevation : NA
Water Level, ft : 200.49	Date Drilled : 12/8/99	

Casing Record

Type : Steel thread	Thickness, in. : 0.500	ID, in. : 11
Top Depth, ft. : 0	Bottom Depth, ft. : 36	
Type : Steel thread	Thickness, in. : 0.500	ID, in. : 8
Top Depth, ft. : 0	Bottom Depth, ft. : 240	

Cement Bottom, ft. 0 Cement Top, ft. : 0

Borehole Notes:

This borehole was drilled during December 1999 to a depth of 240.7 ft. A nominal 11-in.-diameter casing was used from the ground surface to 36.3 ft, with an 8-in.-diameter casing set from the ground surface to 240.0 ft. The casing strings used in the borehole were threaded and flush-jointed. The borehole was uncased from 240.0 to 240.7 ft. Measured wall thickness for both the 11- and 8-in.-diameter casings was 0.5 in. Grout was not present between the casings, which were set flush with the ground surface. The total depth achieved with the logging system was 240.5 ft. The ground surface was used as the zero reference (0 ft) for all logging depths. The ground water level was measured at 200.49 ft.

Equipment Information

Logging System : 2B	Detector Type : HPGe	Detector Efficiency: 35.0 %
Calibration Date : 10/1999	Calibration Reference : GJO-HAN-26	Logging Procedure : MAC-VZCP 1.7.10-1

Logging Information

Log Run Number : 1	Log Run Date : 12/09/1999	Logging Engineer: Bob Spatz
Start Depth, ft.: 240.5	Counting Time, sec.: 100	L/R : L Shield : N
Finish Depth, ft. : 119.0	MSA Interval, ft. : 0.5	Log Speed, ft/min.: n/a

Log Run Number : 2	Log Run Date : 12/09/1999	Logging Engineer: Bob Spatz
Start Depth, ft.: 205.0	Counting Time, sec.: 100	L/R : L Shield : N
Finish Depth, ft. : 193.0	MSA Interval, ft. : 0.5	Log Speed, ft/min.: n/a

Spectral Gamma-Ray Borehole Log Data Report

Borehole 299-W26-13

Log Run Number:	3	Log Run Date:	12/10/1999	Logging Engineer:	Alan Pearson
Start Depth, ft.:	125.0	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 Run Number:	4	Log Run Date:	12/10/1999	Logging Engineer:	Alan Pearson
Start Depth, ft.:	46.0	Counting Time, sec.:	100	L/R: L	Shield: N
Finish Depth, ft.:	34.0	MSA Interval, ft.:	0.5	Log Speed, ft/min.:	n/a

Logging Operation Notes:

This borehole was logged in four log runs. Log runs 1 and 2 were completed on December 9, 1999 inside the 8-in.-diameter casing. Log run 1 covered the interval from 240.5 to 119.0 ft. Log run 2 was a repeat section from 205.0 to 193.0 ft. Log runs 3 and 4 were completed on December 10, 1999 inside the 8- and 11-in.-diameter casings. Log run 3 covered the interval from the ground surface to 125.0 ft. Log run 4 was a repeat section from 34.0 to 46.0 ft. In addition, there is a depth overlap of log data (6 ft) where log runs 1 and 3 were both conducted (119.0 to 125.0 ft). The total logging footage, including the repeat sections, measured 270.5 ft.

Analysis Information

Analyst:	R. R. Spatz		
Data Processing Reference:	MAC-VZCP 1.7.9	Analysis Date:	01/13/2000

Analysis Notes:

The pre-survey and post-survey field verification for each logging run met the acceptance criteria established for peak shape and system efficiency. The energy calibration and peak-shape calibration from the accepted calibration spectrum that most closely matched the field data were used to establish the peak resolution and channel-to-energy parameters used in processing the spectra acquired during the logging operation.

The thicknesses of the different-sized casings were measured on site with a micrometer and are presented in the casing record. Casing corrections for each applicable thickness were determined and applied to the data at the appropriate depth intervals. In addition, a correction for water encountered in the borehole was applied to the data collected below 200.49 ft in depth. These corrections are applied to the raw data recorded in counts per second to derive final radionuclide concentrations.

Shape factor analysis was not applied to the SGLS data because man-made radionuclides were not detected in this borehole.

Log Plot Notes:

Separate log plots are presented to show the man-made (none detected) and naturally occurring radionuclides (K-40, U-238, and Th-232). These plots show the naturally occurring radionuclides which can be used for lithology interpretation and bed boundary identification. The headings of the plots identify the specific gamma rays used to calculate the concentrations. The naturally occurring radionuclide plots are composites of log runs

Spectral Gamma-Ray Borehole Log Data Report

Borehole 299-W26-13

gamma derived from the spectral data. This plot is a composite of log data collected from log runs 1 and 3.

On the repeat log plots, repeat log data from runs 2 and 4 are compared with runs 1 and 3, respectively.

For U-238 concentrations calculated between the ground surface and 36.5 ft, the 1764.51-keV bismuth-214 (Bi-214) gamma ray was substituted for the 609.32-keV Bi-214 gamma ray. For many of those spectra in that interval the 609.32-keV Bi-214 gamma ray was not detected because of heavy gamma-ray attenuation associated with the 1.0-in. double casing wall thickness.

Where shown, the error bars on the plots show the statistical uncertainties for the measurements as 95-percent (2-sigma) confidence intervals. Error bars shown on the log plot include the error associated with calibration measurements, and errors associated with the casing and water corrections, as well as counting error. Open circles on the plots give the minimum detection level (MDL). The MDL of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak is statistically defensible.

Results/Interpretations:

Man-made radionuclides were not detected in this borehole.

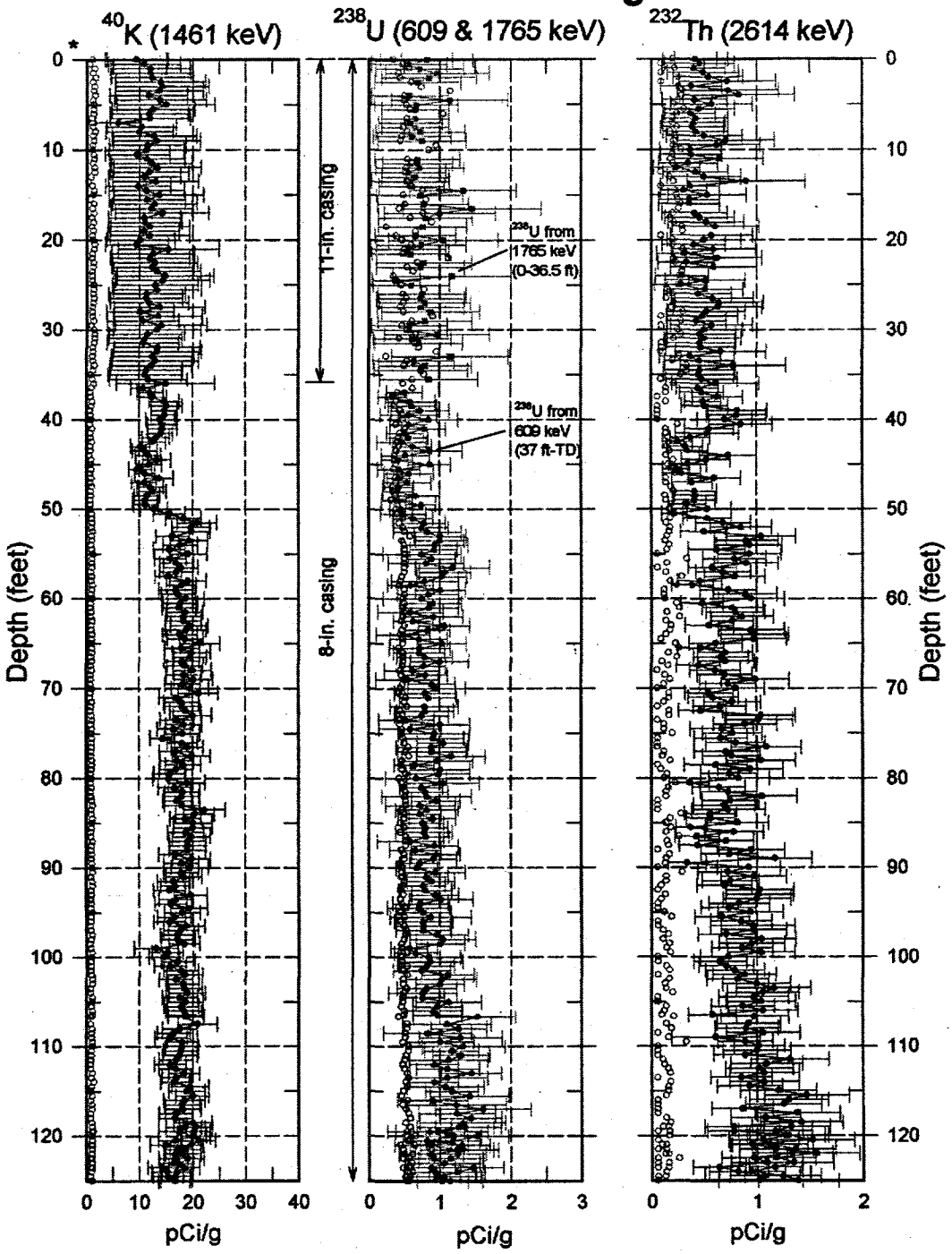
The naturally occurring radionuclides show several changes in the KUT concentrations that indicate lithology changes and bed boundaries.

Error bars representing the 2-sigma uncertainty in the measurements increase above the 36-ft depth and below the 200-ft depth as a result of additional error introduced by the correction for double casing and the presence water, respectively.

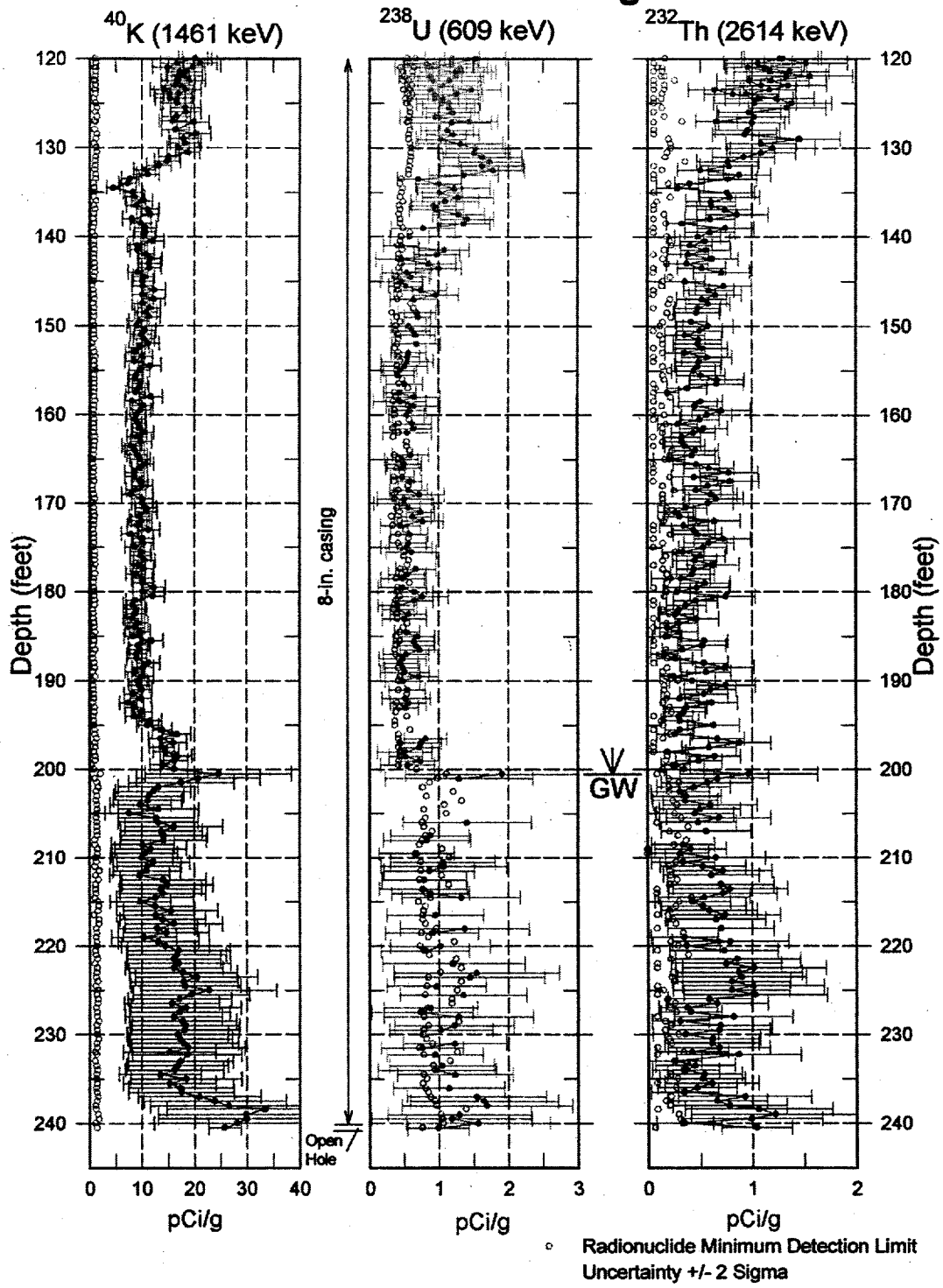
The repeat log plots show good repeatability for the calculated concentrations and depth.

299-W26-13

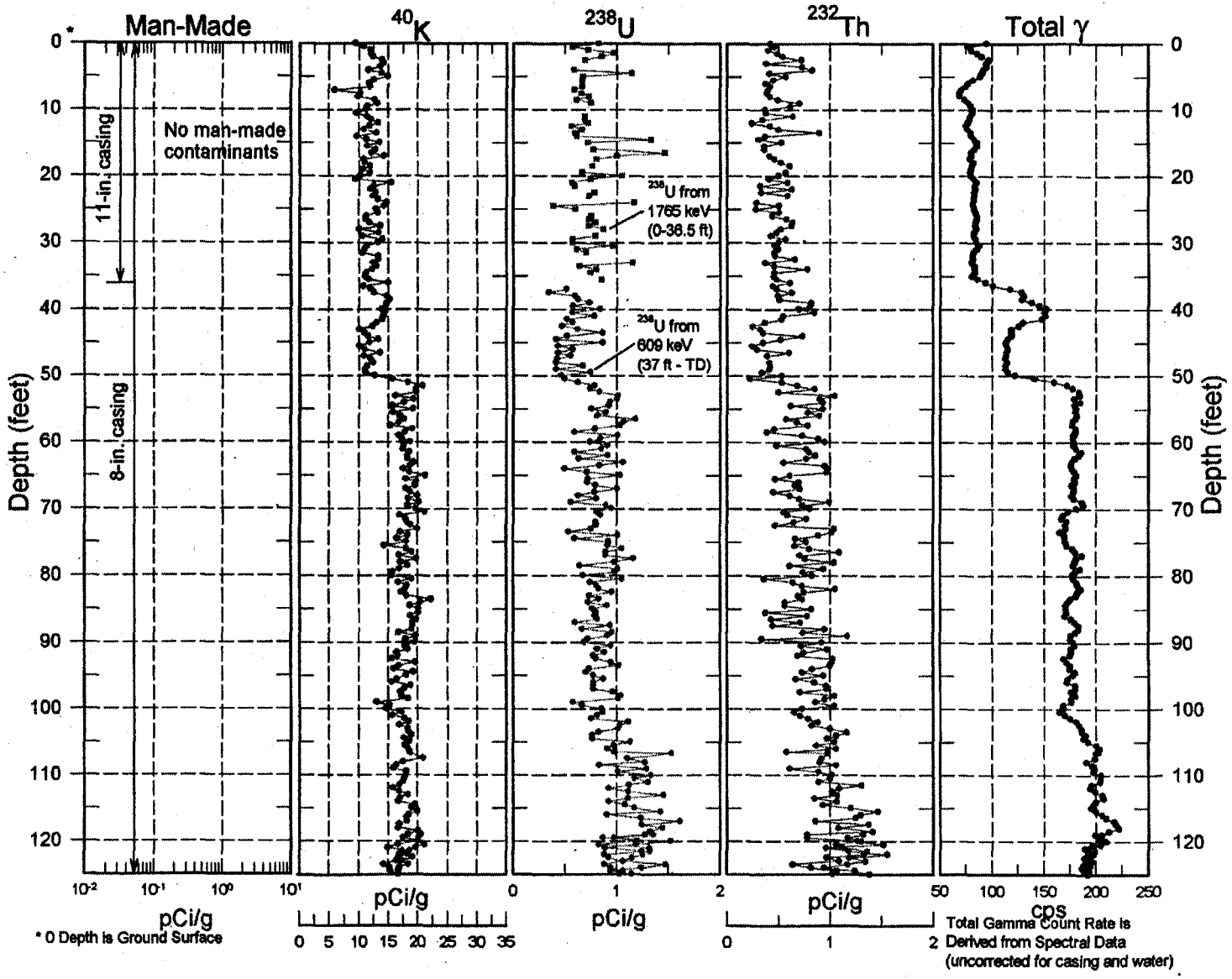
Natural Gamma Logs



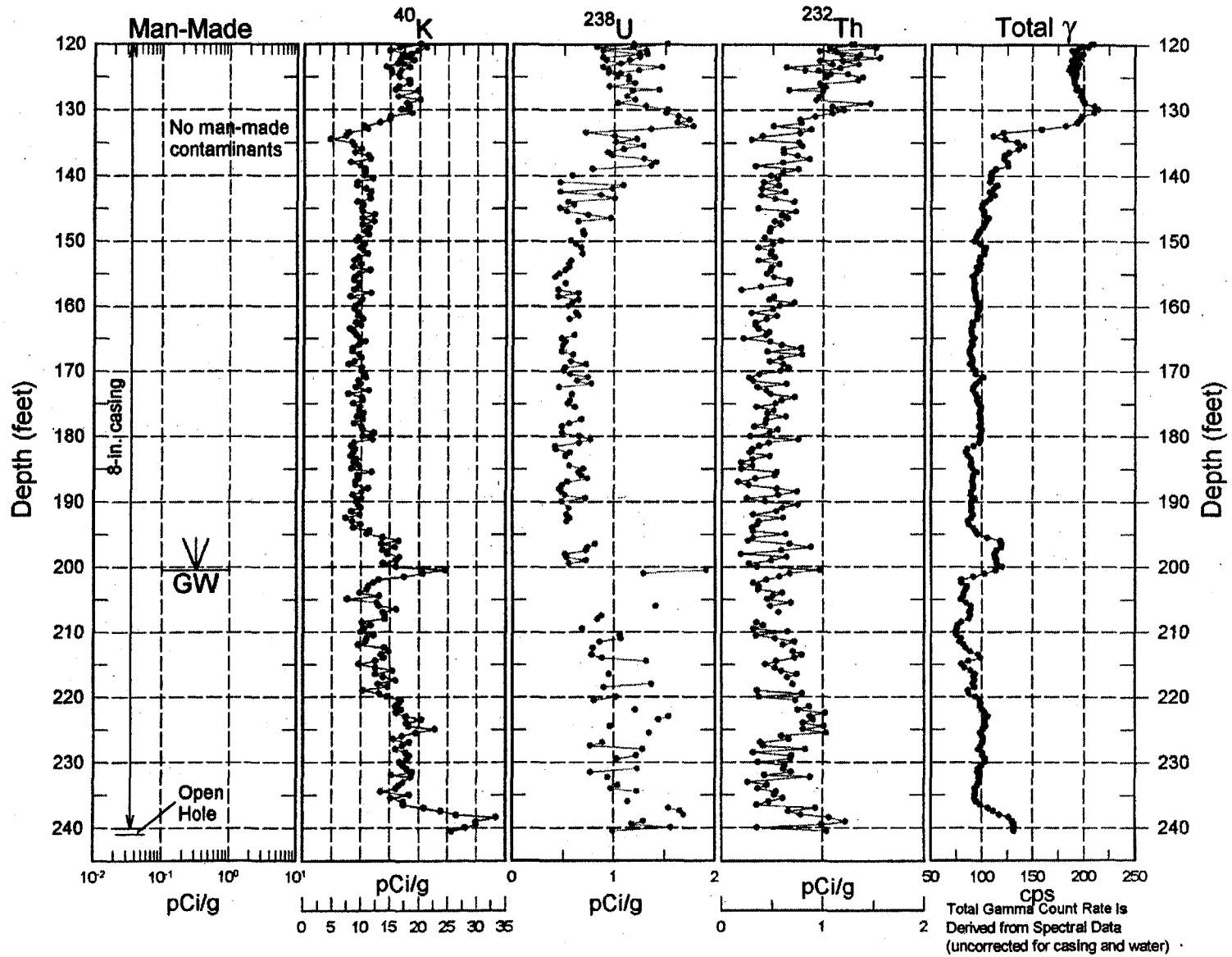
299-W26-13
Natural Gamma Logs



299-W26-13 Combination Plot

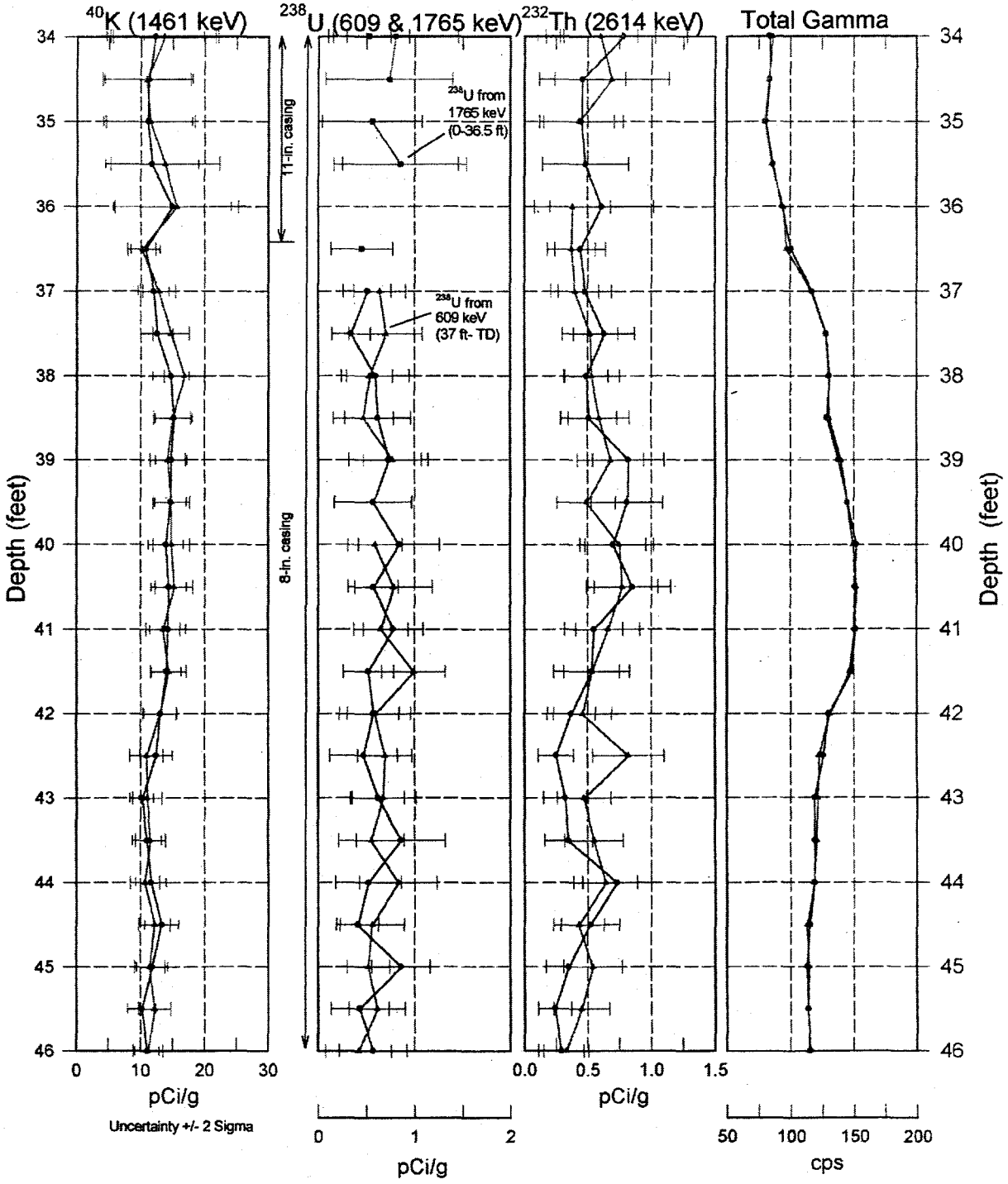


299-W26-13 Combination Plot



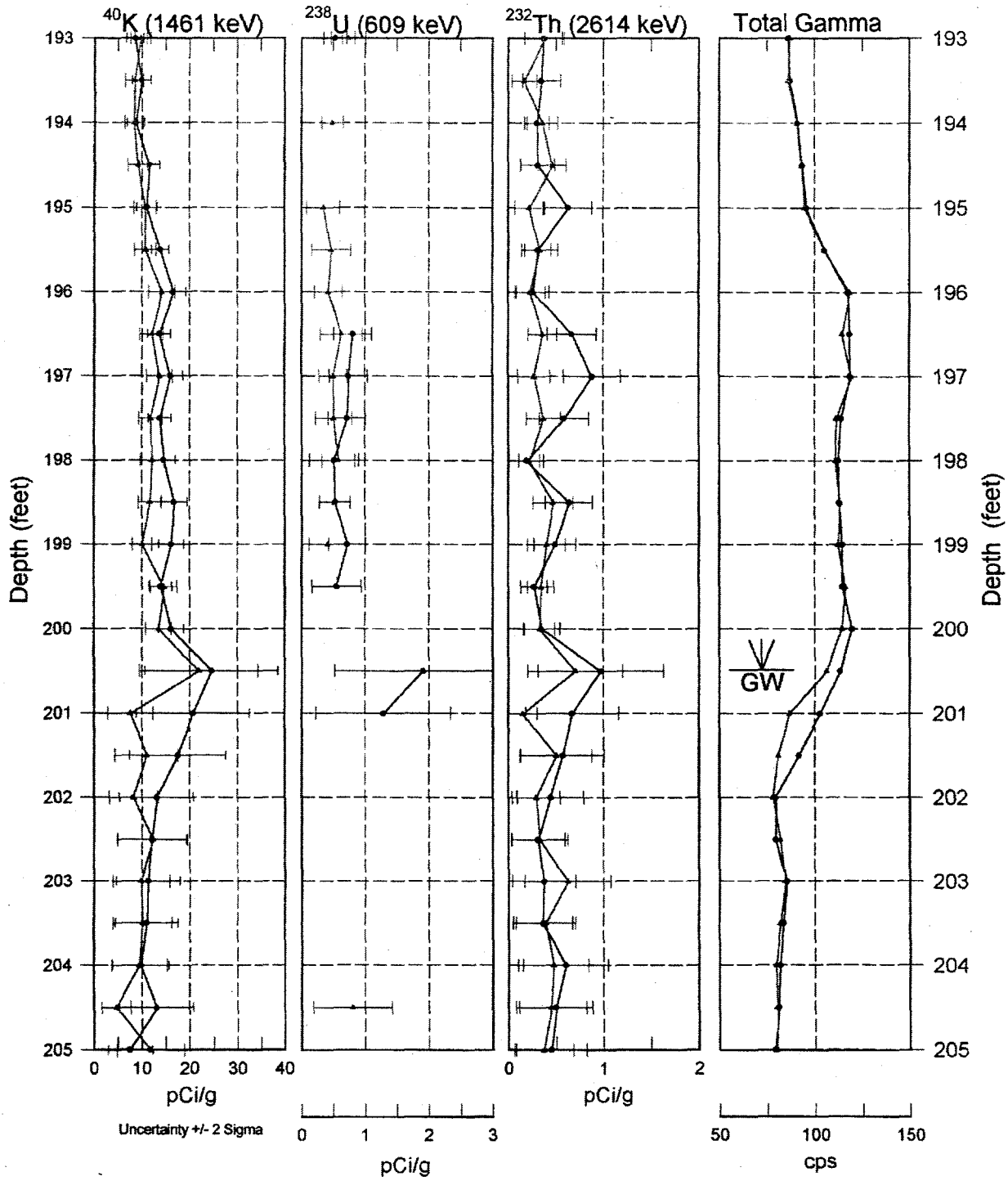
299-W26-13

Repeat Section of Natural Gamma Logs



299-W26-13

Repeat Section of Natural Gamma Logs



Waste Management Technical Services
MACTEC

Report of Geophysical Logging for the 200-CS-1/RCRA Project

This report presents a summary of spectral gamma and neutron-neutron moisture logging that was conducted in borehole B8817 at the 216-S-10 Pond southwest of the 200 West Area. This borehole was utilized for characterization of this waste facility, and at the completion of drilling a monitoring well with the designation 299-W26-13 was constructed.

Summary of Logging Operations

Spectral Gamma Surveys

A spectral gamma survey was conducted in borehole B8817 utilizing a MACTEC operated logging unit designated Gamma 2B. The borehole was logged in four individual log runs in 11-in.- and 8-in.-diameter casings when drilling was complete. Two of these log runs were repeat surveys that were logged to assess the repeatability of the measurements. The depth intervals logged in each log run are indicated on the Spectral Gamma-Ray Borehole Log Data Report for borehole B8817.

All spectral gamma measurements were acquired in a move-stop-acquire mode, at a measurement acquisition rate of 100 seconds (s) live time per 0.5 ft of depth. In the move-stop-acquire mode the logging tool is stationary at each 0.5 ft depth increment throughout the depth interval logged. In the live time acquisition mode, system dead time is accounted for in the acquisition time for each spectrum, e.g., a 100 s live time acquisition with 50 percent dead time would result in a real time measurement of 150 s.

The zero depth reference for all the spectral gamma logging surveys is ground surface. The zero position of the logging is the center of the germanium detector, which is about 5 in. above the bottom of the logging tool. This location is scribed into the tool housing and ensures consistent tool positioning.

The pre- and post- survey field verification spectra met the acceptance criteria established for the peak shape and detector efficiency, confirming that the spectral gamma logging system was operating within specifications. The energy calibration and peak-shape calibration from these spectra were used to establish the channel-to-energy parameters that were used to process the spectra acquired during the log surveys.

Neutron-Neutron Survey

Neutron-neutron moisture logging was conducted in borehole B8817 utilizing a logging system operated by Waste Management Technical Services that is designated Radionuclide Logging System unit 1 (RLS-1). The neutron-neutron moisture-logging tool is calibrated in moisture models with 6-in.- and 8-in.-diameter casing configurations. Since there is no direct calibration standard for 11-in.-diameter casing, the section of well B8817 with 11-in.-diameter casing (ground surface to a depth of 36.3 ft) was not logged. The section of the borehole with 8-in.-diameter casing was logged with the moisture tool from the bottom of the 11 in.-diameter casing to groundwater (36.3 to 200.5 ft). The interval logged and the repeat survey interval are indicated on the Borehole Survey Data Sheet for borehole B8817.

The neutron-neutron moisture data were collected at 0.25-ft depth increments. The data were acquired in a continuous logging mode at a logging speed of 1.0 feet per minute (ft/min); this logging speed resulted

in a data sample time of 15 seconds real (clock) time. Given the count rate of the instrument and sample time, the statistical accuracy is within the specified precision. The guidelines for conducting the neutron-neutron survey are outline in WMNW-CM-004, *Operational Environmental Monitoring, Section 22.0, Rev. 0, Vadose Neutron Moisture Logging Procedure.*

The neutron-neutron moisture logging tool is depth zeroed at the top of the cablehead (the cable to logging tool connection) to minimize exposure to the logging operator or other personnel to the americium-beryllium (AmBe) neutron source. The distance from the top of the cablehead to the scribe line zero of the neutron instrument (half distance between the source and the detector) is entered for the depth datum of the borehole. The neutron-neutron log survey zero reference is ground surface.

The source shield is used as a pre- and post- survey field verification of proper instrument performance. Consistent results for the pre- and post-survey verifications that were conducted before and after the moisture survey was conducted in borehole B8817 indicated the system was operating properly.

Data Processing

The spectra acquired in borehole B8817 during the spectral gamma survey were processed utilizing a variety of software to calculate concentrations of individual gamma-emitting radionuclides. Details regarding the algorithms used to calculate the concentrations and their application are presented in the *Hanford Tank Farms Vadose Zone, Data Analysis Manual* (MAC-VZCP-1.7.9, Rev. 1).

Equipment calibrations are conducted annually and the data acquired during the calibrations are used to derive the factors that convert measured peak area countrate into radionuclide concentrations in picocuries per gram (pCi/g). The calibration dates and calibration reports that present the mathematical functions that determine the calibration factors for the logging unit utilized for logging for this project are referenced on the log headers for each borehole/well log. The details of the base calibration are discussed in Vadose Zone Characterization Project at the Hanford Tank Farms, Calibration of Two Spectral Gamma-Ray Logging Systems for Baseline Characterization Measurements in the Hanford Tank Farms (GJPO-HAN-1). The current calibration report for the logging tool utilized for logging borehole B8817 is *Hanford Tank Farms Vadose Zone, Sixth Biannual Recalibration of Spectral Gamma-Ray Logging Systems Used for Baseline Characterization Measurements in the Hanford Tank Farms* (GJO-HAN-26).

Casing corrections were applied to the data to compensate for the gamma-ray attenuation by the casing. The wall thickness of each casing string utilized in borehole B8817 was measured with a micrometer. The resulting values were applied to correct the data at the appropriate depth intervals. Additionally, constants determined for casing corrections during calibrations are determined for a single-cased borehole/well configuration. In wells where there are depth intervals where more than one casing is in place, the wall thicknesses are assumed to be additive to derive the proper correction. Although this assumption approximates the proper correction, it is known this correction could be slightly in error. The exact casing configuration and wall thicknesses used during data processing are discussed later in this report.

Water corrections were applied to the log data where appropriate. Attenuation of gamma rays from water can be significant and corrections to log data are derived for various borehole/well diameters during system calibrations. This correction is applied to the log data during data processing.

Repeat sections were conducted during some log surveys to document the logging system repeatability. Additionally, there are depth overlaps of log data where separate log runs were conducted. These overlaps are also useful to evaluate system repeatability.

Neutron-Neutron Moisture Data

The neutron-neutron moisture data were acquired in spectral form and converted to gross counts for each 0.250-ft log interval. The counts for each log interval were converted to volume fraction moisture (volume water/volume total) using the calibration transform described in *Radionuclide Logging System In-Situ Vadose Zone Moisture Measurement Calibration* (WHC-SD-EN-TI-306, Rev. 1).

Descriptions of the accuracy and precision estimates for the neutron-neutron measurements are presented in the following discussions. Accuracy is the instrumentation response compared to the calibration model values. The precision is a function of the counting statistics and the instrument response. Both of these characterizations of the instrumentation utilized for this project are quantified and displayed.

Accuracy

The accuracy of the instrumentation as established by the Data Quality Objectives (DQO) for moisture logging instrumentation is to be determined by the comparison of calibrated instrument response to the assigned model values of moisture content as per PNNL assignment during construction PNL-10801, UC606, *"Calibration Models for Measuring Moisture in Unsaturated Formations by Neutron Logging"*, Engleman, et al., October, 1995). The following table provides the results for the 8-in.-diameter casing calibration data that was collected on May 13, 1999 for the logging tool utilized for this project.

8-in. casing model moisture (volume fraction water in %)	Calibrated logging tool results (volume fraction water in %)	Percent difference between model value and instrument measurement
19.7	19.66	-0.2
11.9	11.79	-0.9
5.0	5.01	+0.2

The largest difference between the moisture model values and the logging tool measurements in the three Moisture Models is less than 1% volume fraction of moisture. These observed deviations are within the limits of accuracy established by BHI for this project.

Precision

Precision is the ability of an instrument to reproduce a given measurement; therefore, the variance observed for a given repeat sequence is used to determine the system or instrument's precision. During model data collection, 10 samples or repeat measurements are acquired in each model. These data are then used to compute a root mean square or estimated observed standard deviation. These data are also used to compute a theoretical standard deviation based solely on counting statistics, and the comparison agreed within statistical limits of sample size.

The model data collected for the calibration demonstrated that the observed deviations for any model were the same as predicted by the counting statistics (i.e., no extraneous instrumentation error were introduced). Therefore it is possible to predict the statistical precision for any given logging condition. The total counts observed for each depth sample determine the statistical precision. Furthermore, because the countrate is a function of the observed moisture content, it is possible to derive the statistical precision as a function of moisture for either calibrated casing configuration.

The sample acquisition time per depth increment is multiplied by the projected countrate from the calibration coefficients. This results in the number of counts for each logging sample as a function of

moisture content. Since the moisture log countrate follows a Poisson distribution, the standard deviation for each sample location is equal to the square root of the number of counts measured in the sample. For the given borehole logging, the highest logging speed was 1.0 feet per minute (ft/min) with a sampling frequency of one sample per 0.25 ft. The resulting sampling time is therefore 15 seconds or more. The casing thickness correction for the 0.500-in. wall thickness casing is 0.833. The countrate to volume fraction of moisture content conversion is performed by the following equation:

$$V = FaC^{\alpha},$$

Where V is the instrument reading of volume fraction of moisture, F is the casing correction factor, C is the observed countrate, and the coefficients a and α are the calibration coefficients. For the logging tool utilized for this project, the calibration coefficients were determined to be:

F = 1.2
a = 1.597E-05
α = 2.537

The precision (or repeatability) of the neutron moisture measurements were determined for each of the measurements, and are indicated on the moisture plots as error bars showing the uncertainty at +/- 1 sigma (67 percent confidence interval). The values of volumetric moisture content in borehole B8817 range from less than 1 percent to as high as 15 percent at a depth of 132 ft. The neutron countrate increased sharply at a depth of 200 ft as groundwater was encountered. The calculated moisture values were not plotted at the bottom of the borehole since a higher scale would reduce the resolution of features for the rest of the moisture plot.

Bulk Density Effects

The assumed bulk density for the moisture log is the bulk density of the moisture calibration models and is 1.76 grams per cubic centimeter (g/cc).

Due to the lack of continuous measurements of bulk density over the interval logged bulk density corrections to the moisture data are not possible.

The document *Radionuclide Logging System In-Situ Vadose Zone Moisture Measurement Calibration* (WHC-SD-EN-TI-306, Rev. 1) provides a density correction curve in Figure 6 that is based on computer modeling. This data could be used to provide an estimate of how the density assumption affects accuracy but is not provided herein because accuracy and precision statements of recommendations made per the Geophysical Logging Master Agreement are for "performance under known conditions such as in calibration models."

Casing Thickness Corrections

A casing thickness correction for the 8-in.-diameter casing was applied to the moisture measurements in accordance with WHC-SD-EN-TI-306, Rev. 1. Since there was no direct calibration of the neutron moisture logging tool in 11-in.-diameter casing, the region of borehole B8817 with 11-in.-diameter casing was not logged.

Log Plots

Separate log plots show the man-made and naturally occurring radionuclides potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th). The heading for each of the radionuclide log plots indicate the energy peak utilized to identify the specific radionuclide.

Various log plots show the concentrations of the individual radionculides, the total gamma count rate, and the volumetric moisture content. The total gamma count rate for each 0.5-ft depth increment is a sum of the counts from the spectrum for the particular depth increment divided by the counting time. However, the total gamma countrate is not corrected for water or casing, so a direct relationship between concentration and countrate does not exist. For example, in a borehole that was logged in two separate log runs, one run within a single casing and the other within two casings, the KUT concentrations will approximately repeat in both configurations as a result of the casing corrections. However, the total gamma rate will be much lower in the two-casing configuration run when compared to the single-casing log, because no casing correction is applied to the total gamma log data.

The KUT plots allow correlation of the log data with lithologic features, with intervals of man-made contamination, if it exists, and with moisture content. The statistical uncertainty for gamma-rays emitted from low-concentration radionuclides such as ^{238}U and ^{232}Th can be high for the 100-s acquisition time utilized for logging and the plots of the concentration of these radionuclides show high levels of uncertainty. This uncertainty is shown on the KUT plots by scattering of the data and large error bars. Nevertheless, these data are useful for correlation with geologic data or other borehole logs, e.g. moisture content, contamination intervals, etc.

Error bars shown on the log plots include the error associated with calibration measurements, and error associated with the casing and water corrections as well as counting error. Therefore, increased measurement error as shown on the log plots is the result of data collection that occurred in regions of boreholes containing water, containing casings of greater wall thickness (compared to conventional steel casing), and regions of boreholes where overlapping casings occur. This error is enhanced with increasing radionuclide concentrations.

The minimum detection limit (MDL) of a radionuclide represents the lowest concentration at which positive identification of a gamma-ray peak for that radionclide is statistically defensible. The spectral analysis program calculates the MDL for a particular peak on the basis of a statistical comparison with the background energy in the vicinity of the peak. An MDL for a particular radionuclide increases when additional gamma attenuation is introduced as a result of multiple casings or water in the borehole. Additionally, an MDL may increase with increasing radionuclide concentrations. The MDL's for the radionuclides are indicated on the plots by open circles.

The plots of the volumetric moisture content measured in borehole B8817 is provided with error bars for approximately every fifth moisture measurement. More frequent presentation of measurement error (error bars) obscures features of the log plot. The error bars represent the 68-persent confidence level (+/- 1 standard deviation), which was determined by converting the square root of the counts in each interval to equivalent moisture content. The definition of "Detection Limit" or threshold limit is defined as the minimum concentration or level at which a contaminant or natural element can be positively be identified. Since moisture can be measured to zero volume fraction, threshold limit is not applicable to moisture measurements and is not indicated on the log plots.

Results

Borehole B8817 is located at the 216-S-10 Pond southwest of the 200 West Area. The borehole was drilled in November and December 1999 to a depth of 240.7 ft. A nominal 11-in.-diameter casing was used to advance the borehole from ground surface to a depth of 36.3 ft, and an 8-in.-diameter casing was used to drill to a depth of 240 ft. A short section of the borehole between depths of 240.0 and 240.7 was uncased. Casing wall thickness was measured in the field using a micrometer; the wall thickness of each of the casings is 0.5 in. At the time of logging, both casing strings were set approximately flush with ground surface. The depth to groundwater on the day the borehole was logged was measured at 200.49 ft.

Spectral gamma logging in borehole B8817 was conducted in four log runs. Log runs 1 and 2 were conducted on December 9, 1999 inside the 8-in.-diameter casing. Log run 1 covered the depth interval from 240.5 to 119.0 ft. Log run 2 was a repeat survey between depths of 205.0 and 193.0 ft. Log runs 3 and 4 were conducted on December 10, 1999 inside the 11-in.- and 8-in.-diameter casings. Log run 3 covered the interval between ground surface and a depth of 125.0 ft. Log run 4 was a repeat section between depths of 34.0 and 46.0 ft. In addition, a short overlap of data occurs between depths of 119.0 and 125.0 ft where the survey intervals of log runs 1 and 3 overlapped.

A generalized casing correction function was used to determine casing correction factors. Log runs 1 and 2 were analyzed using a correction for casing with a wall thickness of 0.5 in. Log runs 3 and 4 were analyzed using a correction for 0.5 in.-thick casing in the 8-in.-diameter section of the surveys (between depths of 36.3 and 125.0 ft); a correction for 1.0-in-thick casing was applied to the data acquired in the section of the borehole where both the 11-in.- and 8-in.-diameter casings were present (ground surface to a depth of 36.3 ft). With more than one casing in place, the wall thickness is assumed to be an additive of both casings to derive the proper correction factor. These corrections are applied to the raw data that are recorded in counts per second to adjust the countrates for the attenuation that is caused by the presence of the casing.

Water corrections were applied to the log data collected between depths of 200.49 (the measurement on the day of logging) and 240.5 ft. Attenuation of gamma rays by water can be significant, which is reflected by the sporadic uranium-238 (^{238}U) concentrations below a depth of 200.5 ft.

Separate log plots show the man-made and naturally occurring radionclides potassium-40 (^{40}K), uranium-238 (^{238}U), and thorium-232 (^{232}Th)(KUT); there were no man-made radionuclides detected in borehole B8817. For calculating ^{238}U concentrations between ground surface and a depth of 36.5 ft, the 1764.51-keV bismuth-214 (^{214}Bi) gamma ray was utilized instead of the routinely used 609.32-keV ^{214}Bi gamma ray. For many of the spectra in this depth region of the borehole, the 609.32-keV 214Bi peak was not detected because of the attenuation resulting from the 1.0-in.-thick double casing. Although the yield (intensity) is lower for the 1764.51-keV peak, the higher energy level results in less attenuation by the double casing. The headings of the plots indicate the specific gamma peak that is used to determine the concentrations of the radionuclides. The error bars on the plots represent counting errors as well as errors associated with casing corrections, deadtime corrections, and the calibration function. The error bars represent the statistical uncertainties for the measurements as 95-percent (2-sigma) confidence intervals. Open circles on the plots indicate the minimum detectable level (MDL) of the particular radionuclide. The MDL for a specific radionuclide represents the lowest concentration at which positive identification of the gamma-ray peak is statistically defensible. MDLs generally increase in areas of higher gamma activity, and where additional gamma-ray attenuation occurs as a result of the presence of water or casing with greater wall thickness.

The standard combination log plot includes both the man-made and naturally occurring radionuclides, as well as a plot of the total gamma-ray activity as derived form the gamma spectra. The total gamma count

rate for each 0.5-ft depth interval is a sum of the counts from the spectra divided by the counting time. The combination plots are composites of data acquired in log runs 1 and 3.

Repeat log plots compare the repeat surveys from runs 2 and 4 with log runs 1 and 3, respectively. Repeat surveys were conducted to document the logging system's repeatability. These plots show good repeatability for the calculated radionuclide concentrations and depth control.

The plot of the naturally occurring radionculides shows several distinct concentration changes at depths of 50 ft, 102 ft, 133 ft, 195, and near the bottom of the borehole at a depth of 237 ft. Some of these changes correlate to lithologic features recorded on the borehole geologic log and with the moisture log data. Error bars representing the 2-sigma uncertainty in the measurements increase above a depth of 36 ft and below a depth of 200 ft as a result of additional error introduced by the corrections for double casing and the presence of water.

The combination plot is intended to show both the man-made and naturally occurring radionuclides (KUT), in addition to the total gamma countrate. Because the total gamma countrate is not corrected for casing or water, the total gamma decreases above a depth of 26 ft and below a depth of 200 ft where the double casing and water are present, respectively. The changes observed in the KUT concentrations are reflected in the profile of the gross gamma countrate in particular at the depths mentioned previously.

Moisture logging was conducted in borehole B8817 in the region of the borehole with 8-in.-diameter casing, below the 11- in. diameter casing (36.3 ft) and above the groundwater level (200.5 ft). The logging tool utilized for moisture logging for this project is not calibrated for use in 11-in.-diameter casing. Vigorous calibration has been performed with this logging tool in 6-in.- and 8-in.-diameter casings. A short interval of the borehole between depths of 34 and 36.3 ft was logged to identify the bottom of the 11-in.-diameter casing, and a repeat survey was conducted between depths of 100 and 121.5 ft to verify system performance.

The volumetric moisture content ranges between 2 and 15 percent throughout most of the logged interval. The highest moisture content value of almost 15 percent was measured at a depth of 134 ft. Error bars representing one standard deviation are presented for every fifth moisture measurement for clarity of data presentation.

A short interval was logged in both the 11-in.- and 8-in.-diameter casings (34 to 36.3 ft) to identify the bottom of the 11-in.-diameter casing. A decrease in the moisture content values should have been noticeable due to the attenuation resulting from the presence of both casings; however, a peak of elevated moisture content was observed at a depth of 35 ft. The reason for these elevated moisture values is unknown since the sediments at this depth are described as slightly moist.

The most obvious features on the moisture content plot are the fluctuating moisture values between depths of 90 and about 130 ft where several narrow peaks occur. In this region of the borehole, the moisture content values range between 2 and 14 percent. The geologic log for this borehole indicates the sediments in this region of the borehole range from mostly sand (95 percent) with 1 to 2 in.-thick beds of silt, to slightly silty sand, sandy silt, and silty sand. The peaks of higher moisture content are most likely indicating finer grained materials that retain moisture. There is a very distinctive increase in the KUT concentrations in this region of the borehole.

The highest volumetric moisture content value of almost 15 percent occurs between depths of 134 and 136 ft. A caliche zone is identified on the geologic log between depths of 134 and 139 ft. Sediments of elevated moisture appear to lie on top of this caliche zone. Below the caliche zone to the bottom of the borehole, the sediments are mostly silty sandy gravel, sand, gravelly sand, and sandy gravel. There are no

definitive lithologic features within this region of the borehole with which to correlate the features on the moisture plot, e.g. the peaks of elevated moisture content at depths of 151 and 176 ft, and the region of elevated moisture content between depths of 154 and 169 ft. The moisture content values increase at the bottom of the logged interval as groundwater is encountered.

Data

One compact disk is provided with this report and it contains the following data files:

B8817.JNB	SigmaPlot version 4.0 format of spectral gamma plots for data acquired in borehole B8817
B8817M.JNB	SigmaPlot version 4.0 format of neutron-neutron moisture and moisture-total gamma plots for data acquired in borehole B8817
B8817NNLH.DOC	Word 97 format of the neutron-neutron moisture log header for borehole B8817
B8817NNRpt.DOC	Word 97 format of the neutron-neutron moisture summary report for borehole B8817
B8817LH.PDF	Adobe Acrobat PDF format of the spectral gamma log header for borehole B8817
B8817ANA.XLS	Microsoft Excel 97 spreadsheet of analysis (spectral) data for borehole B8817
B8817MANA.XLS	Microsoft Excel 97 spreadsheet of analysis (moisture) data for borehole B8817
200-CS-1RCRARPT.DOC	Word 97 format of the report text

Neutron-Neutron Moisture Borehole Survey

Log Header

Project: RCRA Drilling 1999 **Well:** 299-W26-13

Borehole Information

Well: # 299-W26-13 Water Depth: 200.49 ft Total Depth: 240.7 ft
Elevation Reference: n/a Elevation: n/a
Depth Reference: Ground surface Casing Stickup: 11.75- in.-0 ft; 8.625 in.-0.1 ft
Casing Diameter: 11.75 in Depth Interval: 0 to 36.3.0 ft Thickness: 0.5 in.
Casing Diameter: 8.625 in Depth Interval: 0 to 240 ft Thickness: 0.5 in.

Logging Information

Log Type:	Neutron-neutron moisture	
Company:	Waste Management Technical Services	
Date:	December 10, 1999	
Logging Engineer(s):	Steven Kos	
Instrument Series:	RLSM00.0	
Logging Unit:	RLS-1	
Depth Interval:	34 to 121.5 ft	Prefix A686
	100 to 201.1 ft	A687
Instrument Calibration Date	May 13, 1999	
Calibration Report:	WHC-SD-EN-TI-306, Rev.0	

Analysis Information

Company:	Waste Management Technical Services
Analyst:	Steven Kos
Date:	January 15, 2000
Depth Reference:	Ground Surface

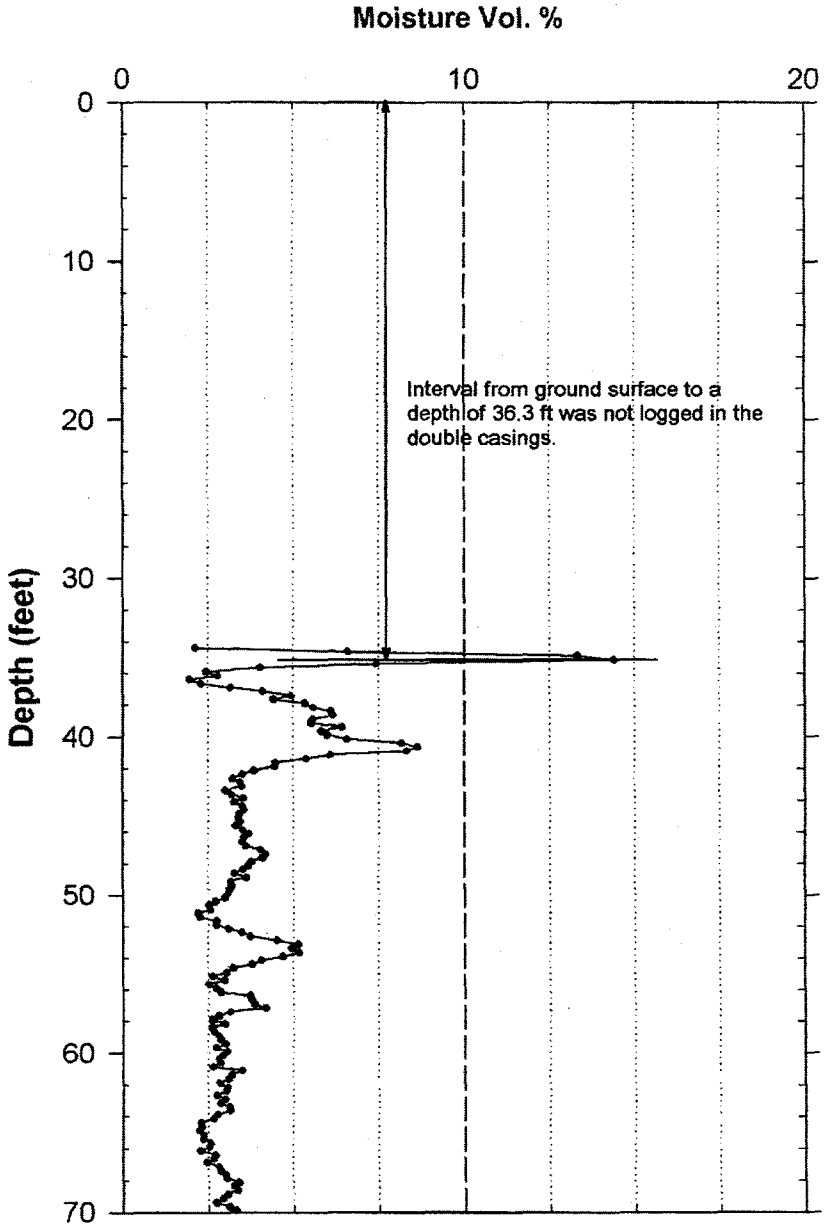
Notes Measurements were acquired at 0.250-ft depth increments at a logging speed of 1.0 ft per minute. The borehole was logged in one log survey in the 8-in.-diameter casing. A short interval was logged in the 11-in.-diameter and 8-in.-diameter casings between depths of 34 and 36.3 ft. The survey was terminated when the logging tool reached groundwater at a depth of 201.1 ft. A repeat survey was conducted between depths of 100 and 121.5 ft.

Neutron-Neutron Moisture Survey

Waste Management Technical Services

Project: RCRA Drilling 1999 Log Date : December 10, 1999

Borehole: 299-W26-13 Depth Datum: Ground Level

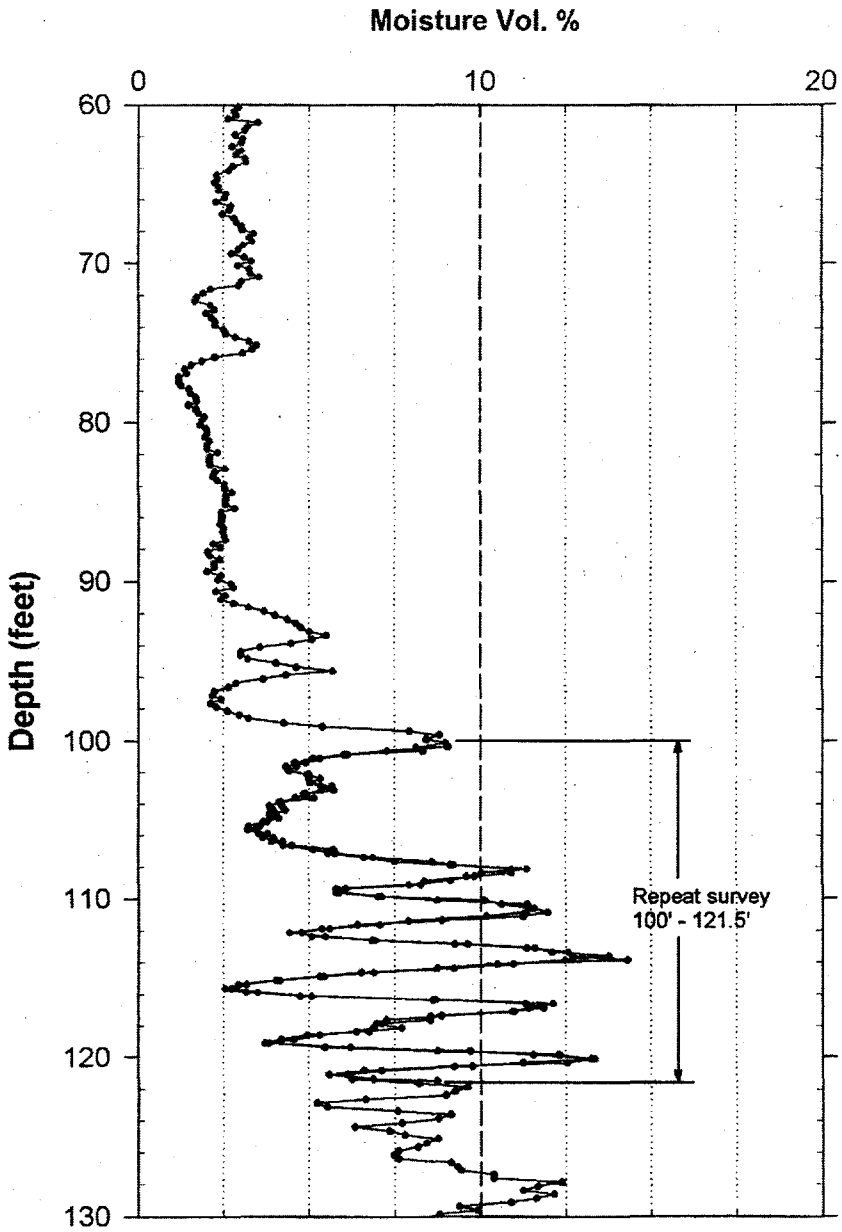


Neutron-Neutron Moisture Survey

Waste Management Technical Services

Project: RCRA Drilling 1999 Log Date : December 10, 1999

Borehole: 299-W26-13 Depth Datum: Ground Level

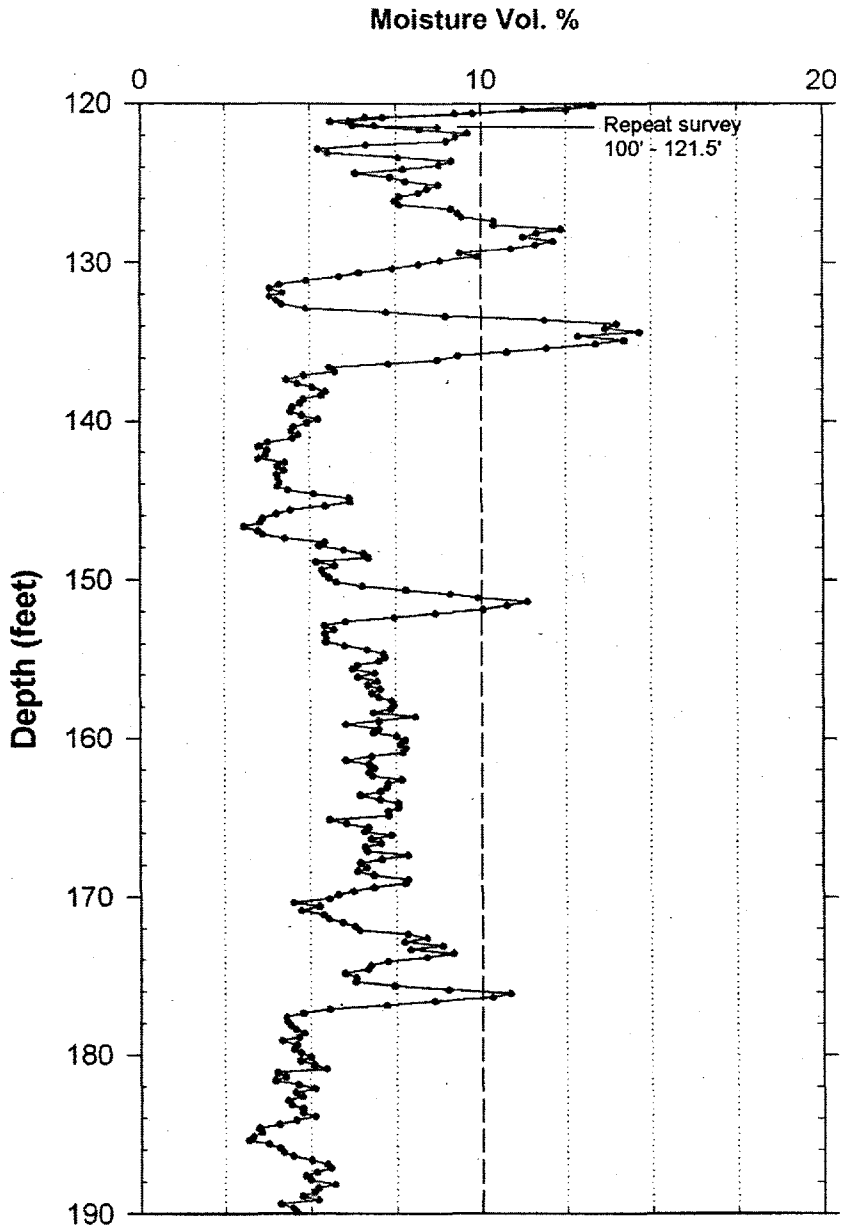


Neutron-Neutron Moisture Survey

Waste Management Technical Services

Project: RCRA Drilling 1999 Log Date : December 10, 1999

Borehole: 299-W26-13 Depth Datum: Ground Level

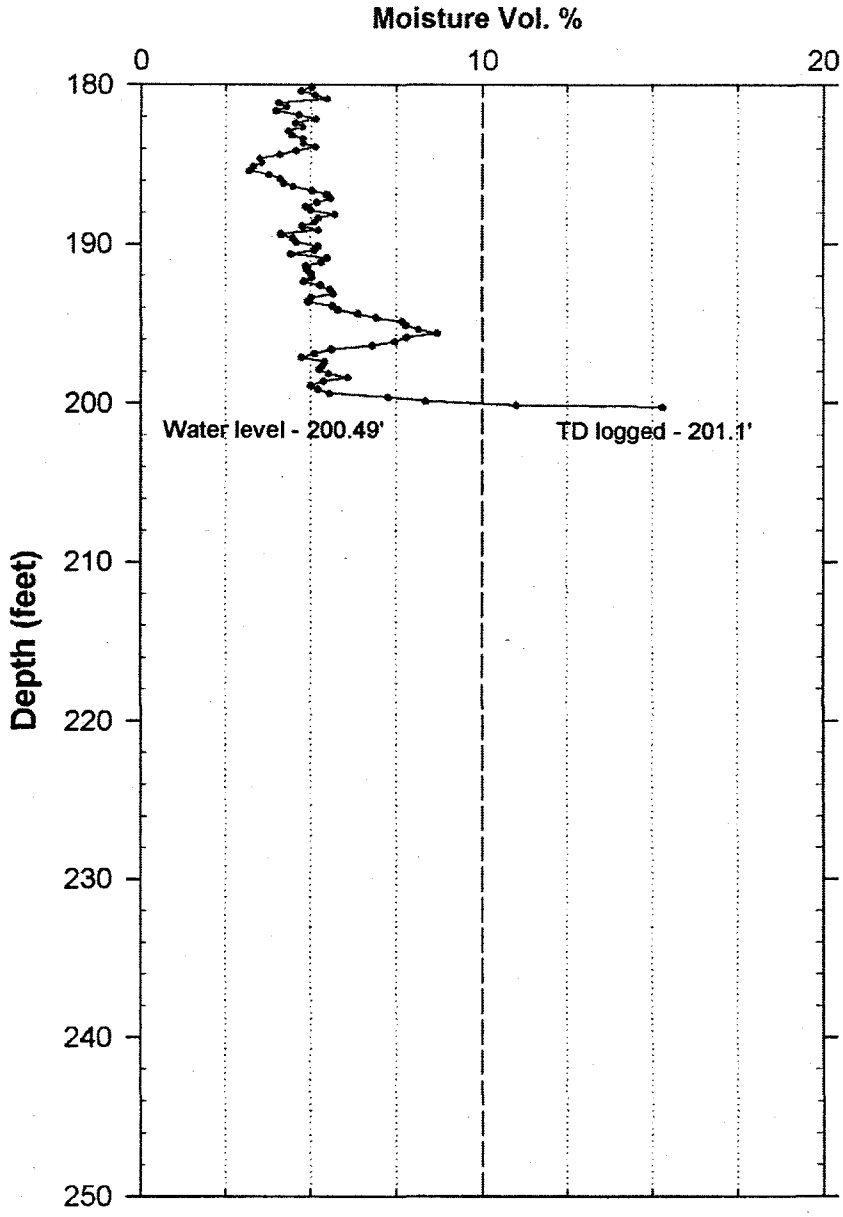


Neutron-Neutron Moisture Survey

Waste Management Technical Services

Project: RCRA Drilling 1999 Log Date : December 10,1999

Borehole: 299-W26-13 Depth Datum: Ground Level



Neutron-Neutron Moisture Borehole Survey

Waste Management Technical Services

Log Analysis Summary Report

Project: 200-CS-1/RCRA
Log Type: Neutron-neutron moisture

Well: 299-W26-13
Log Date: December 10, 1999

General Notes:

All log data were collected relative to ground surface.

Logging was conducted in one log run in the 8-in.-diameter casing. Data were not acquired in the 11-in.-diameter casing between ground surface and a depth of 36.3 ft since the logging tool utilized for this project is not calibrated for this size casing.

Measurement uncertainties of one standard deviation (1 sigma) were calculated for all moisture measurements; for clarity in presentation of the log data, error bars were plotted for every fifth data point.

System Performance Verify:

The pre- and post- survey calibrations indicated the logging system was performing within specifications outlined in the logging procedures.

Repeat Interval:

A repeat survey was performed between depths of 100 and 121.5 ft. The results of the repeat surveys indicate the logging system was operating within specifications.

Environmental Corrections:

The countrates measured with the neutron-neutron logging tool were corrected for the appropriate casing thickness.

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