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Pacific Northwest
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Prepared for The U. S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Summary

This report summarizes results from borehole 299-E17-21, which was drilled in April 1998, at the Immobilized Low-Activity Waste (ILAW) disposal site in support of the Performance Assessment. The ILAW site is located in the south-central part of 200-East Area, southwest of PUREX. In addition to borehole 299-E17-21, two shallow boreholes were drilled adjacent to the principal borehole in support of environmental tracer studies. Borehole 299-E17-21 was drilled to a depth of 480 feet and completed as a groundwater monitoring well in the upper unconfined aquifer. The two shallow boreholes were drilled to a depth of 50 feet and then backfilled. Core was obtained from all three boreholes for characterization studies.

Borehole 299-E17-21 penetrated the Ringold Formation, the Hanford formation, and a surface eolian deposit. The two shallow boreholes penetrated the upper part of the Hanford formation and the surface eolian deposit. The Ringold Formation is at least 144 feet thick and consists of Unit A, Unit E, and the Lower Mud of the Member of Wooded Island. The Hanford formation is 330 feet thick and contains four unconsolidated units: three sandy units that are each distinguished by a capping paleosol horizon, and a gravel unit at the base of the formation. The paleosols occur at drilled depths of 5 feet, 58 feet, and 163 feet; the gravel begins at a depth of 247 feet. The boreholes were located on a stabilized sand dune overlying the upper paleosol.

No radioactive or chemical contaminants were encountered in the vadose zone during drilling. Geophysical logging supports the absence of radionuclides in the vadose zone. Moisture logging of the vadose zone indicates the upper part of the vadose zone has higher moisture content and the moisture occurs primarily in silt- and clay-rich zones.

The unconfined aquifer occurs in the Ringold Formation at the ILAW site. Groundwater samples were collected from above and below the Lower Mud. At the time of this report analytical results from only the groundwater below the Lower Mud have been received. The analysis indicates no contamination present below the Lower Mud. Preliminary field tests on the aquifer above the Lower Mud show no contaminants above drinking water standards.

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1.0 Introduction

The Tank Waste Remediation System (TWRS) is the group at the Hanford Site responsible for the safe underground storage of liquid waste from previous Hanford Site operations, the storage and disposal of immobilized tank waste, and closure of underground tanks. The current plan is to dispose of immobilized low-activity tank waste (ILAW) in new facilities in the southcentral part of 200-East Area (Figure 1) and in four existing vaults along the east side of 200-East Area (Mann et al. 1998).

Boreholes 299-E17-21, B8501, and B8502 were drilled at the southwest corner of the ILAW site in support of the Performance Assessment activities for the disposal options (Mann et al. 1998). This report summarizes the initial geologic findings, field tests conducted on those boreholes, and ongoing studies. The drilling and testing activities performed at the ILAW site are described in Reidel et al. (1995) and Reidel and Reynolds (1998). Because it is customary to report borehole data in feet rather than meters, this report uses the English system of units.

1.1 Boreholes 299-E17-21, B8501, and B8502

One deep (480 feet) borehole and two shallow (50 feet) boreholes were drilled at the southwest corner of the ILAW site (Figure 1 and Table 1). The primary factor dictating the location of the boreholes was their characterization function with respect to developing the geohydrologic model for the site and satisfying associated Data Quality Objectives (DQOs) (Reidel et al. 1995, Reidel and Reynolds 1998). The deep borehole was drilled to characterize subsurface conditions beneath the ILAW site, and two shallow boreholes were drilled to support an ongoing environmental tracer study (Murphy 1997). The tracer study will supply information to the Performance Assessment. All the boreholes provide data on the vadose zone and saturated zone in a previously uncharacterized area.

1.2 Technical Objectives

The principal technical objectives of deep borehole 299-E17-21 were:

1. To provide geologic samples to characterize the sediments in the vadose zone and saturated zone in support of the ILAW Performance Assessment. This includes physical, hydrologic, and geochemical characterization.

2. To provide geologic samples for analysis to estimate recharge by evaluating environmental tracers and support ongoing natural infiltration studies.

3. To characterize the groundwater in the unconfined Hanford aquifer at the ILAW site both above and below the Lower Mud unit of the Ringold Formation. This includes both hydrologic and hydrochemical characterization.

4. To provide a groundwater monitoring well for preoperational baseline monitoring.

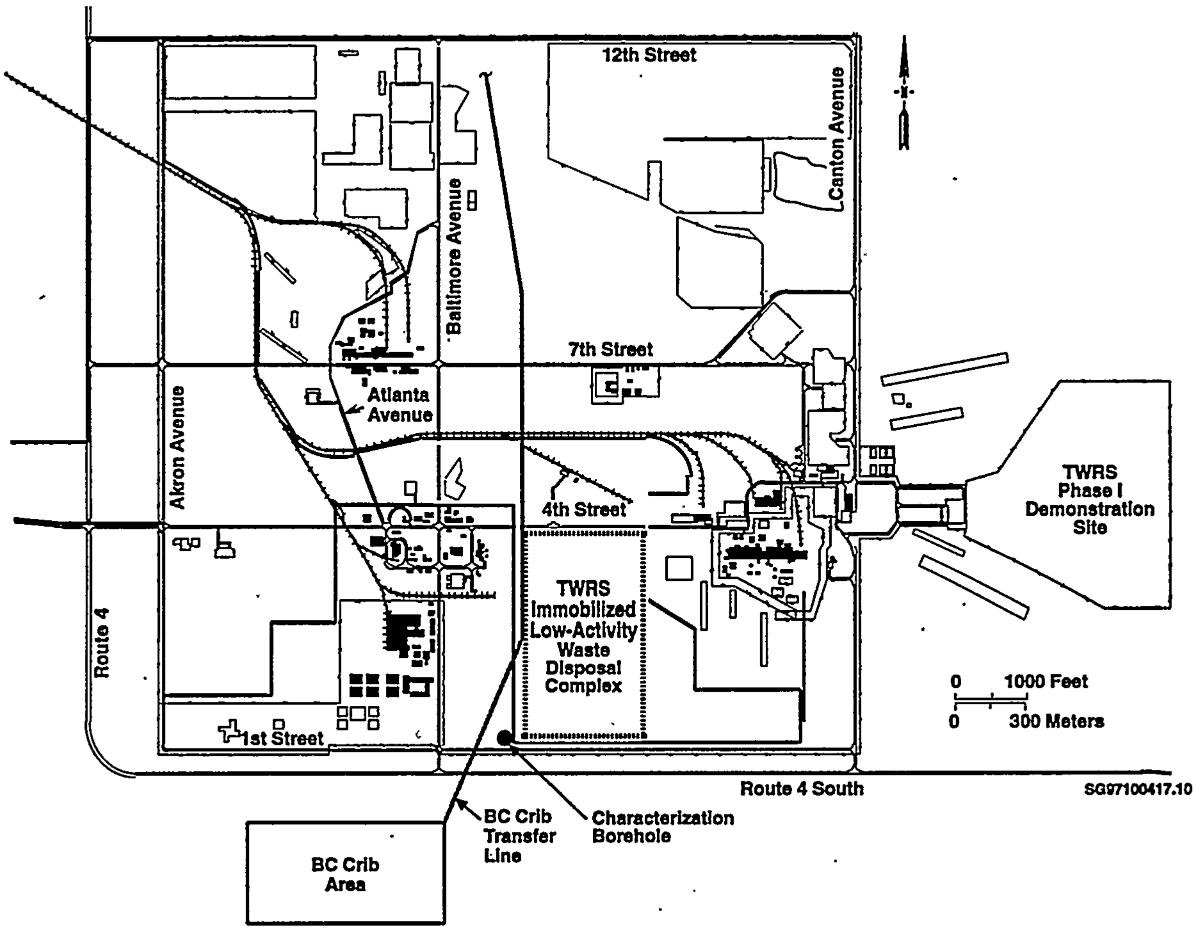


Figure 1. Location Map of the ILAW Site and Borehole 299-E17-21

Table 1. Purpose and Locations for Boreholes 299-E17-21, B8501, and B8502

Borehole #	Type	Purpose	Northing	Easting	Location and Elevation
299-E17-21	Deep	Characterization and Groundwater Monitoring	N134894.21	E574107.02	Southwest corner of ILAW site. 735.7 feet MSL
B8501	Shallow	Environmental Tracer Studies	N134924.68	E574107.02	Approximately 50 feet north of 299-E17-21. 741.1 feet MSL
B8502	Shallow	Environmental Tracer Studies	N134894.21	E574137.48	Approximately 50 feet east of 299-E17-21. 737.8 feet MSL
MSL = Mean Sea Level.					

Laboratory tests being performed on samples from the boreholes are given in Table 2. The results of these tests will be reported separately by the Principal Investigators conducting the tests and studies.

1.3 Report Organization

This report consists of four chapters and four appendixes. The first chapter is the introduction and background for the project. Chapter 2 provides information on the drilling and sampling methods that were used. Chapter 3 summarizes the technical results and Chapter 4 contains references cited. The four appendixes provide the results of the aquifer test (Appendix A), groundwater analyses (Appendix B), borehole construction data (Appendix C), and geophysical logs (Appendix D).

Table 2. Tests to be performed on Borehole Samples and Uses of Data

Test / Use	Chemical Transport Studies (Reidel et al 1995, Section 4.1.2.3.4 as revised by Kaplan [1997])	Physical Properties of Vadose Zone (Reidel et al. 1995, Section 4.1.2.1 as revised by Khaleel [1997])	Estimating Recharge by Environmental Tracers (Reidel et al. 1995, Section 4.1.2.3.3 as revised by Murphy [1997])	Aquifer Characterization (Reidel et al. 1995, Section 4.1.3)
Stratigraphy	X	X	X	X
Geophysical logging	X	X	X	X
Moisture content	X	X	X	
Matric potential		X		
pH	X			
Cation exchange capability	X			
Iron oxide concentration	X			
Mineralogy - XRD	X	X		
Cations	X			
Anions	X			
$CaCO_3$	X		X	
Gravimetric moisture	X	X	X	
Bulk density	X	X	X	X
Particle density	X	X	X	
Particle size	X	X	X	X
Initial porosity		X	X	X
Porosity		X		X
Unsaturated hydraulic conductivity		X	X	
Saturated hydraulic conductivity		X	X	X
Moisture retention	X	X	X	
Chloride			X	
Pore water extraction for ^3H			X	

Table 2. (contd)

Use \ Test	Chemical Transport Studies (Reidel et al. 1995, Section 4.1.2.3.4 as revised by Kaplan [1997])	Physical Properties of Vadose Zone (Reidel et al. 1995, Section 4.1.2.1 as revised by Khaleel [1997])	Estimating Recharge by Environmental Tracers (Reidel et al. 1995, Section 4.1.2.3.3 as revised by Murphy [1997])	Aquifer Characterization (Reidel et al. 1995, Section 4.1.3)
Groundwater Composition				X
Aquifer Testing				X

2.0 ILAW Site Drilling and Sampling Activities

2.1 Background

Drilling, sampling, and well construction objectives for the project are presented in Reidel and Reynolds (1998). That report called for the drilling and sampling of two shallow environmental tracer boreholes and the drilling, sampling, and construction of a groundwater well. To achieve these goals, continuous sample retrieval was needed from the surface to 50 feet below land surface (BLS) in the environmental tracer boreholes and from the surface to groundwater (330 BLS) in the groundwater well. Additionally, the plan requested groundwater sampling at selected intervals from the top of the unconfined aquifer through the total depth of the well.

2.2 Methodology

2.2.1 Drilling

A review of available drilling technology was conducted to determine the most efficient and cost-effective method of drilling and sampling soil and groundwater (Reidel and Reynolds 1998). Taking into consideration the expected subsurface geology, drilling costs per foot, and the DQOs for soil and groundwater sampling, we selected an air-lift, driven casing method referred to as the Becker Hammer®. This drilling method uses a dual-wall temporary casing and a pile driver to advance the temporary casing and bit. Compressed air is supplied down the annular space between the dual casings and the cuttings are lifted up the central void of the dual string. A toothed chisel bit casing shoe cuts the materials at the leading edge of the casing. Air galleys direct the circulating air to the chisel face of the bit, and the hole is advanced by a diesel-powered pile driver positioned at the top of the casing string.

This method provides several advantages over other methods:

- no drilling bit or drill rods have to be removed to provide access for sampling.
- rapid advance rates are possible in unconsolidated materials.
- because air is the circulating medium for cuttings removal, no fluids will affect the soils surrounding or below the borehole.

2.2.2 Soil Sampling

The need for continuous soil sampling through the vadose zone and at selected deeper intervals determined the drilling method and sampling technique. The method we selected consists of a down-hole air-driven hammer in combination with a large-diameter (4.5-inch outside diameter), extended-length (5 to 10 feet) split spoon sampler. This method has been used at Hanford in the past with excellent results for both the acquisition of representative samples and high recovery percentages.

The large diameter and extended lengths of this drilling system have been proven to have the greatest potential for high recovery rates and defensible sample integrity. The large-diameter samplers reduce friction locking as sediments are forced into the sample chamber liners, and the extended sampler lengths reduce sample losses at the top and bottom of the sample runs. Loss can occur with shorter 2-foot length samplers because a portion of sample is potentially lost or disturbed at the bottom of each sampling run. Reducing the number of sample runs increases the recovery rate of continuous preserved samples. The unconsolidated sediments at Hanford drove the development of this sampling method during the extensive efforts to complete RCRA groundwater monitoring well characterization and construction.

2.2.3 Groundwater Sampling and Hydrologic Properties Testing

In order to meet the groundwater sampling objectives described in Reidel and Reynolds (1998) in a cost-effective manner, several techniques were employed.

1. Grab Samples. The Washington Department of Ecology (Ecology) requested that a screening sample of the groundwater be collected at the top of the unconfined aquifer for waste disposal and purge water handling determinations. Tritium and nitrate analyses were to be performed before the purge water could be discharged to the ground surface. Additional tritium samples and basic groundwater parameters were collected at 30- to 50-foot intervals below the water table to provide a vertical profile of the aquifer. An E.G.&G. Berthol, HPLC Radioactivity Monitor (Model # LB 507B) with a detection limit of 10 pCi/ml was used to measure tritium at the drill site.

2. Pumped Samples. The sampling plan called for a groundwater sample be collected using a submersible pump at the total drilled depth of the borehole prior to the abandonment of the lower portion and construction of the permanent well at the top of the unconfined aquifer. To accomplish this goal the following steps were outlined in the Sample and Analysis Plan:

   - Drill to total depth - 480.7 feet BLS.

   - Withdraw the temporary casing a sufficient length (approximately 10 feet) to allow an inflatable packer and a submersible pump to be placed in the open portion of the borehole with the packer straddling the bottom of the casing and sealing to the borehole wall.

   - Initiate pumping at low rate to facilitate laminar flow from the formation.

   - Monitor groundwater parameters until analysis determines results are representative of groundwater conditions for the formation being sampled (i.e., Ringold Unit A).

   - Collect a groundwater sample for laboratory analysis per procedure.

- Record field information on a field activity report for data tracking purposes.

The Sampling and Analysis Plan outlined a testing program for the hydrologic properties of the well. This testing was designed to provide information on recovery rates, effective permeability and other hydrologic properties for the zone in which groundwater was to be monitored. Testing consisted of slug withdrawal testing and analysis (Appendix A). The plan specified the purposes of the testing field procedures, and the analytical procedure for interpretation of the test.

2.2.4 Geophysical Logging

All three boreholes were geophysically logged at the conclusion of drilling. High Purity Germanium (HPGe) logging was conducted to determine the presence of man-made radioactive materials above detection limits, to provide analysis of naturally occurring potassium, thorium, and uranium, and for stratigraphic studies. Additionally, a formation moisture log was obtained to determine the relative *in situ* moisture content of the vadose zone. Appendix D contains copies of the log suites and the logging analysis reports.

2.3 Drilling Activities

2.3.1 Drilling Time

The drilling of borehole B8500 (299-E17-21) began on April 6, 1998 and was completed on April 23, 1998. Sixteen days of field activities were required to drill to a depth of 480 feet depth, collect 38 split-spoon soil samples, collect a pumped groundwater sample from the 470 feet depth, geophysically log the borehole, abandon the lower 122 feet of the borehole; construct a groundwater monitoring well from 358 feet to the surface and develop the well for sampling purposes. Copies of the well construction and completion summary sheets for all three wells can be found in Appendix C.

Borehole B8501 commenced drilling and sampling on April 24, 1998 and was abandoned on April 25, 1998. One day of drilling and sampling for this borehole collected 14 sets of split-spoon samples from the surface to 50 feet depth. The borehole was subsequently geophysically logged and abandoned the following day.

Borehole B8502 commenced drilling and sampling on April 27, 1998 and was abandoned on April 28, 1998. One day of drilling and sampling for this borehole collected 14 sets of split-spoon samples from the surface to 46.9 feet depth. The borehole was subsequently geophysically logged and abandoned the following day.

2.3.2 Soil Sampling

The soil sampling was intended to collect as continuous a set of soil samples as achievable from the surface to the top of groundwater in the deep well and from the surface to a depth of 50 feet in the environmental tracer boreholes. At the onset of drilling borehole 299-E17-21, the drilling contractor attempted to utilize a thin-walled, 3.5-inch outside-diameter, long-length sampler driven by an uphole casing driver. This method resulted in multiple failures as drilling progressed. The primary sediment recovery problems were frictional locking of soils as they entered the sample liners and damage to the liners from fracturing and compression. The failures resulted in recoveries ranging from 40% to occasionally 100%. The overall recovery percentage for the upper 50 feet of the well was 70% with substantial intervals of no recovery. The uphole driving method in combination with small-diameter drilling rod (2.875 inches) used to transmit force to the sampler caused drill rod flexure, sampler and downhole equipment stress, and dissipation of the driving force. These factors resulted in several downhole equipment failures and sample recovery failures. Problems ranged from bending and damaging of the drill rods, breakage of and inability to recover downhole equipment, effective refusal of the sampler to advance in the unconsolidated sands and silts of the area, and loss of sample during or after driving. Equipment failures at 35 feet and 169 feet BLS required removal of the temporary casing to recover the lost or damaged sampling equipment. Because of the continuing low recovery percentages, equipment failures, and the resulting slow borehole advance times, the sampling method was changed to the downhole air hammer method suggested in the Sampling and Analysis Plan. The new method used stiffer, larger diameter 4.5-inch drill rods. However, the extended length samplers still could not be removed when driven the full 10 feet length.

As a result of these problems the drilling contract was changed to allow for less stringent requirements for sampling intervals, lengths, and recoveries. This reduced the requirements dictating continuous recoveries to a minimum of 3 feet of recovery for every 10 feet attempted, or 2 feet of recovery for every 5 feet attempted. This change allowed the drilling contractor to deploy shorter-length samplers totaling only 4.6 feet in length.

Utilizing the downhole hammer, the large-diameter sampling method and shorter sampling lengths, sampling progressed from approximately 90 feet BLS to 249 feet BLS. Sample recoveries improved to an average of 95% recovery for sampled intervals. Sampling was discontinued at 249 feet depth because of formational conditions that precluded sampling with a driven split spoon. Between 246 and 248 feet depth, the grain size of the formation changed from silts and sands to pebble gravels with 1- to 7-inch-diameter clasts. Large-diameter materials cannot be sampled with a driven sampling method.

The two environmental tracer boreholes were drilled and sampled using the modified method of downhole hammer, large-diameter sampling device and large-diameter drill rods. This resulted in average recovery percentages of 79% for borehole B8501 and 84% for borehole B8502. These percentages reflect the inability to recover samples from gravel zones. For non-gravel materials, the total recovery percentages per unit of driven length were well above 95%.

2.3.3 Groundwater Sampling

The first groundwater sample was retrieved directly from the discharge line of the drilling system as drilling reached the water table (330 ft BLS). As per the request from Ecology, analyses for tritium and nitrate content were performed on site. The results of the analyses were recorded in field logbook WM-SML-H12, pages 71 and 75. The detected levels of tritium and nitrate did not exceed the discharge to ground limits imposed by Ecology and were below drinking water standards. An additional sample was collected from the discharge line at 359 to 369 feet BLS (as recorded on page 77 of the field logbook). As a backup to the collection of samples from the discharge line and to provide basic groundwater parameter information (e.g., nitrate content, pH, conductivity, temperature, turbidity, and Eh) additional samples were collected using a Kabis Sampler® at 339 feet, 374 feet and 429 feet BLS. The analytical results from these samples are recorded on page 76 of the field logbook and are given in Appendix B.

The Sampling and Analysis Plan called for a slug withdrawal test to be performed at the conclusion of the well construction and development. This test was completed in June of 1998, and the electric submersible sampling pump was installed on June 15, 1998. The well was then placed on a groundwater-sampling schedule. Appendix A contains the results and interpretations of the slug test.

2.4 Lessons Learned

During the course of this project several inefficiencies and failures were encountered that affected the project's ability to meet the DQOs, and control the overall cost effectiveness. Because of contractual requirements, the project representatives responsible for meeting the DQOs of the project plan were not able to control the directions contained in the drilling contract or direct the field operations without the consent of the contract representative. Field direction by the project technical leads is necessary for several reasons:

1. No contract can fully cover all possible field conditions encountered during completion of field activities. The contractual chain of command required the Pacific Northwest National Laboratory (PNNL)/Waste Management Northwest (WMNW) technical representatives to address all concerns to the BHI field contract representative, who then addressed the drilling contractor. Therefore, the Hanford Site technical personnel with responsibility to accomplish this drilling/characterization did not have preauthorized contractual authority to ensure work was performed in a technically sound manner and within project budget. The current DOE-Bechtel Hanford Inc. (BHI) contract/agreement places drilling contract authority with BHI but does not hold BHI responsible for either the success of the drilling effort or the cost to the project.

2. The language of the original contract did not require or specify the precise methods selected through the DQO process and specified in the Sampling and Analysis Plan for meeting the project goals. BHI contracting representatives indicated that BHI does not direct the subcontractors on how to meet the goals of the project. The only direction provided is on final deliverables to meet the project goals. This approach does not allow for developed methods, goals and objectives to be clearly outlined in the contractual requirements for the sub-contractor. This shortcoming resulted in the sub-contractor's using a sampling technique and equipment proven in the past to be inadequate for the Hanford Site

conditions, which in turn resulted in failure to meet the project goals of a high percentage recovery of the entire soil column. It is recognized that no sampling method is effective for all conditions (in this case large gravels). However, using a better technique from the onset of drilling would have resulted in increased recovery rates, as indicated by recovery rate improvements in the second and third boreholes. Also, using a more effective sampling technique from the onset would have improved field efficiency for both the drilling contractor and the project personnel. In this case, the Hanford Site technical personnel with responsibility to accomplish this project did not have authority to review and approve the contract.

2.5 Recommendations

Making the Project Hanford Management Contractor project representative also the BHI technical representative for the drilling contract could mitigate the conditions discussed above in the future. Where dual projects are contributing funds to the drilling effort, a co-management agreement should be arranged for the contract representative with the driller. The technical representative must have authority to approve the technical terms of the contract. A non-disclosure agreement can be arranged where business-sensitive information might be exchanged through this arrangement.

3.0 Borehole Stratigraphy

Borehole 299-E17-21 encountered sediments that comprise the Ringold Formation, the Hanford formation, and an eolian deposit (Figure 2 and Table 3). Boreholes B8501 and B8502 penetrated only the upper portion of the Hanford formation and the surface eolian deposit. Tables 4, 5, 6, and 7 provide descriptions of the cores collected from these boreholes and selected descriptions from the field logs of intervals not cored. The nomenclature employed in this report is consistent with the standardized use for the Hanford Site (i.e., Delaney et al. 1991; Reidel et al. 1992; Lindsey et al. 1994; Lindsey 1996) and following geologic convention, the discussion proceeds from oldest to youngest units.

3.1 Ringold Formation

The Ringold Formation in borehole 299-E17-21 is at least 145 feet thick and consists of three units of Lindsey's (1996) Member of Wooded Island (Figures 2 and 3). The deepest unit encountered is the lower gravel, Unit A, which extends from a depth of 439 feet to the greatest depth penetrated (480 feet). Lying above Unit A is 61 feet of the Lower Mud unit, which is overlain by an upper gravel, Unit E, that is 43 feet thick. The upper Ringold (sand and silt of the Member of Taylor Flat) is not present in these boreholes. Unit A and Unit E are equivalent to mapping unit P_LMcg, Pliocene-Miocene continental conglomerates of Reidel and Fecht (1994a,b). The Lower Mud is equivalent the mapping unit P_LMc, Pliocene-Miocene continental sand, silt, and clay beds of Reidel and Fecht (1994a,b).

3.1.1 Unit A

The borehole penetrated forty-one feet of Unit A, consisting of well-cemented sandy gravel. There are occasional yellow to white interbedded sand and silt with silt and clay lenses. Green-colored, reduced-iron stain is present on some grains and pebbles. Although the entire unit appears to be cemented, the zone produced abundant high-quality water. No contaminants were detected in the analyzed water sample (Appendix B), but groundwater constituents and concentrations suggest reducing conditions.

3.1.2 Lower Mud

Sixty-one feet of the Lower Mud unit were penetrated in the borehole (378-439 drilled depth). The uppermost 4 feet consist of a yellow sandy to silty mud. The silty mud grades downward into 34 feet of blue mud with zones of silt to slightly silty mud. The blue mud, in turn, grades down into 23 feet of brown silty mud with organic rich zones and occasional wood fragments.

3.1.3 Unit E

The upper contact of the Ringold Formation was encountered between 330 feet and 335 feet; for this report we place the contact at 335 feet drilled depth. A gravel sequence of the Hanford formation directly overlies the contact, making exact placement difficult because both units are gravels.

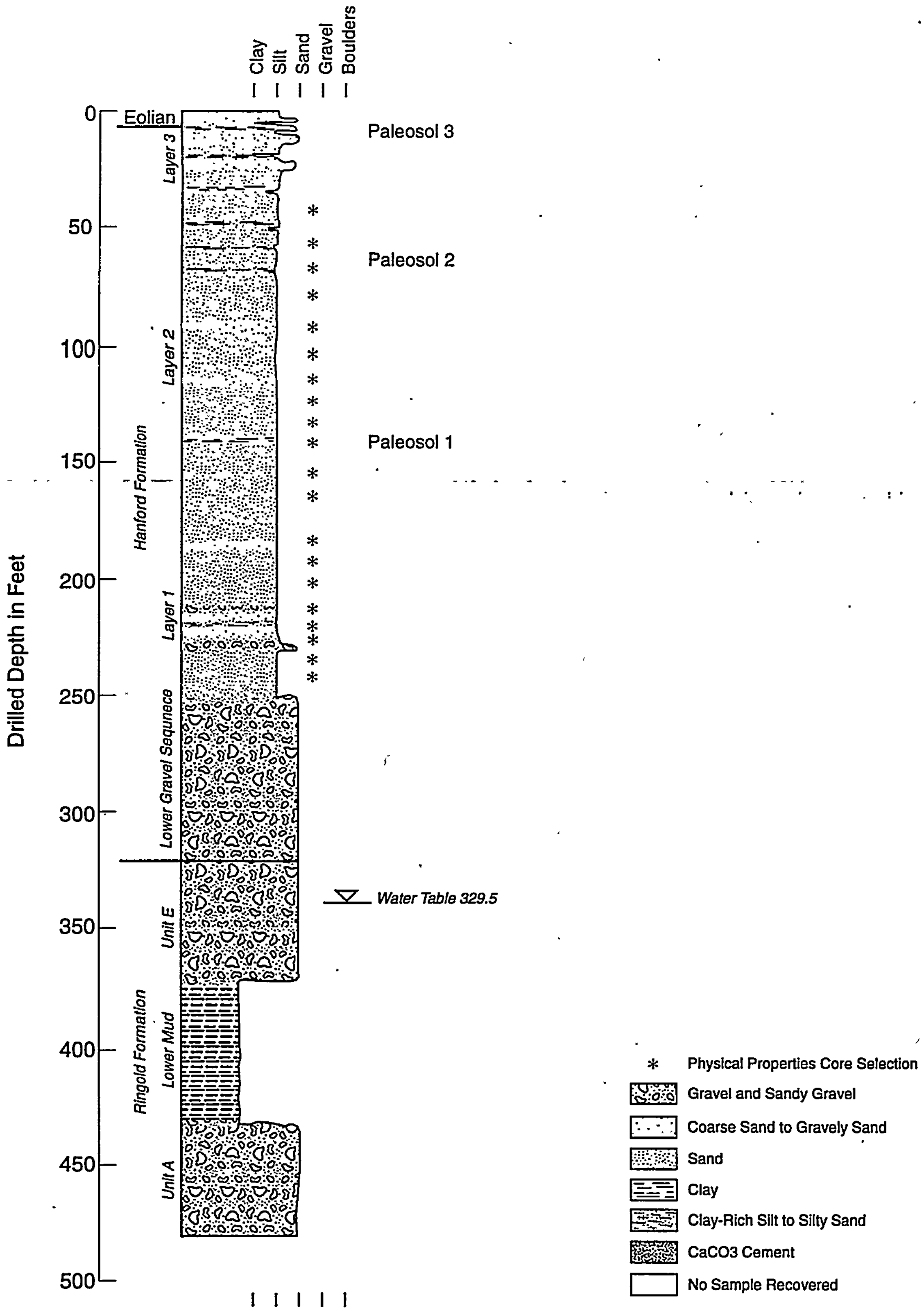


Figure 2. Summary Stratigraphy from Borehole 299-E17-21. See Table 4 for description of cored intervals and Table 7 for selected field described intervals.

Table 3. Stratigraphy of Borehole 299-E17-21

Nomenclature Used in this Report		Equivalent of Lindsey et al. (1994), Lindsey (1996), and Reidel et al. (1992)	Equivalent of Reidel and Fecht (1994a,b)	Drilled Depth Intervals (feet)	Thickness (feet)
Eolian			Qd	0 to 5	5
Hanford formation		H	Qfs and Qfg	5 to 247	330
Sandy Sequence	Layer 3	H2	Qfs_3	5 to 58	53
	Layer 2	H2	Qfs_2	58 to 163	105
	Layer 1	H2 and HZA	Qfs_1 (?)	163 to 247	84
Basal Gravel Sequence		H3	Qfg_1 (?)	247 to 335	88
Ringold Formation, Member of Wooded Island		Ringold Formation, Member of Wooded Island	P_LM	335 to 480	>145
	Unit E	Unit E	P_LMcg	335 to 378	43
	Lower Mud	Lower Mud	P_LMc	378 to 439	61
	Unit A	Unit A	P_LMcg	439 to 480	>41

Unit E consists of 43 feet (335 to 378 drilled depth) of sandy gravel to gravely sand with scattered large pebbles and cobbles up to 10 inches in size. The gravel is well rounded with a sand matrix supporting the cobbles and pebbles. Cementation of this unit ranges between slight and moderate.

3.2 Hanford Formation

The Hanford formation encountered in borehole 299-E17-21 is 330 feet thick, and extends from 5 to 335 feet drilled depth. The Hanford formation consists of pebble to cobble gravel and fine- to coarse-grained sand, with lesser amounts of interstitial and interbedded silt and clay. In the boreholes at the ILAW site it consists of the gravel-dominated and sand-dominated facies. The silt-dominated, slackwater facies (Touchet Beds) are not present.

Boreholes 299-E17-21 and B8502 were surveyed at ground-surface elevations of 735.7 and 737.8 feet above mean sea level, respectively. Borehole B8501 is 50 feet north of 299-E17-21 and was surveyed at a ground-surface elevation of 741.1 feet, approximately 5 feet higher than the other two. For consistency, borehole 299-E17-21 will be used as a reference point unless otherwise noted.

3.2.1 Basal Gravel Sequence

The lowermost 88 feet (247-335 drilled depth) of the Hanford formation encountered in borehole 299-E17-21 consists of the gravel-dominated facies. This was previously interpreted as a sandy gravel sequence based on geologic logs from the nearest wells. Drill core and cuttings from this borehole

Table 4. Summary Description of Core from Borehole 299-E17-21

Core Number	Core Interval (feet)	Description
01A	0 – 2.0	0.0 – 0.6 Pad construction fill. 0.6 – 2.0 Medium- to fine-grained sand; 60% basalt, 40% felsic.
	3.0 – 5.0	No recovery.
02C	9.6 – 11.6	9.6 – 11.6 Very fine- to coarse-grained sand; 1% pebbles up to 0.5 inch in diameter.
02B	11.6 – 12.8	11.6 – 12.6 Coarse- to very coarse-grained basaltic sand; 1-2% subrounded pebbles up to 1 inch in diameter; some bedding present.
02A	12.8 – 14.6	12.8 – 12.9 Fine-grained sand with silt. 12.9 – 14.2 Medium- to coarse-grained sand; 70% basalt, 30% felsic. 14.2 – 14.6 Finely bedded medium- to fine-grained sand up to 20%. 14.3 – 14.6 Silt; fine scale bedding.
	15.0 – 18.5	No recovery.
03B	18.7 – 19.7	18.7 – 19.5 Medium sand; 60% basalt, 40% felsic; sparse 0.5-inch diameter pebbles. 19.5 – 19.7 Brown, fine-grained sand with minor silt.
03A	19.7 – 21.7	19.7 – 19.8 Fine-grained sand. 19.8 – 20.0 Brown, silty sand with 5-10% silt. 20.0 – 20.9 Medium-grained sand; 60% basalt; 40% felsic; rare mica. 20.9 – 21.1 Very fine-grained sand with silt; sharp upper contact. 21.1 Silty, fine-grained sand, slightly moist; 50% basalt, 50% felsic. 21.5 Coarse-grained sand; 50% basalt; 50% felsic; minor pebbles. 21.5 – 21.7 Gravely, coarse-grained sand.
	22.0 – 24.0	No recovery.
04B	28.1 – 28.5	Coarse-grained sand with minor gravel; 50-60% basalt; 40-50% felsic.
04A	28.5 – 30.5	Slightly silty fine- to medium-grained sand; minor gravels up to 1 inch in diameter; grain size decreases slightly downward.
	30.5 – 31.6	No recovery.
05A	31.6 – 33.0	Silty, coarse-grained sands; minor basaltic gravel; contains loose $CaCO_3$ cemented sand grains.
06C	35.7 – 37.0	Silty, coarse-grained sands; minor basaltic gravel; contains $CaCO_3$ coating on sand grains.
06B	37.0 – 38.0	Coarse-grained sand; granular; salt and pepper.
06A	38.0 – 40.0	38.0 – 38.2 Silty coarse-grained sand; minor basaltic gravel; contains $CaCO_3$ coating on sand grains. 38.2 – 40.0 Medium-grained sand, slightly moist.
07B	45.3 – 45.9	Coarse-grained sand; contains some fine- to medium-grained sand.
07A	45.9 – 47.9	Medium- to fine-grained sand with minor silts; sparse pebbles up to 1 inch in diameter; 50% basalt, 50% felsic. 45.9 $CaCO_3$ cementing sand into poorly consolidated nodules.

Table 4. (contd)

Core Number	Core Interval (feet)	Description
08A	49.3 – 50.5	Medium- to coarse-grained sands; 50% basalt, 50% felsic; top 2 inches are fine- to medium-grained sand with less than 50% basalt.
09A	50.1 – 52.5	50.1 – 51.0 Medium-grained sand; 25-50% basalt, remainder felsic. 51.0 – 51.5 Layered medium-grained sand and thin silt lenses; 25-50% basalt. 51.5 – 52.2 Medium-grained sand; 25-50% basalt. 52.2 – 52.5 Coarse-grained sand.
10C	55.9 – 56.8	Medium- to coarse-grained sand; 35-50% basalt, 50-65% felsic; 1-2% gravel; core is disturbed.
10B	56.8 – 57.8	Medium-grained sand; 25-50% basalt, 50-75% felsic.
10A	57.8 – 59.8	57.8 – 58.1 Medium- to coarse-grained sand with some $CaCO_3$. 58.1 – 58.5 Cemented soil zone; fine- to medium-grained sand. 58.5 – 59.8 Medium-grained sand.
11B	59.6 – 60.6	Medium-grained sand; 50% basalt, 50% felsic.
11A	60.6 – 63.1	Medium-grained sand; 50% basalt, 50% felsic; minor caliche flakes present but not as cemented sand.
12A	69.4 – 70.95	69.4 – 70.0 Sloughing. 70.0 – 70.4 Coarse-grained sand; 50% basalt, 50% felsic. 70.4 – 70.7 Clay/silt lens. 70.7 – 70.95 Coarse-grained sand; less than 50% basalt.
13B	75.3 – 75.9	Medium- to coarse-grained sand; 50% basalt, 50% felsic; upper 4 inches is slough.
13A	75.9 – 78.4	Silty, medium- to fine-grained sands; 50% basalt, 50% felsic; minor $CaCO_3$ coating on sand grains.
14B	79.2 – 80.3	Medium-grained sand; 50% basalt, 50% felsic.
14A	80.3 – 82.8	Compacted medium- to fine- grained sand; some silt; 50% basalt, 50% felsic; minor $CaCO_3$ probably as grain coating.
15B	89.4 – 90.5	Medium- to coarse-grained sand fining downward to medium-grained sand; 50% basalt, 50% felsic; grains of $CaCO_3$ apparent; top of the interval is slough and wet.
15A	90.5 – 93.0	Medium- to fine-grained sands; some silt; minor pebbles less than 0.2 inch in diameter; $CaCO_3$ cementing sand grains in places.
16B	99.2 – 100.5	Medium- to coarse-grained sand.
16A	100.5 – 103.0	Medium-grained sand; some $CaCO_3$ coating grains.
17B	109.4 – 109.8	Medium- to coarse-grained salt and pepper sand; 50-70% basalt, 30-50% felsic; top half of interval is slough.
17A	109.8 – 112.2	Fine- to medium-grained sand; some silt.

Table 4. (contd)

Core Number	Core Interval (feet)	Description
18B	115.6 – 116.4	115.6 – 116.3 Coarse-grained sand as slough. 116.3 – 116.4 Coarse- to medium- to fine-grained sand; 50% basalt, 50% felsic.
18A	116.4 – 118.9	Medium- to fine-grained sand, some silt; 50% basalt, 50% felsic; less than 1% basalt pebbles.
	118.9 – 119.5	No recovery.
19B	119.5 – 121.0	Medium-grained sand; 50% basalt, 50% felsic; very minor $CaCO_3$ coating sand grains.
19A	121.0 – 123.5	Medium- to fine-grained sand, some silt; 50% basalt, 50% felsic; bottom 0.3 inch silty to fine-grained sand.
20B	129.2 – 129.7	Medium- to coarse-grained sand; 50% basalt, 50% felsic; entire interval is disturbed.
20A	129.7 – 132.2	Fine- to medium-grained sand, some silt; less than 50% basalt; some $CaCO_3$ as discrete particles and grain coatings.
	135.2 – 138.0	No recovery.
21B	139.3 – 141.5	Medium- to fine-grained sand, some silt; 50% basalt with scattered basalt pebbles up to 0.1 inch in diameter. 139.8 $CaCO_3$ weakly cemented zone.
21A	141.5 – 144.0	Medium-grained sand, 10-20% fine-grained sand; 50% basalt, 50% felsic.
22B	149.4 – 151.9	149.4 – 150.2 Medium-grained sand; slightly moist. 150.2 – 150.9 Compacted, slightly cemented, bedded medium-grained sand and silt; layers are 0.25 inch thick. 150.9 – 151.9 Medium-grained sand; minor $CaCO_3$, probably as coatings on grains.
22A	151.9 – 154.4	Medium-grained sand with minor silt; 50% basalt, 50% felsic; well-developed fine-scale laminations; laminations appear to be due to light and dark minerals; minor $CaCO_3$ disseminated throughout, probably as grain coatings; not compacted but very loose.
23B	159.4 – 160.4	Medium- to fine-grained sand, some silt; less than 50% basalt; $CaCO_3$ is present but probably as grain coatings; upper 4 inches is slough.
	160.4 – 160.4	No recovery.
23A	160.4 – 162.9	Fine-grained sand to silt with well-developed fine-scale laminations; laminations appear to be due to light/dark minerals; 50% basalt, 50% felsic; well-compacted; $CaCO_3$ probably as grain coatings.
	169.6 – 174.2	No recovery.
24B	179.6 – 180.7	Medium-grained sand; 50% basalt, 50% felsic; $CaCO_3$ cemented fragments up to 1.2 inch long; entire core is disturbed.
24A	180.7 – 182.7	Fine- to medium-grained sand; uniform grain size; 50% basalt, 50% felsic; no bedding; well-compacted, minor $CaCO_3$ cement.

Table 4. (contd)

Core Number	Core Interval (feet)	Description
25A	189.7 – 191.9	Medium- to fine-grained sand, some silt; 50% basalt, 50% felsic; 1-inch layer of poorly cemented ($CaCO_3$) sand grains.
26A	196.0 – 198.0	Medium- to fine-grained sand; 50% basalt, 50% felsic.
27A	199.3 – 201.3	199.3 – 199.9 Fining upward sequence of coarse pea gravel (0.13 inch diameter) to fine-grained sand; 50% basalt, 50% felsic; well compacted with $CaCO_3$ coating grains and as minor cement between grains. 199.9 – 200.2 very fine- to fine-grained sand. 200.2 0.5-inch thick silt lens. 200.25 – 200.4 Medium-grained sand.
28A	206.0 – 208.0	Medium-grained sand with minor pebbles; slightly compacted; minor $CaCO_3$ probably as grain coatings.
29A	210.9 – 211.4	Four inches of pea gravel (0.13 inch in diameter) grading upward into medium-grained sands; sand is 50% basalt, 50% felsic; no bedding; well-compacted sands with minor $CaCO_3$ cement.
30A	216.1 – 218.1	Pebbly, 4 inches of pea gravel (0.13 inch in diameter) grading into coarse-grained sand; 2 inch partly $CaCO_3$ cemented zone at 216.2 feet.
31A	219.6 – 221.6	Fine-grained sand compacted but not cemented; faint bedding. 219.0 Pebbles of basalt and andesite; rounded.
32A	226.1 – 228.1	Medium- to coarse-grained sand; well compacted with $CaCO_3$ coating grains; minor moisture.
33A	229.2 – 231.2	229.2 – 229.8 Pebbly, coarse-grained sand; 50-60% basalt, remainder felsic. 229.8 – 230.0 Gravel up to 1.5 inches in diameter; 75% basalt. 230.0 – 230.3 Coarse-grained sand, some fine-grained sand and silt; 60-70% basalt. 230.3 – 231.2 Compacted, medium- to coarse-grained sand some silty, fine-grained sand; 60-70% basalt; moist.
34A	236.1 – 238.1	Coarse-grained sand to pea gravel (up to 0.13 to 0.25 inch in diameter); some compaction but no cementation; damp.
35A	239.5 – 241.5	239.5 – 240.0 Granular to pebbly gravel (0.13 inch in diameter), mainly basalt; no sand matrix, open framework. 240.0 – 240.4 grading into coarser gravel (0.25 to 0.50 inch in diameter); no sand matrix, open framework. 240.4 – 240.9 Coarse gravel with sand matrix; gravel up to 1 inch in diameter; coarse–grained sand; 50% basalt, 50% felsic.
	245.6 – 248.0	No recovery.
36A	268.1 – 270.1	Top 10 inches are slough composed of 3 inches of clean gravel over sandy gravel; remainder of core is gravel with medium-grained sand; 15% gravel, 50% basalt, 50% quartzite and metamorphic pebbles.
37A	349.6 – 350.6	Gravels.
38A	379.7 – 381.7	Ringold Formation, Lower Mud unit.
Note: Footages not included in the table are zones where chip samples were recovered during drilling.		

Table 5. Summary Description of Core from Borehole 8501

Core Number	Core Interval (feet)	Description
01B	0.8 – 1.9	Fill from pad construction and disturbed sand.
01A	1.9 – 3.9	Medium- to fine-grained sand; 50% basalt, 50% felsic.
	3.9 – 4.1	No recovery.
02B	4.1 – 5.0	Medium- to fine-grained sand; some gravel from pad construction (?).
02A	5.0 – 7.0	5.0 – 5.7 Medium-grained sand. 5.7 – 5.9 Coarse-grained sand; wet. 5.9 – 7.0 Medium-grained sand, 50% basalt; 50% felsic.
	7.0 – 7.2	No recovery.
03A	7.2 – 8.0	Medium-grained sand with large pebbles of basalt and quartzite up to 2 inches in diameter.
	8.0 – 9.0	No recovery.
04B	9.0 – 10.2	9.0 – 9.8 Fine-grained sand with minor pebbles. 9.8 Pebble-cobble layer. 9.8 – 10.2 Silty to fine-grained sand coarsening upward.
04A	10.2 – 12.2	10.2 – 11.3 Paleosol horizon; fine-grained sand and basalt pebbles. 11.3 – 12.2 Coarse, pebbly sand; pebbles are quartzite and andesite.
	12.2 – 13.5	No recovery.
05B	13.5 – 14.1	Medium- to fine-grained sand with silt and cobbles; cobbles are basalt and quartzite and are up to 3 inches in diameter.
	14.1 – 16.4	No recovery.
05A	16.4 – 17.5	Medium- to fine-grained sand and silt; 50% basalt, 50% felsic.
	17.5 – 17.7	No recovery.
06B	17.7 – 19.7	Medium-grained sand; 60% basalt; 40% felsic; uniform composition and texture.
06A	19.7 – 21.7 (07B Redrill 19.3 – 21.3)	19.7 – 20.0 Coarse-grained sand; 60% basalt; 40% felsic. 20.0 – 20.2 Silt lens. 20.2 – 21.3 Medium-grained sand; 60% basalt; 40% felsic. 21.3 – 21.6 Fine-grained sand with some silt.
07A	21.3 – 23.3	Medium-grained sand, some silt, 50% basalt; 50% felsic.
	23.3 – 23.6	No recovery.
08A	23.6 – 25.6	Slightly pebbly, medium-grained sand with some silt; 50% basalt, 50% felsic.
09B	25.7 – 27.7	25.7 – 26.0 Fine-grained sand with some pebbles up to 4 inches in diameter. 26.0 – 26.3 Medium- to coarse-grained sand; 50% basalt, 50% felsic. 26.3 – 26.8 Fine- to medium-grained sand. 26.8 – 27.7 Fine-grained sand.
	27.7 – 29.4	No recovery.

Table 5. (contd)

Core Number	Core Interval (feet)	Description
10B	29.4 – 31.4	Medium-grained sand; some silt; 50% basalt; 50% felsic.
10A	31.4 – 33.4	31.4 – 31.6 Fine- to medium-grained sand; 50% basalt, 50% felsic. 31.6 – 33.4 Medium-grained sand; 50% basalt, 50% felsic.
	33.4 – 33.6	No recovery.
11B	33.6 – 35.6	Medium- to coarse-grained sand; some silt; 40% basalt, 60% felsic.
11A	35.6 – 37.6	Medium-grained sand, some silt; 50% basalt, 50% felsic.
12A	37.5 – 39.5	Medium-grained sand; some silt; uniform throughout; 50% basalt, 50% felsic; slough at top.
13B	39.5 – 41.5	Medium-grained sand; some silt; uniform throughout; 50% basalt, 50% felsic.
13A	41.5 – 43.5	Medium-grained sand; some silt; uniform throughout; 50% basalt, 50% felsic.
	43.5 – 46.7	No recovery.
14B	46.7 – 48.0	Medium-grained sand; some silt; uniform throughout; 50% basalt, 50% felsic.
14A	48.0 – 50.0	Medium-grained sand; some silt, minor basalt fragments up to 0.5 inch in diameter; uniform throughout; 50% basalt, 50% felsic.

indicate that the unit is clast-supported pebble- to cobble-gravel with minor amounts of sand in the matrix. The cobbles and pebbles are almost exclusively basalt with no cementation. In outcroppings these deposits display massive bedding, plane to low-angle bedding and large-scale planar cross-bedding, but such features typically cannot be observed in borehole core.

This basal gravel sequence is equivalent to unit H3 of Lindsey et al. (1994), and may be equivalent to mapping unit Qfg_1, Missoula Outburst flood gravel deposits of Reidel and Fecht (1994a,b). Those units are 720 ka and have a reversed magnetic polarity. Further analysis will be required to determine whether this is the correct mapping unit.

3.2.2 Sandy Sequence

The upper portion of the Hanford formation consists of 242 feet of fine- to coarse-grained sand with minor amounts of silt and clay. This sequence is equivalent to unit H2 of Lindsey et al. (1994), and may be equivalent to the following mapping units of Reidel and Fecht (1994a,b): Qfs_1, Qfs_2, and Qfs_3, Missoula Outburst Flood Deposits consisting of sand, silt, and clay.

Three paleosols (soils) were identified in core and drill cuttings: Paleosol Horizon 1 at 163 feet drilled depth, Paleosol Horizon 2 at 58 feet, and Paleosol Horizon 3 at 5 feet (299-E17-21 and B8502; 10 feet in B8501). These three horizons represent significant time intervals when soil development took place and are interpreted to be the tops of three Missoula flood deposits.

Table 6. Summary Description of Core from Borehole 8502

Core Number	Core Interval (feet)	Description
01A	0.6 – 1.5	Crushed gravel from pad construction.
	1.5 – 3.5	No recovery.
02B	3.5 – 4.2	60-70% crushed gravel from pad construction (?); pebbly, medium- to fine-grained sand; 50% basalt, 50% felsic; pebbles up to 1 inch in diameter.
02A	4.2 – 6.2	4.2 – 5.0 Silty sand; 50% basalt, 50% felsic; basalt chips up to 0.3 inch in length. 5.0 – 6.2 Wet silty sand; 50% basalt, 50% felsic; basalt chips up to 0.3 inch in length.
03B	6.4 – 6.8	Pebbly, medium- to fine-grained sand; 50% basalt, 50% felsic; 25% pebbles up to 4 inches in diameter; core is disturbed and damp.
03A	6.8 – 8.8	6.8 – 7.6 Very fine-grained silt with angular clasts of basalt up to 0.4 inch in diameter. 7.6 – 8.2 Rounded pebbles (25%) with angular clasts of basalt in matrix of sand; caliche coating on base of basalt. 8.2 – 8.8 Silt to silty sand; rounded pebbles of basalt up to 0.4 inch in diameter. Core is wet throughout.
	8.8 – 9.1	No recovery.
04B	9.1 – 10.8	9.1 – 9.3 No recovery. 9.3 – 10.1 Pebbly, medium-grained sand fining with depth; silt lenses; wet. 10.1 – 10.3 Basalt and quartzite pebbles in coarse-grained sand overlying thin (2 inch) silt lens; silt lens is wet. 10.3 – 10.8 Medium-grained sand with fragments of $CaCO_3$-cemented silt up to 4 inches thick; visible caliche; dry between silt lenses. 10.6 Silt lens; wet.
04A	10.8 – 12.8	10.8 – 11.1 Fine- to medium-grained sand. 11.2 Clay/silt lens 0.2 inch thick; dry. 11.2 – 11.4 Medium-grained sand; dry. 11.4 – 12.0 Pebbly, coarse-grained sand; pebbles up to 1.2 inches in diameter with some caliche. 12.0 – 12.8 Fining upward sand; 50% basalt, 50% felsic. Core is wet throughout.
05B	13.7 – 14.5	Coarse-grained sand; 60-70% basalt, 30-40% felsic; sparse pebbles of basalt and quartzite. 14.4 Thin lens of clay/silt. Partly disturbed core.
	12.8 – 13.7	No recovery.
05A	14.5 – 16.5	Sand coarsening upward with a few pebbles at top; 50% basalt, 50%; pebbles consist of quartz, quartzite and basalt; some caliche fragments near base of core. 16.3 0.4 inch-thick silt lens.

Table 6. (contd)

Core Number	Core Interval (feet)	Description
06B	16.7 – 18.7	16.7 – 17.5 Medium- to fine-grained sand with minor silt; 50% basalt, 50% felsic. 17.5 – 17.9 Clay/silt lens with horizontal bedding on 0.5 inch scale; dry. 17.9 – 18.7 Medium-to coarse-grained sand; 60% basalt, 40% felsic. Dry core.
06A	18.7 – 20.7	18.7 – 19.0 Clay/silt lens; crude bedding; wet. 19.0 – 20.3 Medium-grained sand; 60% basalt, 40% felsic; sparse $CaCO_3$-cemented clasts of sand up to 0.2 inch in diameter. 20.3 – 20.4 Silt lens; dry. 20.4 – 20.7 Medium-grained sand; 60% basalt, 40% felsic; 3 inch lens of clay/silt at bottom. Silt lenses are wet; sand is dry.
07B	19.7 – 21.7 Redrill	Medium-grained sand; 50% basalt, 50% felsic; sparse pebbles. 21.5 Silt lens; dry.
O7A	21.7 – 23.7	Medium-grained sand; 50% basalt, 50% felsic; uniform throughout.
08B	23.9 – 25.9	23.9 – 24.3 Fine-grained sand; 50% basalt, 50% felsic; damp; 24.3 – 24.6 Silt lens at 24.3 feet; coarse-grained sand; 70% basalt; 30% felsic. 24.6 – 25.4 Pebbly, coarse-grained sand; basalt pebbles up to 1.2 inches in diameter. 25.4 – 25.9 Pebbly sand; 50% basalt, 50% felsic; some caliche particles at base of core.
08A	25.9 – 26.8	Coarse pebbly sand; 50% basalt, 50% felsic; pebbles up to 0.8 inch in diameter.
	26.8 – 27.7	No recovery.
09B	27.7-29.0	Core not available for logging.
10B	29.0 – 31.4 (10A Redrill 31.4 – 33.4)	29.4 – 31.4 Medium-grained sand; 50% basalt, 50% quartz, quartzite, mica and feldspar; some basalt pebbles up to 0.4 inch in diameter. 31.4 Silt lens. 31.4 – 32.4 Medium-grained sand; 50% basalt; 50% felsic. 32.6 – 33.4 Fine- to medium-grained sand; 50% basalt; 50% felsic. 32.7 Silt lenses. 33.0 Silt lens.
11B	33.5 – 35.5	Medium-grained sand; 50% basalt, 50% mixture of quartz, quartzite, mica and feldspar; unconsolidated.
11A	35.5 – 37.5	No recovery.
12A	37.3 – 39.3	Core not available for logging.
13B	39.4 – 41.4	Medium- to coarse-grained sands; 50% basalt, 50% mixture of quartzite, quartz, mica and feldspar; uniform throughout.
13A	41.4 – 43.4	Medium-grained sand; 50% basalt, 50% felsic; some larger clasts up to 0.1 inch in diameter.

Table 6. (contd)

Core Number	Core Interval (feet)	Description
14B	43.8 – 44.7	Medium-grained sand; 25% basalt, 75% felsic; pebbles up to 0.4 inch in diameter. Core is disturbed.
14A	44.7 – 46.7	Medium-grained sand; greater than 50% felsic; some large basalt fragments up to 0.2 inch in diameter. 45.6 Very thin silt lens.

The three paleosols provide reliable horizons to subdivide the Hanford sandy sequence in this area and have the greatest likelihood of forming laterally continuous horizons across the ILAW site. Thus, the terminology employed by this report will use Layer 1 as that part of the Hanford formation extending from the paleosol horizon at 163 feet to the top of the basalt gravel at 247 feet. Layer 2 extends from the top of the second paloesol horizon (58 feet) to the top of the first paleosol at 163 feet. Layer 3 extends from the top of the third paleosol horizon at 5 feet depth to the second paleosol horizon at 58 feet drilled depth.

3.2.2.1 Layer 1

Layer 1 is 84 feet thick in borehole 299-E17-21. The paleosol horizon marking the top of this unit was not retrieved in core; this paleosol was identified during drilling (Figure 3, Table 7). The paleosol is marked by a zone of sand and silt cemented by $CaCO_3$ forming a poorly developed caliche layer. Only the upper several inches are well cemented but cementing and $CaCO_3$ extend to a depth of about 10 feet below the top. $CaCO_3$ fragments or as grain coatings were found to a depth of at least 218 feet (55 feet below the top of Layer 1).

The lower 20 feet of Layer 1 consists of interbedded sands and gravels. The basal gravel sequence underlying Layer 1 appears to grade upward into a sequence of interbedded sands and gravels. At least three upward fining zones of gravels to sands were recognized in Layer 1 (Table 4). These zones are equivalent to unit HZA of Lindsey et al. (1994).

Planar-laminar sands with minor silt lenses dominate the upper 54 feet of Layer 1. This sequence consists of fining upward sands, well-compacted, slightly $CaCO_3$-cemented sands, and well-laminated sands. As noted above, $CaCO_3$ associated with development of the paleosol extends well down into this layer.

Layer 1 is part of unit H2 of Lindsey et al. (1994), and may be equivalent to mapping unit Qfs_1 of Reidel and Fecht (1994a,b). Mapping unit Qfs_1 is a Missoula Outburst Flood Deposits consisting of sand, silt, and clay that is 720 ka and has a reversed magnetic polarity. Further analysis will be required to determine whether this is the correct mapping unit.

Table 7. Field Log Descriptions of Selected Intervals from 299-E17-21

Depth (feet)	Description
33.0 – 35.7	Medium- to coarse-grained sand, 60% basalt, 40% felsic; sparse pebbles/cobble gravel stringers.
70.95 – 75.3	70.5 – 75.3 Fine- to medium-grained sand. 71 – 73 Scattered $CaCO_3$ fragments.
82.8 – 89.4	$CaCO_3$-cemented silt-mud with fine- to very fine-grained sand; blocky fragments; slightly damp; 50% basalt, 50% felsic.
93.0 – 99.2	Silt-mud cemented throughout; $CaCO_3$ coating grains. Predominately medium- to fine-grained sand with silt and clay; possibly silt-rich beds.
103.0 – 109.4	Fine- to medium-grained sand, occasionally granular, 50% basalt, 50% felsic, increasing grain size with depth.
112.2 – 115.6	112-113 Silt-clay cemented with $CaCO_3$.
123.5 – 129.2	123.5 $CaCO_3$-cemented fragments. 124 – 126 Fine-grained sand and silt. 126 – 130 Medium- to coarse-grained sand.
132.2 – 135.2	Fining upward sand.
138.0 – 139.3	Trace of pebble/cobble gravel.
144.0 – 149.4	Medium- to fine-grained sand, sorted; 60% felsic, 40% basalt.
154.4 – 159.4	Coarse-grained sand, occasionally granular; trace of pebbles; 60% basalt, 40% felsic. Medium to coarse-grained sand below 155 feet.
163-170	163 Paleosol. 166 Fine-grained sand cemented by $CaCO_3$; coarse-grained sand immediately below 166 feet.
174.4 – 179.6	Trace of $CaCO_3$ fragments in silt to clay. Medium- to coarse-grained sand with trace of silt; 60% basalt, 40% felsic.
191.9 – 196.0	Sand with trace of pebbles and granular sand. 195 Lag gravel.
198.0 – 199.3	Scattered pebbles and cobbles.
208.0 – 210.9	Small pebbles and cobbles in 0.6 – 1 feet thick lag deposit.
211.4 – 216.1	213 - 214 Gravel and granular sand.
218.1 – 219.6	Medium- to fine-grained sands; trace of fine-grained sand.
231.2 – 236.1	Medium- to coarse-grained sand with silt and clay. Gravel with silty sand, subrounded to sub-angular, medium to poor sorting; 60% basalt, 40% felsic.

Table 7. (contd)

Depth (feet)	Description
241.5 – 245.6	Coarse-grained sand, occasional medium- to fine-grained sand with pebbles. Pebble content increasing with depth.
248.0 – 268.1	Clast supported with little matrix material. 248 Pebble-cobble gravel, 60-70% basalt, 30-40% felsic; occasional grains of sand. 263 Large cobbles greater than 4-6 inches in diameter.
270.1 – 330	Pebble-cobble gravels, rhythmic beds of coarse pebble-cobble gravels. Open-framework gravel, matrix poor to granular, medium-grained sandy gravels, 60-70% basalt.
330 - 378	330 Top of Ringold (estimated; may be as deep as 335 feet). Pebble-cobble gravels with sandy matrix; zones of variable cementation. 337 Variable silt-mud cemented zones.
378	Top of Ringold Lower Mud. Yellow-yellow brown, silty mud to very silty muds/clay, ductile and partly sandy.
381.2	Top of "Blue Mud." Blue-gray to light gray, moderately to very silty mud to slightly muddy silt.
412	Silty- to very fine-grained sand; light to very dark brown, organic-rich with occasional wood fragments, occasionally very silty to muddy.
439	Top of Ringold A. Well-cemented, silty- to clayey pebble-cobble gravel; occasional yellow-white sands with green staining; poorly sorted; 60-70% felsic gravel with abundant metamorphic and granites.
470	Variably cemented gravels with cobbles up to 3-10 inches in diameter.

3.2.2.2 Layer 2

Layer 2 is 105 feet thick (58-163 feet BLS) and consists of sand, interstitial and interbedded silt, and clay lenses. The paleosol horizon marking the top of this unit was intersected only in 299-E17-21; boreholes B8501 and B8502 were too shallow to intersect it. The paleosol horizon consists of about 5 inches of cemented sand and silt. $CaCO_3$ coatings on grains and as distinct flakes are present throughout much of the sand and silt in the upper part of Layer 2.

From the base at 163 feet to 150 feet, the sands are well compacted and laminated. Laminations appear to be due to the presence of light and dark mineral grains. Minor disseminated $CaCO_3$ is present as coatings on grains and as small, isolated nodules of cemented sand grains.

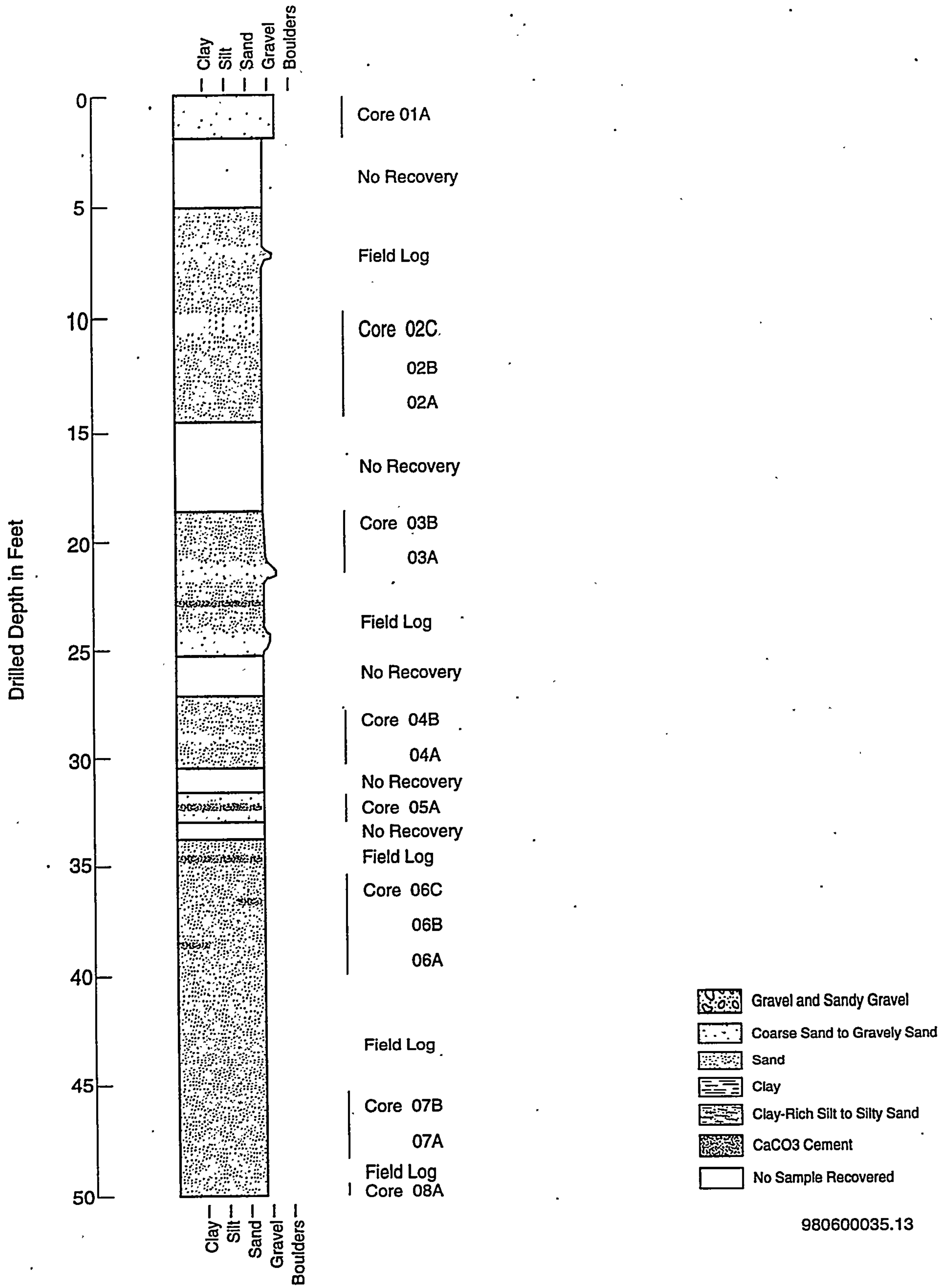


Figure 3. Detailed Geologic Log for Borehole 299-E17-21. See Table 4 for description of cored intervals and Table 7 for selected field described intervals.

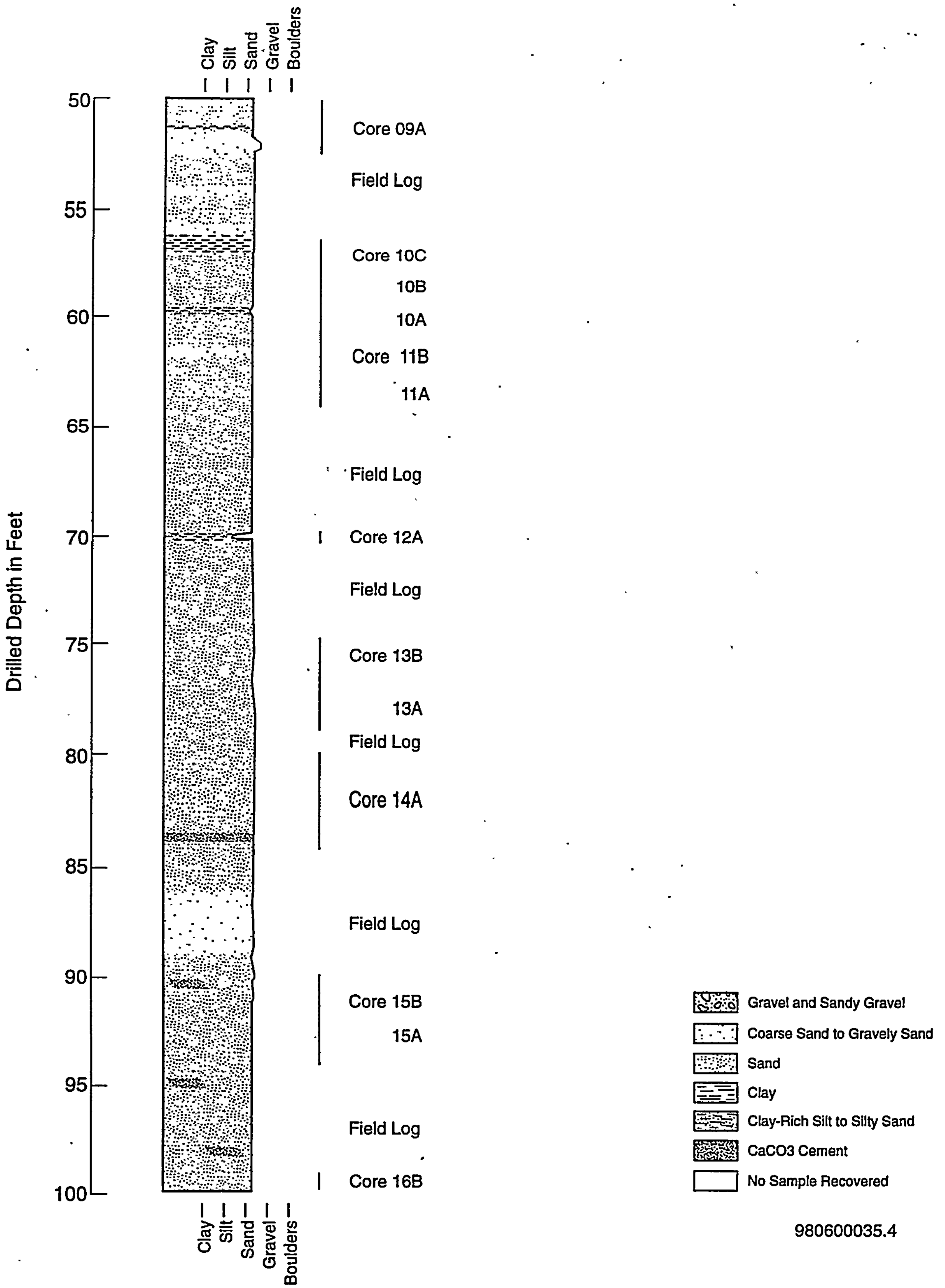
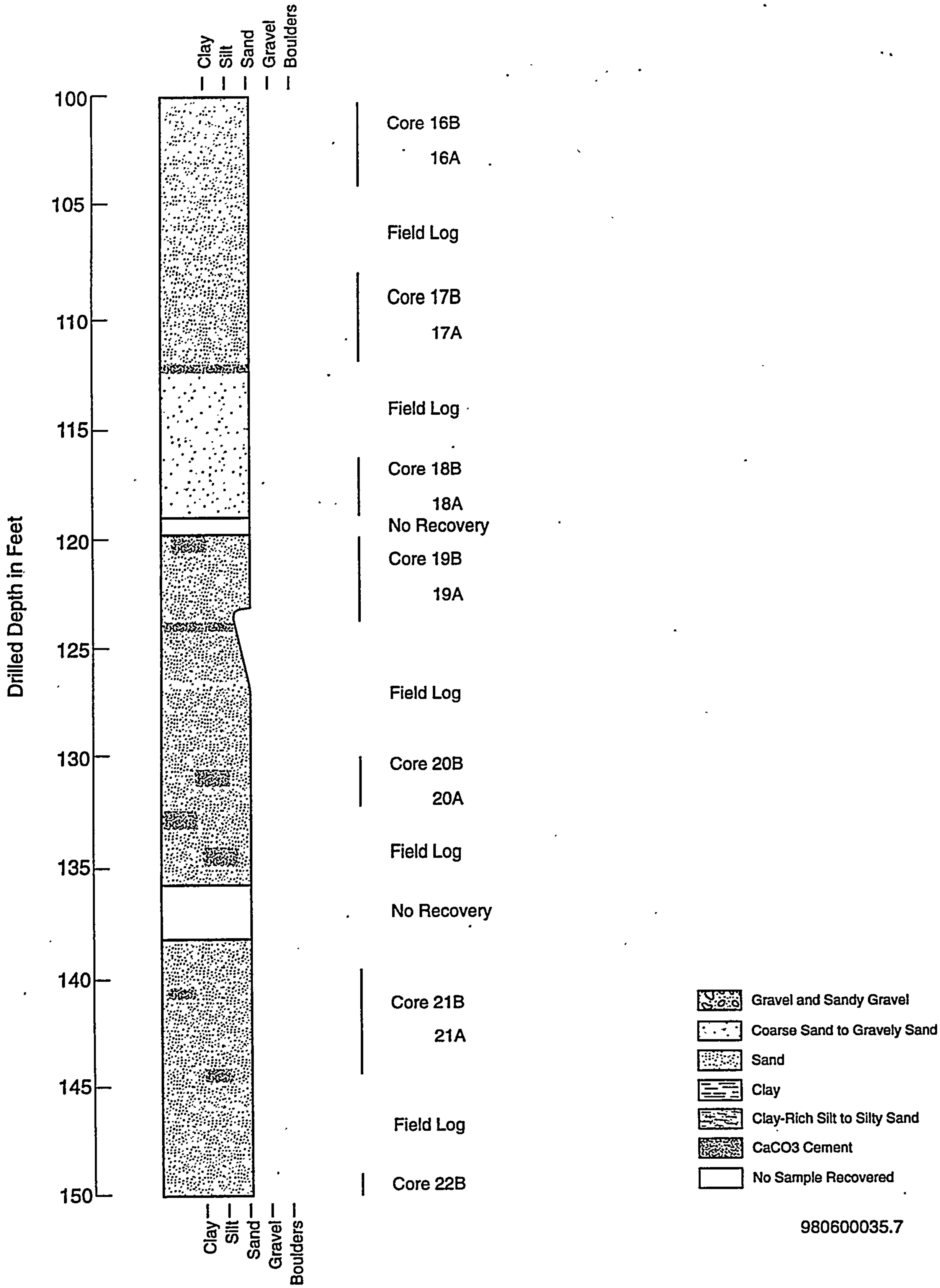


Figure 3. (contd)



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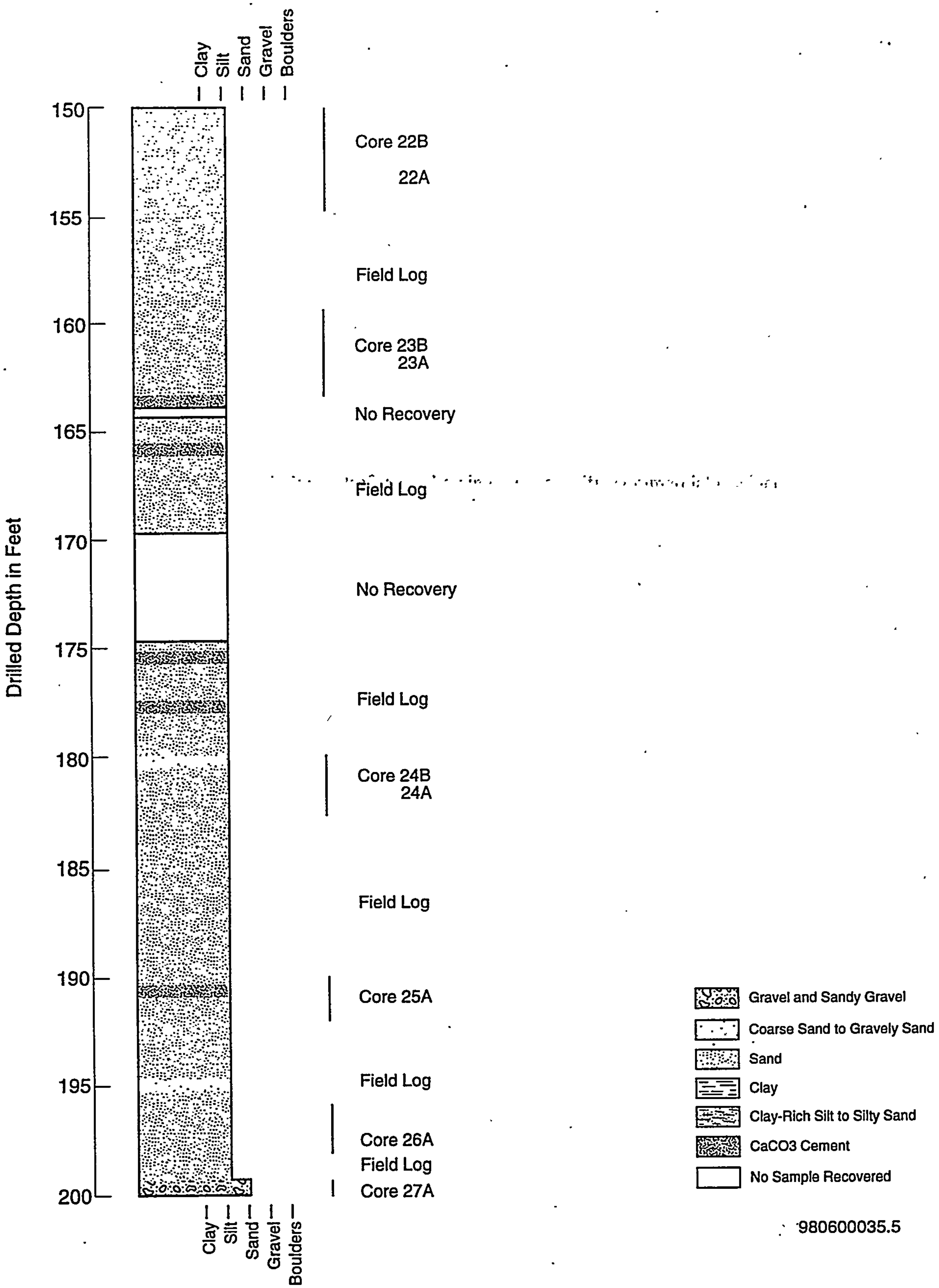

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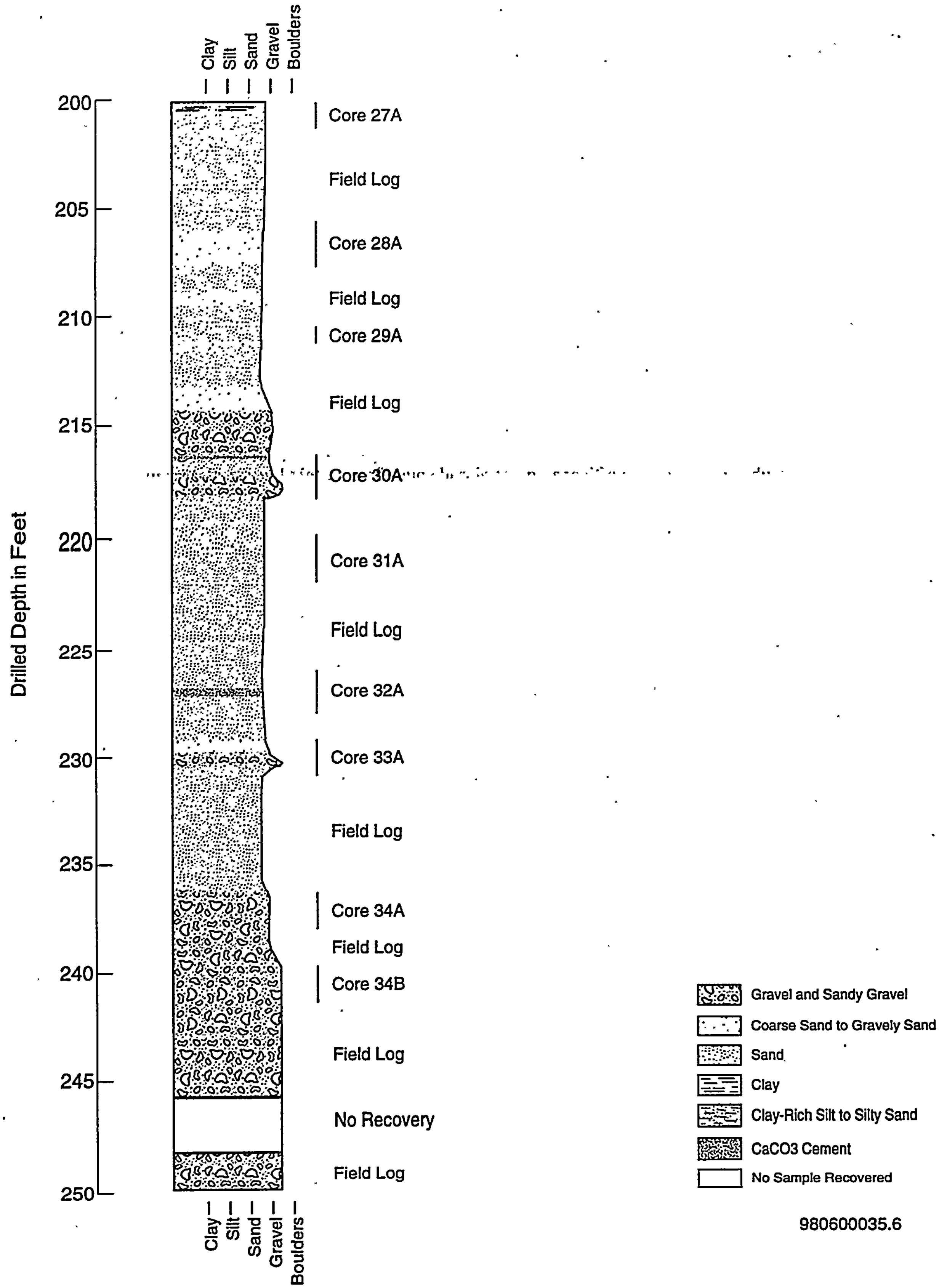

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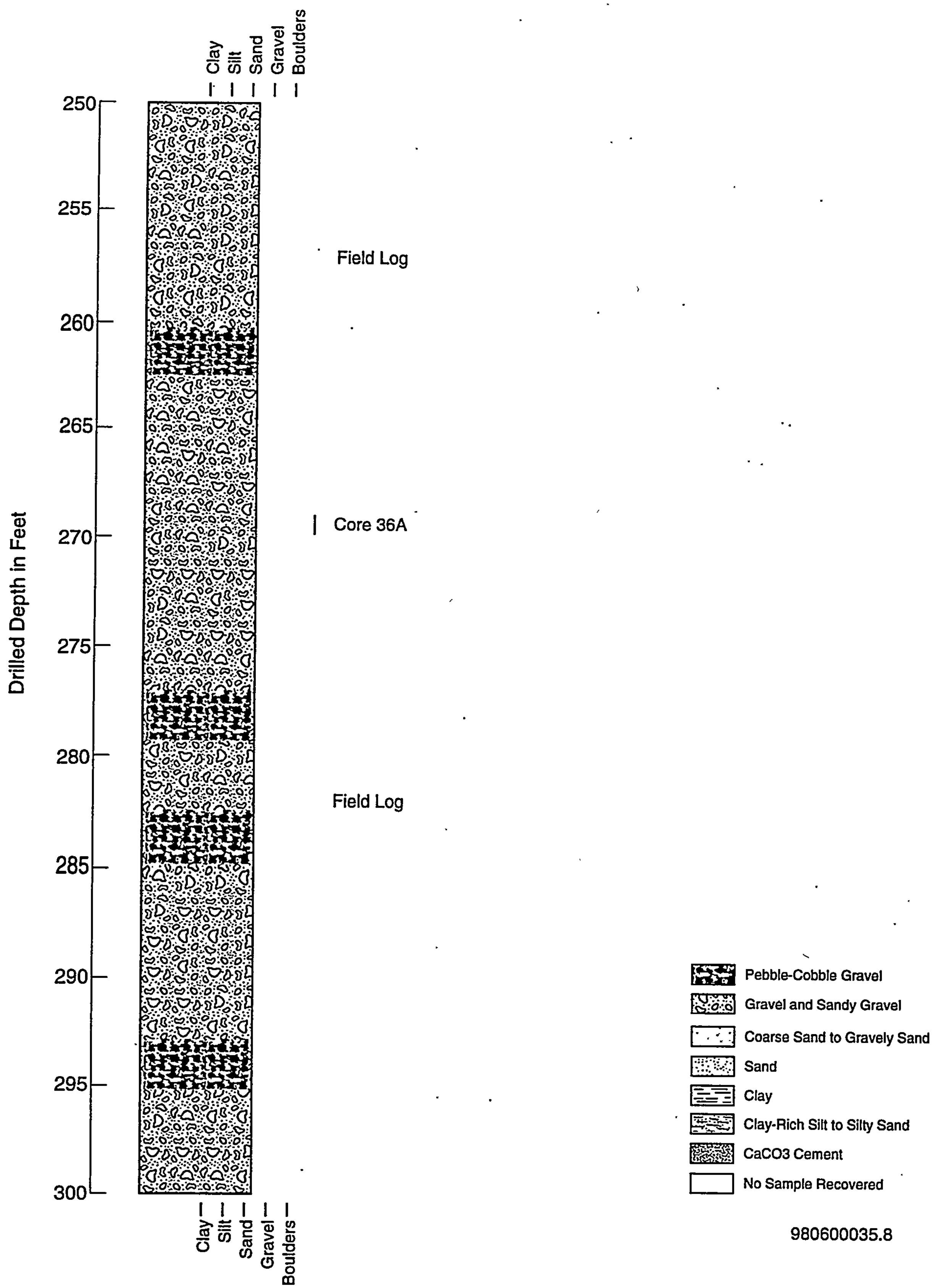
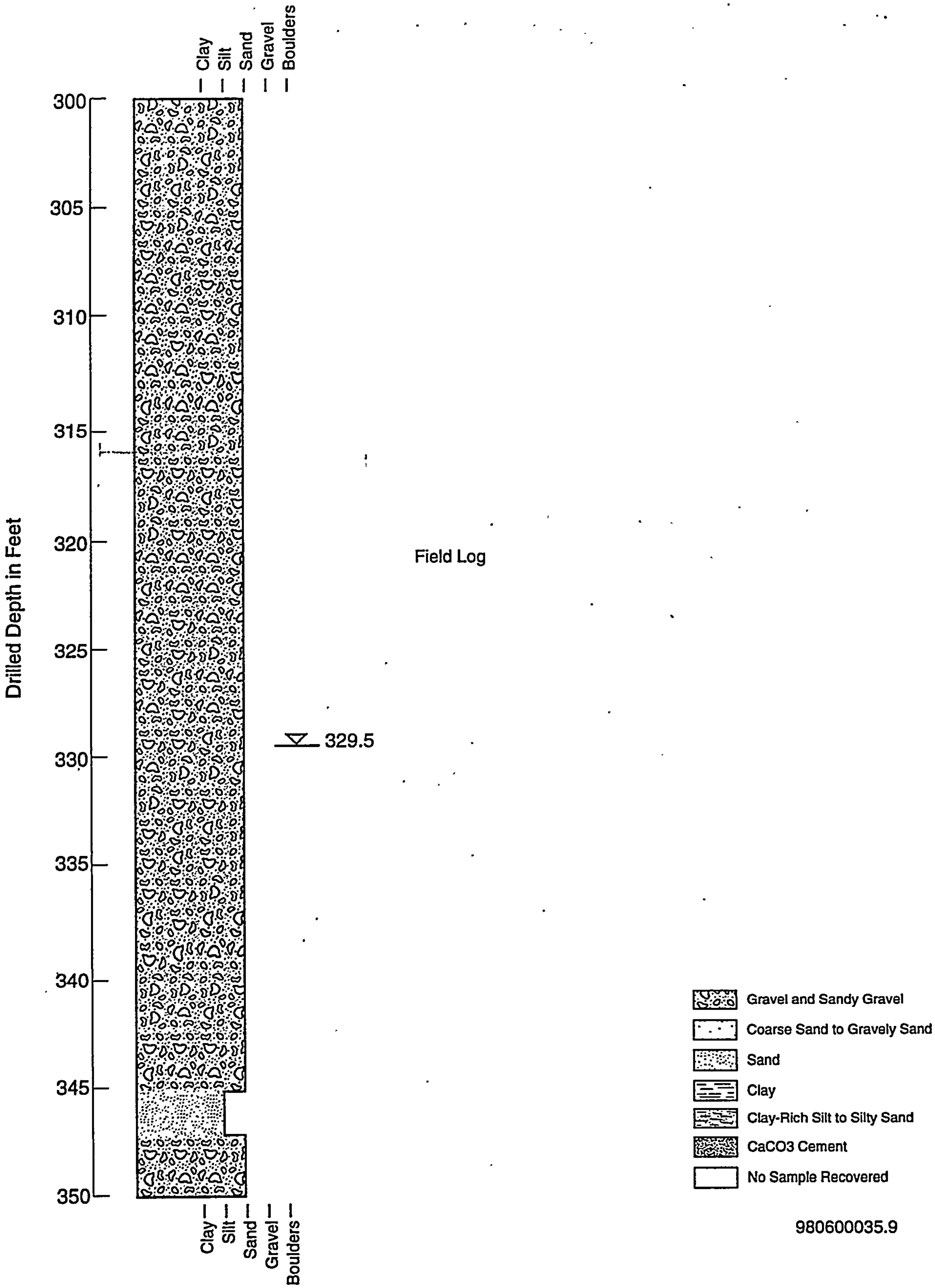


Clay
Silt
Sand
Gravel
Boulders
Drilled Depth in Feet
250
255
260
265
270
275
280
285
290
295
300
Field Log
Core 36A
Field Log
Pebble-Cobble Gravel
Gravel and Sandy Gravel
Coarse Sand to Gravely Sand
Sand
Clay
Clay-Rich Silt to Silty Sand
CaCO3 Cement
No Sample Recovered

980600035.8



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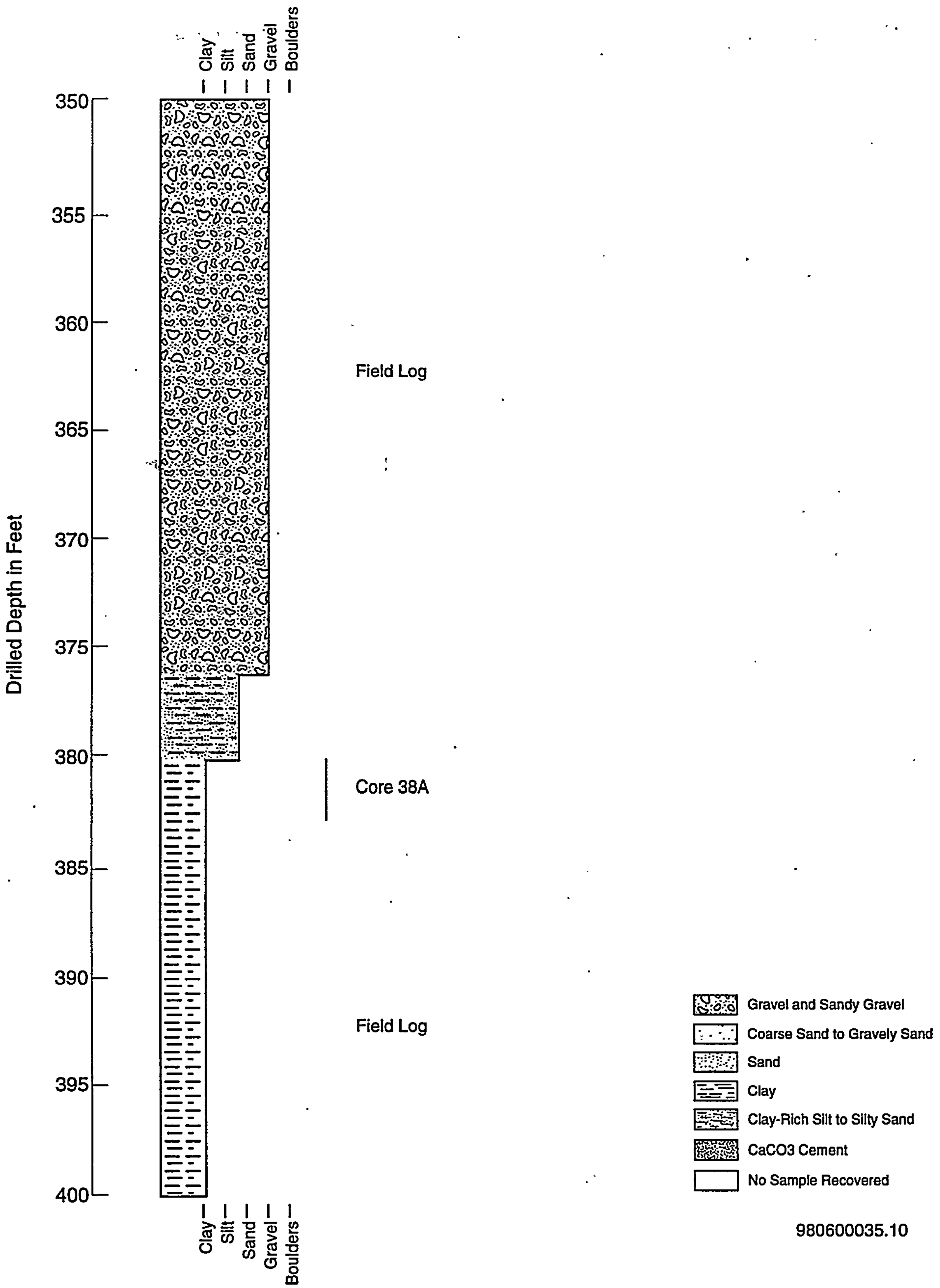

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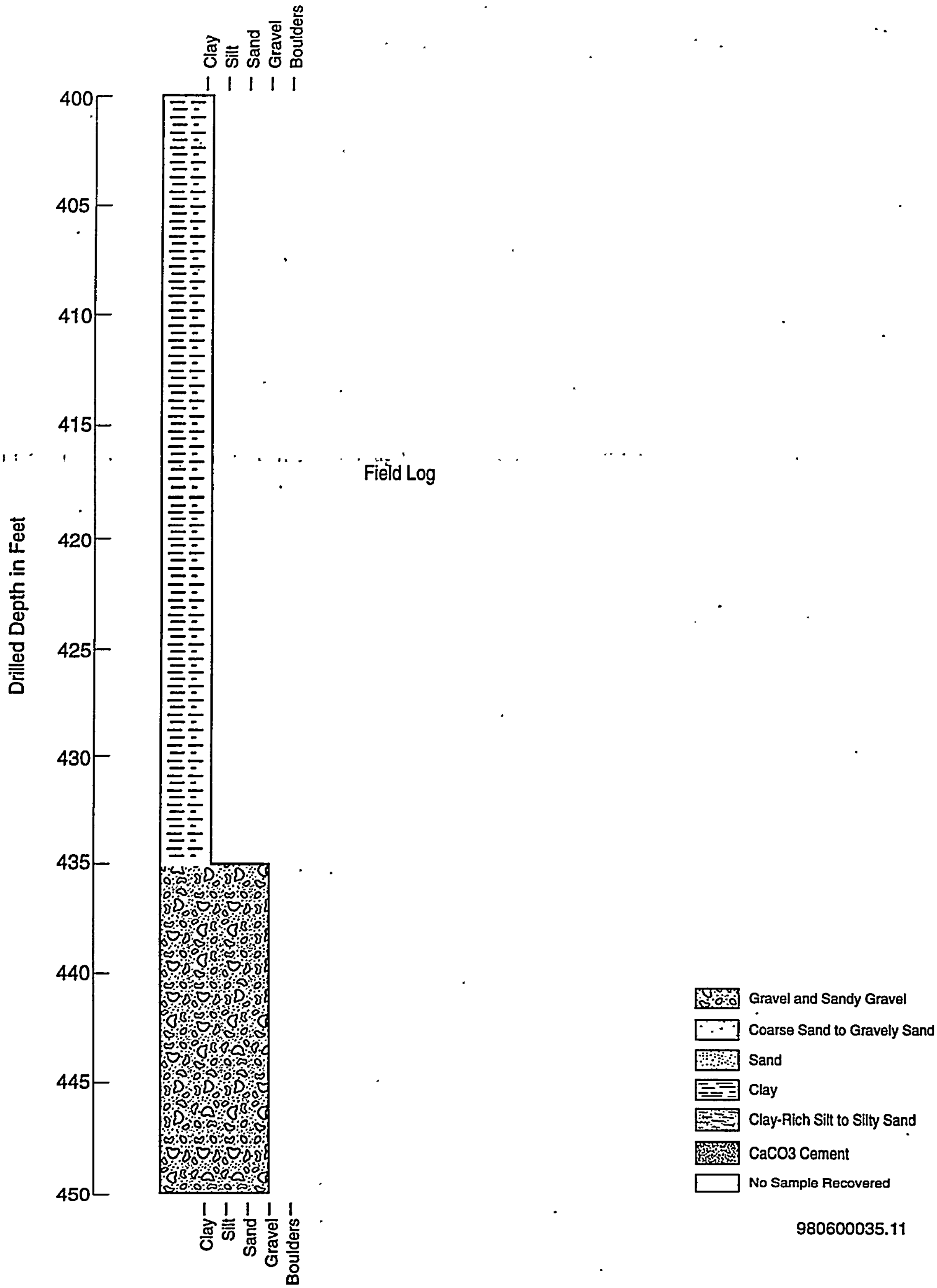

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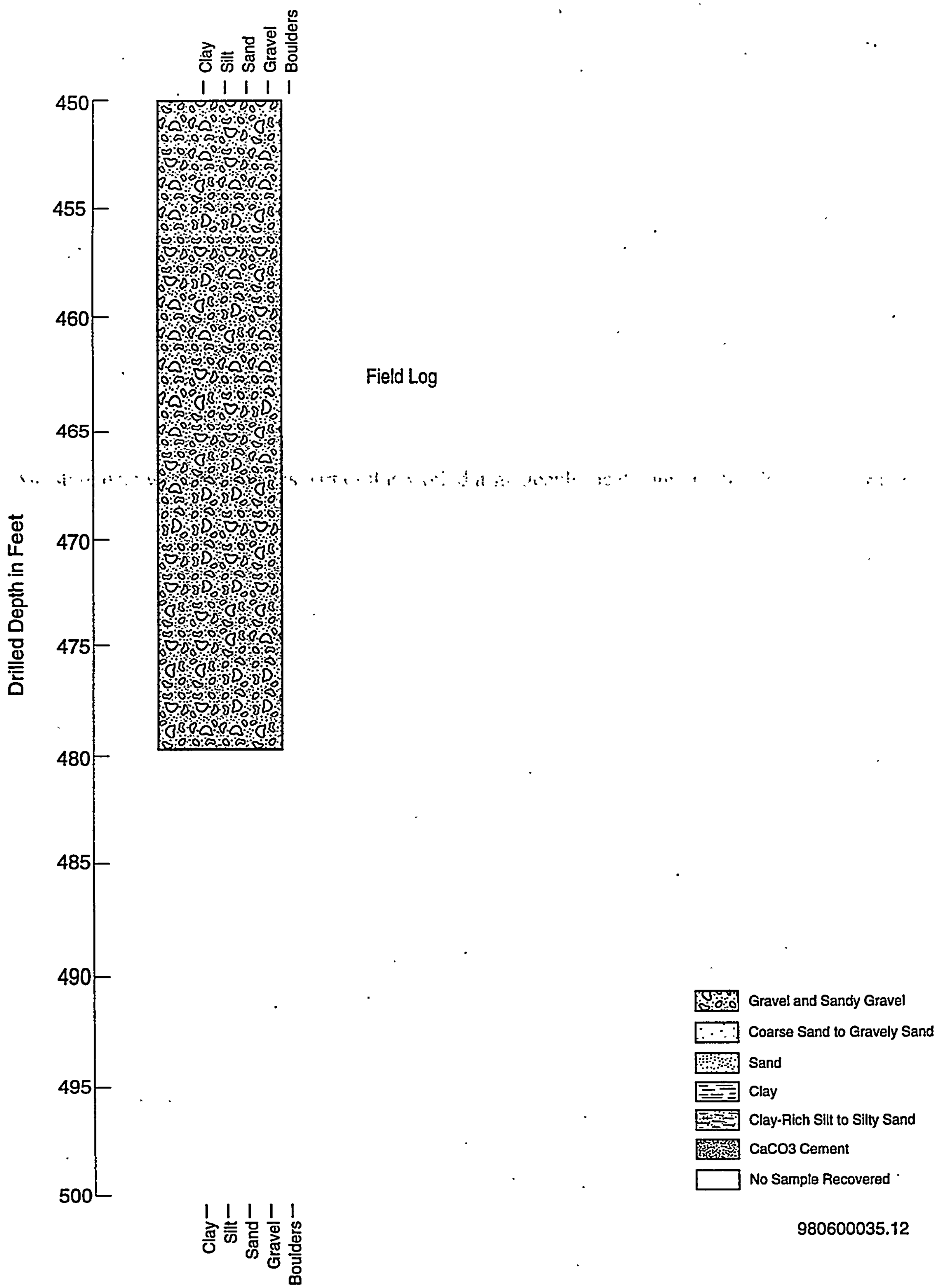

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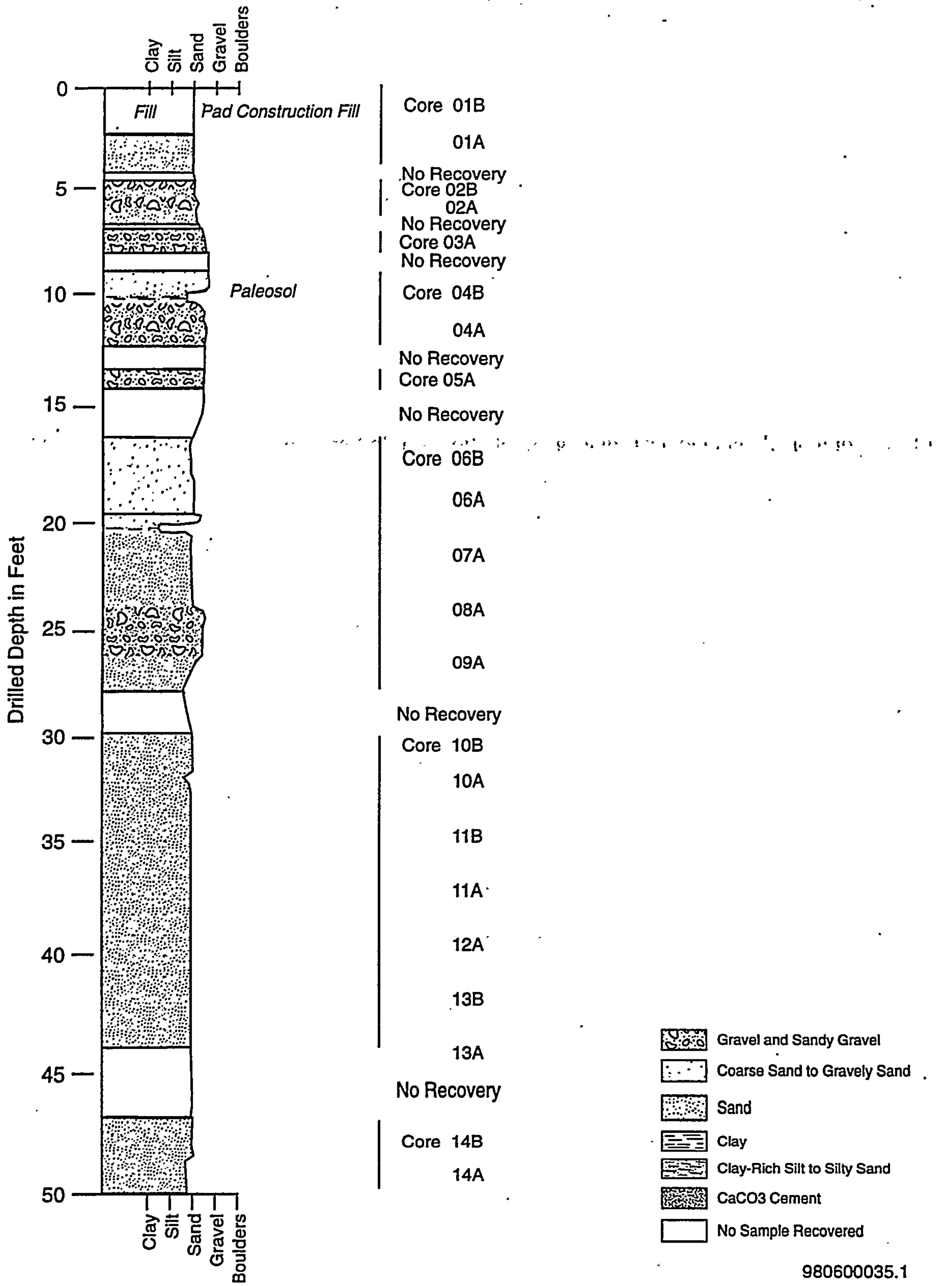

Figure 4. Detailed Geologic Log for Borehole B8501. See Table 5 for description of cored intervals.

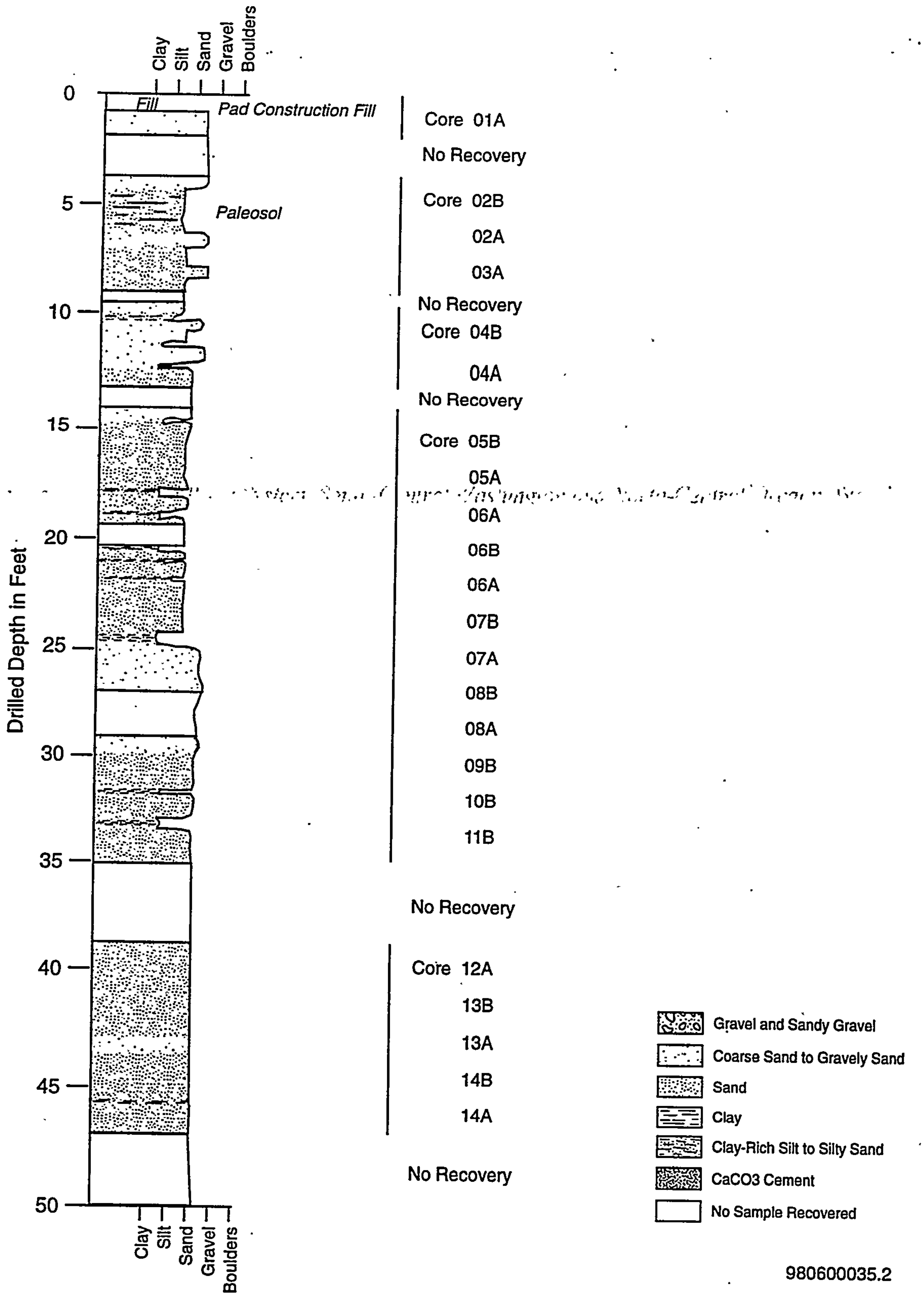

Figure 5. Detailed Geologic Log for Borehole B8502. See Table 6 for description of cored intervals.

The upper 90 feet of Layer 2 is principally fine- to medium-grained sand with minor amounts of interstitial silt. Throughout the sands are disseminated flakes of $CaCO_3$ and $CaCO_3$-cemented sand grains. Several fining upward zones were recognized as well as well-compacted zones of sand and silt with faint laminations.

Layer 2 is also part of unit H2 of Lindsey et al. (1994), and is equivalent to mapping unit Qfs_2 of Reidel and Fecht (1994a,b). It is the Missoula Outburst Flood Deposits consisting of sand, silt and clay that are older than 13 ka and younger than 720 ka. Mapping unit Qfs_2 has a normal magnetic polarity.

3.2.2.3 Layer 3

Layer 3 is 53 feet thick. The principal borehole (299-E17-21) and the two 50-foot deep environmental tracer boreholes (Figures 2 through 5) intersected it. The stratigraphy encountered in all three boreholes is in good agreement although not all features are present in each. This may in part be due to incomplete core recovery and disturbed portions in recovered core.

Cores from boreholes B8501 and B8502 recovered the paleosol horizon that marks the top of Layer 3. Borehole 299-E17-21 did not recover any core between 3 and 9.6 feet where the paleosol horizon is projected to occur (Table 3). Borehole B8501 encountered the paleosol horizon at 10 feet and borehole B8502 encountered it at 5 feet drilled depth. The difference in depth is due to the five feet difference in elevation and 5 feet more sediment in B8501.

In borehole B8501 the paleosol is a 1.1-feet thick, oxidized and leached zone of fine-grained sand and silt with some pebbles. In borehole B8502 the paleosol horizon is about 2 feet thick and consists of leached and oxidized sands and silts with a 4-inch caliche zone (sand and silt cemented by $CaCO_3$).

The lower 25 to 30 feet of Layer 3 (from approximately 25 feet drilled depth down to 58 feet) consists principally of sand with interstitial silt and minor silt lenses. Several minor silt lenses are locally present but are discontinuous, as they do not exist in adjacent cores. Gravely sand marks a transition to finer-grained sand with more silt at a drilled depth of approximately 25 feet.

Several distinct gravelly sands are present within several feet of the paleosol at the top of this layer. Several discontinuous silt lenses are present between the top of Layer 3 and the gravelly sand at 25 feet.

Layer 3 is part of unit H2 of Lindsey et al. (1994) and is equivalent to mapping unit Qfs_3 of Reidel and Fecht (1994a,b) - Outburst Flood Deposits consisting of sand, silt and clay that is about 13 ka. An ash from the 13 ka eruption of Mt. St. Helens (Set S Ash) is typically found near the top of this unit in many places throughout the Pasco basin. The absence of the ash from this borehole suggests that the upper portion may have been eroded prior to soil formation and deposition of the eolian deposit.

3.3 Eolian Unit

The drill pad was sited on a stabilized sand dune at the south end of 200 East area. We interpret the sediment from the surface down to the first paleosol horizon as sediment comprising the sand dune. The eolian-Layer 3 contact is interpreted to be at the same elevation in all three boreholes. The eolian unit is composed of fine- to coarse-grained sands with abundant silt, as layers and as material mixed with the sand. Caliche coating found on the bottom of pebbles and cobbles in drill core through this unit is typical of Holocene caliche development in the Columbia Basin.

This unit is equivalent to mapping unit Qd, Holocene Dune Sand, of Reidel and Fecht (1994a,b).

3.4 Moisture Content

Moisture data were obtained as part of this work during geophysical logging. In addition, Dr. Ellyn Murphy obtained direct moisture measurements of samples from core as part of the environmental tracer studies. Dr. Murphy will report her results elsewhere.

Geophysical logging (Appendix D) indicates higher moisture content in the upper part of the bore-hole. This is consistent with higher than normal precipitation over the past several years. Comparison of the neutron probe moisture logging with the stratigraphy indicates good agreement between fine-grained stratigraphic units in the Hanford formation and higher moisture contents. Paleosol Horizon 3 for Layer 3 showed increased moisture at the depths it was penetrated in the boreholes (5 feet in 299-E17-21 and B8502; 10 feet in B8501).

4.0 References

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Appendix A

Slug Test Analysis Results for Well 299-E17-21

Appendix A

Slug Test Analysis Results for Well 299-E17-21

Frank Spane

A.1 Background

This letter report presents the analysis results for a series of slug tests conducted at well 299-E17-21. The field tests were performed in support of the TWRS Immobilized Low-Activity Waste (ILAW) disposal site. The purpose of the slug tests was to provide initial hydraulic property estimates for the unconfined aquifer, specifically Unit E sandy gravel layer in proximity to well 299-E17-21. The depth interval tested represents the upper 25.7 feet of the unconfined aquifer, from approximately 332.3 to 358 feet BLS. Preliminary geologic information indicates that hydrogeologic Unit E of the Ringold Formation occurs between a depth of 335 to 378 feet BLS (Figure 2). Underlying Unit E are discernable fine-grained silt and clay units of the Lower Mud, occurring between 378 to 439 feet BLS.

The slug tests were conducted on June 10, 1998 following well completion and development activities. The well has a 4-inch diameter well screen completion, which is surrounded by a 2.8-inch annular well sandpack. A Slug Withdrawal test was conducted by removing a slugging rod (slug withdrawal test) of known displacement volume. Slug withdrawal tests were employed rather than slug injection tests (i.e., by rapidly immersing the slugging rod) because of their reported superior results for unconfined aquifer tests where the water table occurs within the well screen section (e.g., Bouwer 1989). In total, seven slug withdrawal tests were conducted. For the first three tests (#1, 2, and 3), the slugging rod displacement volume was 0.127 ft^3. For the next four tests, a larger slugging rod with a displacement volume of 0.327 ft^3 was utilized. Different sized slugging rods were used during testing to impart varying stress levels during testing, which is useful for assessing the effectiveness of well development and the presence of dynamic skin effects (Butler et al. 1996). The similarity in test responses and rapid test recoveries for the two different slug rod sizes used indicates that the well had been adequately developed and that skin effects did not adversely effect the slug test response.

A.1.1 Diagnostic Test Responses

All seven slug tests exhibited nearly complete recovery patterns within 0.5 sec of test initiation. In addition, all slug tests exhibited oscillatory behavior during the first few seconds of the test as shown in Figure A.1. The oscillatory behavior indicates that inertial well effects are significant during the test response and should be taken into account for quantitative test analysis. The rapidity of the response and oscillatory pattern exhibited indicates of highly permeable test formation conditions. Because of the existing high permeability, the test formation was likely recovering during slugging rod removal (implemented to initiate the test), so a "full" stress level associated with the slugging rod volume was not applied to the well/test formation during the test.

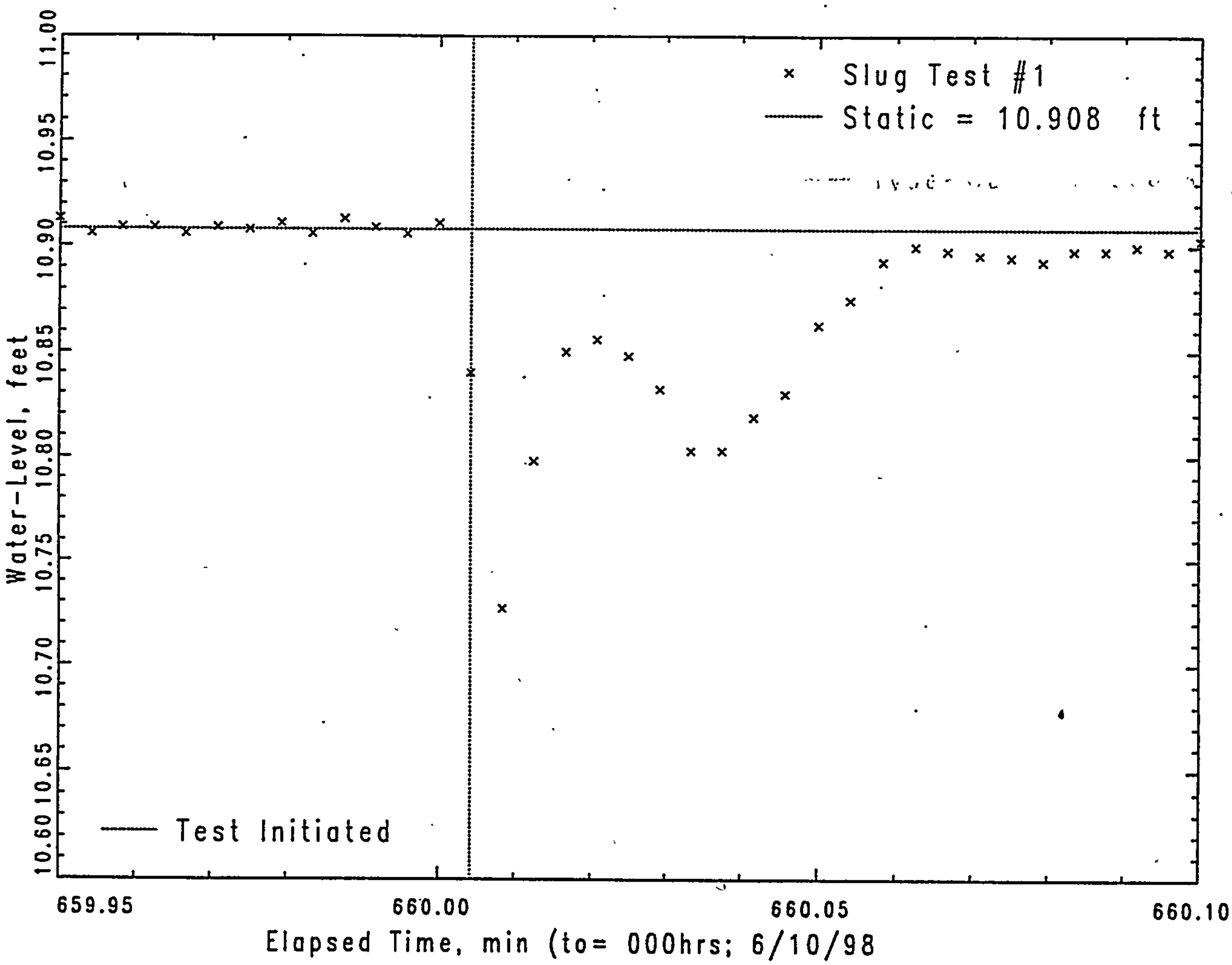

Figure A.1. Slug Withdrawal Test #1 Illustrating Early-Time Oscillatory Behavior

A visual comparison (not shown) of the low stress-level (Tests # 1, 2, and 3) and high stress-level (Tests # 4, 5, 6, and 7) indicates a very similar test response behavior, indicating the well had been adequately developed prior to testing. Because of the similarity in test response, only one low stress test (Test #1) and one high stress test (Test #4) were selected for detailed test analysis.

A.2 Analysis Methods

Standard analytical methods used in the analysis of the slug withdrawal tests conducted within unconfined aquifers include the type-curve matching method presented in Hyder et al. (1994), Hyder and Butler (1995), and Spane and Wurstner (1993), and the semi-empirical straight-line analysis method described in Bouwer and Rice (1976) and Bouwer (1989). Because the type-curve analytical methods can use all or any part of the slug test response in the analysis procedure, they are particularly useful in the analysis of high permeability, unconfined aquifer tests (e.g., as exhibited at well 299-E17-21). They also do not have any of the inherent analytical weaknesses of the commonly-used Bouwer and Rice method (e.g., assumption of steady-state flow, isotropic conditions, etc.), as originally described in Bouwer and Rice (1976) and Bouwer (1989) for unconfined aquifer slug tests. These analytical limitations are discussed in Hyder and Butler (1995), Brown et al. (1995), and Bouwer (1996).

It should be noted that these analytical methods are strictly applicable for slug tests exhibiting an over-damped slug test response, i.e., an exponential decay. All slug tests conducted at well 299-E17-21 exhibited an oscillatory response during the first few seconds of the test (see Figure A.1), and then exponentially decayed (recovered) to pre-test static conditions. This type of composite slug test response is referred to as a "critically damped" slug test response (Van der Kamp 1976, Kipp 1985, Butler 1998) and cannot be quantitatively analyzed using the overdamped slug test analysis methods. PNNL currently does not have software to support quantitative analysis of unconfined aquifer slug tests exhibiting oscillatory or critically damped behavior, and efforts are currently underway to acquire or develop this type of analytical software support. In lieu of performing a quantitative analysis, a preliminary qualitative analysis was attempted using the overdamped slug test type-curve method presented by Hyder and Butler (1995). (Note: the use of over-damped analysis methods for slug tests displaying oscillatory behavior is consistent with procedures described in Butler 1998). Two approaches were attempted. In the first approach, a type-curve best-fit match was applied through (and taking into account) the oscillatory test response exhibited during the low stress Test #1. For the second approach, the type-curve best-fit match was applied only to the non-oscillatory test response exhibited during the high stress Test #4 (i.e., for the initial and later test response). Figures A.2 and A.3 show the relative type-curve matches for the two tests, respectively, using the same hydraulic conductivity value, K_h, of 225 ft/d. As indicated, reasonable type-curve matches utilizing the two approaches were obtained. For comparison purposes, Figure A.4 shows the sensitivity of the predicted test response as applied to Test #4. As shown in the figure, type-curve responses for K_h values 1/3 (75 ft/d) and 3 times (675 ft/d) the best-fit value (225 ft/d) are also presented. The significant difference in type-curve response demonstrates the sensitivity of K_h on slug test response and attests to the acceptability of the final best-fit value.

The type-curves shown in Figures A.2, A.3, and A.4 were calculated using assumed values for vertical anisotropy, K_D, (0.1) and storativity, S, (0.0001). Previous investigations have indicated that these

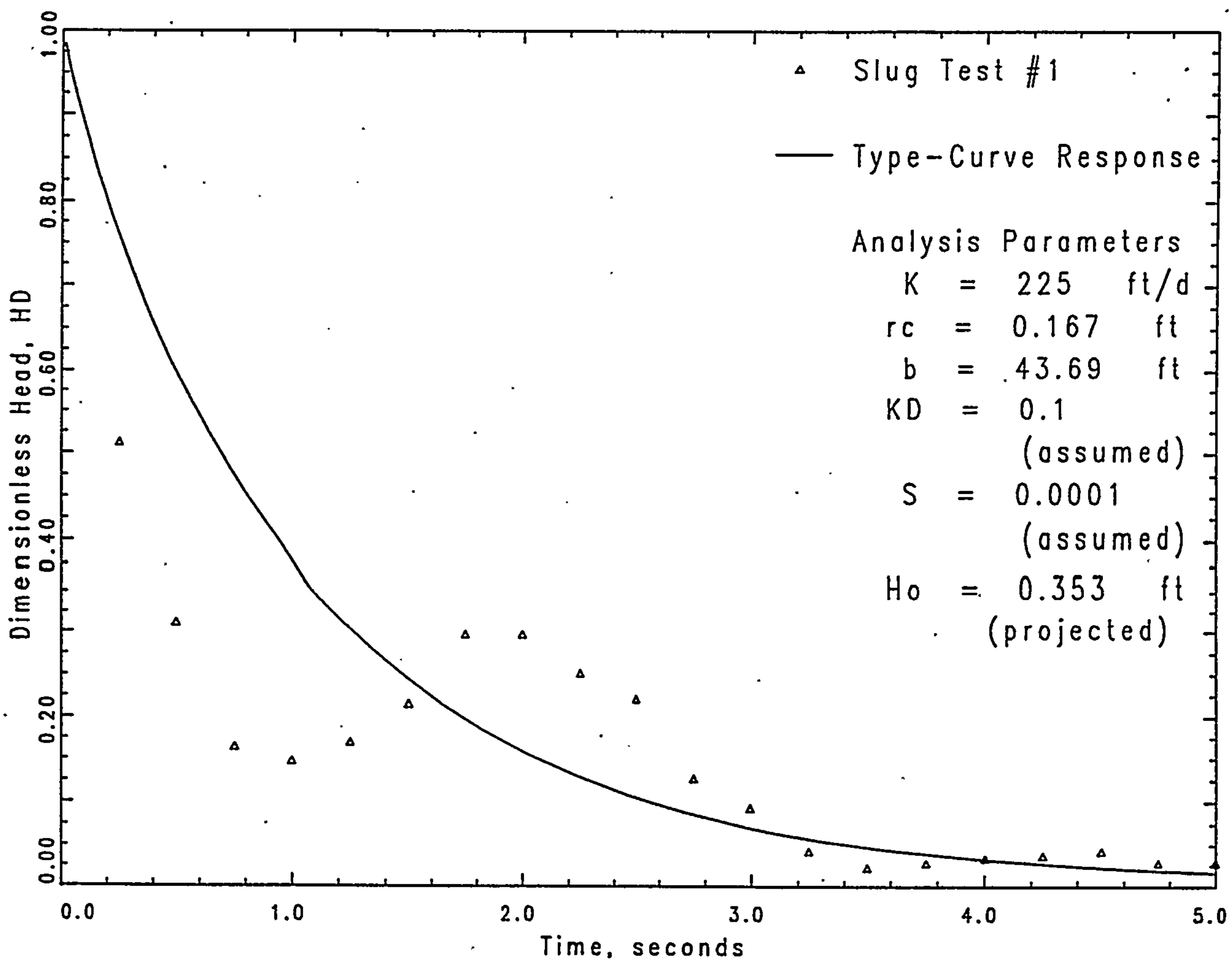

Figure A.2. Qualitative Type-Curve Analysis of Low-Stress, Slug Withdrawal Test #1

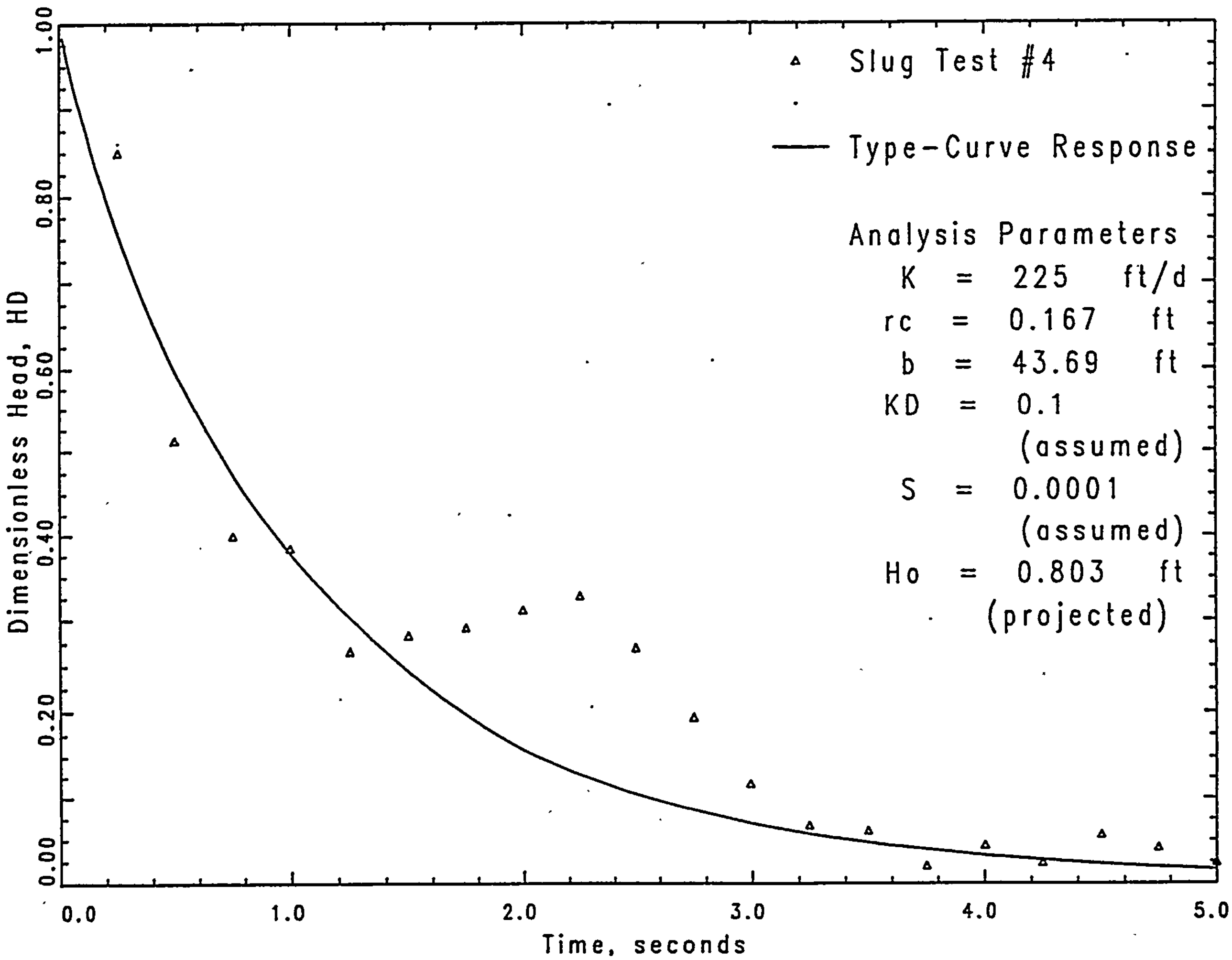

Figure A.3. Qualitative Type-Curve Analysis of High-Stress, Slug Withdrawal Test #4

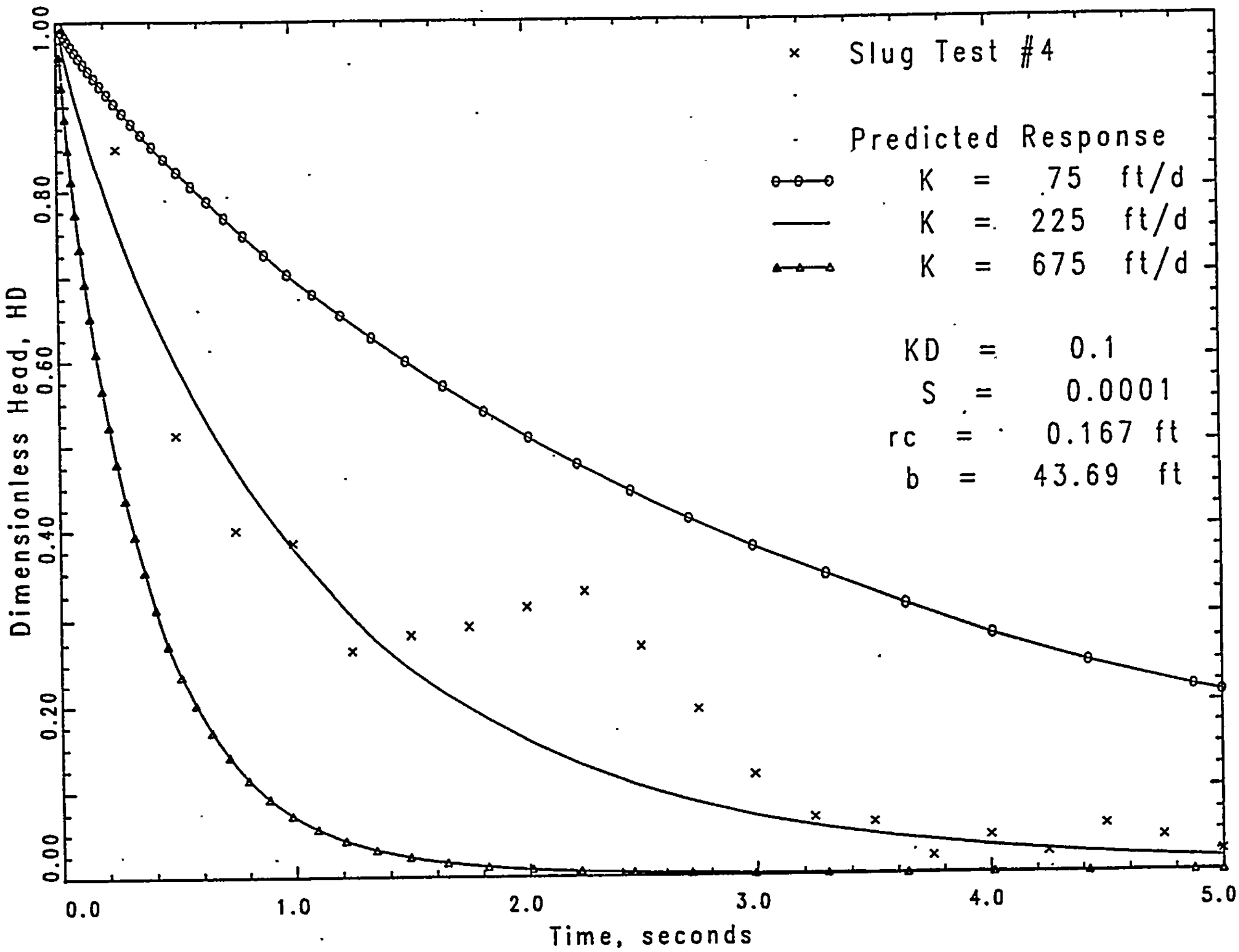

Figure A.4. Sensitivity Analysis of K_h on Predicted Slug Test Type-Curve Response: Slug Withdrawal Test #4 parameters only exert a minor effect on slug test response. In addition, for the slug test analysis, the well screen interval (rather than the sandpack interval) was used to represent the test interval for the analyses. This was based on the assumption that the formation materials within the screened interval have a higher permeability than the sandpack; therefore, test response transmission is expected to propagate faster laterally from the well screen to the surrounding test formation than vertically within the sandpack zone.

A.3 Analysis Results

Based on the preliminary qualitative analysis results (shown in Figures A.2 and A.3) the hydraulic conductivity is estimated to be ≈ 225 ft/d or greater. This value is highly speculative and is only provided to indicate the relative high permeability of this hydrogeologic unit at this well location. To obtain a more quantitative estimate of hydraulic properties, it is recommended that the slug tests at well 299-E17-21 be reanalyzed when new software is acquired that takes into account oscillatory and critically damped slug test behavior. It is also recommended that the low stress tests (Test #1, 2, and 3) be the focus of the new analysis. The low stress test emphasis is due to the likely lower influence of transient effects on early-time oscillatory behavior.

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Appendix B

Groundwater Analytical Results

Appendix B

Groundwater Analytical Results

Table B.1. Results of Groundwater Parameter Sampling during Drilling

Depth (feet)	Nitrate (mg/L)	pH	Conductivity (µs/cm)	Temperature ° (Centigrade)	Turbidity (NTU)	Eh (mV)
339-349	16.72	8.27	441	16.9	113	248.5
359-369	21.56	8.10	453	18.0	354	293.8
374	20.24	8.04	446	18.5	>1000	276.4
409-429	2.64	8.20	359	22.0	>1000	245.3

Table B.2. Results of Groundwater Parameter Analysis During Pumping Sampling. Packer set at 469.4 feet drilled depth and pump at 476 feet drilled depth. Bottom of casing at 471 feet drilled depth.

Time	1155	1225	1250	1315	1330	1345	1425
PH	7.88	7.92	7.97	7.99	7.96	7.96	7.95
Temp (°C)	21.2	21.8	21.8	21.9	22.0	22.1	22.2
Cond. (µs/cm)	336	346	331	340	343	346	343
Turb. (NTU)	904	25.3	15.9	21.9	9.88	5.09	3.56
D.O. (mg/L)	.90	7.80	1.07	1.11	0.75	0.10	1.42
Eh (mV)	81.2	110.5	-183.9	-160.7	-194.8	-200.9	-165.9
2nd Turb. (NTU)						4.65	

Table B.3. Laboratory Groundwater Analysis from Ringold Unit A

Constituent	Result	Units	Counting Error	Total Analytical Error	Qualifier	Filtered?	Drinking Water Std.
Alkalinity	145 146	mg/L				N	
Aluminum	20.6 20.6	ug/L			U	Y	50
Antimony	45.7 45.7	ug/L			U	Y	6
Arsenic	5.0 5.2	ug/L			B	Y	50
Barium	72.0 71.4	ug/L				Y	2
Cadmium	4.6 4.6	ug/L			U	Y	5
Calcium	31600 31600	ug/L			C	Y	
Chloride	3.4 3.32	mg/L				N	250
Chromium	2.1 2.1	ug/L			U	Y	100
Cobalt	3.8 3.8	ug/L			U	Y	
Conductivity	326 323	umhos/cm			U	N	
Copper	3.6 3.6	ug/L			U	Y	1
Fluoride	0.364 0.364	mg/L				N	4,000
Gross Alpha	0.695 0.578	pCi/L	0.609 0.576	0.618 0.584	U	N	15
Gross Beta	7.29 8.44	pCi/L	1.9 1.87	2.02 2.02		N	50
Iodine-129	0.215 -0.159	pCi/L	0.186 0.193	0.187 0.194	U	N	1
Iron	128 131	ug/L			C	Y	300
Magnesium	12100 12000	ug/L				Y	

Table B.3. (contd)

Constituent	Result	Counting Error	Total Analytical Error	Units	Qualifier	Filtered?	Drinking Water Std.
Manganese	74.4 73.8			ug/L		Y	50
Nickel	14.2 14.2			ug/L	U	Y	100
Nitrogen in Nitrate	0.002 0.016			mg/L	U B	N N	10
Nitrogen in Nitrite	0.001 0.001			mg/L	U	N	1
Potassium	6200 6530			ug/L		Y	
Silver	5.1 5.1			ug/L	U	Y	0.1 mg/L
Sodium	16200 16100			ug/L		Y	
Strontium (elemental)	206 204			ug/L		Y	
Sulfate	21.3 21.3			mg/L	D	N	250,000
Technetium-99	-6.37 -5.68	4.85 4.88	15.3 15.3	pCi/L	U	N	900
Total Organic Carbon	0.82 0.858			mg/L	B	N	
Tritium	16.4 43.6	124 126	190 192	pCi/L	U	N	20,000
Uranium	0.259 0.267		0.0349 0.0359	ug/L		Y	
Vanadium	4.4 4.4			ug/L	U	Y	
Zinc	90.8 92.4			ug/L	E	Y	5 mg/L

Appendix C

Borehole Construction Diagrams

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Becker Hammer	Sample Method:	Grab/Split Spoon	WELL NUMBER:	299-E17-21 B8500 TEMPORARY WELL NO: None
Drilling Fluid Used:	Air	Additives Used:	None	Coordinates: N	134,894.21
Driller's Name:	Willie Franklin	WA State Lic Nr:	Not Available	Coordinates: E	574,107.02
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Start Card #:	Not Available
Date Started:	06Apr98	Date Completed:	23Apr98	Elevation Ground Surface:	734.7 m Brass Marker

Depth to Water: 332.5 ft 23Apr98
(Ground surface)

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface: m

Depth of Surface Seal: 311.7 ft

Type of Surface Seal: 4x4 Concrete Pad

GENERALIZED STRATIGRAPHY — Geologist's Log & Geophysical Logs

0 - 3 ft: Fine to very fine, 60-80% felsic, subrud to sub angular mod w sorte, unconsolidated

3 - 247 ft: Hanford:
Sand normally graded sandy beds, varying from grannular, occassionly pebbly, to very fine silty beds, 40-70% felsic, 60-30% mafic, pred. sub angular to sub rounded, occassional paleosol horizon w/slight to strong HCl reax., occassional pebble-cobble gravel stringer/zone.
Inner bedded Hanford sands, silty sands, and occ. gravely stringers

212 - 216 ft: Pebble-cobble sandy gravel, 60-50% mafic 50-40% felsic. Small pebbles to large cobbles, w/grannular to med. sand matrix

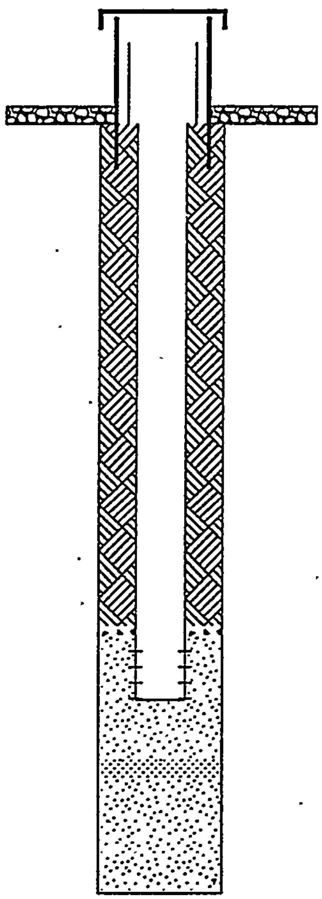
220 - 230 ft: Small pebbles to large cobbles, w/grannular to med. sand matrix

247 - 323 ft: Hanford gravel: Pebble-cobble gravel 70+% mafic, 30% felsic, sub to well rounded open framework, some med. gravel, large cobbles 4-8" dia. common

323 - 376 ft: Top of Ringold 'E'- Sandy gravel, 60-70% felsic, 30-40% mafic, subrounded to rounded pebble-cobble gravel, w/pred. felsic sand matrix, sl cemented, pebble-cobbles 2-6" dia.

376 - 438 ft: Ringold "Lower Mud"
376-381 yellow very sandy silt
381-412 Blue gray very clayey silt. Silty to mod. silty clay rich organic - wood debris - fragments common.
412-436 Dark to med. brown - brown gray, silty to mod. silty clay rich organic - wood debris fragments common.

438 - 481.7 ft: Ringold 'A':
Pebble-cobble gravel mod. sandy, gravel 40-70% felsic, salt and pepper sand, light to dark green chlorite stains on sand, mod.-well cemented in part.



Fill	Casing	Screen
0 - 311.7 ft: 9.6-inch hole	0 - 328.2 ft: 4 inch 4" SS sch. 5 well casing	
311.7 - 319.95 ft: 9.6-inch hole		328.2 - 358.03 ft: 4 inch 4" SS wire warp .020 slot
319.95 - 358.53 ft: 9.6-inch hole	358.03 - 358.53 ft: 4 inch 4" SS cap	
358.53 - 397 ft: 9.6-inch hole		
397 - 409.1 ft: 9.6-inch hole		
409.1 - 480.7 ft: 9.6-inch hole		

480.7 ft : Borehole drilled depth

0 - 480.7 ft : 9.6-in. AP-1000 (Becker Hammer rig) w/9" x 6" dual wall drive pipe, 9-5/8" shoe, & 2000 cfm air available

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 12May98
Print Date: 26May98

Report Form: WELLS Project File: WELLS.GPJ

BECHTEL

Figure C.1. Well Construction and Completion Summary for Borehole 299-E17-21

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-E17-21

WELL DESIGNATION	:	299-E17-21
CERCLA UNIT	:	
RCRA FACILITY	:	
DEPTH DRILLED (GS)	:	480.7 ft
MEASURED DEPTH (GS)	:	358.53 23Apr98
AVAILABLE LOGS	:	Geologist
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	ILAW - Groundwater Monitoring Well
CURRENT USER	:	ILAW - groundwater monitoring
PUMP TYPE	:	Not Documented
MAINTENANCE	:	Data not available
COMMENTS	:	9" x 6" Dual Wall drive pipe w/9-5/8" x 7-1/8' shoe
TV SCAN COMMENTS	:	Not Applicable

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 12May98
Print Date: 20May98

Report Form: WELLS Project File: WELLS.GPJ

Figure C.1. (contd)

WELL DEVELOPMENT AND TESTING DATA

Well Name: 2-E17-21	Well ID: B8500	Well Location: 200E / 1st Av	Date: 4/23/98

Reference Measuring Point (unless otherwise noted): GROUND LEVEL

Has the well been surveyed? ☑ Yes ☐ No — Does the well have a cement pad? ☑ Yes ☐ No

PART 1

STATIC WATER LEVEL:

Start of Job	332' BLS
End of Job	332.7' (pump off 30 min)

DEPTH TO BOTTOM:

Start of Job	358.1'
End of Job	358.5'

PART 2

WELL DEVELOPMENT DATA

Pump Model	- 5hp Grunflos
Intake Depth	Various / see notes
Starting Turbidity	

Pump Start	Stop	Flow Rate
1240	1415	11.5 gal/min
1420	1500	11.5

Total Pumped	1552 gal
Final Turbidity	4.32 NTU
Transducer Range (PSI)	N/A

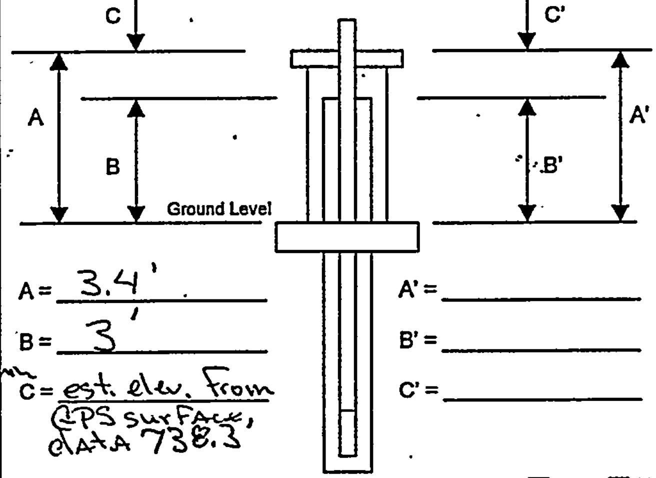
PART 3

INSTANTANEOUS SLUG TEST

Static Water Level (TOC)	
Transducer Depth	
Baseline Start	
Injection Start	
Baseline Start	
Withdrawal Start	
Slug Volume	
Transducer Range (PSI)	

PART 4

Last Recorded Measurements Date: 4/28/98	Current Measurements Date:



A = 3.4'
B = 3'
C = est. elev. from GPS surface, data 738.3

A' =
B' =
C' =

Are there any reference marks on the casing strings? ☐ Yes ☒ No

PART 5

COMMENTS:

Pump placements vary - pumped each depth until under 5 NTU raise pump. See FAR #13
Set at 357' BLS - 2.89 NTU - ~~65~~ for 65 min
355.5' - 4.95 NTU - 10 min
352.5' - 4.25 - 10 min
350.5' - 4.23 20 min
344.5' - 4.58 15 min
343' - 4.5 12 min
340' - pumped dry 3 min
Recover to 332.7' in 31 min

Prepared by (print name): K. Reynolds	Signature:
Reviewed by (print name): [signature]	Signature:

BHI-EE-112 (10/97)

Figure C.1. (contd)

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Becker Hammer	Sample Method:	Grab/Split Spoon	WELL NUMBER:	B8501 B8501	TEMPORARY WELL NO:	None
Drilling Fluid Used:	Air	Additives Used:	None	Coordinates: N	Not documented		
Driller's Name:	B.W. Wright	WA State Lic Nr:	Not Available	Coordinates: E	Not documented		
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Start Card #:	Not Available		
Date Started:	07May98	Date Completed:	07May98	Elevation Ground Surface:			

Depth to Water: 50.2 ft
(Ground surface)

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: NA

Type of Surface Seal: NA

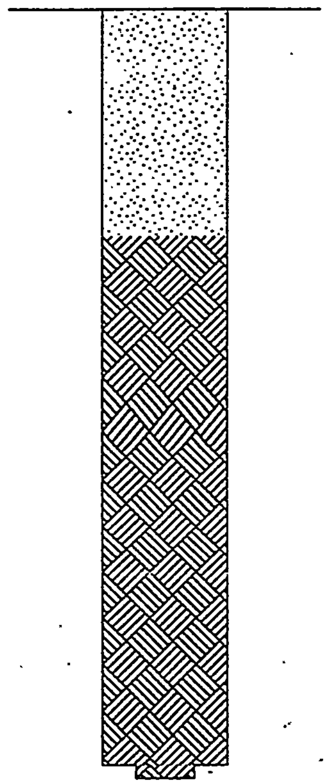
GENERALIZED STRATIGRAPHY Geologist's Log

0 - 3 ft : Surface blow sand

3 - 43 ft : Sand with occassional pebble/cobble clasts/zns. Sand varying from uf-f to med. - grannular, 40-60% basalt, 60-40% felsic sub angular to mod. well rounded, mod. well sorted, very unconsolidated, some grannular to very small pebble zones, slight-mod reax to HCl at 10-12 ft., 25-26 ft., and 49-50.2 ft. Slightly cemented at 10-12 ft.

43 - 46.7 ft : Sandy gravel to gravelly sand, gravel 1 to 5 inch dia. sandy matrix as above.

46.7 - 50.2 ft : Sand as above.



Fill *Casing* *Screen*

0 - 15 ft : 9.6-inch hole 8-10 Sand (8 sks.)

15 - 49.3 ft : 9.6-inch hole Portland cement with 4% bentonite; (22 sks. from 50.2 ft.)

49.3 - 50.2 ft : 4.5-inch hole Portland cement with 4% bentonite

50.2 ft : Borehole drilled depth

0 - 49.3 ft : 9.6-in. AP-1000 (Becker Hammer rig) w/9" x 6" dual wall drive pipe, 9-5/8" shoe, & 2000 cfm air available

49.3 - 50.2 ft : 4.5-in. Split spoon sampler driven from 49.3 to total depth.

Drawing By:	JEA
Reference:	Hanford Wells
Revision:	0
Revision Date:	21May98
Print Date:	21May98

BECHTEL

Report Form: WELLS Project File: WELLS.GPJ

Figure C.2. Well Construction and Completion Summary for Borehole B8501

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - B8501

WELL DESIGNATION	:	B8501
CERCLA UNIT	:	NA
RCRA FACILITY	:	NA
DEPTH DRILLED (GS)	:	50.2 ft
MEASURED DEPTH (GS)	:	50.2 07May98
AVAILABLE LOGS	:	Geologist
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	Vadose characterization
CURRENT USER	:	ILAW - characterization
PUMP TYPE	:	NA
MAINTENANCE	:	Non required
COMMENTS	:	9" x 6" Dual Wall drive pipe w/9-5/8" x 7-1/8' shoe
TV SCAN COMMENTS	:	Not Applicable

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 21May98
Print Date: 21May98

Report Form: WELLS Project File: WELLS.GPJ

Figure C.2. (contd)

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Becker Hammer	Sample Method:	Grab/Split Spoon	WELL NUMBER: B8502 B8502	TEMPORARY WELL NO: v
Drilling Fluid Used:	Air	Additives Used:	None	Coordinates: N	Not documented
Driller's Name:	B.W. Wright	WA State Lic Nr:	Not Available	Coordinates: E	Not documented
Drilling Company:	Layne Christensen	Company Location:	Salt Lake City, Ut	Start Card #:	Not Available
Date Started:	08May98	Date Completed:	08May98	Elevation Ground Surface:	

Depth to Water: 53 ft
(Ground surface)

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: NA

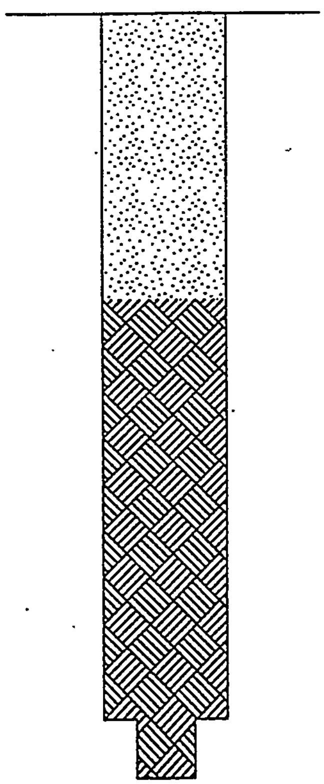
Type of Surface Seal: NA

GENERALIZED STRATIGRAPHY Geologist's Log

0 - 2 ft : Surface blow sand - sand disturbed inpart

3 - 46.9 ft : Sand w/small pebble/cobble zones at 15 to 26 ft., normal graded sand gravel grannular to fine - very fine, 50-70% basalt, 30-50% felsic trace paleosol development at ~3 ft. and at 28-29 ft., slight -mod. HCl reax.

46.9 - 53 ft : Pebble/cobble gravel 4-6 inch dia. some sandy matrix well rounded, 70-60% basalt. Poor sample/cuttings return.



Fill *Casing* *Screen*

0 - 20 ft : 9.6-inch hole 8-10 and 10-20 sand (12 sks.)

20 - 49.2 ft : 9.6-inch hole Portland cement w/6% bentonite (13 sks. from T.D. @ 53 ft.)

49.2 - 53 ft : 4.5-inch hole Portland cement w/6% bentonite

53 ft : Borehole drilled depth

0 - 49.2 ft : 9.6-in. AP-1000 (Becker Hammer rig) w/9" x 6" dual wall drive pipe, 9-5/8" shoe, & 2000 cfm air available
49.2 - 53 ft : 4.5-in. Split spoon sampler attempthed from 49.2 to total depth.

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 21May98
Print Date: 21May98

BECHTEL

Report Form: WELLS Project File: WELLS.GPJ

Figure C.3. Well Construction and Completion Summary for Borehole B8502

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - B8502

WELL DESIGNATION	:	B8502
CERCLA UNIT	:	NA
RCRA FACILITY	:	NA
DEPTH DRILLED (GS)	:	53.0 ft
MEASURED DEPTH (GS)	:	53 08May98
AVAILABLE LOGS	:	Geologist
DATE EVALUATED	:	Data not available
EVAL RECOMMENDATION	:	Data not available
LISTED USE	:	Vadose characterization
CURRENT USER	:	ILAW - characterization
PUMP TYPE	:	NA
MAINTENANCE	:	Non required
COMMENTS	:	9" x 6" Dual Wall drive pipe w/9-5/8" x 7-1/8' shoe
TV SCAN COMMENTS	:	Not Applicable

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 21May98
Print Date: 21May98

Report Form: WELLS Project File: WELLS.GPJ

BECHTEL

Figure C.3. (contd)

Appendix D

Geophysical Logs

RLS Spectral Gamma Ray Borehole Survey
Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) **Well: 299-E17-021**

Log Type: HPGe Spectral Gamma Ray

Borehole Information

Well ID	B8500	Water Depth	330.5 ft	Total Depth	479.8 ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	3.5 ft		
Casing Diameter	9.0 in OD	Depth Interval	0 to 479.8 ft	Thickness	0.500 in
Casing Diameter	6.0 in	Depth Interval	0 to 479.8 ft	Thickness	0.125 in

Logging Information

Log Type	HPGe Spectral Gamma Ray
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 17, 1998 E17021
Logging Engineers	J. Meisner & B. Markes
Instrument Series	RLSG3.1
Logging Unit	RLS2
Depth Interval	277 to 482.5 ft Prefix B202
	240 to 299 ft Prefix B203
	0 to 245 ft Prefix B204
Instrument Calibration Date	Sep. 9, 1997
Calibration Report	WHC-SD-EN-TI-292, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Randall Price
Date	May 7, 1998

Notes: No man-made radionuclides were detected. The casing thickness correction was applied for all, except drill string couplings (every 10 feet) where the steel thickness is greater.

Figure D.1. RLS Spectral Gamma Ray Borehole Survey for Borehole 299-E17-21

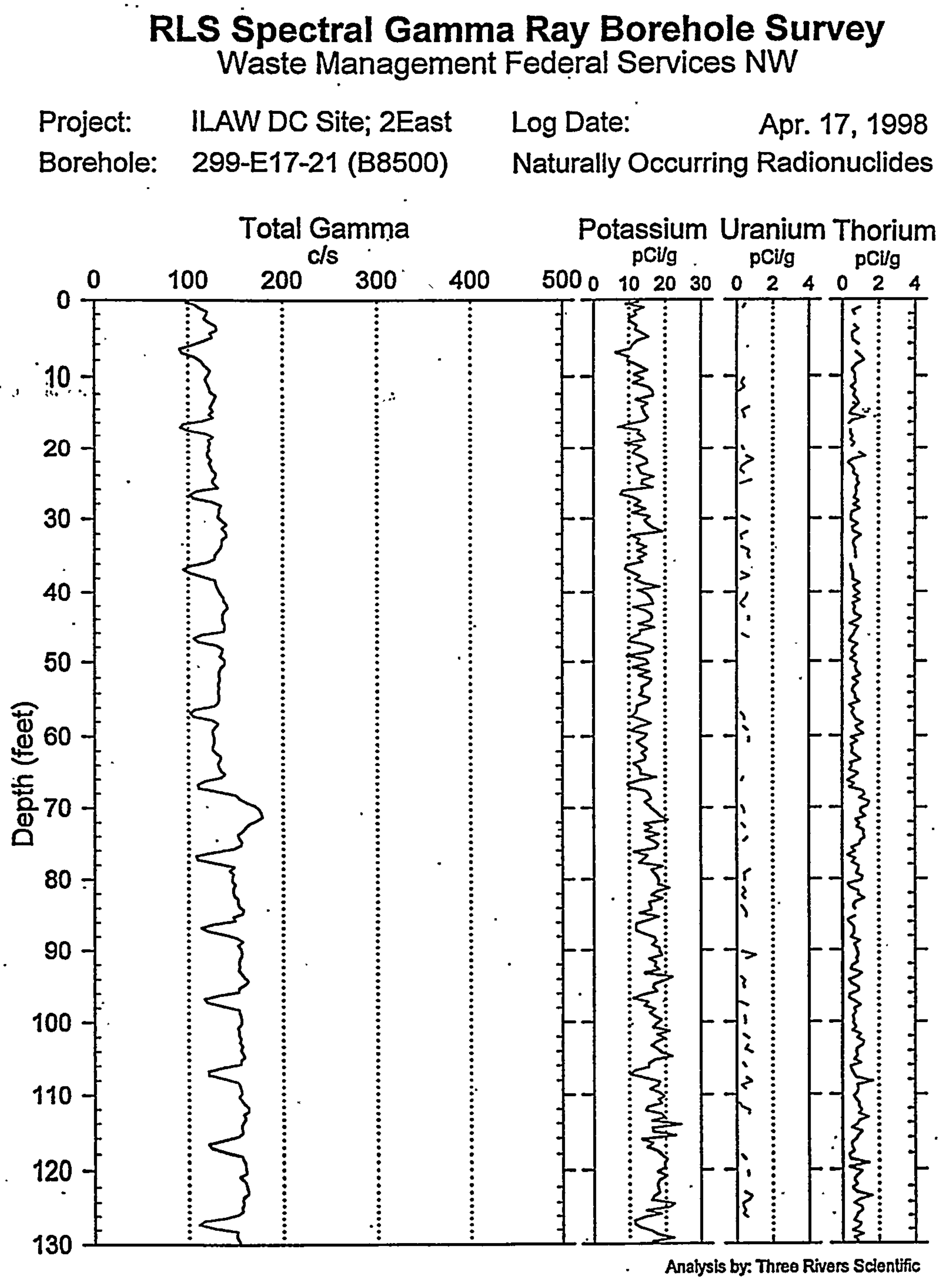


Figure D.1. (contd)

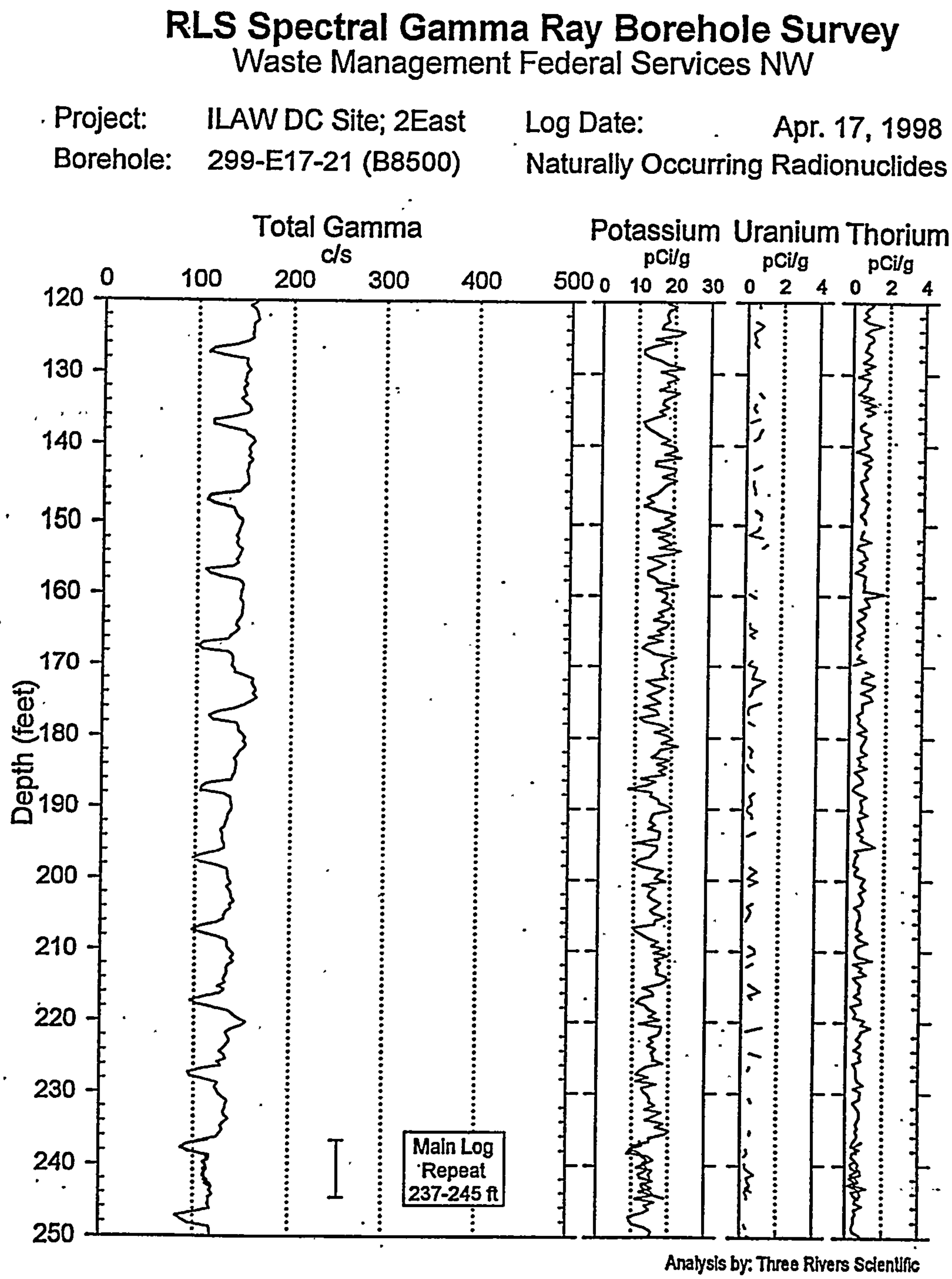


Figure D.1. (contd)

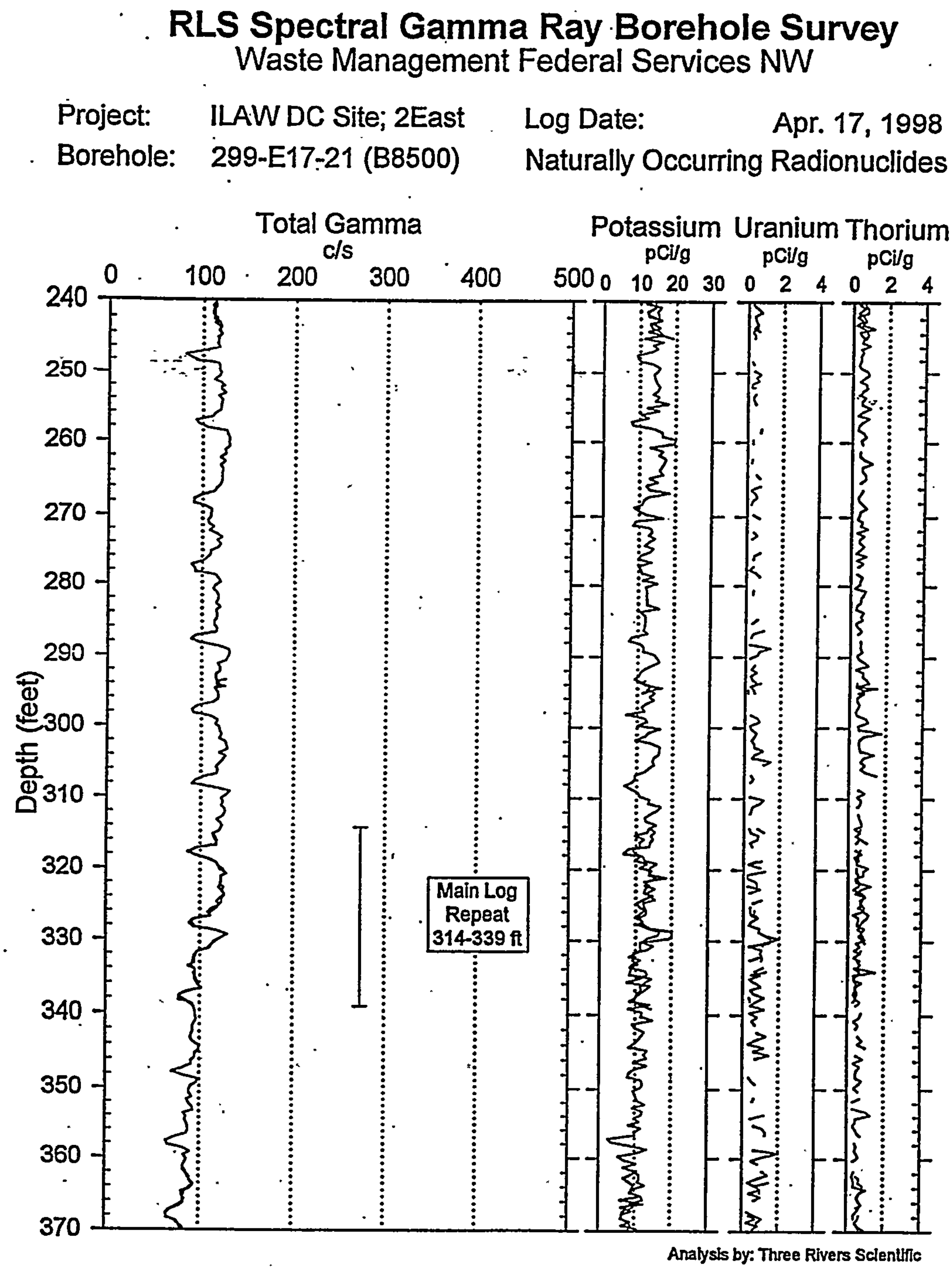


Figure D.1. (contd)

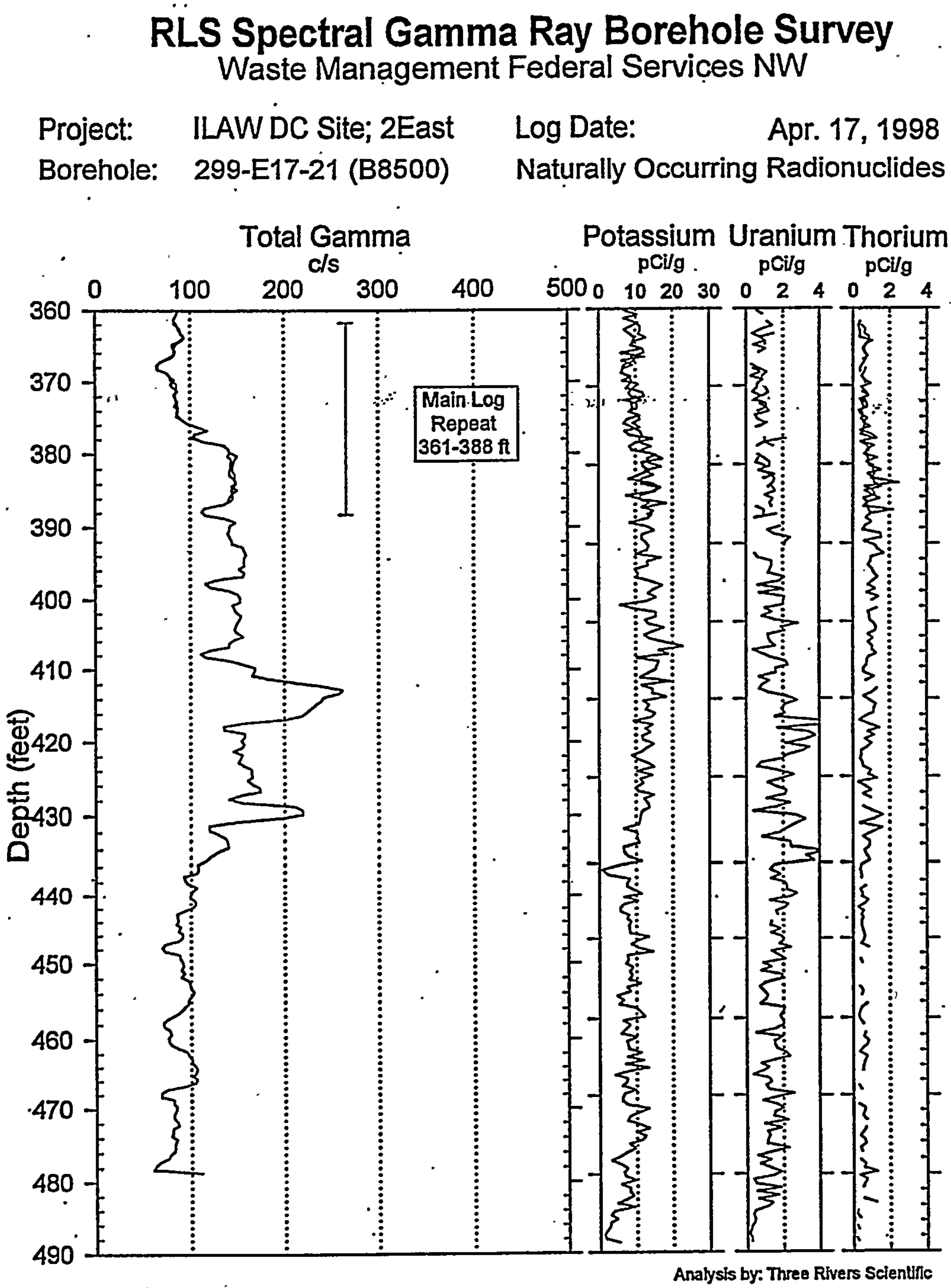


Figure D.1. (contd)

RLS Spectral Gamma Ray Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC Site (200 East)	Well ID:	299-E17-021
Log Type:	HPGe Spectral Gamma-Ray	Log Dates:	Apr. 17, 1998

General Notes:
Total gamma is, in general, a response of formation lithology, except at 10 feet intervals, where increased steel thickness at drill string coupling added to attenuation of gamma rays. Depth offset correction (-3.5 ft) has been applied to survey data sets (prefixes B202 and B203) to adjust depth of datum reference from top of casing to ground level.

System Performance Verification: The pre- and post-log verification was performed using coleman #2 mantle. The maximum FWHM for the 583 keV gamma ray photo peak for the survey was 2.22 keV. The maximum acceptable FWHM resolution is 3.10 keV for probe RLSG3.1 on the log date.

Repeat Interval: The repeat intervals, 237 to 245, 314 to 339, and 361 to 388 feet, agree with the main log within acceptable limits (refer to the Acceptance QA Processing plot for depth interval 366 to 384 ft).

Environmental Corrections: The KUT radionuclide concentrations have been corrected for casing attenuation over the entire well except for increased thickness at drill string couplings. No casing correction was applied to the total gamma due to Compton downscatter interference.

Radionuclides:
No man-made radionuclides were encountered.

Analysis by: Three Rivers Scientific

Figure D.1. (contd)

RLS Moisture Borehole Survey

Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) Well: **299-E17-021**

Log Type: Moisture

Borehole Information

Well ID	B8500	Water Depth	330 ft	Total Depth	479.8 ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	3.9 ft		
Casing Diameter	8.0 in ID	Depth Interval	0 to 479.8 ft	Thickness	0.500 in
Casing Diameter	6.0 in ID	Depth Interval	0 to 479.8 ft	Thickness	0.125 in

Logging Information

Log Type	Moisture
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 18, 1998 E17021
Logging Engineers	J. Meisner
Instrument Series	RLSM3.1
Logging Unit	RLS2
Depth Interval	290 to 329 & 0 to 70 ft Prefix MS52
	68 to 175 ft Prefix MS53
	172 to 275 ft Prefix MS54
	272 to 329 ft Prefix MS55
Instrument Calibration Date	Dec. 18, 1997
Calibration Report	WHC-SD-EN-TI-306, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Russ Randall
Date	May 1, 1998

Notes The casing thickness correction was applied for all, except the drill string couplings, where the steel thickness is greater. The calibration for 8 inch borehole diameter has been applied, since no 9 inch calibration exists.

Figure D.2. RLS Moisture Borehole Survey for Borehole 299-E17-21

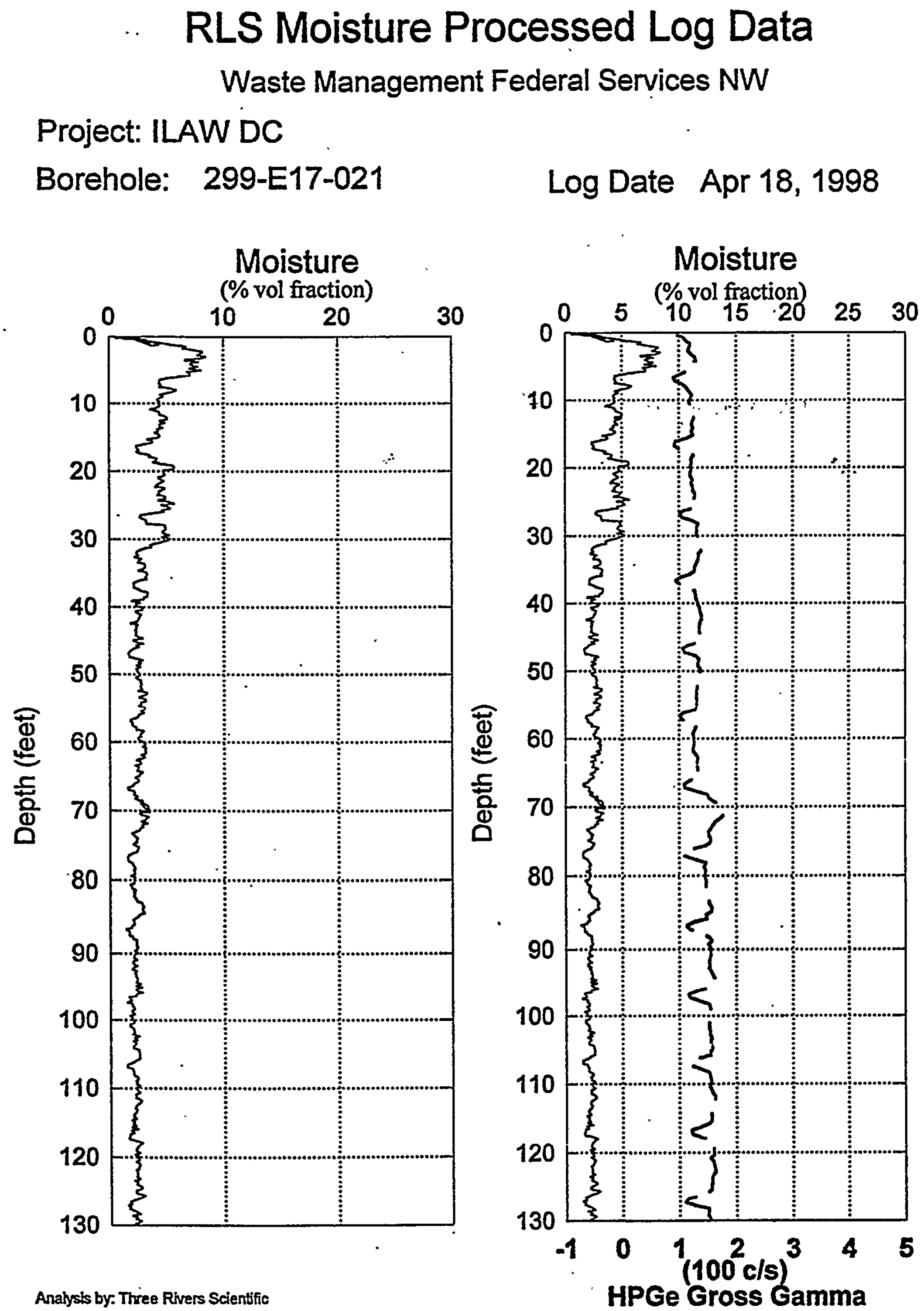


Figure D.2. (contd)

RLS Moisture Processed Log Data

Waste Management Federal Services NW

Project: ILAW DC

Borehole: 299-E17-021 Log Date Apr 18, 1998

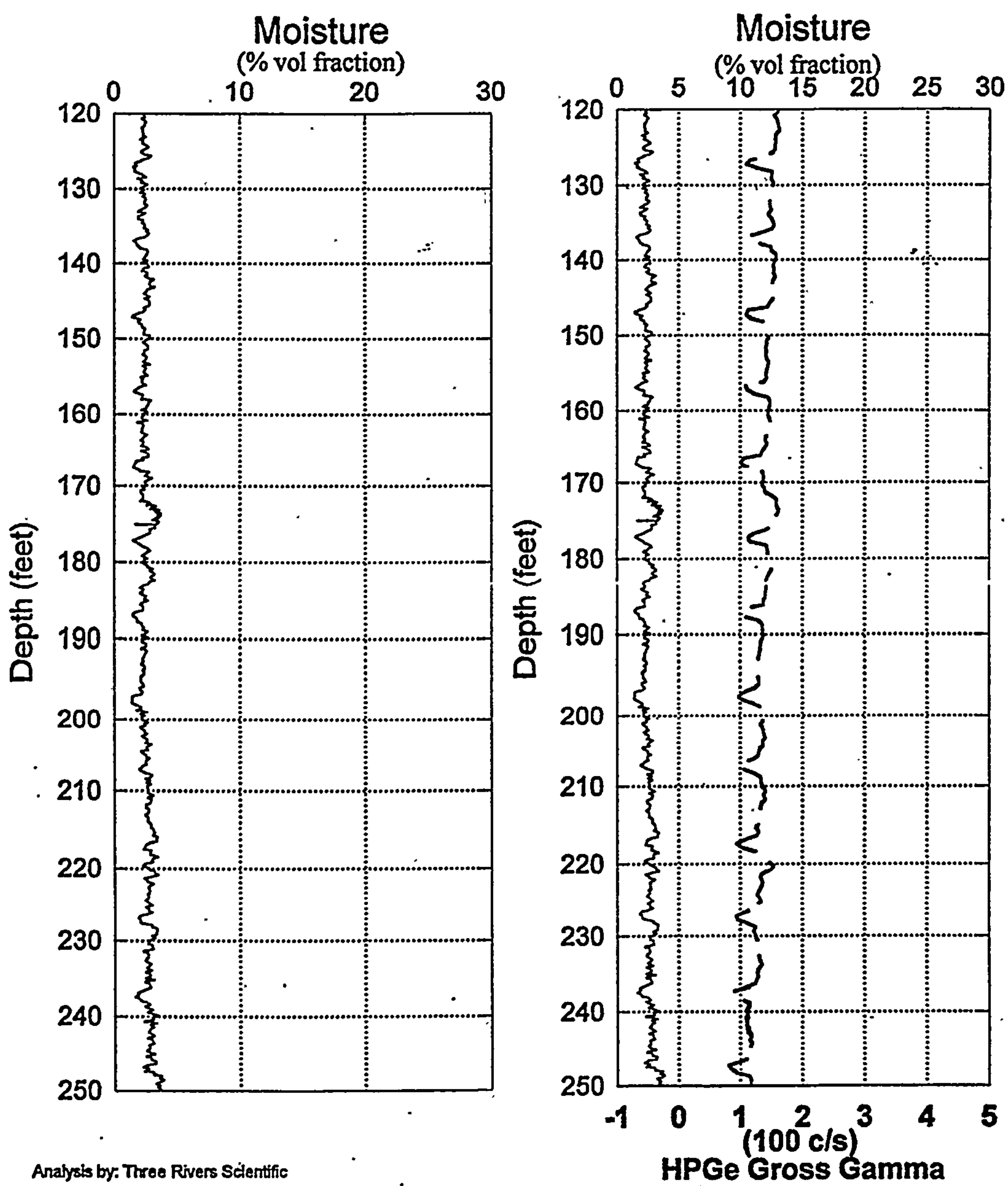


Figure D.2. (contd)

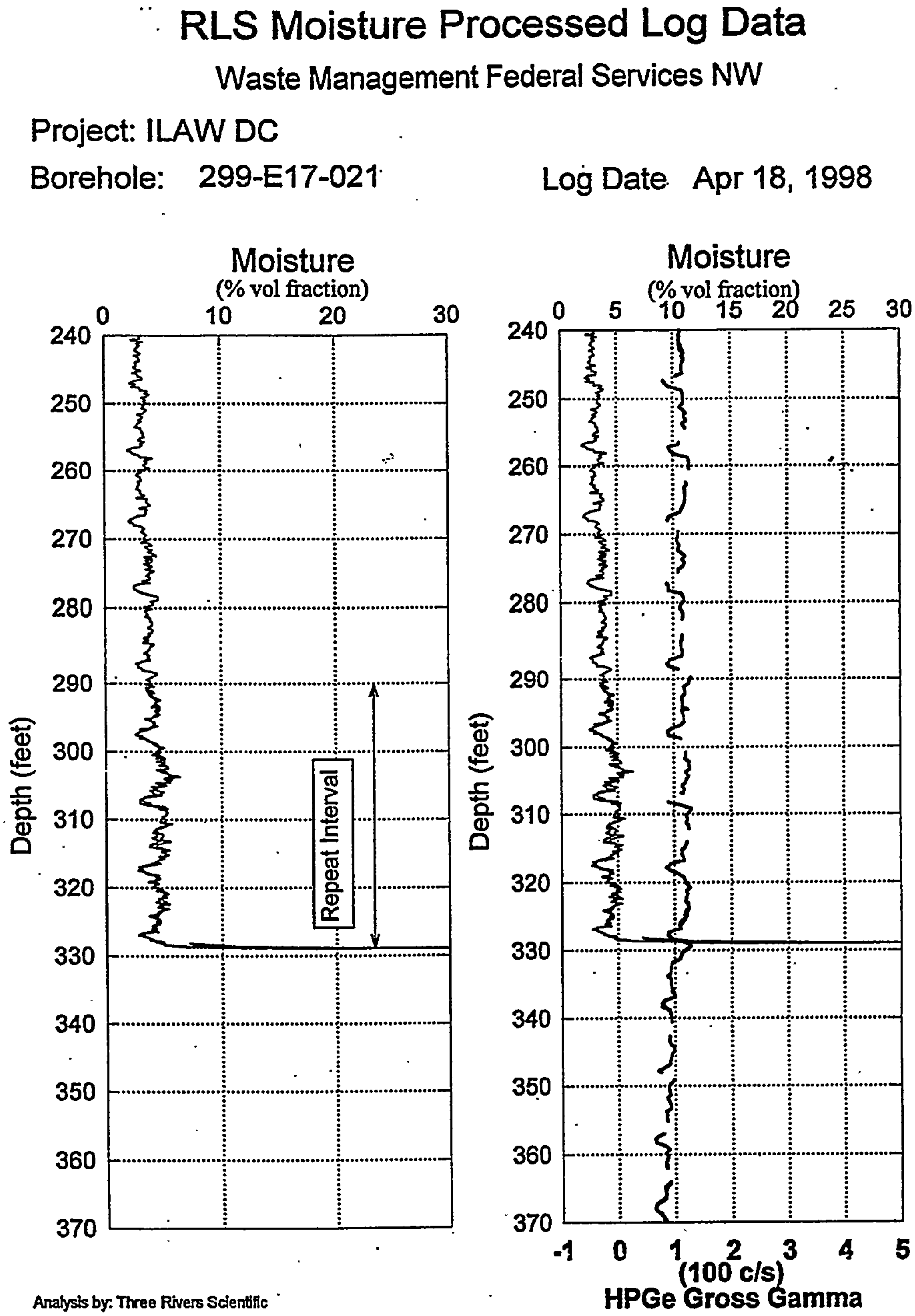


Figure D.2. (contd)

RLS Moisture Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC Site (200 East)	Well ID:	299-E17-021
Log Type:	Moisture	Log Dates:	Apr. 18, 1998

General Notes:

At these low moisture values for the earth surround the borehole, other parameters such as void space and formation density affect the instrument readings more than moisture, since so little moisture is present.

There does appear a small correlation between gross gamma ray (i.e. lithology) and the moisture (excluding collar response) in the change from 32 to 66 feet compared to the interval from 66 to 172 feet. In this upper interval (32 to 66 feet) the average non collar gross gamma is 125 c/s and the moisture reads 4%, while in the lower interval (66 to 172 feet) the gross gamma is 150 c/s and the moisture reads 3%.

System Performance Verification: The pre- and post-log verification was performed using instrument carrier. The pre-log reading is 4% lower than the post-log reading, well within tolerance.

Repeat Interval: The repeat interval, 290 to 329 feet, agrees with the main log within acceptable limits (refer to the Acceptance QA Processing plot).

Environmental Corrections: The casing thickness (other than over the collar intervals), correction has been applied. A density correction was not applied. The extra casing thickness at each collar is not corrected and is visible every 10 feet.

The borehole diameter is a nominal 9 inch value and there is no calibration for this diameter. However, at these low moisture values, an extrapolation would not yield any significant change.

Analysis by: Three Rivers Scientific

Figure D.2. (contd)

RLS Spectral Gamma Ray Borehole Survey

Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) Well: **B8501**

Log Type: HPGe Spectral Gamma Ray

Borehole Information

Well ID	A8501	Water Depth	None ft	Total Depth	48.7 ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	2.0 ft		
Casing Diameter	8.0 in ID	Depth Interval	0 to 51.8 ft	Thickness	0.500 in
Casing Diameter	6.0 in ID	Depth Interval	0 to 51.8 ft	Thickness	0.125 in

Logging Information

Log Type	HPGe Spectral Gamma Ray
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 25, 1998 B8501
Logging Engineers	B. Markes
Instrument Series	RLSG3.1
Logging Unit	RLS2
Depth Interval	0 to 48.7 ft Prefix B205
Instrument Calibration Date	Sep. 9, 1997
Calibration Report	WHC-SD-EN-TI-292, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Randall Price
Date	May 11, 1998

Notes: No man-made radionuclides were detected. The casing thickness correction was applied for all, except drill string couplings (every 10 feet) where the steel thickness is greater.

Figure D.3. RLS Spectral Gamma Ray Borehole Survey for Borehole B8501

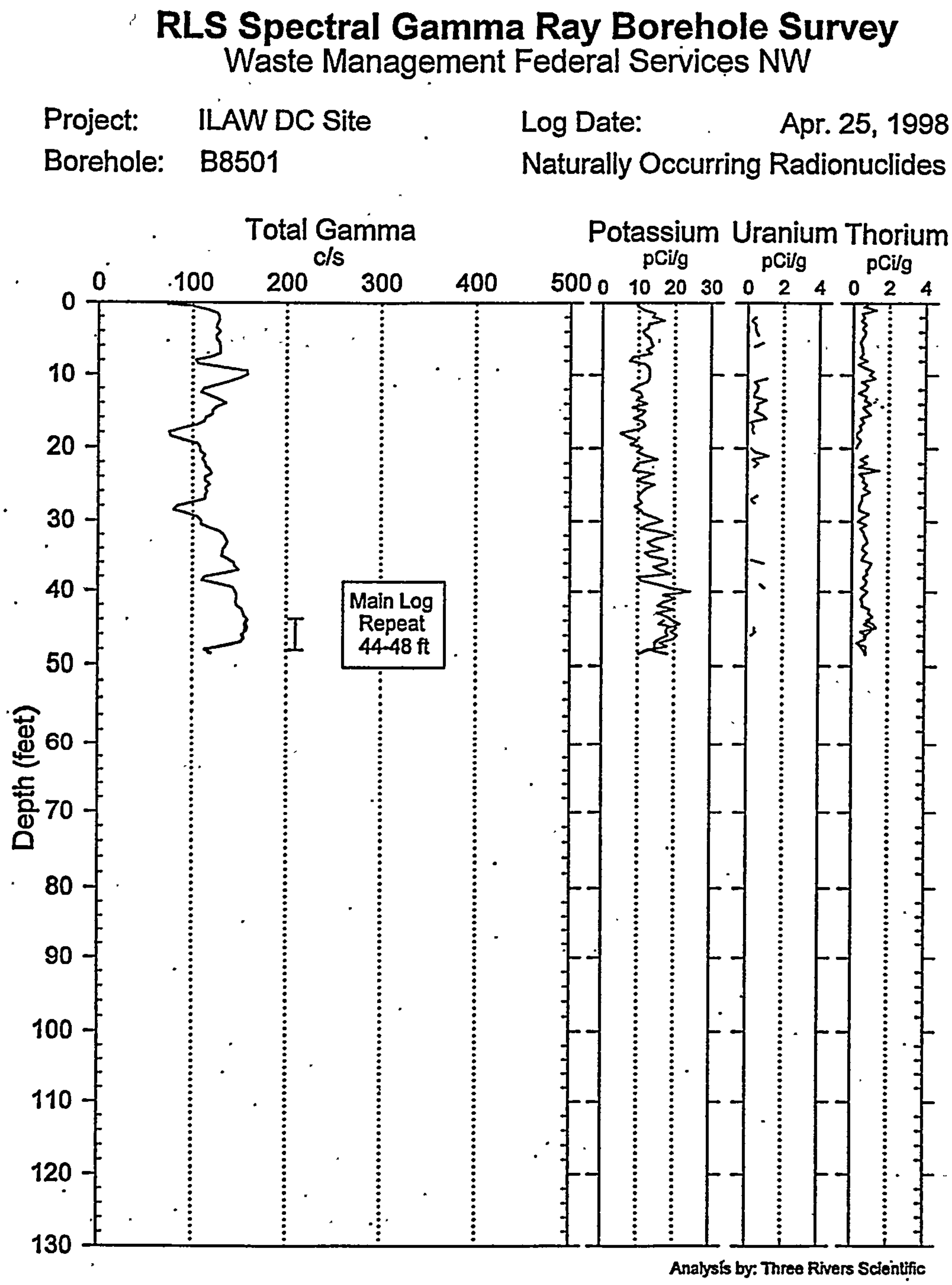


Figure D.3. (contd)

RLS Spectral Gamma Ray Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC Site (200 East)	Well ID:	B8501
Log Type:	HPGe Spectral Gamma Ray	Log Dates:	Apr. 25, 1998

General Notes:

Total gamma is, in general, a response of formation lithology, except at 10 feet intervals, where increased steel thickness at drill string coupling added to attenuation of gamma rays.

The uranium and thorium concentrations are near the detection threshold for the logging conditions. The apparent sharp increase in thorium at 23 feet is most likely statistical in nature and not representative of formation conditions.

System Performance Verification: The pre- and post-log verification was performed using coleman #2 mantle. The maximum FWHM for the 583 keV gamma ray photo peak for the survey date was 2.41 keV. The maximum acceptable FWHM resolution is 3.10 keV for probe RLSG3.1 on the log date.

Repeat Interval: The repeat interval, 44 to 48 feet, agrees with the main log within acceptable limits (refer to the Acceptance QA Processing plot).

Environmental Corrections: The KUT concentrations have been corrected for casing attenuation over the entire well, except for the increased thickness at the drill string couplings. No casing correction was applied to the total gamma due to Compton downscatter interference.

Radionuclides:

No man-made radionuclides were detected.

Analysis by: Three Rivers Scientific

Figure D.3. (contd)

RLS Moisture Borehole Survey
Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) Well: **B8501**

Log Type: Moisture

Borehole Information

Well ID	B8501	Water Depth	None ft	Total Depth	49.1' ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	2.5 ft		
Casing Diameter	8.0 in ID	Depth Interval	0 to 49.6 ft	Thickness	0.500 in
Casing Diameter	6.0 in ID	Depth Interval	0 to 49.6 ft	Thickness	0.125 in

Logging Information

Log Type	Moisture
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 24, 1998 B8501
Logging Engineers	J. Meisner
Instrument Series	RLSM3.1
Logging Unit	RLS2
Depth Interval	0 to 49 ft Prefix MS56
Instrument Calibration Date	Dec. 18, 1997
Calibration Report	WHC-SD-EN-TI-306, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Russ Randall
Date	May 7, 1998

Notes: The casing thickness correction was applied for all, except drill string couplings (every 10 feet) where the steel thickness is greater. The calibration for 8 inch borehole diameter has been applied, since no 9 inch calibration exists.

Figure D.4. RLS Moisture Borehole Survey for Borehole B8501

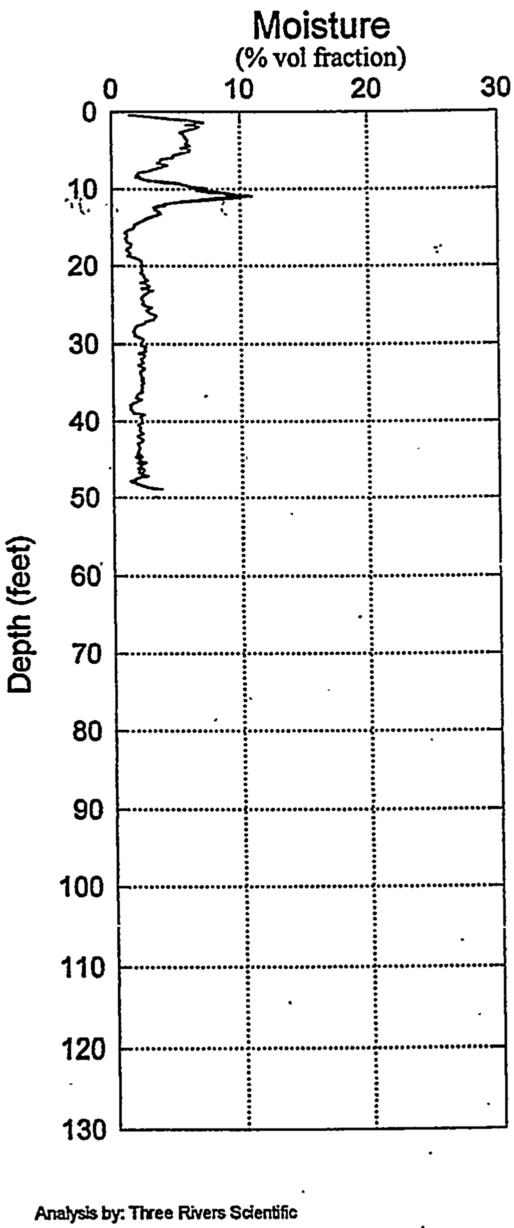
RLS Moisture Processed Log Data

Waste Management Federal Services NW

Project: ILAW DC

Borehole: B8501

Log Date Apr 24, 1998



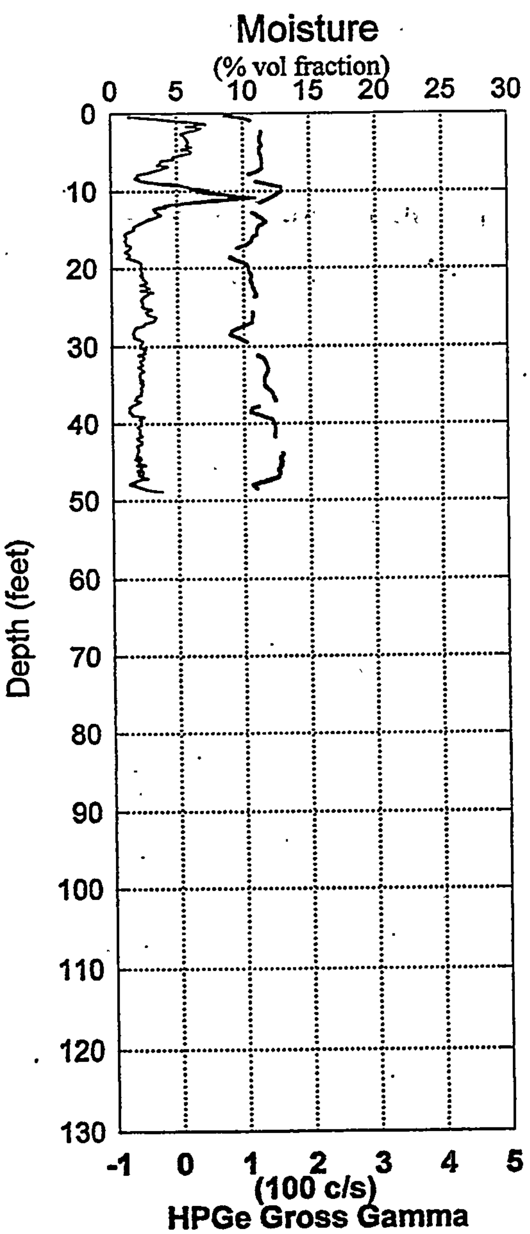


Figure D.4. (contd)

RLS Moisture Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC	Well ID:	B8501
Log Type:	Moisture	Log Dates:	Apr. 24, 1998

General Notes:

At these very low moisture values for the earth surround the borehole, other parameters such as void space and formation density affect the instrument readings more than moisture.

There does appear a small correlation between gross gamma ray (i.e. lithology) and the moisture (excluding collar response) in the change at 11 feet. Likewise, another change is noted at 28 feet in both the average moisture and the gross gamma ray.

System Performance Verification: The pre- and post-log verification was performed using instrument carrier. The pre-log reading is 3.1% lower than the post-log reading, well within tolerance.

Repeat Interval: The repeat intervals, 8 to 14 feet and 44 to 49 feet, agree with the main log within acceptable limits (refer to the Acceptance QA Processing plot).

Environmental Corrections: The casing thickness (other than over the collar intervals), correction has been applied. A density correction was not applied. The extra casing thickness at each collar is not corrected and is visible every 10 feet.

The borehole diameter is a nominal 9 inch value and there is no calibration for this diameter. However, at these low moisture values, an extrapolation would not yield any significant change.

Analysis by: Three Rivers Scientific

Figure D.4. (contd)

RLS Spectral Gamma Ray Borehole Survey

Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) — Well: **B8502**

Log Type: HPGe Spectral Gamma Ray

Borehole Information

Well ID	A8502	Water Depth	None ft	Total Depth	48.2 ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	2.5 ft		
Casing Diameter	8.0 in ID	Depth Interval	0 to 49.5 ft	Thickness	0.500 in
Casing Diameter	6.0 in ID	Depth Interval	0 to 49.5 ft	Thickness	0.125 in

Logging Information

Log Type	HPGe Spectral Gamma Ray
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 27, 1998 B8502
Logging Engineers	J. Meisner
Instrument Series	RLSG3.1
Logging Unit	RLS2
Depth Interval	0 to 48.2 ft Prefix B206
Instrument Calibration Date	Sep. 9, 1997
Calibration Report	WHC-SD-EN-TI-292, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Russ Randall
Date	May 7, 1998

Notes No man-made radionuclides were detected. The casing thickness correction was applied for all, except drill string couplings (every 10 feet) where the steel thickness is greater.

Figure D.5. RLS Spectral Gamma Ray Borehole Survey for Borehole B8502

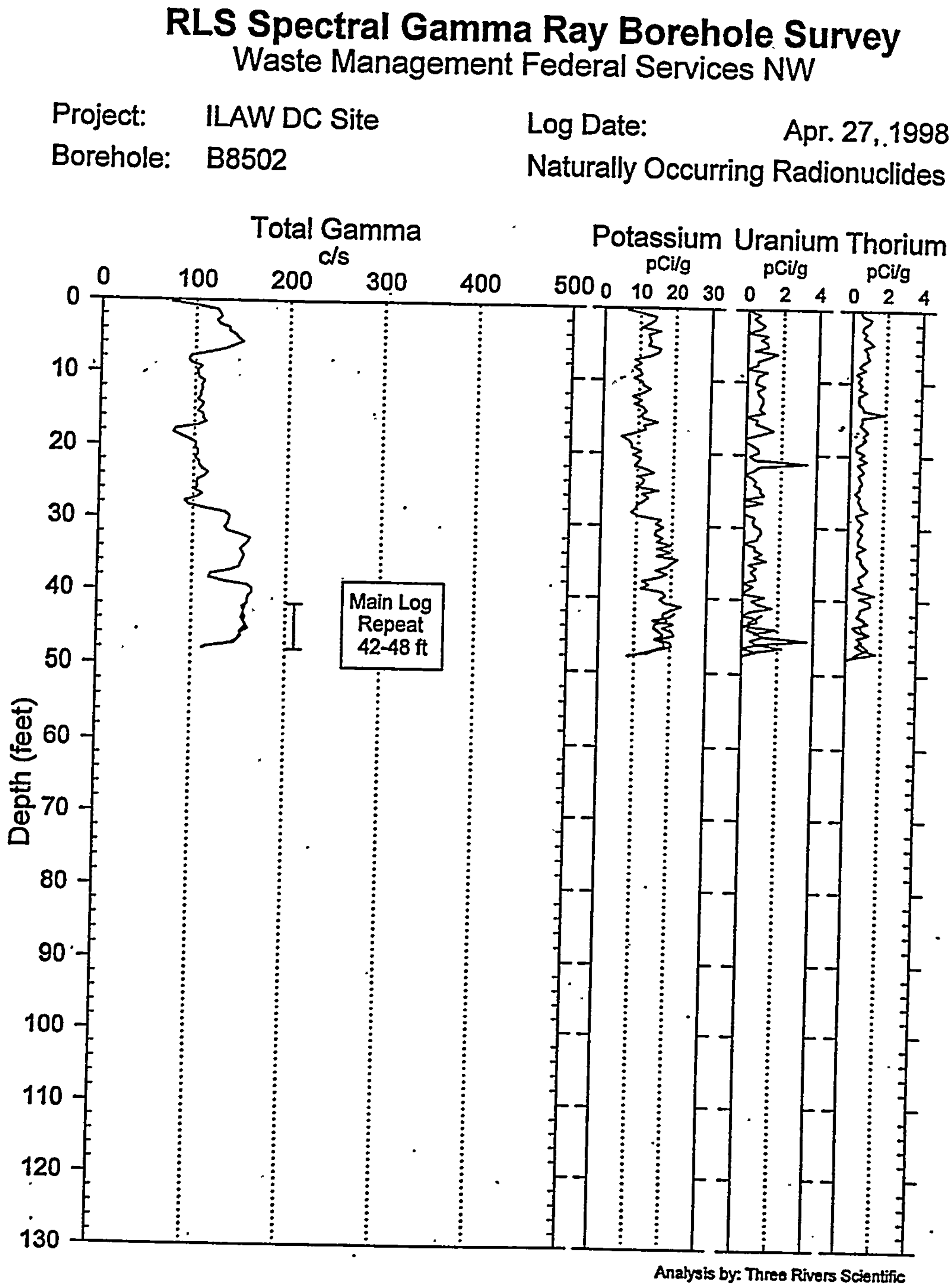


Figure D.5. (contd)

RLS Spectral Gamma Ray Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC Site (200 East)	Well ID:	B8502
Log Type:	HPGe Spectral Gamma Ray	Log Dates:	Apr. 27, 1998

General Notes:

Total gamma is, in general, a response of formation lithology, except at 10 feet intervals, where increased steel thickness at drill string coupling added to attenuation of gamma rays..

The uranium and thorium concentrations are near the detection threshold for the logging conditions. The apparent sharp increase in thorium at 14 feet and in uranium at 21 feet are most likely statistical in nature and not representative of true concentrations.

System Performance Verification: The pre- and post-log verification was performed using coleman #2 mantle. The maximum FWHM for the 583 keV gamma ray photo peak for the survey date was 2.02 keV. The maximum acceptable FWHM resolution is 3.10 keV for probe RLSG3.1 on the log date.

Repeat Interval: The repeat interval, 42 to 48 feet, agrees with the main log within acceptable limits (refer to the Acceptance QA Processing plot).

Environmental Corrections: The KUT concentrations have been corrected for casing attenuation over the entire well, except for the increased thickness at the drill string couplings. No casing correction was applied to the total gamma due to Compton downscatter interference.

Radionuclides:

No man-made radionuclides were detected.

Analysis by: Three Rivers Scientific

Figure D.5. (contd)

RLS Moisture Borehole Survey

Waste Management Federal Services NW

Log Header

Project: ILAW DC Site (200 East) **Well: B8502**

Log Type: Moisture

Borehole Information

Well ID	B8502	Water Depth	None ft	Total Depth	48.2 ft
Elevation Reference	No Data	Elevation	None ft		
Depth Reference	Ground Level	Casing Stickup	2.5 ft		
Casing Diameter	8.0 in ID	Depth Interval	0 to 49.5 ft	Thickness	0.500 in
Casing Diameter	6.0 in ID	Depth Interval	0 to 49.5 ft	Thickness	0.125 in

Logging Information

Log Type	Moisture
Company	Waste Management Federal Services NW
Date/Archive File Name	Apr. 27, 1998 B8502
Logging Engineers	J. Meisner
Instrument Series	RLSM3.1
Logging Unit	RLS2
Depth Interval	0 to 48.2 ft Prefix MS57
Instrument Calibration Date	Dec. 18, 1997
Calibration Report	WHC-SD-EN-TI-306, Rev. 0

Analysis Information

Company	Three Rivers Scientific
Analyst	Russ Randall
Date	May 5, 1998

Notes: The casing thickness correction was applied for all, except drill string couplings (every 10 feet) where the steel thickness is greater. The calibration for 8 inch borehole diameter has been applied, since no 9 inch calibration exists.

Figure D.6. RLS Moisture Borehole Survey for Borehole B8502

RLS Moisture Processed Log Data

Waste Management Federal Services NW

Project: ILAW DC

Borehole: B8502 Log Date Apr 27, 1998

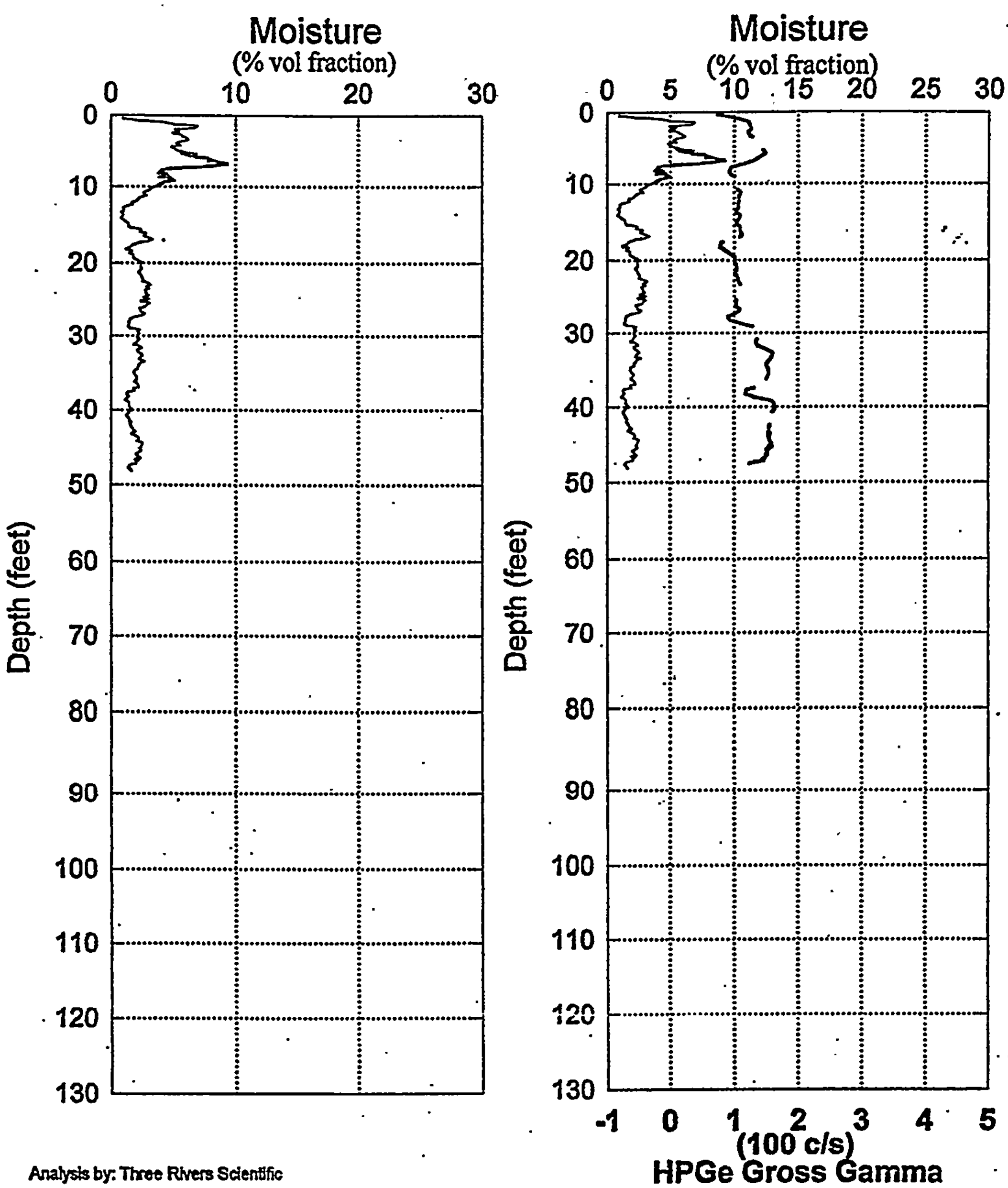


Figure D.6. (contd)

RLS Moisture Borehole Survey

Waste Management Federal Services NW

Log Analysis Summary Report

Project:	ILAW DC	Well ID:	B8502
Log Type:	Moisture	Log Dates:	Apr. 27, 1998

General Notes:

At these very low moisture values for the earth surround the borehole, other parameters such as void space and formation density affect the instrument readings more than moisture.

There does appear a small correlation between gross gamma ray (i.e. lithology) and the moisture (excluding collar response) in the change at 8 feet. Likewise, another change is noted at 29 feet in both the average moisture and the gross gamma ray.

System Performance Verification: The pre- and post-log verification was performed using instrument carrier. The pre-log reading is 0.1% higher than the post-log reading, well within tolerance.

Repeat Interval: The repeat interval, 5 to 9 feet, agrees with the main log within acceptable limits (refer to the Acceptance QA Processing plot).

Environmental Corrections: The casing thickness (other than over the collar intervals), correction has been applied. A density correction was not applied. The extra casing thickness at each collar is not corrected and is visible every 10 feet.

The borehole diameter is a nominal 9 inch value and there is no calibration for this diameter. However, at these low moisture values, an extrapolation would not yield any significant change.

Analysis by: Three Rivers Scientific

Figure D.6. (contd)