DOE/NV11432-170
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**SITE CHARACTERIZATION DATA
FROM THE
AREA 5 SCIENCE BOREHOLES**

**NEVADA TEST SITE
NYE COUNTY, NEVADA**

BY

**DANIEL O. BLOUT, DALE P. HAMMERMEISTER, KIM A. ZUKOSKY
REYNOLDS ELECTRICAL & ENGINEERING CO., INC.**

**KENNETH D. DONNELSON
RAYTHEON SERVICES NEVADA**

FEBRUARY 1995

**PREPARED BY
REYNOLDS ELECTRICAL & ENGINEERING CO., INC.
POST OFFICE BOX 98521
LAS VEGAS, NV 89193-8521**

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**WORK PERFORMED UNDER
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LIST OF ACRONYMS

AP	Air Permeability Borehole
CAU	Casing-advance underreaming
CFR	Code of Federal Regulations
DBS&A	Daniel B. Stephens & Associates, Inc.
DOE/NV	Department of Energy, Nevada Operations Office
DRI	Desert Research Institute
ER&TDD	Environmental Restoration & Technology Development Department
GCD	Greater Confinement Disposal
HGC	Hydro Geo Chem, Inc.
ID	Inner diameter (pipe)
LDR	Land Disposal Restricted
LLW	Low-level waste
MW	Mixed waste
MWL	Meteoric Water Line
N	Neutron-access Borehole
NTS	Nevada Test Site
OD	Outer diameter (pipe)
PVC	Polyvinyl Chloride
QA	Quality Assurance
RCRA	Resource Conservation and Recovery Act
REEC _o	Reynolds Electrical & Engineering Co., Inc.
RP	Radon Pumping Borehole
RWMS	Radioactive Waste Management Site
SMOW	Standard Mean Ocean Water
SOP	Standard Operating Procedure
SPS	Special Projects Section
USCS	Unified Soil Classification System

EXECUTIVE SUMMARY

The Science Borehole Project consists of eight boreholes that were drilled (from 45.7 m [150 ft] to 83.8 m [275 ft] depth) in Area 5 of the Nevada Test Site, Nye County, Nevada, on behalf of the U.S. Department of Energy. These boreholes are part of the Area 5 Site Characterization Program developed to meet data needs associated with regulatory requirements applicable to the disposal of low-level and mixed waste at this site. This series of boreholes was specifically designed to characterize parameters controlling near-surface gas transport and to monitor changes in these and liquid flow-related parameters over time. These boreholes are located along the four sides of the approximately 2.6-km² (1-mi²) Area 5 Radioactive Waste Management Site to provide reasonable spatial coverage for sampling and characterization.

Laboratory testing results of samples taken from core and drill cuttings indicate that the material and hydrologic properties of the alluvial deposits are very similar within and between boreholes. The alluvial deposits have a remarkably similar lithologic composition and are virtually free of layers of secondary carbonate; they are primarily coarse-grained sands and gravels with generally less than 10 percent fines; and they have porosities, saturated hydraulic conductivities, moisture-retention relations, and unsaturated hydraulic conductivities that are typical of coarse-grained material.

Additional tests on the same samples of core and drill cuttings indicate that hydrologic conditions within these alluvial deposits are also similar between Science Boreholes. Both samples of core and drill cuttings are dry (less than 10 percent water content by weight), and water content increases slightly with depth. Water potential measurements on core samples show a large, positive potential gradient (water tends to move upward rather than downward) to a depth of approximately 30.5 m (100 ft) in each borehole and a nearly zero water potential gradient throughout the remaining portion of each borehole.

These hydrologic conditions and hydrologic property data indicate that little net downward liquid flow is occurring, if any, in this portion of the vadose zone. However, gas flow by diffusion, and possibly by advection, may be important transport mechanisms.

Environmental tracer measurements made on water extracted from core samples support the conclusion that little, if any, liquid water movement is occurring in the vadose zone. These measurements included chloride and bromide, and the stable isotopes of hydrogen and oxygen. More specifically, these data strongly suggest that water vapor in the upper portion of the vadose zone is moving upward in response to evaporative demand of the present arid climate.

Finally, four of the boreholes were instrumented and stemmed to facilitate monitoring important pneumatic parameters which control the advective and diffusive flow of subsurface gases. The remaining four boreholes were completed as neutron-moisture logging access boreholes to permit the monitoring of changes in subsurface moisture content.

1.0 INTRODUCTION

The Environmental Restoration & Technology Development Department (ER&TDD), Special Projects Section (SPS) of Reynolds Electrical & Engineering Co., Inc. (REECo) is responsible for characterizing the subsurface geology and hydrology of the Area 5 Radioactive Waste Management Site (RWMS) at the Nevada Test Site (NTS) for the U.S. Department of Energy, Nevada Operations Office (DOE/NV), Waste Management Division. The eight boreholes described in this report are an integral part of the Area 5 Site Characterization Program which is designed to determine the suitability of the Area 5 RWMS for disposal of low-level waste (LLW) and mixed waste (MW).

1.1 Purpose and Justification

This project is the third phase of the Area 5 RWMS drilling program designed to construct boreholes for site characterization, in situ testing, and monitoring. Prior to drilling, lateral transects in existing excavations were sampled and tested to investigate the horizontal variability of alluvial materials (REECo 1993a). The first drilling project consisted of drilling and sampling 10 shallow, intermediate-depth Science Trench Boreholes to a maximum depth of 38.1 m (125 ft) at a single location outside the southeast corner of the Area 5 RWMS (REECo 1993b). Following this project, three deeper Pilot Wells were drilled and sampled in the vicinity of the Area 5 RWMS (REECo 1994). These Pilot Wells were drilled through the vadose zone (which has a thickness greater than 235 m [770 ft]) and approximately 21.3 m (70 ft) into the saturated zone. The laboratory results for core samples from previous studies indicate a data gap between 38.1 m (125 ft) and 83.8 m (275 ft). The Science Boreholes were designed to investigate this intermediate interval in the vadose zone around the perimeter of the Area 5 RWMS and to characterize and monitor parameters affecting the flow and transport of gases throughout the upper portion of the vadose zone. In order to support site characterization, all of the Science Boreholes have been sited to expand spatial coverage of hydrogeologic parameters.

Three types of Science Boreholes were constructed:

- Air Permeability (AP) boreholes (AP-1, AP-2) are located on the east side of the Area 5 RWMS and were designed for pneumatic testing. The boreholes are approximately 83.8 m (275 ft) deep, approximately 5 m (15 ft) apart, and are located at least 61 m (200 ft) from other boreholes.
- Radon Pumping (RP) boreholes (RP-1, RP-2) are located on the south side of the Area 5 RWMS; one borehole was designed for radon gas sampling and the other borehole for temperature and pressure monitoring. The boreholes are approximately 45.7 m (150 ft) deep and approximately 70.1 m (230 ft) apart.
- Neutron-access (N) boreholes (NN-1, NE-1, NW-1, NS-1) are located on all four sides of the Area 5 RWMS, are approximately 61 m (200 ft) deep, and will be used to monitor subsurface moisture conditions with a neutron-moisture meter.

1.2 Scope of Report

This report describes drilling and coring, instrumentation and stemming, and laboratory testing. Qualitative analyses and preliminary interpretations of the data will be offered in this report. Detailed analyses and/or interpretations of the data will be presented in separate reports that are being developed for submittal to peer-reviewed professional journals. This particular report is designed to be a complete and detailed repository of methods and data which can be referenced by interpretative peer-reviewed professional journal publications. The data in the body of this document are reported in SI units, unless otherwise stated; the data in the Appendices have not been converted to this format.

1.3 Overview of Activities

The Science Boreholes were drilled and cored from the ground surface to depths specified in the design of each type of borehole. The drilling was accomplished using a casing-advance underreaming (CAU) system employing air as the drilling fluid to minimize disturbance of the in situ hydraulic conditions (water content and water potential) of the formation and the drill cuttings. Core samples were collected in the alluvium by driving a solid tube (containing segmented Lexan [polycarbonate] liners) into the formation, ahead of the casing, with an air-percussion hammer.

Drill cuttings were collected at 0.76-m (2.5-ft) intervals and cores were taken at selected intervals. The lithology of the cores and drill cuttings were quickly examined and described in the field before samples were packaged to maintain their physical integrity and to minimize water loss by evaporation. Samples were then shipped to various testing laboratories or stored for future use. Laboratory tests were conducted on both drill cuttings and core samples to quantify the distribution with depth of material and hydrologic and environmental tracer parameters. These laboratory data will provide estimates of input parameters required to model liquid and vapor flow in the vadose zone. Finally, both environmental tracer and unsaturated hydrologic parameters will be used to calculate liquid flux under a number of simplifying assumptions.

Upon completion of drilling these boreholes, vadose zone instruments and/or access tubing were installed and stemmed in place. In situ tests will be conducted in the completed AP boreholes to characterize air permeabilities. In addition, monitoring the vadose zone with instruments (including temperature and air pressure transducers) was initiated in the RP boreholes. Finally, the CAU drive casing was left in place in the N boreholes to facilitate neutron-moisture logging. A program will be initiated in which neutron-moisture logging will be conducted quarterly.

1.4 Objectives

The objectives of the Science Borehole Project can be divided into three categories:

1. Conduct drilling, sampling, and laboratory testing for expanded, spatial coverage of site characterization parameters.
 - To collect samples of core and drill cuttings to characterize lithologic, material, hydrologic, and pneumatic properties of the alluvium.
 - To measure environmental tracer concentrations and hydraulic parameters in geologic samples to estimate recharge.
2. Provide boreholes (AP) for in situ testing of bulk air permeability.
 - When in situ testing is completed, these boreholes may be used for monitoring moisture content.
3. Provide boreholes (RP and N) for baseline monitoring.
 - To measure background gas generation and transport, specifically radon, by collecting subsurface gas samples over time in the RP borehole.
 - To measure barometric and temperature changes in the alluvium over time in the RP boreholes and evaluate the importance of barometric pumping in gas-phase contaminant transport.
 - To monitor subsurface moisture conditions over time in the N boreholes.

A number of federal regulations and DOE Orders provide additional justification for the site characterization and baseline monitoring data collection activities. These regulations include specific Resource Conservation and Recovery Act (RCRA) requirements for the land disposal of hazardous waste; requirements for obtaining waivers relating to the land disposal of hazardous waste; DOE Order 5820.2A, "Radioactive Waste Management"; and 40 Code of Federal Regulations (CFR) 191 requirements for land disposal of radioactive waste. Regulatory requirements for characterization and baseline monitoring for the different waste types that DOE/NV is currently, or may in the future consider for disposal at the Area 5 RWMS are summarized in Table 1.1.

1.5 Site Description

The NTS is a DOE facility occupying approximately 3,500 km² (1,350 mi²) in southern Nevada, approximately 105 km (65 mi) northwest of Las Vegas (Figure 1.1). The site is

Table 1.1 Regulatory drivers for site characterization and monitoring.

Requirement	Waste and Facility Category			
	Low-Level Waste	Mixed Waste (new cells)	Mixed Waste (existing cells)	LDR Mixed Waste (no treatment available)
DOE Order 5820.2A				
Performance assessment	Characterization and Monitoring	Characterization and Monitoring	Characterization and Monitoring	Characterization and Monitoring
RCRA (Part B Permit)				
Releases from solid waste management unit (40 CFR 264.90-101) ¹	N/A	Monitoring	N/A	N/A
Groundwater monitoring waiver (40 CFR 264.90(b)(2)) ¹	N/A	N/A	Characterization	N/A
No migration variance (40 CFR 268.6(a)) ²	N/A	N/A	N/A	Characterization and Monitoring
Exemption for liner and LCRS/LDCRS ³ (40 CFR 264.301 (b,d)) ¹	N/A	Characterization	N/A	N/A
Proposed 40 CFR 193 ⁴				
Groundwater protection	Characterization and Monitoring	N/A	N/A	N/A

¹ 40 CFR 264—Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities² 40 CFR 268—Land Disposal Restrictions³ LCRS/LDCRS: Leachate Collection and Removal System/Leachate Detection, Collection, and Removal System⁴ 40 CFR 193—Environmental Standards for the Management, Storage, and Land Disposal of Low-Level Radioactive Waste and Naturally-Occurring and Accelerator-Produced Waste

Figure 1.1 Location of the Area 5 RWMS.

bordered to the north, west, and east by the Nellis Air Force Range, a government-owned, restricted access area. Activities at the NTS include a variety of nuclear and non-nuclear projects and experiments.

The Area 5 RWMS encompasses 3 km² (741 acres) north of Frenchman Flat and is located near the junction of three alluvial fans within the Frenchman Lake drainage basin (Dozier and Rawlinson 1991). The Low-level Waste Management Unit is a 0.39-km² (96-acre) facility located in the southeast section of the Area 5 RWMS. It was established in 1978 for disposing of LLW generated at the NTS and other DOE facilities.

The Area 5 RWMS currently accepts low-level radioactive waste for shallow land burial. In the past, MWs have been accepted for shallow land burial, and high-specific-activity waste has been disposed of in 36.6-m-(120-ft-) deep augured shafts known as the Greater Confinement Disposal (GCD) shafts. Most wastes are disposed of in steel drums, steel boxes, or wooden boxes. DOE/NV currently accepts low-level radioactive waste and has accepted low-level MW containing hazardous constituents that are not land disposal restricted (LDR). Plans are being made to resume acceptance of low-level MW in the near future.

1.6 Science Borehole Locations

The Science Boreholes are located outside historic, current, and future waste disposal areas and are shown in Figure 1.2 (including the Categorical Exclusion areas). The drilling and location data are given in Table 1.2. The Science Boreholes are located on all four sides of the Area 5 RWMS. The ground surface of the east and south sites had previously been disturbed at the surface by heavy equipment, while the north and west sites were previously undisturbed. It was necessary to disturb the ground surface at the west and north sites to construct drill pads. These sites were selected to provide a spatial distribution of hydrogeologic parameters as close as possible to the RWMS, and yet not interfere with future cap closures.

1.7 Site Climate and Meteorology

The climate and meteorology of the region is typical of the upper Mojave Desert province. Two major air movement patterns affect this area: from fall through spring, the effects of the Pacific high-pressure area moving over the Sierra Nevada Range are dominant; and in summer, this high-pressure area dissipates and a warm moist air mass from the Gulf of Mexico exerts its influence. Average daily temperatures range from 2°C (36°F) in January to 24°C (75°F) in August. Precipitation is highly variable in the desert. The summer months are characterized by intense, isolated thunderstorms, while the winter storms are of lesser intensity and longer in duration. The average precipitation is approximately 100 mm (4 in) per year, and the estimated potential evapotranspiration rate is 2,200 mm (87 in) per year (EG&G 1992).

Figure 1.2 Location of the Science Boreholes. Note: Tic spacing is 610 m (2,000 ft).

Table 1.2 Drilling and location data for the Science Boreholes.

Borehole	Drilling Dates		Total Depth m (ft)	Elevation Above Sea Level m (ft)	Nevada State Central Zone Coordinates	
	Start	End			North m (ft)	East m (ft)
AP-1	8-31-93	9-15-93	83.8 (275)	975.2 (3,199.49)	233,911.3 (767,416.06)	216,246.5 (709,461.52)
AP-2	9-15-93	9-28-93	83.8 (275)	975.1 (3,199.25)	233,906.7 (767,401.01)	216,246.5 (709,461.59)
RP-1	10-1-93	10-11-93	45.7 (150)	966.6 (3,169.27)	233,415.7 (765,839.36)	215,829.7 (708,221.73)
RP-2	10-11-93	10-18-93	45.7 (150)	965.9 (3,169.07)	233,430.7 (765,839.57)	215,798.3 (707,094.05)
NN-1	10-27-93	11-3-93	61.0 (200)	976.9 (3,204.88)	234,173.0 (768,274.83)	215,943.4 (708,467.05)
NE-1	9-29-93	10-1-93	61.0 (200)	974.3 (3,196.62)	233,854.3 (767,229.06)	216,237.0 (709,430.37)
NW-1	10-22-93	10-26-93	61.0 (200)	968.6 (3,177.67)	233,691.7 (766,695.75)	215,487.4 (706,971.11)
NS-1	10-18-93	10-21-93	61.0 (200)	966.6 (3,171.16)	233,415.7 (765,790.28)	215,829.7 (708,094.05)

2.0 DRILLING, SAMPLING, AND COMPLETION

This section provides a brief overview of the drilling procedures used and the data obtained, the collection and description of alluvial deposit samples, and the installation and stemming of vadose zone instruments. The methods used to accomplish these activities have been described in detail previously (REECo 1993b; REECo 1994) and/or in the ER&TDD SPS Quality Assurance (QA) Standard Operating Procedures (SOPs) listed in Table 2.1. A brief summary of these methods will be given in the following sections. Information pertaining to those methods and approaches which differ from previous projects (REECo 1993b; REECo 1994) will be emphasized.

2.1 Drilling and Casing

The Science Boreholes were drilled by the Boyles Bros. Company with a Schramm T685H/DHH rig using a Mission SD-4 hammer, CAU drilling system. Air was the only drilling fluid used. The diameter of the borehole was approximately 187.32 mm (7.375 in). The casing was carbon steel Christensen Drive-Ex® System 140.

The drilling start and end dates and total depth are summarized in Table 1.2. Detailed chronological drilling summaries of each borehole are presented in Appendices A.1 to A.8.

2.2 Sampling

Geologic samples (core and drill cuttings) were collected, described, and handled as described in previous reports (REECo 1993b; REECo 1994). These previous studies indicate that the alluvial material around the Area 5 RWMS is lithologically and hydrologically homogeneous. Based on this, fewer geologic samples were collected during this project. Sample collection and handling procedures were designed to minimize the loss of water by evaporation and disturbance of the physical integrity of the core samples. The SOP for the collecting and handling of samples is listed in Table 2.1.

2.2.1 Collecting Samples

Core samples were collected from the alluvium at selected intervals (Tables 2.2 to 2.6) employing drive core sampling methods. An air-percussion hammer was used to drive a 0.76-m (2.5-ft) long by 114.3-mm (4.5-in) outer diameter (pipe) (OD) solid-tube core barrel, containing clear Lexan liner segments (76.2-mm [3.0-in] long by 88.9-mm [3.5-in] OD), to contain the sample material. Past experience demonstrated that the drive core method provided good core recovery and minimized the disturbance of hydrologic conditions and physical properties of relatively dry, coarse-grained, unconsolidated alluvial samples (Hammermeister et. al. 1986). The possible effects of the coring process on the values of parameters that are sensitive to pore size distribution have been discussed previously (REECo 1994). In all cases, the core barrel was transported to a temperature-controlled field

Table 2.1 SOPs applicable to the Science Borehole Project.

Title	Procedure Number	Date	Rev.
Quality Assurance Program Plan for Site Characterization and Monitoring Tasks (Draft)	ER&TDD-SP.01.28	02/16/94	0
Handling and Transport of Characterization Samples (Draft)	ER&TDD-SP.01.04	02/16/94	0
Geologic Logging of Alluvium (Draft)	ER&TDD-SP.01.23	02/16/94	0
Gravimetric Moisture Content Determination (Draft)	ER&TDD-SP.01.05	02/16/94	0
Stemming Well Screen, Casing, and Instruments (Draft)	ER&TDD-SP.01.16	02/16/94	0
Handling In-Progress Data Records (Draft)	ER&TDD-SP.01.11	02/16/94	0
Borehole Abandonment (Draft)	ER&TDD-SP.01.24	02/16/94	0

Table 2.2 Core record for AP-1.

Date	Run No.	Interval		Core Recovery		Penetration Rate (min/m)	Laboratory Tests
		from (m)	to (m)	(m)	(percent)		
08/31/93	1	0.00	0.76	0.76	100	1.67	A,B,C,D,E,ARCH
08/31/93	2	0.76	1.52	0.76	100	1.44	A,B,C,D,E,ARCH
08/31/93	3	1.52	3.05	1.14	75	1.48	A,B,C,D,E,ARCH
08/31/93	4	3.05	3.81	0.53	70	1.97	B,C,D,ARCH
08/31/93	5	3.81	4.57	0.53	70	1.31	B,C,D,ARCH
09/01/93	6	4.57	5.33	0.53	70	1.97	B,C,D,ARCH
09/01/93	7	5.33	6.10	0.69	90	1.74	A,B,C,D,E,ARCH
09/01/93	8	6.10	6.86	0.53	70	1.97	B,C,D,ARCH
09/01/93	9	6.86	7.62	0.61	80	1.57	A,B,C,D,E,ARCH
09/02/93	10	7.62	8.38	0.76	100	1.54	A,B,C,D,E,ARCH
09/02/93	11	8.38	9.14	0.69	90	1.41	B,C,D,ARCH
09/02/93	12	11.89	12.65	0.61	80	2.30	A,C,D,E,ARCH
09/02/93	13	14.94	15.70	0.69	90	5.58	A,B,C,D,E,ARCH
09/03/93	14	17.98	18.75	0.61	80	3.28	A,B,C,D,E,ARCH
09/03/93	15	21.03	21.79	0.61	80	8.99	A,B,C,E,ARCH
09/03/93	16	24.08	24.84	0.76	100	3.81	A,B,C,D,E,ARCH
09/07/93	17	30.02	30.79	0.76	100	1.97	A,B,C,D,E,ARCH
09/08/93	18	33.22	33.99	0.76	100	4.86	A,B,C,D,E,ARCH
09/09/93	19	36.27	37.03	0.30	40	7.35	B,D,ARCH
09/09/93	20	39.32	40.08	0.69	90	7.55	A,B,C,D,E,ARCH
09/09/93	21	42.37	42.67	0.30	100	53.81	B,D,ARCH
09/09/93	22	45.42	46.18	0.69	90	4.53	A,B,C,D,ARCH
09/10/93	23	48.46	49.23	0.76	100	12.60	A,B,C,D,E,ARCH
09/13/93	24	54.56	55.32	0.61	80	11.81	A,B,C,D,E,ARCH
09/13/93	25	60.66	61.37	0.76	107	12.11	A,B,C,D,E,ARCH
09/14/93	26	66.75	67.51	0.76	100	9.32	A,B,C,D,E,ARCH
09/14/93	27	72.85	73.61	0.76	100	7.61	A,B,C,D,E,ARCH
09/15/93	28	78.94	79.63	0.69	100	6.69	A,B,C,D,E,ARCH
09/15/93	29	83.82	84.58	0.61	80	6.56	C,D,ARCH

A: Physical and hydraulic properties (DB1)

B: Water content, bulk density, chloride, bromide, carbon (DB3)

C: Water potential, water content, bulk density (DRI2)

D: Stable isotopes (DRI1)

E: Air permeability (MS1)

ARCH: Archived samples

Table 2.3 Core record for AP-2.

Date	Run No.	Interval		Core Recovery		Penetration Rate (min/m)	Laboratory Tests
		from (m)	to (m)	(m)	(percent)		
09/17/93	1	0.00	0.76	0.76	100	1.57	A,B,C,D,E,ARCH
09/17/93	2	0.76	1.52	0.76	100	1.57	A,B,C,D,E,ARCH
09/17/93	3	1.52	2.29	0.53	70	1.18	B,C,D,E,ARCH
09/17/93	4	2.29	3.05	0.53	70	1.05	A,B,C,D,E,ARCH
09/17/93	5	3.05	3.81	0.38	50	1.31	B,C,ARCH
09/20/93	6	3.81	4.57	0.61	80	1.71	B,C,D,E,ARCH
09/20/93	7	4.57	5.33	0.53	70	2.62	A,B,C,E,ARCH
09/20/93	8	5.33	6.10	0.69	90	2.23	A,B,C,D,E,ARCH
09/20/93	9	6.10	6.86	0.61	80	1.84	A,B,C,D,E,ARCH
09/20/93	10	6.86	7.62	0.69	90	1.97	A,B,C,D,E,ARCH
09/20/93	11	7.62	8.38	0.69	90	2.89	A,B,C,D,E,ARCH
09/20/93	12	8.38	9.14	0.69	90	1.31	A,B,C,D,E,ARCH
09/20/93	13	11.89	12.65	0.61	80	3.54	A,B,C,D,E,ARCH
09/20/93	14	14.94	15.70	0.69	90	3.15	A,B,C,D,E,ARCH
09/21/93	15	17.98	18.75	0.69	90	3.81	A,B,C,D,E,ARCH
09/21/93	16	21.03	21.79	0.69	90	5.25	B,C,D,ARCH
09/21/93	17	24.08	24.84	0.69	90	4.72	A,B,C,D,E,ARCH
09/21/93	18	27.13	27.89	0.69	90	4.46	A,B,C,D,E,ARCH
09/21/93	19	30.18	30.94	0.38	50	5.38	B,E,ARCH
09/22/93	20	33.22	33.99	0.76	100	7.22	A,B,C,D,E,ARCH
09/22/93	21	36.27	37.03	0.53	70	6.82	A,B,C,E,ARCH
09/22/93	22	39.32	40.01	0.69	100	9.06	A,B,C,D,E,ARCH
09/22/93	23	42.37	42.85	0.46	95	31.13	A,B,E,ARCH
09/23/93	24	45.42	46.18	0.76	100	13.12	A,B,C,D,E,ARCH
09/23/93	25	48.46	49.23	0.76	100	10.50	A,B,C,D,E,ARCH
09/24/93	26	54.56	55.32	0.76	100	7.87	A,B,C,D,E,ARCH
09/27/93	27	60.66	61.11	0.46	100	39.37	A,B,C,E,ARCH
09/27/93	28	66.75	67.51	0.76	100	15.75	A,B,C,D,E,ARCH
09/27/93	29	72.85	73.61	0.76	100	21.52	A,B,C,D,E,ARCH
09/28/93	30	78.94	79.71	0.76	100	19.68	A,B,C,D,E,ARCH
09/28/93	31	83.82	84.58	0.76	100	18.37	A,B,C,D,E,ARCH

A: Physical and hydraulic properties (DB1)

B: Water content, bulk density, chloride, bromide, carbon (DB3)

C: Water potential, water content, bulk density (DRI2)

D: Stable isotopes (DRI1)

E: Air permeability (MS1)

ARCH: Archived samples

Table 2.4 Core record for RP-1.

Date	Run No.	Interval		Core Recovery		Penetration Rate (min/m)	Laboratory Tests
		from (m)	to (m)	(m)	(percent)		
10/04/93	1	0.00	0.76	0.69	90	2.23	A,B,C,D,E,ARCH
10/04/93	2	0.76	1.52	0.53	70	4.72	A,B,E,ARCH
10/04/93	3	1.52	2.29	0.53	70	2.10	A,C,D,E,ARCH
10/04/93	4	2.29	3.05	0.69	90	1.31	A,B,C,D,E,ARCH
10/04/93	5	3.05	3.81	0.46	60	3.28	B,C,D,ARCH
10/04/93	6	3.81	4.57	0.53	70	2.36	B,C,D,E,ARCH
10/04/93	7	4.57	5.33	0.53	70	1.97	B,C,D,E,ARCH
10/04/93	8	5.33	6.10	0.61	80	1.44	A,B,C,D,E,ARCH
10/05/93	9	6.10	6.86	0.69	90	2.76	A,B,C,D,E,ARCH
10/05/93	10	6.86	7.62	0.76	100	2.23	A,B,C,D,E,ARCH
10/05/93	11	7.62	8.38	0.76	100	2.76	A,B,C,D,E,ARCH
10/05/93	12	8.38	9.14	0.69	90	3.54	A,B,C,D,E,ARCH
10/05/93	13	9.14	9.91	0.38	50	2.49	A,B,C,ARCH
10/05/93	14	13.41	14.17	0.61	80	4.07	A,B,C,D,E,ARCH
10/05/93	15	14.94	15.70	0.69	90	6.04	A,B,C,D,E,ARCH
10/06/93	16	17.98	18.69	0.76	107	32.38	A,B,C,D,E,ARCH
10/06/93	17	21.03	21.79	0.69	90	4.99	A,B,C,D,E,ARCH
10/06/93	18	24.08	24.84	0.69	90	6.30	A,B,C,D,E,ARCH
10/06/93	19	27.13	27.89	0.69	90	11.02	A,B,C,D,E,ARCH
10/07/93	20	30.18	30.94	0.61	80	11.81	A,B,C,D,E,ARCH
10/07/93	21	33.22	33.99	0.46	60	12.99	B,E,ARCH
10/07/93	22	36.27	37.03	0.69	90	12.34	A,B,C,D,E,ARCH
10/07/93	23	39.32	40.08	0.46	60	20.34	A,B,E,ARCH
10/08/93	24	42.37	43.13	0.76	100	13.39	A,B,C,D,E,ARCH
10/08/93	25	45.72	46.48	0.69	90	11.42	A,B,C,D,E,ARCH

A: Physical and hydraulic properties (DB1)

B: Water content, bulk density, chloride, bromide, carbon (DB3)

C: Water potential, water content, bulk density (DRI2)

D: Stable isotopes (DRI1)

E: Radon emanation (DFE1)

ARCH: Archived samples

Table 2.5 Core record for RP-2.

Date	Run No.	Interval		Core Recovery		Penetration Rate (min/m)	Laboratory Tests
		from (m)	to (m)	(m)	(percent)		
10/11/93	1	0.00	0.76	0.53	70	1.31	B,C,D,E,ARCH
10/11/93	2	0.76	1.52	0.61	80	1.31	A,B,C,D,E,ARCH
10/11/93	3	1.52	2.29	0.61	80	1.44	A,B,C,D,E,ARCH
10/11/93	4	2.29	3.05	0.69	90	1.18	A,B,C,D,E,ARCH
10/11/93	5	3.05	3.81	0.69	90	1.84	A,B,C,D,E,ARCH
10/12/93	6	3.81	4.57	0.69	90	2.10	A,B,C,D,E,ARCH
10/12/93	7	4.57	5.33	0.46	60	3.54	A,B,C,E,ARCH
10/12/93	8	5.33	6.10	0.69	90	1.57	A,B,C,D,E,ARCH
10/12/93	9	6.10	6.86	0.30	40	1.57	B,E,ARCH
10/12/93	10	6.86	7.62	0.69	90	1.97	A,B,C,D,E,ARCH
10/12/93	11	7.62	8.38	0.69	90	2.10	A,B,C,D,E,ARCH
10/12/93	12	8.38	9.14	0.61	80	2.89	A,B,C,D,E,ARCH
10/13/93	13	9.14	9.91	0.69	90	11.81	A,B,C,D,E,ARCH
10/13/93	14	13.41	14.17	0.76	100	38.06	A,B,C,D,E,ARCH
10/13/93	15	14.94	15.70	0.69	90	4.99	A,B,C,D,E,ARCH
10/13/93	16	17.53	18.29	0.53	70	6.82	A,B,C,D,E,ARCH
10/13/93	17	18.29	19.05	0.69	90	5.51	A,B,C,D,E,ARCH
10/13/93	18	19.05	19.81	0.53	70	5.77	A,B,C,D,E,ARCH
10/14/93	19	21.03	21.79	0.61	80	11.02	A,B,C,D,E,ARCH
10/14/93	20	24.08	24.84	0.69	90	4.07	A,B,C,D,E,ARCH
10/14/93	21	27.13	27.89	0.61	80	6.56	A,B,C,D,E,ARCH
10/14/93	22	30.18	30.94	0.76	100	7.48	A,B,C,D,E,ARCH
10/15/93	23	33.22	33.76	0.46	86	39.17	A,B,C,E,ARCH
10/15/93	24	36.27	37.03	0.69	90	20.60	A,B,C,D,E,ARCH
10/15/93	25	39.32	40.08	0.69	90	6.43	A,B,C,D,E,ARCH
10/15/93	26	42.37	43.13	0.76	100	17.72	A,B,C,D,E,ARCH
10/15/93	27	45.72	46.48	0.38	50	8.27	A,B,C,D,ARCH

A: Physical and hydraulic properties (DB1)

B: Water content, bulk density, chloride, bromide, carbon (DB3)

C: Water potential, water content, bulk density (DRI2)

D: Stable isotopes (DRI1)

E: Radon emanation (DFE1)

ARCH: Archived samples

Table 2.6 Core record for NN-1, NE-1, NW-1, and NS-1.

Borehole	Date	Run No.	Interval		Core Recovery		Penetration Rate (min/m)	Laboratory Tests
			from (m)	to (m)	(m)	(percent)		
NN-1	10/28/93	1	5.79	6.55	0.61	80	2.62	A,B,C,D,E,ARCH
	10/28/93	2	11.89	12.65	0.61	80	1.84	A,B,C,D,E,ARCH
	11/02/93	3	30.18	30.94	0.53	70	3.15	A,B,C,D,E,ARCH
	11/03/93	4	54.56	55.32	0.76	100	10.89	A,B,C,D,E,ARCH
NE-1	09/29/93	1	5.79	6.55	0.69	90	3.02	ARCH
	09/29/93	2	11.89	12.65	0.61	80	4.72	ARCH
	09/30/93	3	30.18	30.94	0.76	100	6.69	ARCH
	09/30/93	4	54.56	55.27	0.76	107	25.20	ARCH
NW-1	10/25/93	1	5.79	6.55	0.53	70	7.87	A,B,C,D,E,ARCH
	10/25/93	2	11.89	12.65	0.76	100	6.17	A,B,C,D,E,ARCH
	10/25/93	3	30.18	30.94	0.69	90	9.58	A,B,C,D,E,ARCH
	10/26/93	4	54.56	55.32	0.69	90	7.22	A,B,C,D,E,ARCH
NS-1	10/19/93	1	5.79	6.55	0.76	100	2.36	ARCH
	10/19/93	2	11.89	12.65	0.69	90	12.47	ARCH
	10/20/93	3	30.18	30.94	0.76	100	7.22	ARCH
	10/20/93	4	54.56	55.27	0.53	75	46.98	ARCH

A: Physical and hydraulic properties (DB1)

B: Water content, bulk density, chloride, bromide, carbon (DB3)

C: Water potential, water content, bulk density (DRI2)

D: Stable isotopes (DRI1)

E: Water content, chloride, bromide (HGC)

ARCH: Archived samples

laboratory for geologic description and disposition as soon as possible after removal from the borehole.

As in previous studies, samples of drill cuttings were collected at 0.76-m (2.5-ft) depth intervals from the cyclone separator following sample collection procedures designed to minimize the loss of water by evaporation. Samples of drill cuttings were collected only during initial drilling of any particular interval and never during hole cleaning or related activities. Immediately after drilling each 0.76-m (2.5-ft) interval, a valve on the bottom of the cyclone separator was opened and, as drill cuttings spilled into a wheelbarrow, a representative sample was collected in a bucket. A riffle sample splitter was then used to subdivide the bucket sample into the required number of subsamples. These subsamples were placed in plastic bottles and moisture tins and were delivered to a temperature-controlled field laboratory without delay.

2.2.2 Geologic Description and Disposition of Samples

To ensure that the water content of each sample was representative of in situ formation conditions, both samples of core and drill cuttings were handled in the field laboratory and during subsequent storage and transport in such a manner as to minimize evaporative water loss. Details regarding these procedures may be determined by referencing the appropriate SOPs (Table 2.1).

The labeling system used in the field to assign core segments and samples of drill cuttings for different laboratory tests is summarized in Table 2.7. Each sample label identifies (1) the laboratory testing required, (2) the priority of the test(s), and (3) the laboratory responsible for conducting the analyses. These labels (e.g., DB3, MS1) will be used when referring to specific samples of core and/or drill cuttings in various tables, figures, and appendices.

Liner segments containing core samples were removed from the solid-tube drive core sampler by a pneumatic core extruder. A geologic description was then made on the core by examining the open ends of each segment. This geologic description was recorded on field data sheets (Appendix B).

Apparent magnetic susceptibility measurements were also made on both samples of core and drill cuttings. Changes in magnetic susceptibility may be related to changes in lithology, as well as other factors such as the rate of drill bit wear and the mixing of fine-metal particles into the drill cuttings. These measurements were made on the flat ends of core segments using a Model KT-5 Exploranium meter. Measurements on samples of core and drill cuttings should not be compared because of the different measurement conditions which include sample geometry, density, and type of container.

Table 2.7 Definitions of core and drill cuttings sample labels for the Science Boreholes.

Sample Type	Sample Label	Sample Priority ³	Laboratory Testing Specified	Testing Laboratory
Core	DB1	1	Saturated hydraulic conductivity Moisture-retention ¹ Water content Dry bulk density/porosity Particle size distribution Saturated porosity ¹ Particle density ¹	Daniel B. Stephens & Associates Inc. (DBS&A), Albuquerque, NM
	DB2	2	Replacement for damaged DB1 sample	DBS&A, Albuquerque, NM
	MS1	3 ^a	Air permeability	REECo Environmental Management Division (EMD)/ER&TDD/SPS
	DfE1	3 ^b	Radon emanation	REECo/EMD/ER&TDD/SPS
	DB3	4	Water content Dry bulk density/porosity Chloride/bromide Carbon Sulfate ²	DBS&A, Albuquerque, NM New Mexico Institute of Mining and Technology, Dr. D. Branvold, Socorro, NM
	HGC	4	Water content Chloride/bromide	Hydro Geo Chem, Inc. (HGC), Tucson, AZ
	DRI2	5	Water potential Water content Dry bulk density/porosity	Desert Research Institute (DRI), Dr. S. Tyler, Reno, NV
	DRI1	6	Stable isotopes of hydrogen and oxygen	DRI, Dr. S. Tyler, Reno, NV
	ARCH	7	To be determined	To be determined (in storage)
Drill Cuttings	REECo	1	Gravimetric water content	REECo/EMD/ER&TDD/SPS
	N/A	1	Gamma spectrometry	REECo Health Protection Department
	HGC	1	Water content, chloride/bromide	HGC, Tucson, AZ
	N/A	1	To be determined	To be determined (in storage)
	N/A	1	To be determined	To be determined (in storage)
	N/A	1	To be determined	To be determined (in storage)

¹ Tests conducted on selected samples

² Borehole AP-1 only

³ Sample priority was generally equivalent to core barrel position; the highest priority at the bottom of the core barrel, and the lowest priority at the top of the core barrel

^a Air permeability boreholes

^b Radon pumping boreholes

Following geologic description and measurement of magnetic susceptibility, each core segment was capped, taped, and labeled with the appropriate sample identification and intended laboratory test. Core segments were further sealed in Protec-Core® (a tubular, aluminized mylar laminate which protects the core from tampering and damage when sealed) and labeled again with the same information. Most of the core segments were specified for various types of laboratory tests, while the remainder were stored for future use. Tables 2.2 to 2.6 and Appendix D summarize the specific laboratory tests designated for each core run. Because core recovery was not always 100 percent, and furthermore, because some core segments were more disturbed than others (e.g., disturbance of water content, porosity, and aggregation), the assignment of core segments for various tests was based on a priority system. This system took into account the relative importance of different laboratory tests, as well as the degree of sample disturbance acceptable for each test. This is described in detail in the applicable SOP (Table 2.1).

In addition, a brief, geologic description of the drill cuttings was made after the samples were transported to the temperature-controlled field laboratory (Appendix B). Sample bottles containing drill cuttings were opened briefly, and the same geologic description and magnetic survey procedures referred to previously were followed. Sample bottles were then capped, taped, sealed in Protec-Core®, and labeled again with appropriate sample identification information and intended test. Because these samples were more disturbed than core samples, fewer laboratory tests were specified.

The samples collected in the moisture tins were designated for gravimetric water determination which were performed by SPS personnel. The moisture tins were labeled, capped, and taped to prevent moisture loss until they could be processed.

2.2.3 Radiological Surveys of Geologic Samples

Gamma radiation levels from drill cuttings were monitored continuously with an energy-compensated Geiger-Müller detector mounted directly on the cuttings return line immediately upstream of the cyclone separator. In addition, health physics personnel surveyed samples on a daily basis for gamma emitting radionuclides with gamma spectroscopy, and collected swipe samples on drilling and coring equipment for removable alpha and beta radiation contamination. All radiological monitoring results were consistent with background radiation levels.

2.3 Borehole Completion

This section briefly describes the materials, methods, and design followed to complete the AP and RP Science Boreholes. The completion involved installation and stemming of casing and vadose zone instruments in selected boreholes. Further details of all components of the completion design and operation are given in Appendix C.

2.3.1 Subsurface Completion Design

The Science Boreholes were completed according to two basic designs (Tables 2.8 and 2.9). The AP boreholes were completed with a single string of 77.1-mm (3.0-in) inner diameter (ID), polyvinyl chloride (PVC) casing with 13 slotted intervals. The RP boreholes were completed with 50.8-mm (2.0-in) ID PVC casing. Attached to the outside of the casing were a total of 22 instruments running from the ground surface down to 10 separate instrument stations.

- The AP borehole stations consist of a 154.2-mm (6.0-in) interval of slots in the PVC casing at depths of approximately 6.1, 12.2, 18.3, 24.4, 30.5, 36.6, 42.7, 48.8, 54.9, 61.0, 67.1, 73.2, and 79.2 m (20, 40, 60, 80, 100, 120, 140, 160, 180, 200, 220, 240, and 260 ft).
- Each RP borehole instrument station consists of one solid-state temperature transducer, a 9.525-mm (0.375-in) OD by 6.223-mm (0.245-in) ID continuous 304 stainless steel tube for pressure monitoring, and a 9.52-mm (0.375-in) ID stainless-steel tube for gas sampling located at depths of approximately 1.5, 3.0, 4.6, 6.1, 9.1, 13.7, 18.3, 27.4, 36.6, and 45.7 m (5, 10, 15, 20, 30, 45, 60, 90, 120, and 150 ft).
- The N-series boreholes have the 168.675-mm (6.625-in) OD drive casing left in the hole.

The annular space around each station was stemmed with 6/12-mesh, coarse-grained silica sand to facilitate pneumatic communication with the surrounding formation. The intervals between each station were stemmed with a low permeability mixture to eliminate preferential flow paths between the central casing and the formation. The mixture consisted of Overton sand (60 percent), Baroid Aqua-Gel Gold Seal® bentonite powder (25 percent), and silica flour (15 percent). The air permeability of this mixture was found to be approximately $9.0 \times 10^{-14} \text{ m}^2$ (90 millidarcies) in laboratory tests. This value is at least two orders of magnitude less than the air permeability of the alluvial formation (REECO 1994).

2.3.2 Subsurface Completion Operations

The same rig used for drilling (Schramm T685H/DHH) was used for completion activities for all Science Boreholes as described below. Details concerning materials used, preparation of the central casing and attachment of instruments, casing and instrument installation into the borehole, and stemming of each borehole are given in Appendix C.

Two tremie pipes (25.4-mm [1.0-in] nominal pipe size, schedule 80, flush joint) were run inside the drive casing and secured. One of the tremie pipes was typically used for material delivery while the other was employed to allow tag-line access for depth measurements and as a delivery backup. Next, the casing/instrument bundles were assembled and run downhole, securing each instrument at the desired interval beginning at the bottom of the casing. Then the low permeability dry mix and coarse sand were delivered downhole while simultaneously retracting the drive casing. Delivery was performed using a Shotcrete

Table 2.8 Completion data for AP boreholes.

Stemming Material	AP-1 Depth Interval (m)		AP-2 Depth Interval (m)		Instrument Station Depth (m)
	from	to	from	to	
Dry Mix	0.0	5.8	0.0	5.7	
Sand	5.8	6.3	5.7	6.3	6.1
Dry Mix	6.3	11.6	6.3	11.6	
Sand	11.6	12.3	11.6	12.3	12.2
Dry Mix	12.3	18.0	12.3	17.9	
Sand	18.0	18.6	17.9	18.4	18.3
Dry Mix	18.6	24.1	18.4	24.1	
Sand	24.1	24.6	24.1	24.6	24.4
Dry Mix	24.6	29.8	24.6	29.9	
Sand	29.8	30.7	29.9	30.7	30.5
Dry Mix	30.7	36.2	30.7	36.2	
Sand	36.2	36.8	36.2	36.8	36.6
Dry Mix	36.8	42.4	36.8	42.4	
Sand	42.4	42.9	42.4	43.0	42.7
Dry Mix	42.9	48.5	43.0	48.4	
Sand	48.5	49.0	48.4	49.0	48.8
Dry Mix	49.0	54.5	49.0	54.5	
Sand	54.5	55.0	54.5	55.2	54.9
Dry Mix	55.0	60.7	55.2	60.6	
Sand	60.7	61.2	60.6	61.2	61.0
Dry Mix	61.2	66.8	61.2	66.7	
Sand	66.8	67.4	66.7	67.6	67.1
Dry Mix	67.4	72.9	67.6	72.9	
Sand	72.9	73.4	72.9	73.4	73.2
Dry Mix	73.4	78.8	73.4	78.8	
Sand	78.8	88.6	78.8	79.5	79.2
Dry Mix	88.6	83.7	79.5	84.1	

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

Table 2.9 Completion data for RP boreholes.

Stemming Material	RP-1 Depth Interval (m)		RP-2 Depth Interval (m)		Instrument Station Depth (m)
	from	to	from	to	
Dry Mix	0.0	1.3	0.0	1.4	
Sand	1.3	1.7	1.4	1.6	1.5
Dry Mix	1.7	2.9	1.6	2.8	
Sand	2.9	3.3	2.8	3.3	3.0
Dry Mix	3.3	4.3	3.3	4.4	
Sand	4.3	4.8	4.4	4.7	4.6
Dry Mix	4.8	5.9	4.7	5.7	
Sand	5.9	6.2	5.7	6.2	6.1
Dry Mix	6.2	8.9	6.2	9.0	
Sand	8.9	9.3	9.0	9.4	9.1
Dry Mix	9.3	13.6	9.4	13.6	
Sand	13.6	14.0	13.6	14.0	13.7
Dry Mix	14.0	18.1	14.0	18.1	
Sand	18.1	18.5	18.1	18.4	18.3
Dry Mix	18.5	27.3	18.4	27.3	
Sand	27.3	27.6	27.3	27.7	27.4
Dry Mix	27.6	36.4	27.7	36.4	
Sand	36.4	36.8	36.4	36.7	36.6
Dry Mix	36.8	45.4	36.7	45.4	
Sand	45.4	45.9	45.4	46.1	45.7

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

machine to deliver the dry mix under low air pressure. The coarse-mesh sand was allowed to freefall in the tremies.

The drive casing was retracted in 3-m (10-ft) lengths during material emplacement. A minimum of open hole was left between the top of the annular seal and the bottom of the drive casing to limit caving. In some instances, the material was placed up to 1 m (3 ft) inside the drive casing and allowed to slip out while the casing was retracted. This was done in areas particularly prone to caving and at most instrument stations. Material was progressively placed in the borehole until it was flush with the ground surface.

3.0 LABORATORY TESTING METHODS AND RESULTS

A summary of laboratory tests and testing methods are given in Table 3.1 and specific details are contained in the cited references. In addition, a description of all laboratory testing methods used in the Science Borehole Project are provided in the Science Trench Borehole data report (REECo 1993b).

As described in Section 2.2 and Table 2.7, drill cuttings and core samples were sent to selected testing laboratories to measure material, hydrologic, and geochemical properties. In most cases, a testing laboratory conducted a number of related tests on the same core segment. For example, initial water content, bulk density, porosity, hydraulic conductivity, moisture retention, and particle size distribution measurements were conducted on the same core segment. A number of samples have been placed in storage (archived) for future testing as required.

REECo has audited and approved the QA programs of the following subcontract testing laboratories:

- Daniel B. Stephens & Associates, Inc. (DBS&A), Albuquerque, NM
- Hydro Geo Chem, Inc. (HGC), Tucson, AZ

In addition, DBS&A was responsible for the review and approval of the QA program for their subcontract laboratory (Dr. D. Branvold, New Mexico Institute of Mining and Technology, Socorro, NM). Finally, Sandia National Laboratories was responsible for the review and approval of the QA program for the DRI testing laboratory.

The types and numbers of tests conducted on samples of core and drill cuttings for each borehole are summarized in Table 3.2. The tabular results from these laboratory tests for samples of both core and drill cuttings are summarized in Appendix D. Summary statistics for laboratory measurements, where appropriate, are presented in Tables 3.3 to 3.5. Plots of laboratory results for specific tests are presented in the appropriate following sections.

3.1 General Geologic Description, Lithology, Stratigraphy, and Organic Matter

General geologic descriptive information, as well as specific lithologic and stratigraphic information are useful in identifying the overall geometry of the hydrogeologic flow system, layers with possibly distinctive physical and hydrogeologic properties, and potentially important flow paths.

Table 3.1 Summary of laboratory methods.

Method Description	Reference
Geologic Description of Unconsolidated Alluvium	ASTM D 2488-84. 1987. Standard practice for description and identification of soils (Visual-Manual Procedure). In: 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Moisture Content	ASTM D 2216-90. 1990. Standard method for laboratory determination of water (moisture) content of soil, rock, and soil-aggregate mixtures. In: 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Density	
Dry Bulk	Blake, G. R., and K. H. Hartge. 1986. Bulk density. In: Klute, A. (ed), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 13, pp. 363-367.
Particle	ASTM D 854-91. 1990. Standard test method for specific gravity of soils. In: 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Porosity	Danielson, R. E., and P. L. Sutherland. 1986. Total porosity. In: Klute, A. (ed), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 18, pp. 444-445.
Saturated Hydraulic Conductivity	
Constant Head	ASTM D 2434-68(74). 1987. Standard test method for permeability of granular soils (Constant Head). In: 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Falling Head	Klute, A., and C. Dirksen. 1986. Hydraulic conductivity and diffusivity: Laboratory methods-falling-head method. In: Klute, A. (ed), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 28, pp. 700-703.
Moisture-Retention Curves	
Pressure Plate Extractor	ASTM D 2325-68(81). 1987. Standard test method for capillary-moisture relationships for coarse- and medium-textured soils by porous-plate apparatus. In: 1987 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Hanging Column	Klute, A. 1986. Water retention: Laboratory methods. In: Klute, A. (ed), Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 26, pp. 635-641.
Thermocouple Psychrometer	Operators Manual for the SC-10A Thermocouple Psychrometer Sample Chamber (manufactured by Decagon Devices, Inc., Pullman WA).
Particle Size Characteristics	
Dry Sieve	ASTM D 422-63(90). 1990. Standard method for particle-size analysis of soils. In: 1990 Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, Philadelphia, PA.
Water Potential	Gee, G. W., M. D. Campbell, G. S. Campbell, and J. H. Campbell. 1992. Rapid measurement of low soil water potential using a water activity meter. Soil Sci. Soc. Am. J., Vol. 56, pp. 1068-1071. Campbell G. S., and G. W. Gee. 1986. Water potential measurement using the filter paper methods, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 25, pp. 628-630.

Table 3.1 Summary of laboratory methods (continued).

Method Description	Reference
Chloride and Bromide	
Sample Leaching	Los Alamos National Laboratory - Internal Document, 1992. Sample leaching to extract soluble chloride and bromide. LANL-INC-DP-92.R0. pp. 9-15.
Ion Chromatography Analysis	Los Alamos National Laboratory - Internal Document, 1991. Draft procedure for using ion chromatography to determine chloride and bromide concentrations. LANL-INC-DP-94.R0, pp. 3-25.
Total Organic Carbon	USEPA Method 9060. September 1986. Total organic carbon. Test Methods for Evaluating Solid Waste (SW-846), Chap. 5, Miscellaneous Test Methods, 5p. ASTM D 2579-85. 1990. Test method for determining total organic carbon. In: 1990 Annual Book of ASTM Standards, Vol. 11.02, American Society for Testing and Materials, Philadelphia, PA.
Inorganic Carbon	Nelson, R. E. 1982. Carbonate and gypsum: Pressure-calciometer method. In: Page, A. L., R. H. Miller, and D. R. Keeney (eds), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 11, pp. 188-192.
Stable Isotopes	
Soil Water Extraction	Ingraham, N. L., and C. Shadel. 1992. A comparison of the toluene distillation and vacuum/heat methods for extracting soil water for stable isotope analysis. Journal of Hydrology, Vol. 140, pp. 371-387. Revezs, K., and P. H. Woods. 1990. A method to extract soil water for stable isotope analysis. Journal of Hydrology, Vol. 115, pp. 397-406.
Oxygen Isotope Analysis	Dugan, J. P., J. Borthwich, R. S. Harmon, M. A. Gagnier, J. E. Glahn, E. P. Kinsel, S. MacLeod, J. A. Viglino, and J. W. Hess. 1985. Guanidine hydrochloride method for determination of water oxygen isotope ratios and the oxygen-18 fractionation between carbon dioxide and water at 25°. Anal. Chemistry, Vol. 57, pp. 1734-1736.
Hydrogen Isotope Analysis	Kendall, C., and T. B. Coplen. 1985. Multisample conversion of water to hydrogen by zinc for stable isotope determination. Anal. Chemistry, Vol. 57, pp. 1437-1440.
Mass Spectrometer Analysis	Gonfiantini, R. 1981. The δ -notation and the mass spectrometric measurements techniques. International Atomic Energy Agency, Technical Report Series No. 210, Chapter 4, pp. 35-84.
Water Soluble and Adsorbed Sulfate	Tabatabai, M. A. 1982. Sulfur: inorganic sulfate. In: Page, A. L., R. H. Miller, and D. R. Keeney (eds), Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, 2nd ed., American Society of Agronomy, Madison, WI. Chap. 28, pp. 518-522.

Table 3.2 Summary of tests performed on samples from the Science Boreholes.

Borehole		AP-1		AP-2		RP-1		RP-2		NN-1		NW-1	
Sample type	Core	X		X		X		X		X		X	
	Cuttings		X		X		X		X		X		X
Hydrologic properties	Hydraulic conductivity	19	-	23	-	18	-	10	-	4	-	4	-
	Moisture retention	19	-	23	-	11	-	10	-	4	-	4	-
	Gravimetric water content ¹	74	110	83	111	42	60	46	60	16	103	16	103
	Volumetric water content	74	-	83	-	42	-	46	-	12	-	12	-
	Water potential	26	-	29	-	21	-	26	-	4	-	4	-
Material properties	Dry sieve	19	-	23	-	11	-	10	-	4	-	4	-
	Bulk density	74	-	83	-	42	-	46	-	12	-	12	-
	Grain density	5	-	5	-	5	-	5	-	4	-	4	-
	Calculated porosity	74	-	83	-	42	-	46	-	12	-	12	-
	Saturated porosity	19	-	23	-	11	-	10	-	4	-	4	-
Environmental tracers	Carbon	29	-	31	-	10	-	10	-	4	-	4	-
	Chloride	29	-	31	-	10	-	10	-	6	21	7	20
	Bromide	29	-	31	-	10	-	10	-	6	19	7	20
	Sulfate	29	-	-	-	-	-	-	-	-	-	-	-

¹ NE-1 had 72 samples of drill cuttings tested for gravimetric water content.
NS-1 had 80 samples of drill cuttings tested for gravimetric water content.

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes.

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Saturated hydraulic conductivity (cm/s)							
AP-1	DB1	19	2.7E-04	2.3E-02	2.5E-03	5.3E-03	209.9
AP-2	DB1	23	1.3E-04	1.2E-02	2.4E-03	3.4E-03	143.8
RP-1	DB1	18	4.0E-05	3.6E-03	1.1E-03	1.1E-03	107.0
RP-2	DB1	10	9.3E-05	2.5E-03	9.0E-04	8.2E-04	91.2
NN-1	DB1	4	1.8E-04	4.9E-03	3.3E-03	2.1E-03	64.2
NW-1	DB1	4	1.0E-03	3.9E-03	2.3E-03	1.2E-03	55.1
Gravimetric water content (percent)							
AP-1	DB1	19	3.8	8.9	5.5	1.30	23.6
AP-2	DB1	23	2.7	9.7	5.7	1.80	31.8
RP-1	DB1	11	4.3	8.6	5.7	1.30	22.8
RP-2	DB1	10	4.2	7.9	5.6	1.11	19.9
NN-1	DB1	4	2.7	6.5	5.0	1.63	32.4
NW-1	DB1	4	5.3	6.0	5.6	0.33	6.0
AP-1	DB3	29	2.4	9.1	5.2	1.96	37.8
AP-2	DB3	31	2.7	8.5	5.5	1.67	30.2
RP-1	DB3	10	1.8	7.6	5.1	1.78	35.1
RP-2	DB3	10	2.1	8.0	5.2	1.70	32.8
NN-1	DB3	4	2.8	6.7	4.9	1.61	32.6
NW-1	DB3	4	4.6	5.3	4.9	0.29	6.0
AP-1	DRI2	26	2.4	7.8	5.1	1.63	32.1
AP-2	DRI2	29	1.7	9.2	5.2	1.71	33.1
RP-1	DRI2	21	1.6	6.6	4.5	1.13	25.3
RP-2	DRI2	26	2.7	8.1	4.8	1.39	28.8
NN-1	DRI2	4	2.5	8.4	5.1	2.50	48.0
NW-1	DRI2	4	4.9	5.5	5.2	0.25	4.8
NN-1	HGC	4	1.8	6.0	4.1	1.70	42.3
NW-1	HGC	4	2.8	4.9	3.7	0.90	24.6
AP-1	ALL	74	2.4	9.1	5.2	1.70	32.2
AP-2	ALL	83	1.7	9.7	5.4	1.70	31.5
RP-1	ALL	42	1.6	8.6	4.9	1.40	28.6
RP-2	ALL	46	2.1	8.1	5.1	1.40	28

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Gravimetric water content (percent)							
NN-1	ALL	16	1.8	8.4	4.8	1.74	36.3
NW-1	ALL	16	2.8	6.0	4.8	0.85	17.7
Volumetric water content (percent)							
AP-1	DB1	19	6.2	13.2	8.7	1.83	21.1
AP-2	DB1	23	4.4	14.2	9.0	2.61	29.2
RP-1	DB1	11	6.8	13.2	8.9	1.93	21.7
RP-2	DB1	10	6.8	13.0	9.1	1.97	21.6
NN-1	DB1	4	4.5	10.6	8.2	2.60	31.9
NW-1	DB1	4	7.9	9.4	8.9	0.66	7.4
AP-1	DB3	29	3.6	13.3	8.1	2.92	35.9
AP-2	DB3	31	4.5	11.5	8.5	2.40	28.2
RP-1	DB3	10	3.4	12.2	8.0	2.66	33.1
RP-2	DB3	10	3.4	13.4	8.3	2.83	34.2
NN-1	DB3	4	4.5	10.8	8.1	2.64	32.6
NW-1	DB3	4	7.4	8.7	8.3	0.61	7.4
AP-1	DRI2	26	4.3	12.4	7.6	2.47	32.3
AP-2	DRI2	29	3.7	13.7	8.3	2.56	30.9
RP-1	DRI2	21	3.7	11.1	7.3	2.01	27.4
RP-2	DRI2	26	4.6	12.3	7.9	2.38	30.0
NN-1	DRI2	4	4.5	13.5	8.4	3.80	45.4
NW-1	DRI2	4	8.6	9.7	9.3	0.50	5.5
AP-1	ALL	74	3.6	13.3	8.1	2.50	31.1
AP-2	ALL	83	3.7	14.2	8.6	2.50	29.2
RP-1	ALL	42	3.4	13.2	7.9	2.20	27.9
RP-2	ALL	46	3.4	13.4	8.3	2.40	29.0
NN-1	ALL	12	4.5	13.5	8.2	2.78	33.8
NW-1	ALL	12	7.4	9.7	8.8	0.69	7.8
Water potential (bars)							
AP-1	DRI2	26	-84	-8	-35	21.72	62.3
AP-2	DRI2	29	-82	-8	-29	19.78	67.4
RP-1	DRI2	21	-128	-14	-45	30.90	69

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Water potential (bars)							
RP-2	DRI2	26	-86	-10	-42	26.05	61.5
NN-1	DRI2	4	-92	-14	-47	37.10	79.3
NW-1	DRI2	4	-53	-17	-30	16.70	55.8
Water potential (bars) (below 30.5 m [100 ft])							
AP-1	DRI2	10	-33	-8	-18	7.87	44.9
AP-2	DRI2	11	-19	-8	-13	4.30	32.8
RP-1	DRI2	4	-16	-14	-14	0.97	6.8
RP-2	DRI2	5	-36	-10	-16	10.98	68.2
NN-1	DRI2	1			-14		
NW-1	DRI2	2	-18	-17	-18	0.97	5.5
Sieve analysis (percent passing) No. 4 mesh screen							
AP-1	DB1	19	46.9	92.6	77.1	12.03	15.6
AP-2	DB1	23	58.4	96.6	78.1	11.25	14.4
RP-1	DB1	11	51.0	95.8	81.2	14.75	18.2
RP-2	DB1	10	58.6	89.2	75.4	8.85	11.7
NN-1	DB1	4	71.2	86.9	76.7	7.00	9.1
NW-1	DB1	4	35.3	84.7	66.9	21.97	32.8
No. 200 mesh screen							
AP-1	DB1	19	1.6	7.9	5.4	1.96	36.2
AP-2	DB1	23	0.6	21.4	5.4	4.33	80.6
RP-1	DB1	11	3.1	17.5	7.9	4.34	55.0
RP-2	DB1	10	1.7	9.0	5.3	2.76	51.6
NN-1	DB1	4	2.5	16.5	6.5	6.68	102.9
NW-1	DB1	4	1.6	15.9	6.8	6.32	93.7
Dry bulk density (g/cm ³)							
AP-1	DB1	19	1.40	1.74	1.58	0.10	6.3
AP-2	DB1	23	1.43	1.82	1.59	0.09	5.9
RP-1	DB1	11	1.45	1.87	1.57	0.13	8.3
RP-2	DB1	10	1.53	1.74	1.64	0.07	4.4
NN-1	DB1	4	1.55	1.65	1.62	0.04	3

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Dry bulk density (g/cm ³)							
NW-1	DB1	4	1.49	1.70	1.60	0.11	6.6
AP-1	DB3	29	1.30	1.91	1.59	0.12	7.5
AP-2	DB3	31	1.32	1.74	1.56	0.12	7.4
RP-1	DB3	10	1.28	1.88	1.61	0.17	10.4
RP-2	DB3	10	1.46	1.70	1.59	0.01	4.9
NN-1	DB3	4	1.59	1.71	1.64	0.05	3.3
NW-1	DB3	4	1.59	1.80	1.67	0.09	5.4
AP-1	DRI2	26	1.16	1.91	1.53	0.17	11.2
AP-2	DRI2	29	1.32	2.19	1.63	0.19	11.9
RP-1	DRI2	21	1.33	2.27	1.66	0.23	13.7
RP-2	DRI2	26	1.18	1.90	1.64	0.16	9.9
NN-1	DRI2	4	1.55	1.81	1.66	0.11	6.9
NW-1	DRI2	4	1.65	1.93	1.78	0.15	8.2
AP-1	ALL	74	1.16	1.91	1.56	0.10	8.7
AP-2	ALL	83	1.32	2.19	1.59	0.20	9.1
RP-1	ALL	42	1.28	2.27	1.62	0.20	11.8
RP-2	ALL	46	1.18	1.90	1.63	0.13	8.1
NN-1	ALL	12	1.55	1.81	1.64	0.07	4.4
NW-1	ALL	12	1.49	1.93	1.68	0.13	7.8
Particle density (g/cm ³)							
AP-1	DB1	5	2.47	2.59	2.52	0.06	2.2
AP-2	DB1	5	2.50	2.60	2.55	0.04	1.5
RP-1	DB1	5	2.46	2.56	2.53	0.04	1.7
RP-2	DB1	5	2.52	2.60	2.55	0.03	1.3
NN-1	DB1	4	2.51	2.59	2.55	0.04	1.4
NW-1	DB1	4	2.49	2.59	2.56	0.05	1.8
Porosity, calculated (percent)							
AP-1	DB1	19	30.8	44.5	37.2	3.71	10.0
AP-2	DB1	23	28.7	43.0	37.5	3.54	9.4
RP-1	DB1	11	27.1	42.8	37.9	4.97	13.1
RP-2	DB1	10	32.1	40.6	35.7	2.85	8

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Porosity, calculated (percent)							
NN-1	DB1	4	35.0	39.0	36.7	1.75	4.8
NW-1	DB1	4	34.3	41.2	37.6	3.58	9.5
AP-1	DB3	29	24.3	48.5	37.1	4.68	12.6
AP-2	DB3	31	31.6	48.2	39.0	4.52	11.6
RP-1	DB3	10	25.5	49.5	36.4	6.67	18.4
RP-2	DB3	10	33.2	42.6	37.7	3.01	8.0
NN-1	DB3	4	33.0	37.7	35.7	2.11	5.9
NW-1	DB3	4	29.6	37.7	34.6	3.52	10.2
AP-1	DRI2	26	24.2	54.0	39.4	6.81	17.3
AP-2	DRI2	29	14.3	48.3	36.2	7.62	21.1
RP-1	DRI2	21	10.3	47.5	34.6	8.94	25.9
RP-2	DRI2	10	32.0	39.4	34.9	2.25	6.4
NN-1	DRI2	4	27.9	38.2	33.8	4.55	13.5
NW-1	DRI2	4	24.6	35.5	30.5	5.70	18.7
AP-1	ALL	74	24.2	54.0	38.0	5.40	14.2
AP-2	ALL	83	14.3	48.3	37.6	5.70	15.1
RP-1	ALL	42	10.3	49.5	35.9	7.50	21.0
RP-2	ALL	46	25.5	53.8	36.1	5.16	14.3
NN-1	ALL	12	27.9	39.0	35.4	3.04	8.2
NW-1	ALL	12	24.6	41.2	34.2	5.00	14.6
Porosity, saturated (percent)							
AP-1	DB1	19	30.8	41.5	35.2	3.36	9.6
AP-2	DB1	23	25.3	42.3	33.9	3.73	11.0
RP-1	DB1	11	28.2	41.1	36.4	3.86	10.6
RP-2	DB1	10	32.0	39.4	34.9	2.30	6.4
NN-1	DB1	4	36.2	40.1	38.4	2.00	5.2
NW-1	DB1	4	31.5	38.7	34.9	3.27	9.4
Inorganic carbon in soil (percent)							
AP-1	DB3	29	0.15	1.50	0.60	0.28	45.8
AP-2	DB3	31	0.16	1.40	0.66	0.30	45.0
RP-1	DB3	10	0.12	1.18	0.70	0.36	51

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Inorganic carbon in soil (percent)							
RP-2	DB3	10	0.18	2.58	0.94	0.66	70.7
NN-1	DB3	4	0.09	1.11	0.49	0.45	92.4
NW-1	DB3	4	0.10	0.86	0.42	0.35	85.5
Organic carbon in soil (percent)							
AP-1	DB3	29	0.02	0.12	0.05	0.03	53.7
AP-2	DB3	25	0.02	0.17	0.06	0.04	60.9
RP-1	DB3	10	0.02	0.16	0.07	0.04	61.3
RP-2	DB3	10	0.02	0.13	0.07	0.04	53.5
NN-1	DB3	4	0.02	0.07	0.04	0.03	61.2
NW-1	DB3	4	0.01	0.09	0.05	0.03	67.0
Total carbon in soil (percent)							
AP-1	DB3	29	0.17	1.60	0.66	0.30	45.0
AP-2	DB3	25	0.18	1.51	0.73	0.30	41.6
RP-1	DB3	10	0.14	1.34	0.77	0.39	51.0
RP-2	DB3	10	0.20	2.71	1.01	0.69	69.0
NN-1	DB3	4	0.11	1.18	0.53	0.48	89.8
NW-1	DB3	4	0.11	0.95	0.46	0.38	83.0
Chloride-Bromide ratio (below 30.5 m [100 ft])							
AP-1	DB3	29	100.0	186.4	162.9	21.23	13.0
AP-2	DB3	31	80.0	169.4	145.8	17.58	12.1
RP-1	DB3	10	146.4	177.8	160.1	10.89	6.8
RP-2	DB3	10	113.0	300.0	154.6	58.13	37.6
NN-1	DB3	4	83.3	130.2	112.5	21.70	19.3
NN-1	HGC	2	112.0	130.0	121.0	12.73	10.5
NN-1	ALL	6	83.3	130.2	115.3	18.28	15.9
NW-1	DB3	4	62.5	104.8	90.0	18.99	21.1
NW-1	HGC	3	101.0	217.0	145.0	62.86	43.4
NW-1	ALL	7	62.5	217.0	113.6	48.60	42.8
Stable Isotope ratios							
D/H							
AP-2	DRI1	14	-14.2	-2.3	-7.8	4.1	52.1
RP-2	DRI1	11	-13.9	-2.9	-6.9	3.6	52.9

Table 3.3 Summary of descriptive statistics of alluvium core samples from the Science Boreholes (continued).

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Stable Isotope ratios							
D/H							
NN-1	DRI1	4	-14.6	-6.6	-11	3.7	33.1
NW-1	DRI1	4	-8.1	-6.9	-7.6	0.5	6.5
Stable Isotope ratios ¹⁸ O/ ¹⁶ O							
AP-2	DRI1	14	-116	-64	-91.2	16.5	18.1
RP-2	DRI1	11	-121	-73	-88.9	16.5	18.5
NN-1	DRI1	4	-126	-89	-110.5	16.1	14.6
NW-1	DRI1	4	-81	-71	-76	4.1	5.4
Soluble sulfate (ppm)							
AP-1 (below 30.5 m [100ft])	DB3	29	1.8	1,700.0	224.9	453.4	201.6

Table 3.4 Summary of descriptive statistics of alluvium drill cutting samples from the Science Boreholes.

	Sample ID	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation (percent)
Gravimetric water content (percent)							
AP-1	REEC0	110	2.3	7.2	4.7	1.08	23.1
AP-2	REEC0	111	2.0	7.6	4.9	1.11	22.9
RP-1	REEC0	60	2.9	7.4	4.4	0.95	21.5
RP-2	REEC0	60	2.4	6.0	4.4	0.73	16.8
NN-1	REEC0	80	2.5	7.1	4.8	1.04	21.6
NE-1	REEC0	72	1.6	7.8	4.7	1.49	31.4
NW-1	REEC0	80	2.3	6.3	4.6	0.81	17.6
NS-1	REEC0	80	3.2	7.1	4.7	0.79	16.8
NN-1	HGC	23	2.4	6.6	4.2	1.22	29.2
NW-1	HGC	23	2.3	7.2	4.4	1.15	26.4
NN-1	ALL	103	2.4	7.1	4.7	1.11	23.7
NW-1	ALL	103	2.3	7.2	4.5	0.90	19.7
Chloride-Bromide Ratio (below 30.5m [100 ft])							
NN-1	HGC	5	76.0	140.4	106.9	24.60	23.0
NW-1	HGC	5	80.0	188.0	116.0	42.1	36.3

Table 3.5 Summary of descriptive statistics of moisture-retention curves for core samples from the Science Boreholes (s is the number of samples).

Borehole	Statistic	θ_r (percent)	θ_s (percent)	α (cm ⁻¹)	n
<u>AP-1</u> (s = 19)	Minimum	0.0	31.0	0.015	1.15
	Maximum	9.4	42.0	0.809	3.17
	Mean	6.8	35.3	0.082	1.61
	Standard Deviation	0.005	3.5	0.179	0.42
	Coefficient of Variation (percent)	0.6	9.8	219.6	26.0
<u>AP-2</u> (s = 23)	Minimum	0.0	25.0	0.008	1.15
	Maximum	11.3	42.0	0.398	2.94
	Mean	6.0	33.9	0.060	1.64
	Standard Deviation	3.6	3.7	0.084	0.51
	Coefficient of Variation (percent)	59.7	11.0	140.5	31.3
<u>RP-1</u> (s = 11)	Minimum	4.7	28.0	0.014	1.23
	Maximum	11.6	41.0	0.375	3.19
	Mean	7.6	36.5	0.069	1.68
	Standard Deviation	2.3	3.9	0.112	0.66
	Coefficient of Variation (percent)	29.8	10.7	160.1	39.3
<u>RP-2</u> (s = 10)	Minimum	0.0	32.0	0.018	1.13
	Maximum	10.9	39.0	0.830	1.55
	Mean	6.4	34.8	0.147	1.41
	Standard Deviation	2.8	2.2	0.262	0.13
	Coefficient of Variation (percent)	44.7	6.3	178.3	9.4
<u>NN-1</u> (s = 4)	Minimum	0.0	36.0	0.028	1.18
	Maximum	1.6	40.0	0.597	1.32
	Mean	0.6	38.3	0.239	1.25
	Standard Deviation	0.8	2.1	0.247	0.06
	Coefficient of Variation (percent)	127.7	5.4	103.7	4.9
<u>NW-1</u> (s = 4)	Minimum	0.0	33.0	0.018	1.17
	Maximum	1.2	39.0	0.431	1.35
	Mean	0.3	36.3	0.252	1.23
	Standard Deviation	0.6	2.5	0.172	0.08
	Coefficient of Variation (percent)	200.0	6.9	68.2	6.6

3.1.1 General Geologic, Lithologic, and Stratigraphic Data for Alluvium

Visual geologic descriptions were made on both samples of core and drill cuttings (Sections 2.2.1 and 2.2.2) and recorded on the borehole log sheets (Appendix B.1 to B.8) and drill cuttings log data sheets (Appendix B.9 to B.16). This included a field description of lithology, texture, color, cementation, and reaction to hydrochloric acid. The geologic descriptive information is summarized below.

As found in previous studies (REECo 1993b; REECo 1994), clasts in the geologic samples were primarily tuff with occasional quartzite and limestone. The degree of welding in the tuff clasts (observable only in large clasts) ranged from welded to nonwelded. These samples were generally weakly cemented to uncemented and exhibited a weak to strong reaction to dilute hydrochloric acid. Poorly-graded gravels and coarse-sand fractions were more subangular than well-graded fractions of similar particle size. Cobbles were generally subrounded. The general color of the alluvial samples was predominantly very pale brown to light yellowish brown. Gravels, when separated from other size fractions, were pink and gray in color.

The Unified Soil Classification System (USCS) textural data are summarized for alluvial core samples in Table 3.6 and laboratory results are presented in Appendix D. These textural classes are composed primarily of sand with silt and some gravel. These soils are similar to those found in both the shallow Science Trench Boreholes (REECo 1993b) and the deeper Pilot Wells (REECo 1994). This similarity in textural groups over different thicknesses of alluvial strata at different locations is remarkable and suggests that the alluvial sediments beneath the Area 5 RWMS are very homogeneous materials. Data and more qualitative arguments supporting this conclusion are presented in Sections 3.2 and 3.3. Similar data and qualitative arguments have been presented for the Science Trench Boreholes and Pilot Wells (REECo 1993b; REECo 1994).

3.1.2 Secondary Mineralogy and Organic Matter

Depth profiles of inorganic carbon in core samples for all Science Boreholes are illustrated in Figure 3.1. Tabular values of inorganic and organic carbon measurements, as well as calculated values of total carbon for core samples are presented in Appendix D for samples from the alluvium, and descriptive statistics for these data are summarized in Table 3.3.

The data show that inorganic carbon concentrations are very low (mean values are less than 1 percent by weight) and nearly constant. Slight increases in inorganic carbon concentrations (up to 3 percent) were noted between approximately 13.7 m (45 ft) and 18.3 m (60 ft) in AP and RP boreholes. In addition, visible evidence of calcium carbonate was noted in several core samples from these depths (Appendix B.1 to B.8). However, corresponding significant changes in hydrologic and related properties were not found at these depths and are discussed in the following sections.

Table 3.6 Summary of USCS group names for core samples from the Science Boreholes.

Borehole	Number and percent of samples with given USCS group name.									Total
	SM	SP-SM	SW-SM	SP	SW	GM	GP	GW	GW-GM	
AP-1		2 (10.5)	10 (52.6)		6 (31.6)				1 (5.3)	19 (100)
AP-2	1 (4.3)	2 (8.7)	7 (30.4)	2 (8.7)	11 (47.8)					23 (100)
RP-1	1 (9.1)	3 (27.3)	4 (36.4)	1 (9.1)	1 (9.1)			1 (9.1)		11 (100)
RP-2		1 (10.0)	4 (40.0)		5 (50.0)					10 (100)
NN-1	1 (25.0)				3 (75.0)					4 (100)
NW-1	1 (25.0)			1 (25.0)	2 (50.0)					4 (100)
Total	4 (5.6)	8 (11.3)	25 (35.2)	4 (5.6)	28 (39.4)			1 (1.4)	1 (1.4)	71 (100)

SM: Silty sand (greater than 12 percent silt)
 SP-SM: Poorly-graded sand with silt (5 to 12 percent silt)
 SW-SM: Well-graded sand with silt (5 to 12 percent silt)
 SP: Poorly-graded sand (less than 5 percent silt)
 SW: Well-graded sand (less than 5 percent silt)

GM: Silty gravel (greater than 12 percent silt)
 GP: Poorly-graded gravel (less than 5 percent silt)
 GW: Well-graded gravel (less than 5 percent silt)
 GW-GM: Well-graded gravel with silt (5 to 12 percent silt)

Figure 3.1 Depth profiles of inorganic carbon for core samples from the Science Boreholes.

Organic carbon values were generally an order of magnitude lower and equally as constant, demonstrating the absence of humus accumulation. The virtual absence of inorganic carbon (caliche) and humus layers helps support the argument (which will be expanded in the following sections) that the hydrogeologic system can be treated as a homogeneous alluvial unit.

3.2 Physical Properties

Several physical properties are relatively easy and inexpensive to measure and provide valuable insight into understanding the hydrogeologic system beneath the Area 5 RWMS. The physical properties include particle size distribution, dry bulk density, particle density, and porosity. Bulk density and porosity measurements are dependent on the arrangement and degree of packing of unconsolidated alluvial particles, and therefore were made only on intact core samples.

3.2.1 Particle Size Distribution

Particle size distribution analyses were conducted on one core segment from each core run using a dry sieve method. Previous analyses (REECO 1993b) indicated only small differences between dry sieve and the much more expensive wet sieve methods on these relatively coarse-grained alluvial materials.

Since the sieve process destroys the physical integrity of the core sample, this test always followed a series of nondestructive physical and hydrologic tests on the same core sample. These precursor tests included saturated porosity, saturated hydraulic conductivity, and moisture-retention measurements.

The results of particle size distribution analyses are presented in tabular form in Appendix D. Data from the No. 4 and No. 200 sieve screens (percent of material passing) for alluvial core samples are plotted vs. depth in Figures 3.2 to 3.7. These figures illustrate the relative percent of materials falling into the gravel, sand, and silt/clay fractions at each depth and show that the particle size distribution of alluvial materials is remarkably similar with depth. These materials are predominantly composed of sand-sized particles with considerable amounts of gravel and usually contain less than 10 percent silt/clay. Descriptive statistics of No. 4 and No. 200 sieve screen data for core samples are summarized in Table 3.3 and support this conclusion.

3.2.2 Bulk Density, Particle Density, and Porosity

Dry bulk densities were determined on two core segments from each core run in the alluvium. These data are listed in tabular form in Appendix D. Possible outliers were retained in the computation of the descriptive statistics of the alluvium core samples which are presented in Table 3.3. Plots of alluvial bulk densities vs. depth are illustrated in Figures 3.8 to 3.13. The DB1 sample appears to provide the most representative

Figure 3.2 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from AP-1.

Figure 3.3 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from AP-2.

Figure 3.4 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from RP-1.

Figure 3.5 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from RP-2.

Figure 3.6 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from NN-1.

Figure 3.7 Depth profiles of dry sieve analyses (percent passing No. 4 and No. 200 mesh screens) for core samples from NW-1.

Figure 3.8 Depth profiles of dry bulk density for core samples from AP-1.

Figure 3.9 Depth profiles of dry bulk density for core samples from AP-2.

Figure 3.10 Depth profiles of dry bulk density for core samples from RP-1.

Figure 3.11 Depth profiles of dry bulk density for core samples from RP-2.

Figure 3.12 Depth profiles of dry bulk density for core samples from NN-1.

Figure 3.13 Depth profiles of dry bulk density for core samples from NW-1.

measurement of formation conditions due to lower core barrel position, and therefore, the least amount of disturbance, while the DRI1 sample yields the least representative measurement due to upper core barrel position and greatest disturbance. There appear to be no consistent trends in bulk densities with depth. This may be due in part to the similarity of the particle size distribution (Section 3.2.1) and consistency in lithology.

Particle densities were determined on five core samples from each AP and RP borehole and four core samples for two N boreholes. These data are presented in tabular form in Appendix D. Plots of particle density vs. depth are presented in Figure 3.14 and illustrate that the particle density distribution of the alluvial materials is remarkably similar with depth.

Alluvial core porosities were calculated (by definition) from dry bulk densities and the average particle density for each borehole. These data are presented in tabular form in Appendix D. In addition, water-saturated porosities were measured on alluvial core segments after laboratory saturated hydraulic conductivity measurements were conducted on the same core segment (Section 3.3.1). Both calculated and water-saturated porosities of core samples are plotted vs. depth in Figures 3.15 to 3.20. The DRI1 measurement appears to be least representative of formation conditions due to its upper core barrel position which results in significant disturbance of the sample. Water-saturated porosities were noticeably lower than calculated porosities.

Descriptive statistics of dry bulk density, particle density, and porosity of alluvium core samples are summarized in Table 3.3. Mean values and coefficients of variation of dry bulk densities, particle densities, and calculated porosities for each Science Borehole were nearly identical. Bulk density and porosity values near both the lower and higher ends of the range may reflect sampling disturbance rather than in situ conditions.

3.3 Hydrologic Properties

Hydrologic properties are required, together with hydrologic conditions, to estimate rates of water movement and potential travel times. Hydrologic property measurements include saturated hydraulic conductivities and moisture-retention curves. For this study, unsaturated hydraulic conductivities were calculated from these properties. Unsaturated hydraulic conductivities are very difficult, if not impossible, to measure in the laboratory at the very dry in situ water contents (Section 3.4.1) found in the vadose zone beneath the Area 5 RWMS.

3.3.1 Saturated Hydraulic Conductivity

Saturated hydraulic conductivity measurements were conducted on one core segment from each core run. Saturated hydraulic conductivity profiles are presented in Figure 3.21, descriptive statistics are summarized in Table 3.3 (possible outliers were retained in computation of the descriptive statistics), and tabular data are listed in Appendix D. There are no obvious trends as a function of depth, and these values are typical of sandy alluvial

Figure 3.14 Depth profiles of particle density for core samples from the Science Boreholes.

Figure 3.15 Depth profiles of calculated and water-saturated porosity for core samples from AP-1.

Figure 3.16 Depth profiles of calculated and water-saturated porosity for core samples from AP-2.

Figure 3.17 Depth profiles of calculated and water-saturated porosity for core samples from RP-1.

Figure 3.18 Depth profiles of calculated and water-saturated porosity for core samples from RP-2.

Figure 3.19 Depth profiles of calculated and water-saturated porosity for core samples from NN-1.

Figure 3.20 Depth profiles of calculated and water-saturated porosity for core samples from NW-1.

Figure 3.21 Depth profiles of saturated hydraulic conductivity for core samples from the Science Boreholes.

deposits (Freeze and Cherry 1979). Statistical analyses have indicated hydraulic conductivity might be log-normally distributed. A case could be made for presenting the geometric means and standard deviations; rather than the arithmetic means, standard geometric means, and standard deviations; or rather than arithmetic means and standard deviations. However, arithmetic means and standard deviations were used to facilitate comparison with other values reported in the literature.

3.3.2 Moisture-Retention Relations

Following saturated hydraulic conductivity measurements, core samples were subjected to moisture-retention measurements. These measurements (curves) are presented in graphical form in Figures 3.22 to 3.27; tabular data are listed in Appendix D. Core interval depths for each curve are not identified in these plots. The general shape of these moisture-retention curves is (without exception) typical of coarse-grained deposits (Hillel 1980).

Moisture-retention data were fitted to the van Genuchten (1978, 1980) parameterization of the water-retention curve described by:

$$\theta = \theta_r + (\theta_s - \theta_r) [1 + (-\alpha h)^n]^{-m}$$

where θ is volumetric water content (cm^3/cm^3), θ_s is the saturated volumetric water content, θ_r is the residual volumetric water content, h is matric potential (cm), α (cm^{-1}) and n (dimensionless) are curve-fitting parameters, and m is $(1-1/n)$.

A nonlinear, least squares computer code is used to calculate the curve-fitting parameters α and n , and residual saturation, θ_r (van Genuchten 1978). These parameters are tabulated in Appendix D for core samples, and summary descriptive statistics are given in Table 3.6. There is some evidence α is log-normally distributed. The arithmetic mean and standard deviation were reported to facilitate comparison with other values reported in the literature. Observed values of α are consistent with values calculated for a number of coarse-grained materials (van Genuchten 1978).

3.3.3 Unsaturated Hydraulic Conductivity

Unsaturated hydraulic conductivity, $K(S)$, of core samples are generally calculated from moisture-retention data and saturated hydraulic conductivity rather than being experimentally measured. This is primarily because experimental measurements, especially at low water contents, are extremely difficult, if not impossible to obtain. The equation used to calculate

Figure 3.22 Composite moisture-retention curve data for core samples from AP-1.

Figure 3.23 Composite moisture-retention curve data for core samples from AP-2.

Figure 3.24 Composite moisture-retention curve data for core samples from RP-1.

Figure 3.25 Composite moisture-retention curve data for core samples from RP-2.

Figure 3.26 Composite moisture-retention curve data for core samples from NN-1.

Figure 3.27 Composite moisture-retention curve data for core samples from NW-1.

K(S) in this program (van Genuchten 1978, 1980) is derived by substituting the van Genuchten moisture-retention, curve-fitting parameters into the Mualem (1976) model of unsaturated hydraulic conductivity to obtain the following:

$$K(S) = K_s S^{1/2} [1 - (1 - S^{1/m})^m]^2 \quad (1)$$

where K_s is the saturated hydraulic conductivity, m is as in the van Genuchten water-retention curve, and S is effective saturation as defined by:

$$S = (\theta - \theta_r) (\theta_s - \theta_r)^{-1} \quad (2)$$

The resulting K(S) data, which have been converted to K(θ) data through Equation 2, are illustrated in Figures 3.28 to 3.33. The parameters required to calculate unsaturated hydraulic conductivities for core samples are summarized in Appendix D.

These plots illustrate that unsaturated hydraulic conductivities decrease rapidly with decreasing water contents. At the low, in situ formation water contents (Section 3.4.1), the unsaturated hydraulic conductivities are many orders of magnitude less than saturated hydraulic conductivities.

3.4 Hydrologic Conditions

Hydrologic conditions are expressed by parameters, such as water content and water potential, which can vary over time. Water content is defined as the amount of liquid water in a specified quantity of soil. The gradient of water potential values (i.e., the difference in value between two points divided by the distance separating these points) is one of the primary forces which drive the movement of liquid water.

3.4.1 Water Content

Water content on a weight basis (gravimetric water content) was determined for both drill cuttings and core samples. Water content on a volume basis (volumetric water content) was determined only for core samples. These data are in tabular form in Appendix D. Descriptive statistics for core samples are presented in Table 3.3 and samples of drill cuttings are presented in Table 3.4. Water content for both samples of core and drill cuttings from the alluvium are plotted vs. depth in Figures 3.34 to 3.39.

Figure 3.28 Fitted unsaturated hydraulic conductivity functions for core samples from AP-1.

Figure 3.29 Fitted unsaturated hydraulic conductivity functions for core samples from AP-2.

Figure 3.30 Fitted unsaturated hydraulic conductivity functions for core samples from RP-1.

Figure 3.31 Fitted unsaturated hydraulic conductivity functions for core samples from RP-2.

Figure 3.32 Fitted unsaturated hydraulic conductivity functions for core samples from NN-1.

Figure 3.33 Fitted unsaturated hydraulic conductivity functions for core samples from NW-1.

Figure 3.34 Depth profiles of water content for samples of core and drill cuttings from AP-1.

Figure 3.35 Depth profiles of water content for samples of core and drill cuttings from AP-2.

Figure 3.36 Depth profiles of water content for samples of core and drill cuttings from RP-1.

Figure 3.37 Depth profiles of water content for samples of core and drill cuttings from RP-2.

Figure 3.38 Depth profiles of water content for samples of core and drill cuttings from NN-1.

Figure 3.39 Depth profiles of water content for samples of core and drill cuttings from NW-1.

The mean gravimetric water content of alluvial drill cuttings samples was approximately 0.5 percent lower than the gravimetric water content of core samples. This is because samples of the drill cuttings were subjected to drying by air drilling fluid as they were lifted out of the borehole.

A comparison of the alluvial volumetric water content profiles (Figures 3.34 to 3.39) illustrates that water content values were remarkably low and constant. The only noticeable trend is a possible slight increase in water content from the ground surface to a depth of approximately 30.5 m (100 ft). The mean water contents of these plots correspond to the steeply sloping portion of the moisture-retention curves, shown in Figures 3.22 to 3.27, indicating that in situ alluvial materials exist in a highly drained state. This suggests that little if any water is presently draining from the system. Both the unsaturated hydraulic conductivity data discussed previously (Section 3.3.3) and the water potential data discussed below (Section 3.4.2) support this picture of the system.

3.4.2 Water Potential

Depth profiles of water potential data from geologic samples are in tabular form in Appendix D and descriptive statistics are given in Table 3.3. Water potential measurements were made on one core sample from each run.

The hydraulic potential gradient, which is the total driving force, can be defined as the gravitational potential gradient plus the water potential gradient minus the osmotic potential gradient. In the upper 30 m (100 ft), the water potential gradient is the principal driving force moving liquid water because other potential gradients affecting water movement are small when compared to the water potential gradient. For example, the water potential gradient (difference in water potential between points divided by the distance between the points) near the ground surface is very large; the osmotic component of this potential is comparatively small based on dissolved salt data; and the gravitational potential gradient is equal to unity (1.0) by definition.

Water potential depth profile data (distance is positive downwards), presented in Figure 3.40, show a positive gradient (upward flow) to at least a depth of approximately 30.5 m (100 ft). These data, coupled with unsaturated hydraulic conductivity data (Figures 3.28 to 3.33), indicate that liquid water is probably moving upward very slowly in this region.

Environmental tracer data from the Science Boreholes (Section 3.5) suggest that the upward movement of liquid water, indicated by water potential measurements, results from evaporation at least in the upper 30.5 m (100 ft). At greater depths, the water potential gradient appears to be nearly zero. This is illustrated in Figure 3.40 and supported by descriptive statistics (Table 3.3) for alluvium beneath 30.5 m.

The nearly zero water potential gradient at depth implies that the unit gravitational gradient is the main driver of liquid water movement and is equal to the hydraulic gradient. It follows then (from Darcy's law assuming one-dimensional flow) that the flux of water can be derived from knowledge of the unsaturated hydraulic conductivity at the water content of interest. For

Figure 3.40 Depth profiles of water potential for core samples from the Science Boreholes.

example, unsaturated hydraulic conductivity or water flux values (Figures 3.28 to 3.33) are in all cases below 1×10^{-10} cm/s (1×3.9^{-11} in/s) at the mean borehole water content. These exceedingly low values indicate that the downward rate of liquid water movement is nearly zero. Similar results and conclusions were reached in a previous study (REECo 1994).

3.5 Environmental Tracers

Environmental tracers provide a method, independent of the hydraulic parameters mentioned above, for estimating water movement in the vadose zone. The basic premise of this method is that infiltrating water (from precipitation and runoff) contains dissolved natural and man-made tracers that travel with the liquid water as it moves into and through the vadose zone. The concentrations of these tracers are measured with depth, and the analysis of the profile data yields information concerning the history of water movement through the unsaturated zone. Further, it is assumed that formation materials do not contribute to the concentrations of these tracers. In the following sections, only general qualitative observations will be made concerning the tracer profile data. More quantitative analyses and interpretations will be presented in the future in peer-reviewed publications.

3.5.1 Chloride-Bromide Profiles

Chloride and bromide ions can serve as tracers because their negative charge discourages sorption with negatively charged mineral surfaces at solution values commonly found in alkaline-desert soils and alluvium. It is generally assumed that chloride and bromide ions enter the soil primarily as a dissolved component of precipitation. These ions also enter the soil in probably lesser and more variable amounts as a solid component (salts) of wind-blown dust which can dissolve as precipitation falls on the ground surface. These dissolved ions then move into the soil as a component of the liquid soil water. As water evaporates from the soil, the concentration of these ions increases in the soil water. Plots of the concentration of these ions vs. depth provides an indication of the relative amount of evaporation and infiltration accumulating over time.

Chloride and bromide concentrations were measured on selected drill cuttings and core samples. Descriptive statistics for the chloride-bromide ratios for core samples and drill cuttings are presented in Table 3.3 and Table 3.4, respectively. Tabular data are listed in Appendix D.

Depth profiles of chloride and bromide concentrations (per unit dry weight of soil) for selected Science Boreholes are illustrated in Figures 3.41 and 3.42. These concentration data will be converted to a per unit volume basis when quantitative analysis of the data is conducted. Both samples of core and drill cuttings were used to generate depth profile plots for NW-1 and NN-1 in Figures 3.43 and 3.44 because only four core samples were available from each of these boreholes. Depth profiles of chloride concentrations for samples of core and drill cuttings from these two N-series boreholes indicate good agreement. Similar agreement is found between bromide concentration data in drill cuttings and core samples from these boreholes.

Figure 3.41 Depth profiles of dry soil chloride concentrations for core samples from the Science Boreholes.

Figure 3.42 Depth profiles of dry soil bromide concentrations for core samples from the Science Boreholes.

Figure 3.43 Depth profiles of dry soil chloride concentrations for samples of core and drill cuttings from NW-1 and NN-1.

Figure 3.44 Depth profiles of dry soil bromide concentrations for samples of core and drill cuttings from NW-1 and NN-1.

Depth profiles of chloride-bromide ratios in both drill cuttings and core samples are presented in Figures 3.45. The ratios for the AP and RP boreholes are relatively constant throughout most of the profile reflecting relatively constant ratios found in precipitation and indicating good precision in laboratory measurements. The lower ratios for the N series boreholes, which were purposely located in swales (runoff areas), suggest that the source of infiltrating water may have been a mix of precipitation and runoff.

The relatively high concentrations of chloride and bromide in the shallow subsurface (Figures 3.41 to 3.44) suggest that evaporation rates are high compared to the downward movement of water under the present climate. The very low concentrations of chloride at depth suggest that this water entered the system under much wetter past climate conditions when recharge rates compared to evaporation rates were much higher than present rates (Conrad 1993). These data support the general conclusion drawn previously from hydraulic data (Section 3.4.2); that is, the net downward movement of water under the present climate is very low.

The large differences in the shapes of the chloride (and bromide) profiles in the upper portions of the Science Boreholes may be due to a number of factors. Differences in the amount of surface water runoff at each Science Borehole site will definitely affect the amount of infiltration, and ultimately, the accumulation of chloride and bromide. The differences are most pronounced in the NW-1 and NN-1 boreholes which were located in swales compared to the AP and RP boreholes which do not appear to be located in swales. Note that the latter boreholes were located in disturbed areas making it difficult to reconstruct the original surface topography.

In addition, variations in plant communities and their rooting habits affect relative amounts of evapotranspiration and infiltration, and therefore chloride and bromide concentrations. Finally, the relative rates of aggradation may play an important role in affecting the concentration profiles. However, variations in plant communities and rates of aggradation are not expected to be significant between these relatively closely spaced boreholes.

3.5.2 Stable Isotope Profiles

The stable isotopes of hydrogen (D and H) and oxygen (^{18}O and ^{16}O) are excellent tracers of water movement because they are a component of the water molecule itself. Stable isotopes are used in unsaturated zone studies to infer the source of soil water and to determine if evaporation has occurred. Results are reported as a ratio of heavy-to-light isotopes (D/H and $^{18}\text{O}/^{16}\text{O}$) in delta notation (δ) relative to Standard Mean Ocean Water (SMOW) (Craig 1961a).

Fractionation (a change in the ratio) occurs during phase change processes. Therefore, condensation and evaporation processes are both reflected in the isotopic ratios. The condensation of precipitation from the atmosphere occurs under very nearly thermodynamic,

Figure 3.45 Depth profiles of dry soil chloride-bromide ratios for core samples from the Science Boreholes.

equilibrium conditions, resulting in a linear relationship between hydrogen and oxygen isotopes in worldwide precipitation known as the meteoric water line (MWL) (Craig 1961a). Evaporation of water generally occurs under nonequilibrium conditions, and fractionation of the oxygen isotopes is greater than that of hydrogen isotopes. The water remaining behind in the evaporation process thus develops an isotopic composition that plots to the right of the MWL. Descriptive statistics of core samples are summarized in Table 3.3. Depth profiles for these boreholes are presented in Figure 3.46. Stable isotope data from selected Science Borehole core samples are presented in Appendix D. In general, these profiles show more enrichment of heavy isotopes in the upper vadose zone, suggesting that shallow water has been subjected to more evaporation. Less enrichment is found in one of the boreholes located in swales (NW-1 and NN-1). This finding is consistent with the chloride-bromide data discussed previously. However, more enrichment is found in NN-1 which is also located in a swale. The reason for the differences is not known.

A plot of oxygen isotope ratios from selected core samples, with the MWL for reference, is shown in Figure 3.47. The shallow samples plot to the right of the MWL on a line with a smaller slope. This slope is consistent with the range found by Allison (1982) in experiments of water evaporating from sand columns and strongly supports the hypothesis (Section 3.4.2) that evaporation rates are high relative to the downward rate of water movement in the upper vadose zone under the present climate (REECo 1994). The stable isotope plots for Science Boreholes mentioned above are similar to plots obtained from previous studies (REECo 1993b; REECo 1994).

3.5.3 Soluble Sulfate

Sulfate is not generally considered an environmental tracer because it is far less mobile than chloride and bromide for a number of reasons including the lower solubility of sulfate salts. Moreover, there are many potentially important sources of sulfate, in addition to rainfall and runoff, which complicate the interpretation of depth concentration profile data. These sources include a number of common secondary minerals (e.g., gypsum) which occur in soils, alluvium, and source rock. Even with these complicating factors, sulfate depth profile data can provide useful additional information concerning the relative importance of evaporation and infiltration processes under the present arid climate, as well as under a previous more humid climate. These data are discussed below.

Soluble sulfate measurements were made on core samples from AP-1. The depth profiles of sulfate data from the AP-1 core samples are presented in Figure 3.48; tabular data for core samples are presented in Appendix D. This profile is somewhat similar in shape to chloride and bromide profiles (Section 3.5.1); however, the depth (approximately 30.5 m [100 ft]) at which these concentrations decrease to lower values is much shallower for sulfate. These differences are probably due to the lower mobility of the sulfate anion resulting (at least in part) from the typically lower solubility of sulfate salts compared to chloride and bromide salts. This interpretation is supported further by descriptive statistics for sulfate concentrations below 30.5 m (Table 3.3).

Figure 3.46 Depth profiles of stable isotopes for core samples from the Science Boreholes.

Figure 3.47 Comparison of measured stable isotopes for core samples from the Science Boreholes with stable isotope data for the global MWL.

Figure 3.48 Depth profile of soluble sulfate for core samples from AP-1.

In summary, this sulfate concentration profile supports the picture of water movement in the vadose zone suggested by the analyses of the other environmental tracers. Specifically, this profile implies that under the present arid climate, the liquid water which moves into the upper vadose zone migrates out of the vadose zone primarily by vapor flow in response to a high evaporative demand.

4.0 FIELD TESTING METHODS AND RESULTS

4.1 Borehole Geophysical Logging

Neutron-moisture meter logging was conducted in AP and RP boreholes prior to the removal of the CAU drive casing. The CAU drive casing was left in place in the N boreholes, and quarterly neutron-moisture logging will be initiated. Methods and data for neutron-moisture logging in the Science Boreholes will be presented in separate reports which correlate results from core data and demonstrate that alluvial deposits are uniformly very dry to the total depth of the boreholes.

4.2 Other In Situ Measurements

Methods and data for the other in situ testing and monitoring in Science Boreholes will be presented in separate reports. Results of air permeability tests conducted in AP boreholes will be presented in a report which examines the spatial variability of the measurements. Temperature, barometric pressure, and radon concentration monitoring data obtained from the RP boreholes will be presented in a report describing the relative importance of advective and diffusive gas-flow processes in the upper vadose zone.

5.0 SUMMARY

Eight Science Boreholes have been drilled and completed in the vicinity of the Area 5 RWMS to meet data needs mandated by regulatory requirements applicable to the disposal of low-level, mixed, and high-specific-activity waste at this site. This series of boreholes was specifically designed to characterize the near-surface gas transport properties and allow monitoring of water content changes over time in the upper vadose zone.

This report has described the methods and results of drilling, geologic sample collection, field geologic descriptions, laboratory testing of geologic samples, borehole and vadose zone monitoring system completion, and geophysical logging. These results (data) are required to understand and model flow and transport processes both in the vadose zone and the uppermost aquifer. This report has provided only qualitative analyses and preliminary interpretations.

Some of the important findings of this study are:

- The alluvial deposits penetrated by each Science Borehole are lithologically homogeneous and do not contain layers of secondary carbonate.
- The alluvial deposits are virtually homogeneous with respect to particle size distribution and are primarily composed of sands with some gravel and small amounts of silt and clay.
- Hydrologic properties including porosity, saturated hydraulic conductivity, moisture-retention relations, and unsaturated hydraulic conductivity are typical of coarse-grained materials.
- Alluvial deposits are very dry near the surface and increase in water content only slightly with depth.
- Water potential measurements on core samples show a large positive potential gradient (water moves upward) in the upper 30.5 m (100 ft) in each borehole, and a nearly zero potential gradient throughout the remaining portion of each borehole.
- Unsaturated hydraulic conductivity data, together with water potential data, indicate that very little liquid flow is occurring (if any) throughout the alluvial deposits, and the direction of liquid flow is upward in the upper portion of the vadose zone. Vapor movement is probably the dominant mechanism of water movement in this region.
- Environmental tracer measurements of chloride, bromide, sulfate, and hydrogen and oxygen stable isotope concentrations in soil water vs. depth provide strong evidence that the direction of movement for both liquid water and vapor in the upper vadose zone is upward in response to the evaporative demand of the present arid climate.
- Vadose zone monitoring instruments and equipment, which were stemmed in place around the central casing in selected Science Boreholes, are being used to make in situ measurements of important hydrologic and pneumatic parameters and to monitor changes in these parameters over time.

6.0 REFERENCES

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APPENDICES

APPENDIX A

Drilling Information

Appendix A.1 Chronological drilling summary for AP-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
8-25			Kickoff meeting with Boyles Bros. REEC Co Safety. Contracts and SPS. Schramm, T685H/DHH Rotadrill Setup on AP-1. Trench excavated for electrical hookup to logging trailer.
8-26			Moved logging trailer to site and unloaded equipment.
8-27			Picked up casing shoe, steam cleaned equipment, placed liner under rig.
8-30			Placed electrical conduit in trench. Steam cleaned casing, fabricated casing seal.
8-31	12.5	1,2,3,4,5	Advanced casing with Odex 140 system. Used Mission SD-4 hammer to drive 2.5' and 5' core barrels to 15 ft.
9-1	25	6,7,8,9	Continuous core runs. Partly backfilled electrical trench.
9-2	49	10,11,12,13	Continuous core runs to 30' and at 10' intervals thereafter.
9-3	79	14,15,16	Core runs at 10' intervals. Repaired exhaust leak on rig muffler.
9-7	99	17	Skipped core interval due to caving conditions near 89'.
9-8	109	18	Fabricated yoke cradle for bull hose. Electrical hooked up to trailer. New hydraulic core extruder arrived.
9-9	149	19,20,21,22	Had to cut off sampler from top sub with torch.
9-10	159	23	
9-13	209	24,25	
9-14	259	26,27	
9-15	275	28,29	Drilled to T.D. Moved off hole.

Appendix A.2 Chronological drilling summary for AP-2.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
9-15			Set up on AP-2.
9-16			Fabricated support and connections for secondary cyclone. Cleaned casing and drill rods.
9-17	10	1,2,3,4,5	Continuous core runs to 12.5'.
9-20	49	6,7,8,9,10,11,12,13,14	Continuous core runs to 30' and at 10' intervals thereafter.
9-21	109	15,16,17,18,19	Core runs at 10' intervals.
9-22	149	20,21,22,23	Core runs at 10' intervals.
9-23	159	24,25	Sampler broke off in hole at 161.5'.
9-24	179	26	Retrieved core barrel with overshot barrel.
9-27	239	27,28,29	
9-28	275	30,31	Drilled to T.D. Moved logging trailer.

Appendix A.3 Chronological drilling summary for RP-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
10-1			Set up on RP-1.
10-4	20	1,2,3,4,5,6,7,8	Continuous core runs.
10-5	49	9,10,11,12,13,14,15	Continuous core runs to 32.5ft and at 10ft intervals thereafter. Possible carbonate paleosol at 60ft.
10-6	89	16,17,18,19	Core runs at 10ft intervals.
10-7	139	20,21,22,23	Core runs at 10ft intervals.
10-8	150	24,25	Drilled to T.D.
10-11			Moved off hole.

Appendix A.4 Chronological drilling summary for RP-2.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
10-11	10	1,2,3,4,5	Set up on RP-2. Continuous core runs to 12.5ft.
10-12	27.5	6,7,8,9,10,11,12	Continuous core runs to 30ft.
10-13	62.5	13,14,15,16,17,18	Took continuous core runs from 57.5 - 65ft to identify possible paleosol encountered in RP-1.
10-14	109	19,20,21,22	Core runs at 10ft intervals.
10-15	150	23,24,25,26,27	Drilled to T.D. Core runs at 10ft intervals.
10-18			Moved rig off hole.

Appendix A.5 Chronological drilling summary for NN-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
10-27			Set up on NN-1.
10-28	39	1,2	
11-2	157.5	3	
11-3	200	4	Drilled to T.D.

Appendix A.6 Chronological drilling summary for NE-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
9-29	39	1,2	Set up on NE-1.
9-30	179	3,4	
10-1	200		Drilled to T.D. Moved off hole.

Appendix A.7 Chronological drilling summary for NW-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
10-22			Set up on NW-1.
10-25	101.5	1,2,3	
10-26	200	4	Drilled to T.D.
10-27			Moved rig off hole.

Appendix A.8 Chronological drilling summary for NS-1.

DATE 1993	CASING DEPTH (ft)	CORE RUN NO.	ACTIVITIES & PROBLEMS
10-18			Set up on NS-1.
10-19	77.5	1,2	
10-20	177.5	3	
10-21	200	4	Drilled to T.D.
10-22			Rig moved off hole.

APPENDIX B

Core and Drill Cuttings Sample Description Data

Appendix B.9 Drill cuttings log data for AP-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. SAND SIZE ³	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0.0-2.5	SM	10-15	¼	F	—	M-S	M
2.5-5.0	SM	5	¼	F	1.98	M	M
5.0-7.5	SM	15	½	F-M	2.47	M	D
7.5-10.0	SW-SM	30	¾	C	2.51	M	D
10.0-12.5	SW-SM	30	½	C	3.14	M	D
12.5-15.0	SM	10	¼	F	4.14	M	D
15.0-17.5	SM	10	¼	F	3.39	M	D-M
17.5-20.0	SM	15	¼	F	2.73	S	D-M
20.0-22.5	SM	10	¼	F	2.5	M	D-M
22.5-25.0	SM	15	¼	F	1.86	S	D-M
25.0-27.5	SM	25	¾	F-M	3.35	M	D-M
27.5-30.0	SW-SM	25	¼	F-M	1.68	W	D-M
30.0-32.5	SM	10	¼	F	1.26	S	D-M
32.5-35.0	SM	10	¼	F	1.35	S	D-M
35.0-37.5	SM	10	¼	F	1.03	S	D-M
37.5-40.0	SM	15	¾	F	1.19	S	D-M
40.0-42.5	SM	15	¾	F	1.06	S	D-M
42.5-45.0	SM	15	¾	F	1.02	S	D-M
45.0-47.5	SM	10	¾	F	1.06	S	D-M
47.5-50.0	SM	10	¾	F	1.30	S	D-M
50.0-52.5	SM	10	¾	F	1.38	S	D-M
52.5-55.0	SM	10	¾	F	1.93	S	D-M
55.0-57.5	SM	10	¾	F	1.86	S	D-M
57.5-60.0	SM	30	¾	F	1.67	M	D-M
60.0-62.5	SM	10	¾	F	1.50	S	D-M
62.5-65.0	SM	10	¾	F	1.37	S	D-M
65.0-67.5	SM	10	¾	F	1.68	M	D-M
67.5-70.0	SM	15	¼	F	1.8	S	M
70.0-72.5	SM	15	¼	F	1.6	S	M
72.5-75.0	SM	15	¼	F	1.34	S	M
75.0-77.5	SM	15	¼	F	1.11	S	M
77.5-80.0	SM	10	¼	F	1.23	S	D-M

Appendix B.9 Drill cuttings log data for AP-1 (continued).

80.0-82.5	SM	10	¼	F	1.42	S	D-M
82.5-85.0	SM	10	¼	F	1.34	S	D-M
85.0-87.5	SM	10	¼	F	1.27	S	D-M
87.5-90.0	SM	5	¼	F	1.79	S	D-M
90.0-92.5	SM	40	½	F	1.16	S	D-M
92.5-95.0	SM	10	¼	F-M	1.86	S	D-M
95.0-97.5	SM	10	¼	F	1.31	S	D-M
97.5-100.0	SM	5	¼	VF	1.17	S	D-M
100.0-102.5	SM	5	¼	VF	1.06	S	D-M
102.5-105.0	SM	10	¼	VF	1.00	S	D-M
105.0-107.5	SM	5	¼	VF	1.09	S	D-M
107.5-110.0	SM(SP?)	10	¼	VF	1.37	M	D-M
110.0-112.5	SM	10	¼	VF	1.18	M	D-M
112.5-115.0	SM	10	¼	VF	1.07	M	D-M
115.0-117.5	SM(SP?)	10	¼	VF	1.14	M	D-M
117.5-120.0	SM	10	¼	F	1.27	S	D-M
120.0-122.5	SM	10	¼	F	1.53	S	D-M
122.5-125.0	SM	5	¼	VF	1.64	S	D-M
125.0-127.5	SM	5	¼	VF	1.54	S	D-M
127.5-130.0	SM	30	½	VF	1.37	M	M
130.0-132.5	SW-SM	10	½	F	1.23	M	M
132.5-135.0	SW-SM	25	½	F	1.47	M	M
135.0-137.5	SW-SM	25	½	F	1.45	M	M
137.5-140.0	SM	20	½	F	1.40	W-M	M
140.0-142.5	SM	5	¾	VF	1.27	M	M
142.5-145.0	SM?	15	¾	F	1.11	S	M
145.0-147.5	SM?	15	¾	F	1.45	S	M
147.5-150.0	SM	20	½	F	1.56	M	M
150.0-152.5	SM	20	½	F	1.94	M	M
152.5-155.0	SW-SM	40	½	F-C	1.66	S	M
155.0-157.5	SW-SM	40	½	F-C	1.92	M	M
157.5-160.0	SM	30	¾	F	1.43	S	M
160.0-162.5	SM	20	¾	F	1.65	M	M
162.5-165.0	SM?	20	¾	F	1.98	M	M

Appendix B.9 Drill cuttings log data for AP-1 (continued).

165.0-167.5	SM?	20	$\frac{3}{8}$	F	1.33	S	M
167.5-170.0	SM?	20	$\frac{3}{8}$	F	1.78	NONE	M
170.0-172.5	SM?	20	$\frac{3}{8}$	F	2.12	S	M
172.5-175.0	SM	20	$\frac{3}{8}$	F	2.07	S	M
175.0-177.5	SW-SM	40	$\frac{3}{8}$	F-C	2.14	NONE	D-M
177.5-180.0	SW	30	$\frac{3}{8}$	F-C	2.22	W	D-M
180.0-182.5	SW-SM	25	$\frac{1}{2}$	F-C	1.97	W	D-M
182.5-185.0	SM	15	$\frac{3}{8}$	F	1.92	M	D-M
185.0-187.5	SW-SM	15	$\frac{3}{8}$	F-C	1.76	M	D-M
187.5-190.0	SW-SM	30	$\frac{1}{2}$	F-C	1.45	W	D-M
190.0-192.5	SW-SM	30	$\frac{1}{2}$	F-C	2.35	M	D-M
192.5-195.0	SW-SM	35	$\frac{1}{2}$	F-C	2.10	W-M	D-M
195.0-197.5	SM	20	$\frac{1}{2}$	F-C	1.25	M	D-M
197.5-200.0	SW-SM	30	$\frac{1}{2}$	F-C	2.12	W-M	D-M
200.0-202.5	SW-SM	20	$\frac{1}{2}$	F-C	2.63	W-M	D-M
202.5-205.0	SM	20	$\frac{1}{2}$	F-C	1.57	W-M	D-M
205.0-207.5	SW-SM	30	$\frac{1}{2}$	F-C	1.20	M	D-M
207.5-210.0	SM	25	$\frac{1}{2}$	F	2.13	W-M	D-M
210.0-212.5	SM	20	$\frac{1}{2}$	F	2.06	M	M
212.5-215.0	SW-SM	30	$\frac{1}{2}$	F-C	1.82	W-M	D-M
215.0-217.5	SW-SM	20	$\frac{1}{2}$	F-C	1.75	W-M	D-M
217.5-220.0	SW-SM	20	$-\frac{1}{2}$	F-C	2.17	M	D-M
220.0-222.5	SM	10	$-\frac{1}{4}$	F	1.20	S	M
222.5-225.0	SM	25	$\frac{3}{8}$	F	1.65	M-S	M
225.0-227.5	SM	25	$\frac{3}{8}$	F	2.05	S	M
227.5-230.0	SW-SM	30	$\frac{3}{8}$	F-C	2.52	M	D-M
230.0-232.5	SM	20	$\frac{3}{8}$	F-C	2.65	W-M	M
232.5-235.0	SW-SM	20	$\frac{3}{8}$	F-C	2.04	W-M	D-M
235.0-237.5	SW-SM	30	$\frac{1}{2}$	F-C	2.18	W	D-M
237.5-240.0	SM	10	$\frac{1}{4}$	F	2.35	M	D-M
240.0-242.5	SW-SM	25	$\frac{3}{8}$	F-C	2.20	M	D-M
242.5-245.0	SM	10	$\frac{1}{4}$	F	1.81	S	D-M
245.0-247.5	SM	15	$\frac{3}{8}$	F	1.81	S	M
247.5-250.0	SW	30	$\frac{3}{8}$	F-C	1.73	N	D-M

Appendix B.9 Drill cuttings log data for AP-1 (continued).

250.0-252.5	SW-SM	10	¼	F-C	1.85	W	D-M
252.5-255.0	SM	15	¾	F-C	1.54	S	M
255.0-257.5	SM	15	¾	F	1.86	M	M
257.5-260.0	SW-SM	15	¼	F-C	2.86	M	D-M
260.0-262.5	SM	20	¾	F-C	2.23	M-S	M
262.5-265.0	SM	20	½	F-C	2.26	S	M
265.0-267.5	SM-SP	10	¼	V-F	1.70	S	M
267.5-270.0	SM	10	¼	F	2.10	S	M
270.0-272.5	SW-SM	20	¾	F-C	2.21	W-M	D-M
272.5-275.0	SW-SM	25	¾	F-C	2.41	W	D-M

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.10 Drill cuttings log data for AP-2.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC ⁴ SUSCEPTI- BILITY	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM-SP	—5	—¼	V-F	—	W-M	D-M
2.5-5.0	SM-SP	—5	—¼	V-F	1.59	S	M
5.0-7.5	SM-SW	—5	—¼	F	2.20	M-S	D
7.5-10.0	SM-SW	30	—¼	C	2.20	M	D
10.0-12.5	SW	35	—¾	F-C	3.93	W-M	D
12.5-15.0	SM-SW	30	—¾	F-C	2.52	W-M	D
15.0-17.5	SM	10	—¼	F	2.67	S	D-M
17.5-20.0	SM	15	—¼	F	2.65	M	D
20.0-22.5	SM	15	—¼	F	2.14	M	D
22.5-25.0	SM	10	—¼	F	2.06	M	D
25.0-27.5	SM	15	—¼	F	1.90	M	D
27.5-30.0	SW	30	¾	C	1.68	M	D
30.0-32.5	SM	10	¼	F	1.51	M	D
32.5-35.0	SM	10	¼	F	1.46	M	D
35.0-37.5	SM	25	¾	F	1.12	S	D
37.5-40.0	SM	15	¼	F	1.56	M	D
40.0-42.5	SM	10	¼	F	1.55	M	D
42.5-45.0	SM-SW	25	¾	F-C	1.32	S	D
45.0-47.5	SM	15	¾	F	1.34	S	D
47.5-50.0	SM	5	¼	F	1.32	M	D-M
50.0-52.5	SM	5	¼	V,F	1.93	S	D-M
52.5-55.0	SM	5	¼	V,F	1.69	S	D-M
55.0-57.5	SM	15	¾	F	1.91	S	D-M
57.5-60.0	SM-SW	20	¾	F-C	2.29	M	D-M
60.0-62.5	SM	30	—½	F	1.44	S	D-M
62.5-65.0	SM	15	¾	F	1.36	S	D-M
65.0-67.5	SM	10	—¼	F	1.62	S	D-M
67.5-70.0	SM-SW	10	¼	F-C	1.82	M	D-M
70.0-72.5	SM	15	—¾	F	1.48	M-S	D-M
72.5-75.0	SM	15	¾	F	1.42	M-S	D-M
75.0-77.5	SM	10	¼	F	1.09	S	D-M
77.5-80.0	SM	10	¼	F	1.21	M-S	D-M

Appendix B.10 Drill cuttings log data for AP-2 (continued).

80.0-82.5	SM	15	¼	F	1.20	M-S	D-M
82.5-85.0	SM-SW	25	¾	F-C	1.44	M-S	D-M
85.0-87.5	SM	10	¼	VF	1.50	M-S	D-M
87.5-90.0	SM	15	¾	VF	1.55	M	D-M
90.0-92.5	SM	15	¾	F	1.88	S	D-M
92.5-95.0	SM	15	¾	F	1.78	S	D-M
95.0-97.5	SM	15	¾	F	1.36	S	D-M
97.5-100.0	SM	15	¼	F	1.19	M-S	D-M
100.0-102.5	SM	10	¼	F	1.26	M-S	D-M
102.5-105.0	SM	10	¼	VF	1.03	S	D-M
105.0-107.5	SM	10	¼	F	1.38	S	D-M
107.5-110.0	SM	5	¼	F	1.41	M-S	M
110.0-112.5	SM	5	¼	F	1.40	S	M
112.5-115.0	SM	10	¼	F	1.22	S	M
115.0-117.5	SM	10	¼	F	1.46	S	M
117.5-120.0	SM	—	—	F	1.39	M	M
120.0-122.5	SM-SW	10	—	F-C	1.36	M	M
122.5-125.0	SM	—	—	F	1.34	S	M
125.0-127.5	SM	—	—	F	1.22	S	M
127.5-130.0	SM-SM	30	½	F-C	1.34	M-S	M
130.0-132.5	SM	20	¾	F	1.21	M-S	M
132.5-135.0	SM	25	¾	F	1.54	M-S	M
135.0-137.5	SM	25	¾	F	1.32	M-S	M
137.5-140.0	SM	20	¾	F	1.38	M	M
140.0-142.5	SM	10	¼	VF	1.05	S	M
142.5-145.0	SM	15	¾	VF	1.31	S	M
145.0-147.5	SM-SW	30	¾	F-C	1.36	S	M
147.5-150.0	SM	10	¼	F	1.59	S	M
150.0-152.5	SM	10	¼	F	1.40	S	M
152.5-155.0	SM	10	¼	F	1.64	S	M
155.0-157.5	SM	10	¼	F	1.64	S	M
157.5-160.0	SM	25	¾	VF	1.95	S	M
160.0-162.5	SM	25	¾	VF	1.56	S	SM
162.5-165.0	SM	25	¾	VF	1.50	S	SM

Appendix B.10 Drill cuttings log data for AP-2 (continued).

165.0-167.5	SM	10	¼	VF	1.78	S	SM
167.5-170.0	SM	10	¼	VF	1.94	S	SM
170.0-172.5	SM	10	¼	VF	1.91	S	SM
172.5-175.0	SM	30	¾	VF	1.95	S	SM
175.0-177.5	SM-SW	25	¼	M-C	2.20	M	SM
177.5-179.0	SM-SW	25	¼	M-C	1.87	M	SM
179.0-180.0	GP	90	½	C	2.30	NONE	D
180.0-182.5	SM	30	¾	C	1.76	M	D-M
182.5-185.0	SM	15	¾	C	1.47	M	BRN, M
185.0-187.5	SM-SW	30	¾	F-C	2.14F	W-M	D-M
187.5-190.0	SM-SW	30	¾	F-C	2.26	M	D-M
190.0-192.5	SM-SW	40	½	F-C	2.19	M	D-M
192.5-195.0	SM-SW	30	½	F-C	2.16	W	D-M
195.0-197.5	SM-SW	30	½	F-C	2.17	W-M	D-M
197.5-200.0	SW-SM	20	½	F-C	1.83	W	D-M
200.0-202.5	SW-SM	25	½	FC	1.79	W	D-M
202.5-205.0	SM	10	¾	F	1.89	S	M
205.0-207.5	SM	20	¾	F	1.67	M	M
207.5-210.0	SW-SM	35	½	F-C	1.70	M	D-M
210.0-212.5	SM	25	¾	F	1.69	M-S	M
212.5-215.0	SM-SW	30	½	F-C	2.02	M	D-M
215.0-217.5	SM	20	¾	F	1.79	M	D
217.5-220.0	SM	30	¾	F	1.83	W-M	M
220.0-222.5	SM	5	¼	F	1.75	W-M	M
222.5-225.0	SM	30	¾	F	1.50	W	M
225.0-227.5	SM	20	¾	F	2.05	M	M
227.5-230.0	SW	40	¾	F-C	2.42	W	D-M
230.0-232.5	SM	15	¼	F	2.20	M	M
232.5-235.0	SM-SW	25	¾	F-C	2.43	M	D-M
235.0-237.5	SM	30	½	F	2.61	M-S	M
237.5-240.0	SW-SM	30	-½		2.06	W	P-M
240.0-242.5	SM	25	¾		1.35	W	D-M
242.5-245.0	SM	10	¼		1.84	M	BRN, M
245.0-247.5	SM	10	¼		1.58	M	BRN, M

Appendix B.10 Drill cuttings log data for AP-2 (continued).

247.5-250.0	SM	25	$\frac{3}{8}$		1.82	W	D-M
250.0-252.5	SM	25	$\frac{3}{8}$		1.63	W	D-M
252.5-255.0	SM-SW	30	$\frac{3}{8}$		2.18	W	D-M
255.0-257.5	SM-SW	30	$\frac{3}{8}$		1.99	M	D-M
257.5-260.0	SW-SM	40	$-\frac{1}{2}$	F-C	2.22	W	D-M
260.0-262.5	SM	10	$\frac{1}{4}$	F	2.32	M	M
262.5-265.0	SM	10	$\frac{1}{4}$	F	2.19	M	M
265.0-267.5	SM-SW	15	$\frac{1}{4}$	F-C	2.27	W	D-M
267.5-270.0	SP-SM	10	$\frac{3}{8}$	F	2.19	S	M
270.0-272.5	SM	20	$\frac{3}{8}$	F	2.38	M	M
272.5-275.0	SP	25	$\frac{1}{4}$	C	2.40	W	D-M
272.5-275.0	SP	25	$\frac{1}{4}$	C	2.40	W	D-M

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.11 Drill cuttings log data for RP-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM	5	—¼	F	1.22	M	
2.5-5	SM	10	—¼	F	1.23	S	
5-7.5	SM	10	—¼	F	1.66	S	
7.5-10	SM	20	—¼	F-C	2.60	S	
10-12.5	SW-SM	40	¾	F-C	1.88	M	
12.5-15	SM	15	¼	F	2.09	S	
15-17.5	SM	15	¼	F-C	2.01	S	
17.5-20	SM	10	¼	F	1.93	S	
20-22.5	SM	10	¼	F	1.64	M	
22.5-25	SM	5	¼	F	1.50	M-S	
25-27.5	SM	15	¼	F	1.82	M	
27.5-30	SM	15	¼	F	1.34	S	
30-32.5	SM	30	¾	F	1.39	S	
32.5-35	SM	15	¾	F	1.10	S	
35-37.5	SM	25	¾	F	0.94	S	
37.5-40	SM	20	¼	F	1.13	S	
40-42.5	SM	5	¼	VF	1.24	S	
42.5-45	SM	10	¾	F	1.26	S	
45-47.5	SM	10	¾	F	1.19	S	
47.5-50	SM	30	¾	F	1.81	M	
50-52.5	SM	30	¾	F	2.32	M	
52.5-55	SM-SW	40	¾	F-C	1.83	M	
55-57.5	GM-GP	50	½	F-C	1.01	M	
57.5-60	SM	10	¼	F	1.12	M	
60-62.5	SM	5	¼	VF	1.09	M	
62.5-65	SM	10	¾	F	1.35	S	
65-67.5	SM	10	¼	F	1.40	S	
67.5-70	SM	15	¾	F	2.04	S	
70-72.5	SM	5	¼	F	1.65	S	
72.5-75	SM	10	¼	F	1.24	S	
75-77.5	SM	20	¾	F	1.54	S	
77.5-80	SM	15	¼	VF	1.32	S	

Appendix B.11 Drill cuttings log data for RP-1 (continued).

80-82.5	SM	10	¼	F	1.77	S	
82.5-85	SM	20	¾	F	1.85	S	
85-87.5	SM	30	½	F	1.52	S	
87.5-90	SM	15	¾	F	1.67	M	
90-92.5	SM	20	½	F	1.56	S	
92.5-95	SM	20	½	F	1.69	M	
95-97.5	SM-SW?	25	½	F-C	1.67	M	
97.5-100	SM-SW?	10	¾	F-C	1.88	M	
100-102.5	SM-SW?	30	½	F-C	2.32	M	
102.5-105	SM-SW?	20	½	F-C	2.33	M	
105-107.5	SM	15	½	F	1.69	S	
107.5-110	SM	20	¾	C	1.56	M-S	
110-112.5	SM	25	½	C	1.96	M-S	
112.5-115	GP-GM	75	½	C	1.89	M	
115-117.5	GP-GM	75	½	C	1.85	W	
117.5-120	SM-SW	25	¾	F-C	2.06	M	
120-122.5	SM-SW	25	¾	F-C	2.02	M	
122.5-125	SM	35	½	C	1.89	S	
125-127.5	SW-SW	25	½	F-C	1.57	S	
127.5-130	SM-SW	25	¾	F-C	2.75	M	
130-132.5	SM-SW	30	¾	F-C	1.77	M	
132.5-135	SM	25	¾	F	2.03	S	
135-137.5	SM	35	½	F	1.87	S	
137.5-140	SM	15	¼	F	2.53	M	
140-142.5	SM-SW	30	¼	F-C	2.34	W	
142.5-145	SM	20	¾	F	2.02	M	
145-147.5	SM	25	¾	F	1.51	M	
147.5-150	SM-SW	30	¾	F-C	2.28	M	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.12 Drill cuttings log data for RP-2.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM	5	¼	F	1.29	M	M
2.5-5	SM	10	¼	F	—	S	
5.7.5	SM	5	¼	F	1.40	S	
7.5-10	SM	5	¼	F	1.84	S	
10-12.5	SM-SW	10	¼	F-C	1.84	W-M	
12.5-15	SM	5	¼	VF	2.25	M-S	
15-17.5	SM	5	¼	F	1.88	M	
17.5-20	SM	5	¼	VF	1.69	M-S	
20-22.5	SM	5	¼	VF	1.79	S	
22.5-25	SM	10	¼	F	1.91	M-S	
25-27.5	SM	10	¼	F	2.04	M	
27.5-30	SM	20	¼	F	1.35	M	
30-32.5	GM	60	¼	F	1.43	M-S	
32.5-35	SM	5	¼	VF	1.05	S	
35-37.5	SM	5	¼	VF	1.35	S	
37.5-40	SM	5	¾	VF	1.34	S	
40-42.5	SM	5	¼	VF	0.91	S	
42.5-45	SM	15	¼	VF	1.31	M	
45-47.5	SM	10	¼	VF	2.03	M-S	
47.5-50	SM	15	¼	F	1.99	S	
50-52.5	SM	15	¼	F	1.60	S	
52.5-5	SM	25	¾	F	1.34	S	
55-57.5	SM	20	¾	F	1.34	S	
57.5-60	SM-SW	15	¾	F-C	1.57	S	
60-62.5	SM	10	¼	F	1.69	S	
62.5-65	SM	10	¼	F	1.65	M	
65-67.5	SM-SW	25	¾	F-C	1.76	W-M	
67.5-70	SM	20	¾	F	1.46	S	
70-72.5	SM	10	¼	F	1.30	S	
72.5-75	SM	20	¾	F	1.22	VS	
75-77.5	SM-SW	25	¾	F-C	1.31	S	
77.5-80	SM	20	¾	F	1.89	S	

Appendix B.12 Drill cuttings log data for RP-2 (continued).

80-82.5	SW-SM	35	½	F-C	1.52	S	
82.5-85	SM	20	¼	F	1.85	M	
85-87.5	SM	20	¼	F	1.61	S	
87.5-90	SM-SW	20	¾	F-C	1.63	S	
90-92.5	SW	40	¾	F-C	1.78	W	
92.5-95	SM-SW	30	¾	F-C	1.70	S	
95-97.5	SM	20	¾	F	1.86	S	
97.5-100	SM	15	¾	F	2.22	M	
100-102.5	SM	20	½	F	1.89	S	
102.5-105	SM-SW	25	½	F-C	2.18	S	
105-107.5	SM-SW	35	½	F-C	1.41	M	
107.5-110	SM-SW	30	¾	F-C	1.41	M-W	
110-112.5	SM-SW	30	½	F-C	1.78	M	
112.5-115	SM	15	¼	F	1.85	M	
115-117.5	GW-GM	60	½	F-C	1.65	M	
117.5-120	SW-SM	30	¾	F-C	1.64	M-S	
120-122.5	SW-SM	30	¾	F-C	1.95	M-S	
122.5-125	SM	25	¾	F-C	1.76	S	
125-127.5	SW-SM	40	¼	F-C	2.40	W-M	
127.5-130	SM	20	¾	F	1.90	W-M	
130-132.5	SM-SW	15	¾	F-C	2.18	W-M	
132.5-135	SM-SW	25	¾	F-C	2.34	S	
135-137.5	SW	45	½	F-C	2.77	W	
137.5-140	SM-SW	30	¾	F-C	2.49	W	
140-142.5	SM-SW	25	¾	F-C	1.29	M-S	
142.5-145	SM-SW	35	½	F-C	1.69	M	
145-147.5	SM-SW	45	½	F-C	1.70	W-M	
147.5-150	SM-SW	20	½	F-C	2.86	M-S	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.13 Drill cuttings log data for NN-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM	5	½	VF	1.46	S	
2.5-5	SM	5	½	VF	1.35	S	
5-7.5	SM	5	½	VF	1.88	S	
7.5-10	SM-SW	5	¾	F-C	2.25	S	
10-12.5	GW	50	¾	C	3.68	M-S	
12.5-15	SM	15	¾	F	2.10	S	
15-17.5	SM	15	¾	F	2.36	S	
17.5-20	SM-SW	5	¼	F-C	1.84	S	D
20-22.5	SM	10	¼	F	3.12	S	D
22.5-25	SM	10	¼	F	2.20	VS	D
25-27.5	SM	25	¾	F	1.82	S	D
27.5-30	SM	20	¾	F	1.31	S	D
30-32.5	SM	30	¾	F	12.14	S	D
32.5-35	SM	10	¼	VF	1.12	VS	D
35-37.5	SM	10	¼	VF	1.17	VS	D
37.5-40	SM	5	¼	VF	1.55	W-M	
40-42.5	SM	5	¼	VF	1.53	W-M	
42.5-45	SM	10	¼	F	1.43	S	
45-47.5	SM	10	¼	F	1.40	S	
47.5-50	SM	15	¾	F	1.31	S	
50-52.5	SM	15	¾	F	1.43	S	
52.5-55	SM	15	¾	F	1.26	S	
55-57.5	SM	25	¾	F	1.09	S	
57.5-60	SM	10	¼	F	1.33	S	
60-62.5	SM	10	¼	F	1.17	M-S	
62.5-65	SM	10	¼	F	1.02	M-S	
65-67.5	SM	15	—¼	F	1.24	S	
67.5-70	SM	10	¼	F	1.22	S	
70-72.5	SM	5	¼	F	1.12	S	
72.5-75	SM	5	¼	F	.93	S	
75-77.5	SM	5	¼	F	.89	S	
77.5-80	SM	5	¼	F	.63	W-M	

Appendix B.13 Drill cuttings log data for NN-1 (continued).

80-82.5	SM	5	¼	F	.79	S	
82.5-85	SM	5	¼	F	.70	S	
85-87.5	SM	5	¼	F	.80	S	
87.5-90	SM	10	¾	F	.92	S	
90-92.5	SM	5	¾	F	.95	VS	
92.5-95	SM	10	¾	F	.75	VS	
95-97.5	SM	10	¾	F	1.21	S	
97.5-100	SM	10	¾	F	1.33	W-M	
100-102.5	SM	10	¾	F	.96	M	
102.5-105	SM	15	¾	F	1.42	M	
105-107.5	SM	15	¾	F	1.00	S	
107.5-110	SM	15	¼	F	1.10	S	
110-112.5	SM	15	¼	F	1.20	S	
112.5-115	SM	15	¼	F	1.45	S	
115-117.5	SM	20	¾	F	1.22	VS	
117.5-120	SM	15	¾	F	1.34	S	
120-122.5	SM	15	¾	F	1.37	S	
122.5-125	SM	20	¾	F	1.85	S	
125-127.5	SM	30	¾	F	1.17	S	
127.5-130	SM	15	—¼	F	1.58	VS	
130-132.5	SW-SM	30	¾	F-C	1.35	M-W	
132.5-135	SM	40	¾	F	2.04	S	
135-137.5	SM	20	¾	F	2.47	S	
137.5-140	SM-SW	30	¾	F-C	2.30	M	
140-142.5	SM-SW	30	¾	F-C	1.60	W-M	
142.5-145	SM-SW	30	¾	F-C	1.47	W-M	
145-147.5	SM	20	¾	F	1.84	S	
147.5-150	SM	25	¾	F	1.76	S	
150-152.5	SM	10	¼	F	2.13	S	
152.5-155	SM	20	¾	F	1.95	S	
155-157.5	SM-SW	20	¾	F-C	2.06	M-S	
157.5-160	SM-SP	20	¾	F	1.63	M	
160-162.5	SM-SP	10	¾	F	1.76	M	
162.5-165	SM-SP	10	¾	F	1.77	S	

Appendix B.13 Drill cuttings log data for NN-1 (continued).

165-167.5	SM-SW	10	¼	F-C	1.56	M	
167.5-170	SM-SW	20	¾	F-C	1.58	W-M	
170-172.5	SM-SW	15	¾	F-C	1.69	M	
172.5-175	SM-SW	25	¼	F-C	1.21	M-W	
175-177.5	SM-SW	10	¼	F-C	1.76	S	
177.5-180	SM	10	¼	F	2.13	M	
180-182.5	SM	10	¼	F	2.05	M	
182.5-185	SM	10	¼	F	2.11	M	
185-187.5	SM-SW	15	¾	F-C	1.94	S	
187.5-190	SM	5	¼	F	1.85	S	
190-192.5	SM	5	¼	F	3.23	S	
192.5-195	SM-SW	10	¼	F-C	1.91	W-M	
195-197.5	SM-SW	10	¼	F-C	1.55	S	
197.5-200	SM	15	¼	F	2.37	M	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.14 Drill cuttings log data for NE-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM	10	¼	1			
2.5-5.0	SM	5	¼	1			
5.0-7.5	SM-SW	10	¼	F-C	2.50	S	
7.5-10.0	SM-SW	5	¼	F-C	2.75	S	
10.0-12.5	SM-SW	20	¾	F-C	2.77	M	
12.5-15.0	SW	20	¾	F-C	5.52	M	
15.0-17.5	SM-SW	20	¾	F-C	1.72	S	
17.5-20.0	SW-SM	30	½	F-C	1.88	S	
20.0-22.5	SM	15	¼	F	2.19	M	
22.5-25.0	SM	10	¼	F	1.54	S	
25.0-27.5	SM-SW	10	¼	F-C	1.70	M	
27.5-30.0	SM	10	¼	F	1.79	S	
30.0-32.5	SM	10	¼	F	1.34	S	
32.5-35.0	SM	10	¼	F	1.36	S	
35.0-37.5	SM	10	¼	F	1.20	S	
37.5-40.0	SM	5	¼	F	1.33	W-M	
40.0-42.5	SM	5	¼	F	1.30	S	
42.5-45.0	SM	10	¼	F	1.21	S	
45.0-47.5	SM	10	¼	F	1.20	S	
47.5-50.0	SM	5	¼	F	1.13	S	
50.0-52.5	SM	5	¼	F	1.36	S	
52.5-55.0	SM	20	¾	F	1.49	S	
55.0-57.5	SM	10	¼	F	1.66	S-M	
57.5-60.0	SW-SM	20	¾	F-C	1.75	S-M	
60.0-62.5	SM	10	¼	F	1.34	S	
62.5-65.0	SM	5	¼	F	1.38	S	
65-67.5	SM	5	¼	F	0.4-0.8	S	
67.5-70	SM	10	¼	F	1.41	S	
70-72.5	SM	5	¼	F	1.85	S	
72.5-75	SM	5	¼	F	1.67	S	
75-77.5	SM	2	¼	VF	1.17	S	
77.5-80	SM	10	¾	F	1.17	S	

Appendix B.14 Drill cuttings log data for NE-1 (continued).

80.82.5	SM	10	$\frac{3}{8}$	F	1.27	M	
82.5-85	SP-SM	10	$\frac{1}{4}$	F	1.31	M-S	
85-87.5	SP-SM	10	$\frac{1}{4}$	F	1.32	M-S	
87.5-90	SM	10	$\frac{1}{4}$	VF	1.49	S	
90-92.5	SM	15	$\frac{1}{4}$	VF	1.32	S	
92.5-95	SM	5	$\frac{1}{4}$	VF	1.63	S	
95-97.5	SM-SP	10	$\frac{1}{4}$	F	1.24	S	
97.5-100	SM	10	$\frac{1}{4}$	F	1.01	S-M	
100-102.5	SM	15	$\frac{1}{4}$	F	1.19	M	
102.5-105	SM	10	$\frac{1}{4}$	F	1.11	M-S	
105-107.5	SM	10	$\frac{1}{4}$	F	1.18	S	
107.5-110	SM	10	$\frac{1}{4}$	F	1.05	S	
110-112.5	SM	15	$\frac{1}{4}$	F	0.94	S	
112.5-115	SM	10	$\frac{1}{4}$	F	1.17	S	
115-117.5	SM	10	$\frac{1}{4}$	F	1.29	S	
117.5-120	SM	15	$\frac{1}{4}$	F	1.14	S	
120-122.5	SM	5	$\frac{1}{4}$	F	1.33	S	
122.5-125	SM	5	$\frac{1}{4}$	F	1.07	S	
125-127.5	SM	10	$\frac{1}{4}$	F	1.13	S	
127.5-130	SM-SW?	25	$\frac{3}{8}$	F-C	1.21	S	
130-132.5	SM-SW?	25	$\frac{3}{8}$	F-C	0.4-0.8	S	
132.5-135	SM-SW?	25	$\frac{3}{8}$	F-C	1.15	M	
135-137.5	SM-SW?	25	$\frac{3}{8}$	F-C	1.13	S	
137.5-140	SM	15	$\frac{1}{4}$	F	1.39	S	
140-142.5	SM-SW	30	$\frac{3}{8}$	F-C	1.30	S	
142.5-145	SM	15	$\frac{1}{4}$	F	1.37	S	
145-147.5	SM	20	$\frac{1}{4}$	F	1.71	S	
147.5-150	SM	25	$\frac{3}{8}$	F	1.34	S	
150-152.5	SM-SW	40	$\frac{3}{8}$	F-C	1.58	M	
152.5-155	SM-SW	40	$\frac{3}{8}$	F-C	1.62	M	
155-157.5	SM	30	$\frac{3}{8}$	F	1.32	S	
157.5-160	SM	15	$\frac{3}{8}$	F	1.61	S	
160-162.5	SM	20	$\frac{3}{8}$	F	1.87	S	
162.5-165	SM	20	$\frac{3}{8}$	F	1.52	VS	

Appendix B.14 Drill cuttings log data for NE-1 (continued).

165-167.5	SM	25	$\frac{3}{8}$	F	1.67	VS	
167.5-170	SM	5	$\frac{1}{4}$	F	1.75	S	
170-172.5	SM	15	$\frac{3}{8}$	F	1.90	S	
172.5-175	SM-SW	25	$\frac{3}{8}$	F-C	2.38	S	
175-177.5	SM-SW	30	$\frac{3}{8}$	F-C	2.20	M	
177.5-180	SM	15	$\frac{1}{4}$	F	2.00	M	
180-182.5	SM	15	$\frac{1}{4}$	F	1.74	M	
182.5-185	SM	15	$\frac{1}{4}$	F	1.73	M	
185-187.5	SM-SW	40	$\frac{3}{8}$	F-C	1.80	W	
187.5-190	SM-SW	30	$\frac{3}{8}$	F-C	2.19	W	
190-192.5	SM-SW	40	$\frac{3}{8}$	F-C	1.78	W-M	
192.5-195	SM-SW	40	$\frac{3}{8}$	F-C	2.08	W	
195-197.5	SM-SW	40	$\frac{3}{8}$	F-C	1.86	W-M	
197.5-200	SM-SW	25	$\frac{3}{8}$	F-C	2.16	W	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.15 Drill cuttings log data for NW-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	MOISTURE ⁶
0-2.5	SM	15	1	F	1.35	S	
2.5-5	GM-GW	50	3/8	C	1.64	W	
5-7.5	SM	5	1/4	VF	1.18	S	
7.5-10	SM	1	1/4	VF	1.50	S	
10-12.5	SM	5	1/4	F	1.65	S	
12.5-15	SM	10	1/4	F	1.38	S	
15-17.5	SM	15	1/4	F	1.38	VS	
17.5-20	SM	10	—1/4	F	1.31	S	
20-22.5	SM	15	1/4	F	1.36	VS	
22.5-25	SM	25	3/8	F	1.08	VS	
25-27.5	SM	20	3/8	F	1.19	VS	
27.5-30	SM	10	1/4	F	1.30	VS	
32.5-35	SM	10	1/4	F	1.46	VS	
35-37.5	SM	10	1/4	F	1.53	VS	
37.5-40	SM	10	1/4	F	1.73	VS	
40-42.5	SM	5	1/4	F	1.66	VS	
42.5-45	SM	10	1/4	F	1.34	VS	
45-47.5	SM	25	3/8	F	1.05	VS	
47.5-50	SM	15	3/8	F	1.77	VS	
50-52.5	SM-SW	40	3/8	F-C	2.11	M	
52.5-55	SM	20	3/8	F	1.76	VS	
55-57.5	SM	5	1/4	F	1.43	VS	
57.5-60	SM	15	1/4	F	1.56	VS	
60-62.5	SW-SW	30	3/8	F-C	1.37	VS	
62.5-65	SM-SW	35	3/8	F-C	1.94	S	
65-67.5	SM-SW	35	3/8	F-C	1.60	S	
67.5-70	SM	30	3/8	F	1.71	S	
70-72.5	SM-SW	30	3/8	F-C	1.52	S	
72.5-75	SM	30	3/8	F	1.75	S	
75-77.5	SM	30	3/8	F	1.79	S	
77.5-80	SM	30	3/8	F	1.92	VS	
80-82.5	SM	20	3/8	F	1.98	S	

Appendix B.15 Drill cuttings log data for NW-1 (continued).

82.5-85	SM	20	$\frac{3}{8}$	F	1.72	S	
85-87.5	SM	20	$\frac{3}{8}$	F	1.66	VS	
87.5-90	SM	20	$\frac{3}{8}$	F	1.75	VS	
90-92.5	SM	10	$\frac{3}{8}$	F	1.52	VS	
92.5-95	SM	20	$\frac{3}{8}$	F	1.55	S	
95-97.5	SM	20	$\frac{3}{8}$	F	1.49	S	
97.5-100	SM-SW	25	$\frac{3}{8}$	F-C	2.52	M	
100-102.5	SM-SW	40	$\frac{3}{8}$	F-C	2.75	W	
102.5-105	SM-SW	30	$\frac{3}{8}$	F-C	1.87	W	
105-107.5	SM	25	$\frac{3}{8}$	F-C	2.44	M-S	
107.5-110	SM	20	$\frac{3}{8}$	F	2.95	M	
110-112.5	SM	25	$\frac{3}{8}$	F	2.22	W-M	
112.5-115	GW	50	$\frac{3}{8}$	C	1.85	W	
115.0-117.5	SM-SW	30	$\frac{3}{8}$	F-C	1.65	W-M	
117.5-120	GW	50	$\frac{3}{8}$	C	2.29	W-M	
120-122.5	GW	50	$\frac{3}{8}$	C	3.93	N	
122.5-125	SW	40	$\frac{3}{8}$	F-C	2.85	N	
125-127.5	SM	30	$\frac{3}{8}$	F	1.44	M-S	
127.5-130	SM	25	$\frac{3}{8}$	F	1.91	M-S	
130-132.5	SM	35	$\frac{3}{8}$	F	1.93	M-W	
132.5-135	SW-SM	45	$\frac{3}{8}$	F-C	1.53	W-N	
135-137.5	SM	30	$\frac{3}{8}$	F	1.73	S	
137.5-140	SM-SW	30	$\frac{3}{8}$	F-C	1.91	W-M	
140-142.5	SM	20	$\frac{3}{8}$	F	2.60	S	
142.5-145	SM	20	$\frac{3}{8}$	F	1.93	S	
145-147.5	GW	50	$\frac{3}{8}$	C	1.99	W-M	
147.5-150	SM-SW	20	$\frac{3}{8}$	F-C	1.82	M-S	
150-152.5	GW	60	$\frac{3}{8}$	C	1.98	W-M	
152.5-155	SM	30	$\frac{3}{8}$	F	2.08	VS	
155-157.5	SM	30	$\frac{3}{8}$	F	2.41	S	
157.5-160	SM-SW	40	$\frac{3}{8}$	F-C	2.04	S	
160-162.5	SM	25	$\frac{3}{8}$	F	1.66	S	
162.5-165	SM-SW	20	$\frac{3}{8}$	F-C	2.21	M-S	
165-167.5	SM	20	$\frac{3}{8}$	F	2.36	S	

Appendix B.15 Drill cuttings log data for NW-1 (continued).

167.5-170	SM-SW	25	$\frac{3}{8}$	F-C	2.01	W	
170-172.5	SM-SW	25	$\frac{3}{8}$	F-C	2.62	W-M	
172.5-175	SM	10	$\frac{3}{8}$	F	2.45	S	
175-177.5	SM	15	$\frac{3}{8}$	F	1.29	S	
177.5-180	SW-SM	30	$\frac{3}{8}$	F-C	2.23	S	
180-182.5	SW-SM	30	$\frac{3}{8}$	F-C	1.43	W	
182.5-185	SM	25	$\frac{3}{8}$	F	2.03	S	
185-187.5	SM	20	$\frac{3}{8}$	F	1.98	M	
187.5-190	SM	20	$\frac{3}{8}$	F	2.21	M	
190-192.5	SM	30	$\frac{3}{8}$	F	2.41	M	
192.5-195	SM	20	$\frac{3}{8}$	F	2.26	M-W	
195-197.5	SM	25	$\frac{3}{8}$	F	2.48	M-S	
197.5-200	SW-SM	30	$\frac{3}{8}$	F-C	2.43	W-M	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

Appendix B.16 Drill cuttings log data for NS-1.

DEPTH INTERVAL (ft)	USCS ¹	% + 4 ² MESH.	PREDOM. GRAVEL SIZE (in)	PREDOM. ³ SAND SIZE	MAGNETIC SUSCEPTI- BILITY ⁴	10% HCL REACTION ⁵	Moisture ⁶
0-2.5	SM	10	3/8	F	1.01	S	
2.5-5	SM	25	3/8	F	1.28	S	
5-7.5	SM	20	3/8	F	1.28	S	
7.5-10	SM	15	3/8	F	1.24	S	
10-12.5	SM-SW	10	1/4	F-C	2.09	M	
12.5-15	SM-SW	10	1/4	F-C	2.61	M	
15-17.5	SM	15	3/8	F	1.69	M-S	
17.5-20	SM	< 5	1/4	F	1.86	M	
20-22.5	SM-SW	10	3/8	F-C	1.50	M	
22.5-25	SM	5	1/4	F-C	1.30	M	
25-27.5	SM-SW	10	3/8	F-C	1.49	M	
27.5-30	SM	10	3/8	F	1.66	M	
30-32.5	SM	15	3/8	F	1.30	M	
32.5-35	SM	20	3/8	F	1.05	S	
35-37.5	SM	15	3/8	F	0.66	S	
37.5-40	SM	15	1/4	F	1.32	M	
40-42.5	SM	15	1/4	F	1.04	S	
42.5-45	SM	15	1/4	F	0.82	S	
45-47.5	SM	15	3/8	F	0.62	S	
47.5-50	SM	5	1/4	VF	1.15	S	
50-52.5	SM	5	1/4	VF	1.15	S	
52.5-55	SM	110	1/4	F	1.41	S	
55-57.5	SM	15	1/4	F	1.58	S	
57.5-60	SM	10	1/4	VF	1.17	V.S	
60-62.5	SM	20	3/8	F	1.45	V.S	
62.5-65	SM	15	3/8	F	1.42	VS	
65-67.5	SM-SW	20	3/8	F-C	1.48	S	
67.5-70	SP-SM	15	3/8	F	1.56	M-S	
70-72.5	SM	15	3/8	F	1.22	VS	
72.5-75	SM	15	3/8	F	1.16	VS	
75-77.5	SM	15	3/8	F	0.96	V.S	
77.5-80	SM	15	3/8	F	1.53	V.S	

Appendix B.16 Drill cuttings log data for NS-1 (continued).

80-82.5	SM	20	$\frac{3}{8}$	F	1.82	M-S	
82.5-85	SM	20	$\frac{3}{8}$	F	1.68	M	Bm
85-87.5	SM	20	$\frac{3}{8}$	F	1.21	M	
87.5-90	SM	20	$\frac{3}{8}$	F	1.34	S	
90-92.5	SM	25	$\frac{1}{2}$	F	1.16	M	
92.5-95	SM	25	$\frac{1}{2}$	F	1.06	S	
95-97.5	SM	25	$\frac{1}{2}$	F	1.16	S	
97.5-100	SM	20	$\frac{3}{8}$	F	2.14	S	
100-102.5	SM	20	$\frac{3}{8}$	F	2.08	S	
102.5-105	SM	25	$\frac{3}{8}$	F	1.59	S	
105-107.5	SM	25	$\frac{3}{8}$	F	1.13	S	Brown
107.5-110	SM	30	$\frac{1}{2}$	F	1.03	VS	
110-112.5	SM	30	$\frac{1}{2}$	F	1.35	VS	
112.5-115	GM	50	$\frac{1}{2}$	C	0.46	VS	
115-117.5	GM	45	$\frac{1}{2}$	C	0.79	S	
117.5-120	SM	35	$\frac{1}{2}$	F	0.45	S	
120-122.5	SM	35	$\frac{1}{2}$	F	0.08	M	
122.5-125	SM	55	$\frac{1}{2}$	F	0.23	S	
125-127.5	SM	25	$\frac{1}{2}$	F	0.03	VS	
127.5-130	GM-GW	50	$\frac{1}{2}$	C	0.65	VS	
130-132.5	SM	40	$\frac{1}{2}$	F	1.73	S	
132.5-135	SM	45	$\frac{1}{2}$	F	1.76	V.S	
135-137.5	SM	35	$\frac{1}{2}$	F	2.59	S	
137.5-140	SM-SW	35	$\frac{1}{2}$	F-C	2.69	S	
140-142.5	SM	25	$\frac{1}{2}$	F	2.78	S	
142.5-145	SM	30	$\frac{1}{2}$	F	1.65	S	
145-147.5	GM	50	$\frac{1}{2}$	C	1.62	VS	
147.5-150	GW	60	$\frac{3}{8}$	C	2.72	W	Loose
150-152.5	GW	60	$\frac{3}{8}$	C	4.18	W	
152.5-155	GW-GM	50	$\frac{1}{2}$	C	2.55	S	
155-157.5	GW-GM	50	$\frac{1}{2}$	C	2.15	M	
157.5-160	GM	50	$\frac{1}{2}$	C	2.01	FS	
160-162.5	GM-GW	50	$\frac{1}{2}$	C	2.08	S	
162.5-165	SM-SW	40	$\frac{1}{2}$	F-C	1.82	S	

Appendix B.16 Drill cuttings log data for NS-1 (continued).

154-167.5	SM	30	½	F	2.00	W-M	
167.5-170	SM	40	½	F	1.84	S	
170-172.5	GW-GM	60	½	C	1.96	W	
172.5-175	GW-GM	50	½	C	2.08	W	
175-177.5	SM	20	¾	F	1.66	S	
177.5-180	SM	10	¾	F	1.95	M	
180-182.5	SM-SW	25	¾	F-C	2.26	M	
182.5-185	SM-SW	35	¾	F-C	1.67	M-W	
185-187.5	SM	20	¾	F	1.39	S	
187.5-190	SM	15	¼	F	1.82	M-S	
190-192.5	SM	15	¼	F	1.69	M-S	
195-197.5	SM-SW	20	¾	F-C	1.80	W	
197.5-200	SM	15	¾	F	0.88	S	

¹ Visual Classification.

² Volumetric Determination on No. 4 Mesh Screen.

³ Visual Estimate: F-fine, M-medium, C-coarse.

⁴ S.I. Units. Measured with KT-5 Meter at Base of 500 ml Nalgene bottle.

⁵ Visual Estimate: W-weak, M-moderate, S-strong.

⁶ Moisture: D-dry, M-moist.

APPENDIX C

Completion Data (AP and RP Boreholes)

Appendix C.2.1 AP-1 stemming summary.

Stemming Material	Depth Interval (ft)		Amount of material (lbs)	Borehole diameter (in)	Instrument Station Depth (ft)
	from	to			
Dry Mix	0.0	19.2	860.0	9.7	
Sand	19.2	20.6	40.1	8.0	20
Dry Mix	20.6	38.1	380.0	7.2	
Sand	38.1	40.3	20.1	5.4	40
Dry Mix	40.3	59.2	240.0	6.0	
Sand	59.2	60.9	26.7	6.3	60
Dry Mix	60.9	79.2	270.0	6.3	
Sand	79.2	80.6	20.1	6.2	80
Dry Mix	80.6	97.9	250.0	6.2	
Sand	97.9	100.7	26.7	5.4	100
Dry Mix	100.7	118.9	280.0	6.4	
Sand	118.9	120.8	26.7	6.2	120
Dry Mix	120.8	139.0	290.0	6.4	
Sand	139.0	140.9	26.7	6.2	140
Dry Mix	140.9	159.1	305.0	6.6	
Sand	159.1	160.7	33.4	7.1	160
Dry Mix	160.7	178.8	340.0	6.8	
Sand	178.8	180.5	20.1	5.9	180
Dry Mix	180.5	199.2	380.0	7.0	
Sand	199.2	200.8	27.7	6.6	200
Dry Mix	200.8	219.2	300.0	6.5	
Sand	219.2	221.0	31.3	6.6	220
Dry Mix	221.0	239.1	340.0	6.8	
Sand	239.1	240.8	22.0	6.0	240
Dry Mix	240.8	258.5	300.0	6.6	
Sand	258.5	260.8	35.0	6.3	260
Dry Mix	260.8	274.6	267.0	6.0	

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

Appendix C.2.2 AP-2 stemming summary.

Stemming Material	Depth Interval (ft)		Amount of material (lbs)	Borehole diameter (in)	Instrument Station Depth (ft)
	from	to			
Dry Mix	0.0	18.9	590.0	8.3	
Sand	18.9	20.6	26.7	6.3	20
Dry Mix	20.6	38.1	348.0	7.0	
Sand	38.1	40.3	26.7	5.8	40
Dry Mix	40.3	58.7	360.0	6.9	
Sand	58.7	60.3	26.7	6.5	60
Dry Mix	60.3	78.9	326.0	6.7	
Sand	78.9	80.6	26.7	6.4	80
Dry Mix	80.6	98.2	325.0	6.8	
Sand	98.2	100.6	26.7	5.7	100
Dry Mix	100.6	118.7	340.0	6.8	
Sand	118.7	120.7	26.7	6.0	120
Dry Mix	120.7	139.2	350.0	6.9	
Sand	139.2	141.1	26.7	6.1	140
Dry Mix	141.1	158.9	360.0	7.0	
Sand	158.9	160.7	26.7	6.3	160
Dry Mix	160.7	179.0	460.0	7.6	
Sand	179.0	181.1	26.7	6.0	180
Dry Mix	181.1	198.8	316.0	6.7	
Sand	198.8	200.7	26.7	6.2	200
Dry Mix	200.7	218.8	360.0	7.0	
Sand	218.8	221.9	26.7	5.3	220
Dry Mix	221.9	239.2	400.0	7.4	
Sand	239.2	240.7	26.7	6.7	240
Dry Mix	240.7	258.5	416.0	7.4	
Sand	258.4	260.8	26.7	5.8	260
Dry Mix	260.8	276.0	370.0	6.7	

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

Appendix C.2.3 RP-1 stemming summary.

Stemming Material	Depth Interval (ft)		Amount of material (lbs)	Borehole diameter (in)	Instrument Station Depth (ft)
	from	to			
Dry Mix	0.0	4.4	150.0	8.3	
Sand	4.4	5.6	175.1	16.9	5
Dry Mix	5.6	9.4	180.0	9.6	
Sand	9.4	10.7	23.4	6.2	10
Dry Mix	10.7	14.3	65.0	6.3	
Sand	14.3	15.6	20.1	5.7	15
Dry Mix	15.6	19.4	74.0	6.5	
Sand	19.4	20.4	26.7	7.6	20
Dry Mix	20.4	29.4	210.0	7.0	
Sand	29.4	30.6	20.1	5.9	30
Dry Mix	30.6	44.7	320.0	6.9	
Sand	44.7	45.8	20.1	6.1	45
Dry Mix	45.8	59.5	330.0	7.1	
Sand	59.5	60.7	20.1	6.0	60
Dry Mix	60.7	89.5	620.0	6.7	
Sand	89.5	90.7	20.1	6	90
Dry Mix	90.7	119.4	580.0	6.5	
Sand	119.4	120.8	20.1	5.6	120
Dry Mix	120.8	149.0	660.0	7.0	
Sand	149.0	150.8	53.5	7.9	150

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

Appendix C.2.4 RP-2 stemming summary.

Stemming Material	Depth Interval (ft)		Amount of material (lbs)	Borehole diameter (in)	Instrument Station Depth (ft)
	from	to			
Dry Mix	0.0	4.5	80.0	6.2	
Sand	4.5	5.4	33.4	8.8	5
Dry Mix	5.4	9.3	40.0	4.9	
Sand	9.3	10.9	16.7	5.0	10
Dry Mix	10.9	14.5	45.0	5.4	
Sand	14.5	15.5	20.1	6.4	15
Dry Mix	15.5	18.8	54.0	6.0	
Sand	18.8	20.3	16.7	5.2	20
Dry Mix	20.3	29.5	165.0	6.2	
Sand	29.5	30.8	16.7	5.4	30
Dry Mix	30.8	44.7	254.0	6.3	
Sand	44.7	46.0	20.1	5.9	45
Dry Mix	46.0	59.5	280.0	6.6	
Sand	59.5	60.3	16.7	6.7	60
Dry Mix	60.3	89.6	540.0	6.3	
Sand	89.6	90.8	16.7	5.5	90
Dry Mix	90.8	119.5	520.0	6.2	
Sand	119.5	120.6	13.4	5.4	120
Dry Mix	120.6	149.1	620.0	6.7	
Sand	149.1	151.1	26.7	5.4	150

Sand: 6/12-coarse-mesh sand

Dry Mix: 60 percent Overton sand, 25 percent bentonite powder, 15 percent silica flour

Appendix D.1.27 Moisture-retention data for core samples from AP-1.

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
4	37.5	-0.00	39	34.2	-0.00
	34.6	-0.02		30.1	-0.03
	28.3	-0.06		25.0	-0.05
	21.9	-0.11		19.0	-0.11
	16.1	-0.52		14.8	-0.51
	11.0	-3.02		11.2	-2.64
	8.4	-14.68		8.0	-14.96
6	31.7	-0.00	49	37.8	-0.00
	28.8	-0.02		34.7	-0.03
	24.2	-0.06		30.3	-0.05
	17.7	-0.11		23.1	-0.11
	12.3	-0.52		17.7	-0.51
	8.1	-4.44		12.5	-2.98
	5.9	-22.74		9.7	-11.97
8	33.7	-0.00	60	31.2	-0.00
	30.1	-0.02		28.8	-0.03
	23.5	-0.06		25.9	-0.05
	18.2	-0.11		22.7	-0.10
	13.8	-0.52		16.7	-0.51
	9.2	-2.90		10.5	-4.01
	7.2	-12.55		8.4	-10.64
19	36.6	-0.00	80	39.9	-0.00
	33.6	-0.03		36.9	-0.03
	28.6	-0.05		28.4	-0.05
	20.7	-0.11		21.4	-0.10
	15.7	-0.51		16.0	-0.51
	10.1	-3.02		10.3	-4.08
	7.9	-12.48		7.3	-18.07
24	33.7	-0.00	100	41.5	-0.00
	31.0	-0.03		39.5	-0.03
	25.4	-0.05		36.5	-0.05
	17.0	-0.11		18.2	-0.11
	13.3	-0.51		12.4	-0.51
	8.0	-2.97		9.1	-2.49
	6.2	-21.93		7.2	-11.07
26	39.7	-0.00	110	37.8	-0.00
	37.0	-0.03		36.0	-0.03
	33.0	-0.05		31.3	-0.05
	21.3	-0.11		24.9	-0.10
	14.8	-0.51		17.0	-0.51
	10.7	-3.02		10.8	-3.24
	8.3	-10.77		9.9	-10.64

Appendix D.1.27 Moisture-retention data for core samples from AP-1 (continued).

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
130	38.5	-0.00	200	33.0	-0.00
	26.6	-0.02		29.8	-0.03
	21.9	-0.05		21.1	-0.05
	19.4	-0.10		17.5	-0.10
	16.5	-0.51		13.5	-0.51
	15.4	-1.01		10.4	-3.73
	13.2	-3.60		7.5	-22.03
	8.6	-15.40			
151	32.0	-0.00	240	35.3	-0.00
	29.3	-0.02		28.8	-0.03
	25.6	-0.05		21.3	-0.05
	21.2	-0.10		17.9	-0.10
	15.9	-0.51		13.5	-0.51
	14.4	-1.01		9.6	-5.13
	11.9	-3.65		8.2	-12.45
	8.4	-17.67			
161	31.1	-0.00	261	33.0	-0.00
	27.0	-0.03		21.5	-0.02
	19.7	-0.05		14.5	-0.06
	16.2	-0.10		12.9	-0.11
	12.9	-0.51		10.8	-0.52
	9.3	-3.38		8.1	-2.59
	7.4	-21.38		6.0	-26.50
180	30.8	-0.00			
	25.5	-0.02			
	20.3	-0.06			
	16.9	-0.11			
	13.2	-0.52			
	9.2	-4.09			
	6.8	-29.47			

Appendix D.1.28 Moisture-retention data for core samples from AP-2.

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
3	36.	-0.00	26	33.3	-0.00
	35.3	-0.02		30.7	-0.03
	28.2	-0.05		26.5	-0.05
	22.0	-0.10		16.7	-0.10
	16.3	-0.51		13.0	-0.51
	15.0	-1.02		12.2	-1.02
	11.5	-2.79		9.7	-2.84
	8.8	-14.04		7.0	-11.78
8	30.1	-0.00	29	33.7	-0.00
	28.0	-0.02		17.1	-0.03
	20.3	-0.05		10.2	-0.11
	17.5	-0.10		8.7	-0.51
	14.6	-0.51		8.7	-1.02
	13.5	-1.02		6.1	-2.34
	9.8	-5.35		4.0	-16.97
	8.8	-11.54			
16	33.4	-0.00	40	33.7	-0.00
	30.8	-0.03		31.8	-0.03
	26.9	-0.05		29.3	-0.05
	19.1	-0.10		24.3	-0.10
	14.0	-0.51		18.2	-0.51
	13.0	-1.02		16.4	-1.02
	9.3	-3.69		12.5	-3.31
	7.9	-11.64		8.5	-18.00
19	35.9	-0.00	51	39.8	-0.00
	34.2	-0.02		38.2	-0.02
	18.6	-0.05		32.6	-0.05
	14.2	-0.10		26.3	-0.10
	11.8	-0.51		19.4	-0.51
	11.0	-1.02		17.1	-1.02
	9.1	-2.39		12.4	-3.65
	6.6	-16.31		8.0	-14.75
21	25.3	-0.00	60	30.2	-0.00
	24.0	-0.02		28.5	-0.03
	20.9	-0.05		27.1	-0.05
	15.7	-0.10		21.7	-0.10
	11.7	-0.51		15.8	-0.51
	10.5	-1.02		14.7	-1.02
	7.4	-2.89		9.7	-2.88
	5.7	-10.44		6.1	-16.70

Appendix D.1.28 Moisture-retention data for core samples from AP-2 (continued).

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
24	39.3	-0.00	80	34.0	-0.00
	37.7	-0.03		32.6	-0.03
	33.0	-0.05		25.2	-0.11
	20.0	-0.10		18.1	-0.51
	14.4	-0.51		17.8	1.02
	13.5	-1.02		12.6	-3.65
	11.4	-2.43		6.1	-31.17
	6.9	-25.50			
90	35.4	-0.00	199	32.3	-0.00
	34.4	-0.02		24.4	-0.03
	32.8	-0.06		17.2	-0.05
	24.1	-0.10		14.7	-0.11
	15.8	-0.51		12.3	-0.52
	13.0	-1.02		11.2	-1.02
	10.1	-4.89		8.8	-4.70
	7.5	-19.17		6.1	-31.91
110	37.4	-0.00	220	42.3	-0.00
	35.8	-0.03		41.6	-0.02
	22.7	-0.11		39.7	-0.06
	17.3	-0.51		35.6	-0.10
	16.9	-1.02		20.9	-0.51
	12.8	-2.97		17.8	-1.02
	8.5	-22.72		12.6	-2.50
	9.4	-24.43			
139	35.2	-0.00	240	32.7	-0.00
	28.1	-0.03		31.4	-0.02
	22.0	-0.11		18.5	-0.06
	18.6	-0.51		14.5	-0.10
	18.2	-1.02		12.5	-0.51
	14.3	-2.73		11.6	-1.02
	11.0	-20.18		9.5	-3.27
	6.7	-23.53			
151	31.3	-0.00	260	34.6	-0.00
	27.2	-0.03		33.9	-0.02
	20.6	-0.11		28.2	-0.05
	16.5	-0.51		18.3	-0.10
	15.4	-1.02		13.9	-0.51
	11.9	-3.03		12.9	-1.02
	9.3	-15.60		10.2	-3.08
				7.7	-31.29

Appendix D.1.28 Moisture-retention data for core samples from AP-2 (continued).

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
161	32.1	-0.00	276	33.7	-0.00
	27.9	-0.02		29.1	-0.02
	22.6	-0.05		16.6	-0.06
	17.5	-0.10		14.0	-0.10
	14.5	-0.51		12.5	-0.51
	13.5	-1.02		11.5	-1.02
	10.6	-2.58		9.9	-2.85
	6.5	-21.61		7.5	-23.78
180	28.7	-0.00			
	21.7	-0.02			
	6.8	-0.05			
	14.0	-0.10			
	12.3	-0.51			
	11.6	-1.02			
	9.6	-4.44			
	7.4	-19.15			

Appendix D.1.29 Moisture-retention data for core samples from RP-1.

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
1	36.5	-0.00	45	37.9	-0.00
	34.8	-0.03		37.2	-0.03
	34.2	-0.05		34.8	-0.05
	26.9	-0.10		28.5	-0.11
	17.9	-0.51		21.5	-0.52
	16.5	-1.02		18.8	-1.02
	12.2	-2.88		15.0	-4.08
	9.9	-11.90		10.5	-14.41
3	40.6	-0.00	60	36.1	-0.00
	39.0	-0.03		33.3	-0.03
	36.7	-0.05		29.8	-0.05
	29.5	-0.10		26.5	-0.11
	21.2	-0.51		22.6	-0.52
	19.1	-1.02		20.0	-1.02
	13.8	-2.59		14.9	-4.10
	10.7	-11.45		14.9	-15.33
8	32.8	-0.00	90	32.7	-0.00
	31.9	-0.02		24.1	-0.02
	29.6	-0.05		19.7	-0.06
	22.4	-0.10		16.5	-0.10
	16.3	-0.51		13.1	-0.51
	15.4	-1.02		12.6	-1.02
	11.4	-2.64		10.2	-4.23
	9.3	-15.87		8.3	-13.12
19	38.7	-0.00	120	36.7	-0.00
	36.7	-0.03		30.3	-0.02
	24.9	-0.07		26.4	-0.06
	18.9	-0.10		21.0	-0.10
	14.2	-0.51		13.7	-0.51
	13.7	-1.02		13.4	-1.02
	10.2	-3.22		9.5	-5.89
	7.4	-14.89		7.7	-17.37
24	41.1	-0.00	150	28.2	-0.00
	38.9	-0.03		19.0	-0.02
	36.4	-0.05		16.3	-0.06
	20.1	-0.10		14.2	-0.10
	15.0	-0.51		11.4	-0.51
	14.0	-1.02		11.4	-1.02
	10.5	-3.42		8.5	-2.71
	7.5	-11.31		8.2	-11.51

Appendix D.1.29 Moisture-retention data for core samples from RP-1. (continued)

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
31	39.2	-0.00			
	38.2	-0.03			
	36.9	-0.05			
	23.6	-0.11			
	15.7	-0.52			
	14.1	-1.02			
	10.6	-4.24			
	6.8	-16.55			

Appendix D.1.30 Moisture-retention data for core samples from RP-2.

Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)	Sample Depth (ft)	Volumetric Water Content (percent)	Water Potential (bars)
5	34.4	-0.00	45	33.3	-0.00
	33.4	-0.03		25.1	-0.02
	29.4	-0.05		22.3	-0.05
	23.1	-0.10		20.2	-0.10
	17.2	-0.52		17.0	-0.51
	15.3	-1.02		17.0	-1.02
	12.1	-3.06		11.6	-4.81
	9.5	-15.92		9.8	-19.62
10	39.4	-0.00	62	35.0	-0.00
	37.5	-0.03		32.1	-0.02
	34.8	-0.05		30.2	-0.05
	24.3	-0.10		23.1	-0.10
	16.8	-0.52		14.1	-0.51
	17.1	-1.02		13.4	-1.02
	10.8	-3.81		9.1	-5.01
	8.6	-15.25		7.1	-17.70
15	33.8	-0.00	90	33.7	-0.00
	32.6	-0.03		30.0	-0.02
	29.5	-0.05		24.3	-0.05
	22.1	-0.10		18.7	-0.10
	14.5	-0.52		14.5	-0.51
	15.6	-1.02		13.9	-1.02
	9.6	-5.15		9.8	-5.03
	6.4	-23.59		8.1	-14.05
19	33.3	-0.00	120	32.0	-0.00
	32.0	-0.03		27.1	-0.02
	29.7	-0.05		20.9	-0.05
	22.2	-0.10		17.5	-0.10
	15.8	-0.52		14.2	-0.51
	14.5	-1.02		13.6	-1.02
	9.3	-3.55		10.5	-5.05
	7.5	-17.62		8.0	-20.51
30	37.0	-0.00	150	37.0	-0.00
	30.9	-0.03		32.9	-0.02
	26.8	-0.05		25.5	-0.05
	22.8	-0.10		20.0	-0.10
	18.2	-0.52		15.7	-0.51
	16.2	-1.02		15.9	-1.02
	13.5	-3.47		12.5	-4.74
	10.1	-18.20		10.0	-20.53

Appendix D.1.31 Moisture-retention data for core samples from NN-1.

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
21	40.1	-0.00	41	36.2	-0.00
	25.4	-0.03		33.1	-0.03
	17.1	-0.05		31.8	-0.05
	17.0	-0.10		31.1	-0.10
	10.5	-0.51		18.6	-0.51
	9.7	-1.02		16.9	-1.02
	5.2	-3.24		9.7	-3.15
	3.6	-20.63		6.9	-34.37
	1.6	-1371.54		3.6	-1448.19
100	40.1	-0.00	181	37.2	-0.00
	28.9	-0.03		23.1	-0.03
	22.6	-0.05		19.6	-0.05
	22.6	-0.10		19.5	-0.10
	15.7	-0.51		15.9	-0.51
	15.0	-1.02		14.8	-1.02
	7.8	-5.02		7.6	-5.01
	6.4	-26.39		4.9	-17.15
	1.8	-1448.19		2.2	-1571.81

Appendix D.1.32 Moisture-retention data for core samples from NW-1.

Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>	Sample Depth <u>(ft)</u>	Volumetric Water Content <u>(percent)</u>	Water Potential <u>(bars)</u>
20	38.7	-0.00	40	36.5	-0.00
	23.4	-0.03		34.0	-0.03
	20.6	-0.05		31.5	-0.05
	19.1	-0.10		27.5	-0.10
	17.2	-0.51		17.6	-0.51
	15.9	-1.02		15.3	-1.02
	5.5	-5.01		6.5	-4.48
	5.3	-17.15		6.5	-28.23
	1.8	-1571.81		2.1	-1448.19
101	31.5	-0.00	181	33.0	-0.00
	23.8	-0.03		15.0	-0.03
	18.9	-0.05		13.4	-0.05
	16.2	-0.10		13.3	-0.10
	13.2	-0.51		11.5	-0.51
	12.3	-1.02		11.1	-1.02
	5.6	-3.97		5.0	-2.97
	5.5	-23.94		4.0	-18.72
	1.8	-1448.19		2.2	-1371.54

Appendix D.1.34 Results of laboratory tests for stable isotopes for core samples from the Science Boreholes.

Borehole	Depth Interval		$\delta^{18}\text{O}$	δD
	from	to		
	(ft)			
			(‰)	
AP-2	0.25	0.50	-8.5	-92
	3.25	3.50	-2.3	-64
	6.50	6.75	-3.6	-76
	7.75	8.00	-4.1	-76
	13.25	13.50	-5.2	-80
	17.75	18.00	-4.6	-78
	21.50	21.75	-5.4	-85
	24.25	24.50	-4.9	-81
	39.25	39.50	-7.5	-94
	79.25	79.50	-10.9	-105
	129.25	129.50	-12.0	-108
	181.00	181.25	-12.9	-111
	240.75	241.00	-13.0	-111
	275.50	275.75	-14.2	-116
RP-2	1.50	1.75	-8.4	-100
	4.25	4.50	-2.9	-74
	6.75	7.00	-3.5	-73
	9.25	9.50	-4.2	-76
	11.25	11.50	-4.4	-75
	12.75	13.00	-5.1	-79
	17.75	18.00	-5.4	-82
	25.75	26.00	-6.7	-90
	45.00	45.25	-8.5	-96
	80.75	81.00	-12.5	-112
	150.75	151.00	-13.9	-121
	NN-1	19.75	20.00	-6.6
39.75		40.00	-9.5	-108
99.25		99.50	-13.3	-119
180.25		180.50	-14.6	-126
NW-1	19.50	19.75	-6.9	-81
	39.50	39.75	-7.6	-76
	100.00	100.25	-8.1	-71
	180.00	180.25	-7.6	-76

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Dale P. Hammermeister
6020 Academy NE
Suite 100
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Kim A. Zukosky
817 Griffith Avenue
Las Vegas, NV 89104

Kenneth D. Donnelson
3800 Liberator Way
North Las Vegas, NV 89031

David P. Gallegos
Sandia National Laboratories
Department 6331
Post Office Box 5800
Albuquerque, NM 87185

Dr. Scott Tyler
Desert Research Institute
Water Resources Center
7010 Dandini Boulevard
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817 Griffith Avenue
Las Vegas, Nevada 89104

Dr. Scott Tyler
Desert Research Institute
Water Resources Center
7010 Dandini Boulevard
Reno, Nevada 89512

Jon C. Newsom
Newsom Industries
2681 Newcastle Road
Newcastle, California 95658

David P. Gallegos
Sandia National Laboratories
Department 6331
Post Office Box 5800
Albuquerque, New Mexico 87185