DRILLING, CONSTRUCTION, AND SUBSURFACE DATA FOR PIEZOMETERS ON EDWARDS AIR FORCE BASE, ANTELOPE VALLEY, CALIFORNIA, 1991-92

by Diane L. Rewis

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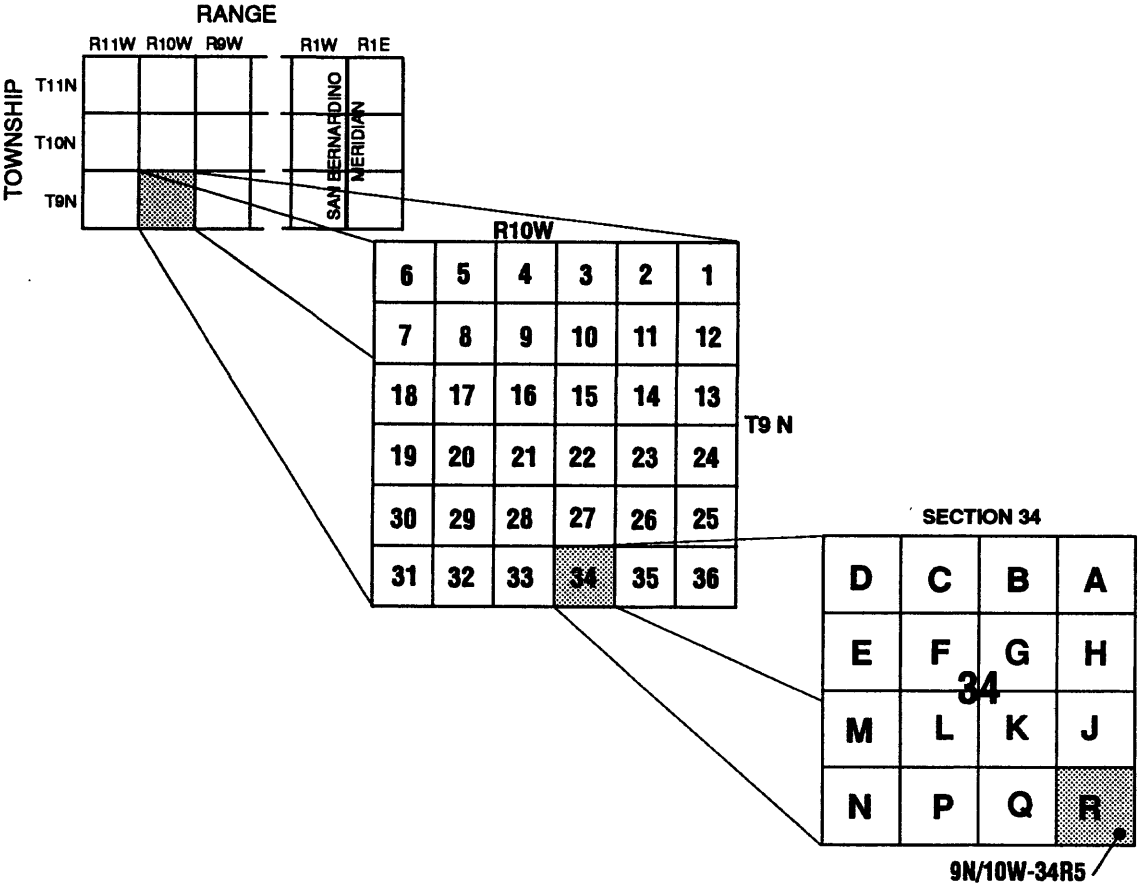
Multiply	By	To obtain
acre	0.4047	hectare
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
foot per hour (ft/h)	0.3048	meter per hour
foot per second (ft/s)	0.3048	meter per second
mile (mi)	1.609	kilometer

Vertical datum

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Well-numbering system

Wells are numbered according to their location in the rectangular system for subdivision of public land. For example, in well number 009N010W34R005S, the identification number consists of the township number, north or south; the range number, east or west; and the section number. Each section is further divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with A in the northeast corner of the section and progressing in a sinusoidal manner to R in the southeast corner. Within each 40-acre tract, wells are sequentially numbered in the order that they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). Because all wells in the study area are referenced to the San Bernardino base line and meridian (S), the final letter will be omitted. Commonly, and in this report, well numbers are abbreviated and written 9N/10W-34R5. Wells in the same township and range may be referred to only by their section designation, 34R5.



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Abstract

As part of a study by the U.S. Geological Survey, a drilling program was implemented to collect subsurface data needed to determine the relation between ground-water withdrawals and land-surface deformation at Edwards Air Force Base, Antelope Valley, California. Drilling and geologic data were collected from 18 boreholes at 13 sites on the base during 1991 and 1992. Forty single and nested piezometers were installed in these boreholes. Drill penetration rate logs were produced from drill-time data. Borehole geophysical logs were made of the deepest borehole at each site, except the Buckhorn, South Shore, and Branch Park sites. Lithologic logs were compiled from drill cutting and core sample descriptions, and from borehole geophysical data.

INTRODUCTION

The playa surface of Rogers Lake at Edwards Air Force Base (EAFB) in Antelope Valley, California, is used by the U.S. Department of the Air Force and the National Aeronautics and Space Administration (NASA) for test aircraft and space shuttle landings (fig. 1). The playa surface and area around the southern part of Rogers Lake have long been affected by land subsidence and deformation in the form of earth fissures, sinklike depressions, and giant polygonal desiccation cracks (Motts and Carpenter, 1970; Blodgett and Williams, 1992). These conditions strategically and economically affect base operations in terms of aircraft safety and runway maintenance. The U.S. Geological Survey (USGS) began a study in 1989 to determine the relation between ground-water withdrawals and land-surface deformation at EAFB. As part of this study, a drilling program was started in October 1989 to collect subsurface data needed to evaluate hydrogeologic factors related to aquifer system compaction. Londquist and others (1993) presented an overview of historic and current hydrogeologic conditions at EAFB. They included data on the magnitude of land subsidence occurring since 1961, aquifer-system compaction rates, ground-water-level changes, ground-water quality, initial well and piezometer drilling and construction, and geologic and geophysical subsurface data collected during 1989 and 1990. Drilling and data collection continued through 1992.

This report presents drilling, piezometer construction, and subsurface data collected during 1991 and 1992 from 40 piezometers installed in 18 boreholes drilled at 13 sites on EAFB. Piezometers are tubes or small diameter wells used to measure hydraulic heads, which help determine other physical properties of an aquifer. Data for the piezometers include site name, State well number, land-surface altitude, construction, and ground-water levels. Subsurface data include construction diagrams, drill penetration rate logs, core sample descriptions, borehole geophysical logs, and lithologic logs.

These data are being used in ongoing investigations to evaluate the hydrogeologic properties of the aquifer system, and relate these properties to aquifer-system compaction and land-surface deformation. Intermittent and continuous ground-water-level measurements are being collected from each of the piezometers described in this report to monitor and evaluate seasonal ground-water-level changes.

The author would like to thank the many individuals and offices at EAFB who provided facility access and technical support: the Air Force Flight

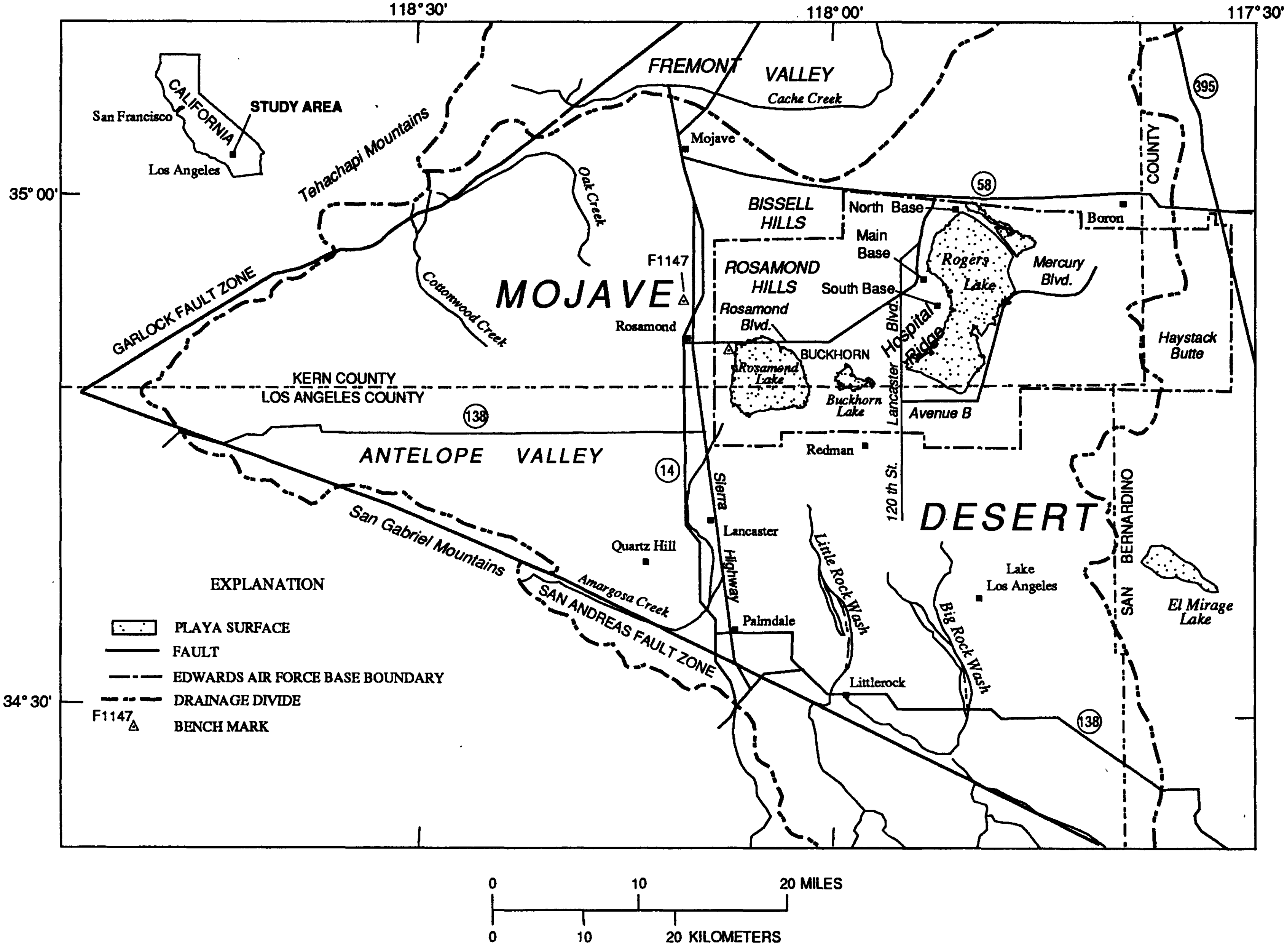

Figure 1. Location of study area. (Modified from Londquist and others, 1993).

Test Center, who authorized security clearance and coordinated cooperation with the other offices on base; Civil Engineering, who provided permits, technical support, and production well data; Environmental Engineering, who assisted in locating sites in environmentally sensitive areas; and Base Operations, who authorized access to the lakebed surface of Rogers Lake.

DRILLING AND PIEZOMETER CONSTRUCTION

Forty piezometers were installed in 18 boreholes at 13 sites (fig. 2). Boreholes were drilled using a hydraulic mud rotary rig operated by the U.S. Geological Survey. Drill bit diameters ranged from 5-3/4 to 7-7/8 in. Borehole depths ranged from 55 to 1,000 ft below land surface. At sites where more than one borehole was drilled, the deepest borehole was drilled first.

The piezometers generally were constructed as single or nested, 2- or 3-inch diameter, schedule 40 polyvinyl chloride (PVC) casings, with 10- to 40-foot slotted screen intervals (figs. 3 and 4, at back of report; table 1). Slot size was 0.02 in. on 1/4-inch spacing. Screen intervals were sand packed with #3 Monterey sand. Bentonite grout was placed between sand packs to hydraulically isolate the sand packs of the nested piezometers. Bentonite grout also was placed between the top of the sand pack of the shallowest piezometer and land surface to seal the boreholes from surface infiltration. Those parts of the piezometers extending above land surface were encased in protective 3 ft by 6-7/8 to 8-7/8 in. diameter steel surface casings secured in place with concrete. The steel surface casings were fitted with locking lids for security purposes.

An exception to the installations described above was piezometer 9N/10W-16F1 near the Graham Ranch well field (fig. 2). The borehole containing this piezometer was drilled to 420 ft then cased with 6-3/4 in. diameter, blank steel casing from 1.7 ft above land surface to 275 ft below land surface (fig. 4*D*, table 1). The annular space around the casing was sealed from 245 to 271 ft below land surface with portland cement held in place with two steel cement baskets welded to the outside of the casing. Bentonite grout was pumped on top of the cement to 1 ft below land surface, and a 2×3×1 ft concrete pad was constructed flush with the land surface. After the seals cured for more than 24 hours, drilling continued through the casing and was completed to 458 ft below land surface. The borehole is not cased from 275 to 458 ft below land surface, and the piezometer is open to the bedrock formation. The piezometer is fitted with a locking lid similar to the other sites.

Piezometers 8N/10W-5A2 through 5A6 and 9N/10W-34R5 (figs. 3*A* and 3*B*) were installed at sites where deeper piezometers were drilled and installed in 1989 (Londquist and others, 1993). Borehole geophysical and lithologic logs for these sites were reported by Londquist and others (1993) and are not repeated here. Borehole geophysical logs for piezometers 9N/10W25P1 and 25P2 (fig. 3*C*) are not presented in this report because the recording equipment malfunctioned.

Land-surface altitudes of the piezometers were derived from third-order differential leveling from bench marks along adjusted level lines originating at bench mark F1147 (fig. 1) with first-order standards, and Global Positioning System (GPS) surveys (J.C. Blodgett and M.E. Ikehara, U.S. Geological Survey, written commun., 1993). Precision for the leveling was to a thousandth of a foot. The average standard error for the vertical component for six observation sites observed using short-static and pseudo-Kinematic GPS methods was 1.1 in. or 0.1 ft. The altitude values presented here were rounded to the nearest tenth of a foot (table 1).

SUBSURFACE DATA

DRILL PENETRATION RATE LOGS

Drill-time logs were recorded for seven of the boreholes. The logs record the amount of time, in minutes, to drill a 20-foot section of borehole. The drill-time data were converted to drill penetration rates with units of foot per hour.

Drill penetration rate logs illustrate relative changes in drilling rates that denote differential consolidation or competence of the subsurface material. Logs for boreholes completed in alluvium show general trends of decreasing penetration rates with depth. Logs for boreholes completed in bedrock show sharp declines in penetration rates across the alluvium-bedrock contact.

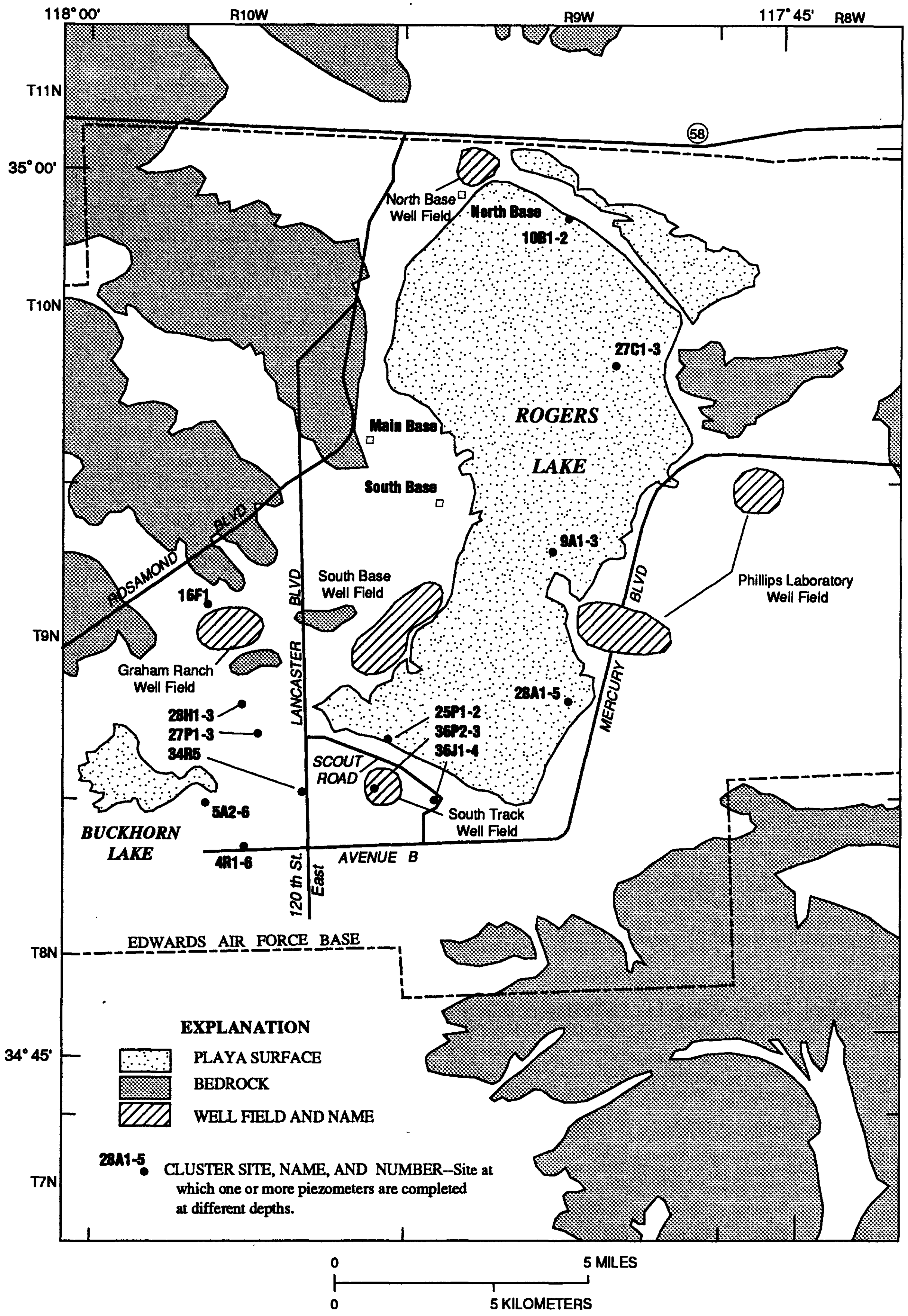

Figure 2. Location of piezometers drilled on Edwards Air Force Base, 1991-92.

Table 1. Construction data for piezometers completed in 1991 and 1992 at Edwards Air Force Base

[State well No. with asterisk (*) designates nested piezometers. Altitude of land surface in feet above sea level. Depth drilled, casing depth, sand pack and screen intervals, and depth to water in feet below land surface. Casing diameter, in inches. Type of finish: Sand, #3 Monterey sand; Open, open to the formation]

Site name and State well No.	Altitude of land surface	Depth drilled	Date of completion	Casing		Type of finish	Sand pack interval	Screen interval	Date	Depth to water
				Diameter	Depth					
Sled Track										
8N/10W- 4R1*	2,301.4	1,000	3-13-91	2	980	Sand	900-1,000	920-960	7-19-91	146.40
4R2				2	750	Sand	690-750	700-740	7-19-91	145.17
4R3				2	546	Sand	480-550	496-536	7-19-91	143.36
4R4				2	250	Sand	205-251	220-240	7-19-91	135.11
8N/10W- 4R5*	2,301.4	150	3-28-91	2	150	Sand	130-150	135-150	10-30-91	89.54
4R6				2	95	Sand	70-100	75-95	10-30-91	59.56
Buckhorn										
8N/10W- 5A2*	2,287.2	560	3-26-91	2	560	Sand	520-560	530-550	7-15-91	127.02
5A3				2	390	Sand	350-390	360-380	7-15-91	127.11
5A4				2	274	Sand	242-274	246-266	7-15-91	121.99
5A5				2	144	Sand	88-144	96-136	7-15-91	121.82
8N/10W- 5A6	2,287.2	55	3-27-91	2	55	Sand	26-55	30-50	7-15-91	28.02
Peninsula										
9N/9W- 9A1*	2,271.1	396	2-11-91	2	345	Sand	298-345	320-340	7-16-91	85.36
9A2				2	175	Sand	149-175	160-170	7-16-91	84.76
9A3				2	75	Sand	47-84	50-69	7-16-91	dry
Fissure										
9N/9W- 28A1*	2,271.1	761	2-22-91	2	755	Sand	725-760	735-745	6-19-91	93.47
28A2				2	524	Sand	472-524	494-514	6-19-91	95.09
28A3				2	350	Sand	300-360	320-340	6-19-91	89.07
28A4				2	220	Sand	175-220	195-215	6-19-91	87.80
9N/9W- 28A5	2,271.1	103	2-27-91	3	65	Sand	30-65	40-60	6-19-91	40.30
Gravity Well										
9N/10W- 16F1	2,320.7	458	8-22-91	6.75	275	Open	--	--	1-08-92	111.53

Table 1. Construction data for piezometers completed in 1991 and 1992 at Edwards Air Force Base--*Continued*

Site name and State well No.	Altitude of land surface	Depth drilled	Date of completion	Casing Diameter	Casing Depth	Type of finish	Sand pack interval	Screen interval	Date	Depth to water
Southshore										
9N/10W- 25P1*	2,269.5	500	10-30-91	2	480	Sand	400-500	450-470	11-08-91	110.72
25P2				2	130	Sand	54-145	100-120	11-08-91	71.60
Fossil Springs										
9N/10W- 27P1*	2,278.6	565	8-16-92	3	560	Sand	520-562	530-550	9-07-92	127.65
27P2				2	410	Sand	370-410	380-400	9-07-92	130.09
9N/10W- 27P3	2,278.8	220	8-26-92	2	220	Sand	190-220	200-220	9-07-92	121.55
Homestead										
9N/10W- 28H1*	2,288.6	500	8-25-92	2	500	Sand	465-500	475-495	9-07-92	125.94
28H2				2	305	Sand	265-315	275-295	9-07-92	131.92
28H3				2	135	Sand	105-140	115-135	9-07-92	dry
Branch Park										
9N/10W- 34R5	2,290.6	90	3-14-91	2	90	Sand	55-90	60-80	10-09-91	17.90
Survival School										
9N/10W- 36J1*	2,283.0	900	4-29-91	2	900	Sand	850-900	870-890	7-16-91	127.70
36J2				2	529	Sand	480-552	503-523	7-16-91	131.92
36J3				2	237	Sand	190-250	212-232	7-16-91	125.31
36J4				2	95	Sand	60-110	70-90	7-16-91	21.90
South Track										
9N/10W- 36P2	2,290.9	497	10-24-91	2	465	Sand	360-497	435-455	11-08-91	135.35
9N/10W- 36P3	2,291.2	144	10-25-91	2	120	Sand	63-144	90-110	11-08-91	27.88
North Shore										
10N/9W- 10B1*	2,278.6	315	2-08-91	2	312	Sand	275-312	282-302	10-10-91	95.42
10B2				2	150	Sand	110-163	117-137	10-10-91	95.10
Santa Fe Trail										
10N/9W- 27C1*	2,272.4	225	2-25-91	2	222	Sand	200-225	207-217	7-16-91	79.59
27C2				2	160	Sand	120-160	130-150	7-16-91	78.39
27C3				2	80	Sand	45-80	55-75	7-16-91	70.29

CORE SAMPLE DESCRIPTIONS

Core samples were taken from boreholes at the South Shore, Fissure, Gravity Well, and Fossil Springs sites (figs. 3*C*, 4*C*, 4*D*, and 4*E*). Core sample descriptions and core interval depths are shown in table 2. Core barrels used to collect the samples were 2 or 3 in. in diameter and 2 or 5 ft in length. Recovery percentages ranged from 10 to 100 percent. Low cement content of the alluvium and a higher degree of weathering of the bedrock attributed to the loss of core through the core catcher at the bottom of the core barrel. Detailed mineralogies, lithologies, and characteristics of the core samples were compared with the drill cuttings to determine the exact composition of the material and distinguish changes seen in the cuttings.

BOREHOLE GEOPHYSICAL LOGS

Upon completion of drilling the deepest borehole at each site, a suite of borehole geophysical logs was made in the uncased borehole. The logs generally included spontaneous potential, 16-in. and 64-in. normal resistivity, guard resistivity, natural gamma, acoustic, and caliper logs (fig. 4). Data derived from these logs were used to determine the length and location of the piezometer screen intervals.

Spontaneous potential logs, in conjunction with 16- and 64-in. normal resistivity logs, are used to distinguish general formation changes between medium- or coarse-grained units and very fine-grained units, and possible water-quality differences (Keys and MacCary, 1971). Guard resistivity logs are used to determine bedding variability within a unit. Natural gamma logs illustrate the intensities of gamma-ray emissions given off by the decay of potassium-40 and daughter products of uranium and thorium. These elements generally concentrate in clay and shale, and in some granitic materials, such as granitic gravel and consolidated granitic bedrock. Sonic logs were made of interval transit times of acoustic pulses through the rock surrounding the borehole between the probe's transmitters and receivers. Transit times have units of microseconds per foot. These data were converted to acoustic velocities having units of feet per second and are presented here as acoustic logs. Acoustic velocity is related to mechanical properties of the rock and is useful in identifying lithologic units of differing mechanical properties; for example, density, size, distribution, and type of grains and pore space, and degree of cementation. Caliper log values in this report are the mean diameter of the boreholes measured by three-armed caliper tools.

The boreholes for piezometers 8N/10W-4R1 through 4R4 (fig. 4*A*), 9N/9W-28A1 through 28A4 (fig. 4*C*), 9N/10W-27P1 and 27P2 (fig. 4*E*), 9N/10W-28H1 through 28H3 (fig. 4*F*), 9N/10W-36J1 through 36J4 (fig. 4*G*), and 9N/10W-36P2 (fig. 4*H*) were commercially logged, and the boreholes for piezometers 9N/9W-9A1 through 9A3 (fig. 4*B*), 0N/9W-10B1 and 10B2 (fig. 4*I*) and 10N/9W-27C1 through 27C3 (fig. 4*J*) were logged by the USGS. Piezometer 9N/10W-16F1 (fig. 4*D*) was logged commercially after the borehole was drilled to a depth of 315 ft below land surface. The USGS ran spontaneous potential and resistivity logs after the borehole was deepened to 420 ft below land surface and before the steel casing was set. These logs were superimposed into the commercial logs in figure 4*D* using a dotted curve to show the similarities and differences of the logs in the upper section and to complete the logging of the lower section. The USGS' spontaneous potential log is not shown because of mechanical problems with the tool. After the borehole was completed to 458 ft below land surface, the USGS ran natural gamma and caliper logs from the bottom of the borehole up through the open hole and steel casing to the surface (fig. 4*D*).

Log-scale increments in figure 4 are the same or proportional for each site. For example, resistivity log scales for piezometers 9N/10W-16F1 (fig. 4*D*) and 9N/10W-28H1 through 28H3 (fig. 4*F*) are two times the scale shown for the borehole log for piezometers 10N/9W-27C1 through 27C3, and four times the scale shown for the other borehole logs (figs. 4*A*, 4*B*, 4*C*, 4*E*, 4*G*, 4*H*, and 4*I*). The natural gamma log for piezometers 9N/10W-27P1 and 27P2 (fig. 4*E*) has an exceptionally high value of about 798 counts per second between 381 and 388 ft below land surface. An insert of the log for the 300 to 500 ft interval shows the log at a horizontal scale of 0 to 900 counts per second, five times the regular scale. The caliper log for piezometers 9N\10W-28H1 through 28H3 shows a large washout between 265 and 330 ft below land surface; the scale for this log is 1.5 times the regular scale.

Table 2. Description of cores from boreholes drilled in 1991 and 1992 on Edwards Air Force Base

[Depths are in feet below land surface. Soil and rock color is from Munsell® Color system; 10YR 8/2: 10YR is hue, 8 is value (lightness), and 2 is chroma (saturation) (Geological Society of America, 1991). ft, foot; in., inch; ohm-m, ohm-meter]

Core description
Fissure deep borehole. Core interval depth, 759 to 761 ft; 25 percent recovery, 0.5 ft. Core is a very pale orange (10YR 8/2); moderately sorted, massive subangular to subrounded, fine sandy silt that is well consolidated when dry with a siliceous cement, disintegrating when wet. Siltstone is composed of about 40 to 45 percent muddy silt matrix, 35 percent pore space, and 20 to 25 percent fine quartz sand. No resistivity values available for this bottom hole core. Piezometers 9N/9W-28A1, 28A2, 28A2, 28A3, and 28A4 completed in this borehole.
Gravity Well borehole. Eight core intervals from various depths are described below; recovery percentages also vary. Piezometer 9N/10W-16F1 completed in this borehole.
Core interval depth, 136 to 138 ft; 25 percent recovery, 0.5 ft. Core is very pale orange (10YR 8/2) to grayish orange (10YR 7/4), weathered quartz monzonite, with a friable phaneritic-granular texture and color index of 10. Quartz and feldspar minerals are anhedral; biotite minerals are subhedral to euhedral, to 0.24 in. across and 0.12 in. thick. Weathered products are white (N9) sericite and pale yellowish orange (10YR 8/6) goethite. Estimated composition of the weathered bedrock is about 30 percent white plagioclase, 35 percent light gray quartz, 20 percent pinkish gray potassium feldspar, and 15 percent black biotite. 16-inch normal resistivity values range from 46 to 48 ohm-m (fig. 4*D*).
Core interval depth, 221 to 223 ft; 75 percent recovery, 1.5 ft. Core has the same color, texture, and estimated composition as above, but is more competent and less friable. Numerous coring-induced fractures occur randomly throughout the length of core. Two natural fractures are discernible. 16-inch normal resistivity is about 38 ohm-m.
Separated subvertical fracture at 221.0 ft, oriented about 5 to 10° from vertical, with secondary mineralization of moderate to dark reddish brown (10R 4/6 to 3/4) material lining the fracture wall. Fracture terminates at about 222.0 ft.
Separated fracture at 222.2 ft, oriented about 40° from vertical with the footwall lined with mottled pale yellowish orange (10YR 8/6) and grayish orange (10YR 7/4) cryptocrystalline material.
Core interval depth, 260 to 262.5 ft; 70 percent recovery, 1.75 ft. Core is a competent, very light gray (N8) to pinkish gray (5YR 8/1) quartz monzonite, with a phaneritic-granular texture and color index of 15. Estimated composition of the rock is about 35 percent white plagioclase, 30 percent medium light gray to greenish gray quartz, 20 percent pinkish gray potassium feldspar, and 15 percent greenish black biotite. Core is broken by numerous coring-induced and separated natural fractures. Orientation of the natural fractures range from 20 to 55° from vertical and are lined with either pale yellowish orange (10YR 8/6) microcrystalline goethite or streaked mottled moderate reddish brown (10R 4/6), pale yellowish orange (10YR 8/6), greenish gray (5GY 6/1), and dark greenish gray (5GY 4/1) cryptocrystalline material. One fracture oriented 55° from vertical is filled with a thin zone of gouge about 0.1 in. wide. 16-inch normal resistivity values decrease with depth from 117 to 111 ohm-m (fig. 4*D*).
Core interval depth, 300 to 302 ft; 85 percent recovery, 1.7 ft. Core is a very competent, light gray (N7) quartz monzonite with a phaneritic-granular texture and color index of about 10. Estimated composition is about 40 percent white plagioclase, 30 percent grayish green quartz, 20 percent grayish pink potassium feldspar, and 10 percent greenish black biotite. Core has three coring-induced fractures and five separated and two filled natural fractures. 16-inch normal resistivities decrease with depth from 74 to 48 ohm-m.
Separated fracture at 300.1 ft, oriented 20° from vertical, with hanging wall lined with grayish red (5R 4/2) cryptocrystalline material. Footwall portion is missing.
Separated vertical fracture at 300.2 ft, lined with mottled greenish gray (5GY 6/1) and grayish red (5R 4/2) cryptocrystalline material. Fracture terminates at about 300.7 ft with an orientation of about 10° from vertical.
Filled vertical hairline fracture at 300.2 ft, with similar mineralization as above. Fracture terminates at about 300.1 ft and 10° from vertical.

Core description

Gravity Well borehole.--*Continued*

Core interval depth, 300 to 302 ft--Continued

Separated fracture at 300.3 ft, oriented 40° from vertical. Foot-wall lined with similar mineralization as the separated fracture at 300.2 ft. Hanging wall portion is missing.

Two separated subparallel fractures at 300.9 ft, 0.75 to 1 in. apart, oriented about 55 to 60° from vertical. Both footwalls and hanging walls are lined with mottled greenish black (5GY 2/1), greenish gray (5GY 6/1), and white (N9) cryptocrystalline material. Fractures crosscut the filled vertical fracture from 300.2 ft above.

Hairline fracture at 301.5 ft, oriented about 50° from vertical. Unable to determine any filling or gouge.

Core interval depth, 311 to 313.5 ft; 44 percent recovery, 1.1 ft. 16-inch normal resistivity values increase with depth from 107 to 154 ohm-m (fig. 4*D*).

Clay, moderate yellowish brown (10YR 5/4), very cohesive; no silt. Depth, 311.0; thickness, 0.3 ft.

Clay grades to mottled, silty sandy clay, white (N9), moderate orange pink (5YR 8/4), grayish red (10R 4/2), greenish gray (5GY 6/1) and light bluish gray (5B 7/1), cohesive. Depth, 311.3; thickness, 0.6 ft.

Quartz monzonite, broken, subangular fragments from 0.6 to 2.2 in. in diameter. Depth, 311.9; thickness, 0.2 ft.

Core interval depth, 340 to 342 ft; 100 percent recovery, 2 ft. Core is light gray (N7), very competent quartz monzonite with a phaneritic-granular texture and a color index of 10. A thin section was made from a portion of core at the 340.4-foot depth. The rock is classified as a quartz monzonite using the AGI Peterson classification (Raymond, 1984, fig. 15*C*, p. 55-57), with a composition of 38 percent plagioclase, 32 percent quartz, 22 percent potassium feldspar, 7 percent biotite, 1 percent hornblende, and a trace of manganese oxide stain. The rock has undergone sericitic and chloritic alteration. The anorthosite content of the plagioclase is between 40 to 60 percent (G. Dixon, Geologist, U.S. Geological Survey, oral comm., 1993). The core has four coring-induced fractures, three natural fractures and a pegmatite dike. 16-inch normal resistivity values range from 207 to 216 ohm-m (fig. 4*D*).

Filled fracture at 340.9 ft, oriented about 30° from vertical 0.02 to 0.08 in. wide, filled with medium bluish gray (5B 5/1) cryptocrystalline material. Fracture terminates at about 341.4 ft.

Separated fracture at 341.0 ft, oriented about 45° from vertical, crosscutting and offsetting filled fracture above by 0.6 in. Footwall and hanging wall are lined with mottled and streaked white (N9), greenish gray (5G 6/1), moderate orange pink (5YR 8/4) and grayish red (5R 4/2) cryptocrystalline material. Movement along fracture is oblique, right lateral, normal slip indicated by offset and slickensides with a 50° pitch relative to the strike of the fracture.

Pegmatite dike at 341.5 ft, oriented about 40° from vertical of moderate orange pink potassium feldspar, light gray quartz and black hornblende. The dike is about 0.5 to 0.75 in. thick and is crosscut by the separated fracture described above.

Subvertical, hairline fracture at 341.5 ft, crosscutting the dike described above, filled with dark greenish gray (5G 4/1) to greenish black (5G 2/1) microcrystalline material.

Core changes color to light greenish gray (5G 8/1) at 341.8 ft; the quartz monzonite becomes sericitic with a friable, sugary texture. Depth, 341.8; thickness, 0.2 ft.

Core description

Gravity Well borehole.--*Continued*

Core interval depth 390 to 392 ft; 100 percent recovery, 2 ft. Core is the same color, type, texture, and composition as the upper part of the 340 to 342 ft interval. Core has six coring-induced fractures and three discernible natural fractures. 16-inch normal resistivity values range from 237 to 240 ohm-m (fig. 4*D*).

Separated vertical fracture at 390.0 ft, lined with streaked greenish black (5G 2/1) dark greenish gray (5G 4/1), grayish red (5R 4/2), and white (N9) cryptocrystalline material that forms slickensides with a 55° pitch indicating oblique, right lateral movement. Fracture terminates at about 390.8 ft with an orientation of about 5° from vertical.

Separated subvertical fracture at 390.0 ft, oriented about 10° from vertical and lined with similar secondary mineralization as above. Slickensides have a 45° pitch indicating oblique, normal, right lateral movement. The footwall rock has short hairline flow structures filled with black (N1) cryptocrystalline material.

Separated fracture at 391.8 ft, oriented 20° from vertical, lined with streaked greenish gray (5GY 6/1), white (N9), black (N1), and dusky red (5R 3/4) cryptocrystalline material forming slickensides on the hanging wall with a pitch of about 45° that suggests oblique, normal, right lateral movement. The footwall is missing.

Core interval depth 420 to 422 ft; 100 percent recovery, 2 ft. Core is light greenish gray (5GY 8/1) with the same texture and composition as the rock above. Core has coring-induced fractures near the top and in the last one-half of the core. A single vertical-subvertical hairline fracture runs the entire length of the core. Fracture is filled in the upper one-half of the core and is broken open in the lower one-half. Mottled greenish black (5GY 2/1), greenish gray (5GY 6/1), light greenish gray (5GY 8/1) sugary microcrystalline material lines the fracture. No resistivity values available for this interval.

South Shore borehole. Core interval depth 459 to 461 ft; 10 percent recovery, 0.2 ft. Core is a pale grayish orange (10YR 8/4), poorly sorted, subangular to subrounded, fine- to medium-grained arkosic alluvium. Alluvium has a bronze mica- and sericite-rich matrix with occasional pegmatite gravel to 0.7 in., and is poorly consolidated with a small amount of siliceous cement. No resistivity values available for this bottom hole core. Piezometers 9N\10W-25P1 and 25P22 are completed in this borehole.

Fossil Springs deep borehole. Core interval depth 560 to 565 ft; 80 percent recovery, 4 ft. Core is a white (N9) to yellowish green (5Y 8/1), poorly sorted, subrounded, fine to coarse grained, arkosic alluvium that is moderately consolidated when dry with a siliceous cement, disintegrating when wet. Alluvium is a fine pebbly gravel to 0.3 in., with a matrix of medium- to coarse-grained sand, and silt. Grains are composed of about 40 to 45 percent white plagioclase that is mostly altered to sericite, 30 to 35 percent gray quartz, 20 to 25 percent pink potassium feldspar, 5 percent black and bronze mica, and a trace of brownish yellow hematite. No resistivity values available for this bottom hole core. Piezometers 9N/10W-27P1 and 27P2 completed in this borehole.

LITHOLOGIC LOGS

A lithologic log was compiled for each site using descriptions of drill cuttings logged from the deepest borehole, core samples, and borehole geophysical logs (table 2, figs. 3*B* and 4). Drill cuttings were logged at 10-foot intervals and where formation changes were distinguishable by texture, color, and drill penetration rate differences; also the cuttings were compared to core samples taken at specified intervals. Borehole geophysical logs were used to identify the depths of contacts between units.

SUMMARY

The playa surface of Rogers Lake at Edwards Air Force Base, Antelope Valley, California, is used for test aircraft and space shuttle landings; however, this surface has long been affected by land subsidence and land-surface deformation. In 1989, the U.S. Geological Survey (USGS) began a study to determine the relation between ground-water withdrawals and land-surface deformation. As part of this study, the USGS began a drilling program to collect subsurface data needed to evaluate hydrogeologic factors related to compaction of aquifer material, and provide ground-water level data to monitor seasonal changes in the aquifer system. This report is a compilation of drilling, construction, and subsurface data collected during the installation of 40 piezometers at 13 sites on the base in 1991 and 1992.

Boreholes were drilled using a hydraulic mud rotary rig. Piezometers were installed in the boreholes as single or nested piezometers with isolated screen intervals at depths ranging from 60 to 960 ft below land surface.

Drill penetration rate logs illustrate relative changes in consolidation or competence of the subsurface material. Descriptions of core samples collected while drilling were used to determine the mineralogy, lithology, and characteristics of the subsurface materials. Borehole geophysical logs from each site, except South Shore, were used to identify the subsurface lithologies and depths of unit contacts. Lithologic logs were compiled on the basis of drill penetration rate logs, drill cutting and core sample descriptions, and borehole geophysical logs.

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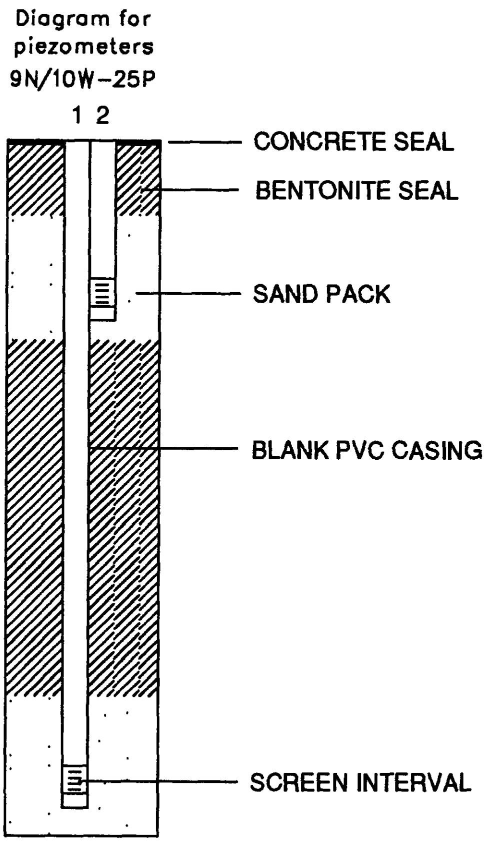
(PAGE 13 FOLLOW

DRILL PENETRATION RATE LOGS, CONSTRUCTION DIAGRAMS, LITHOLOGIC LOGS, AND GEOPHYSICAL LOGS

EXPLANATION FOR FIGURES 3 AND 4



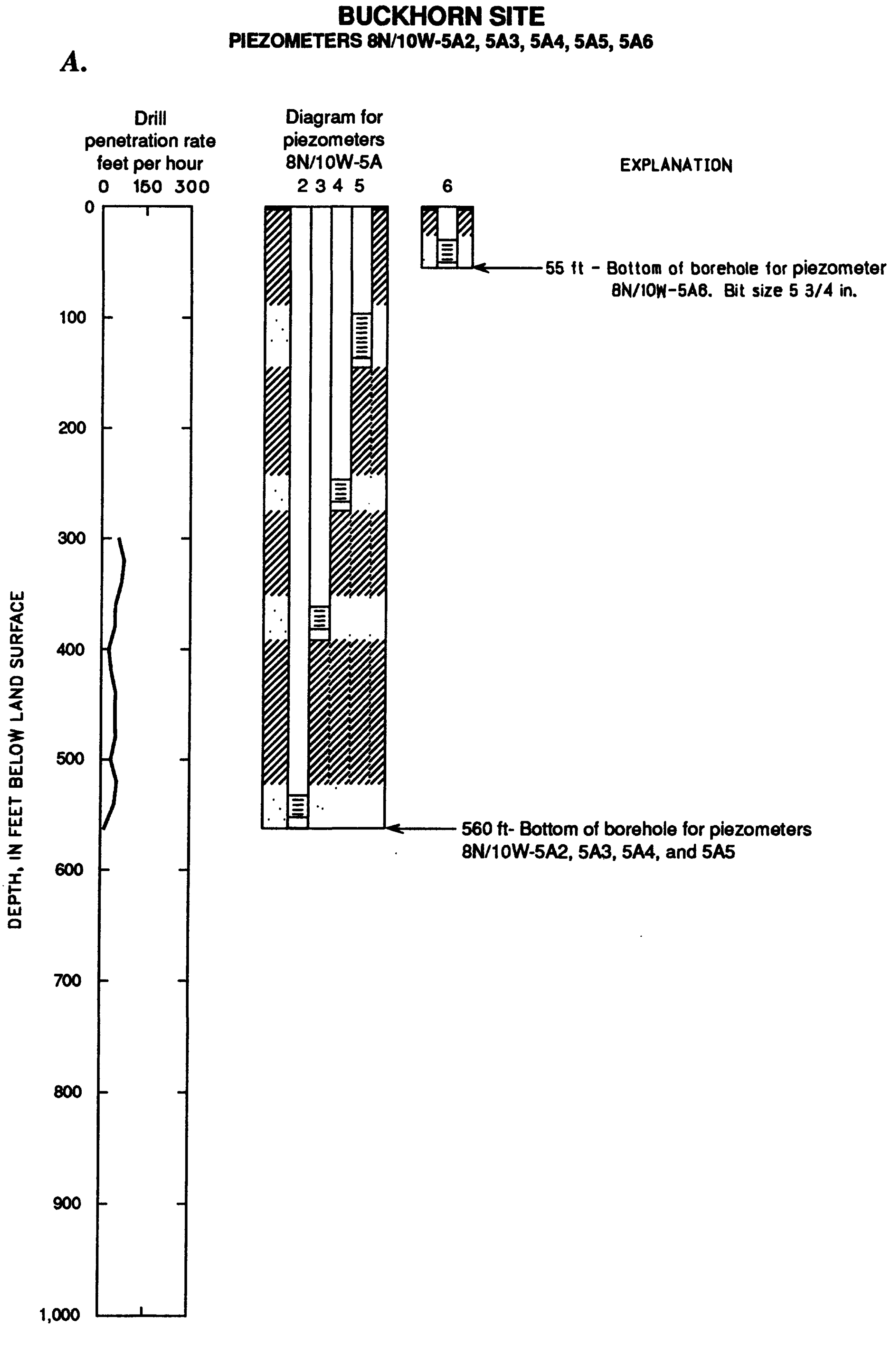
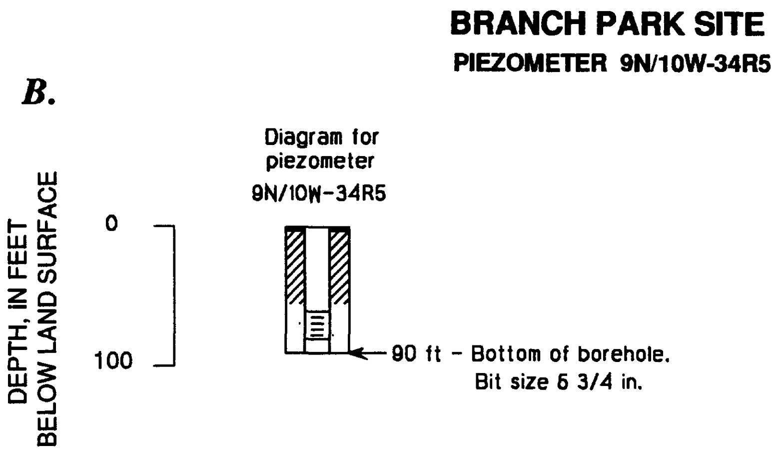


Figure 3. Drill penetration rate logs, construction diagrams, and lithologic logs for piezometers at the Buckhorn, Branch Park, and South Shore sites on Edwards Air Force Base, 1991-92.



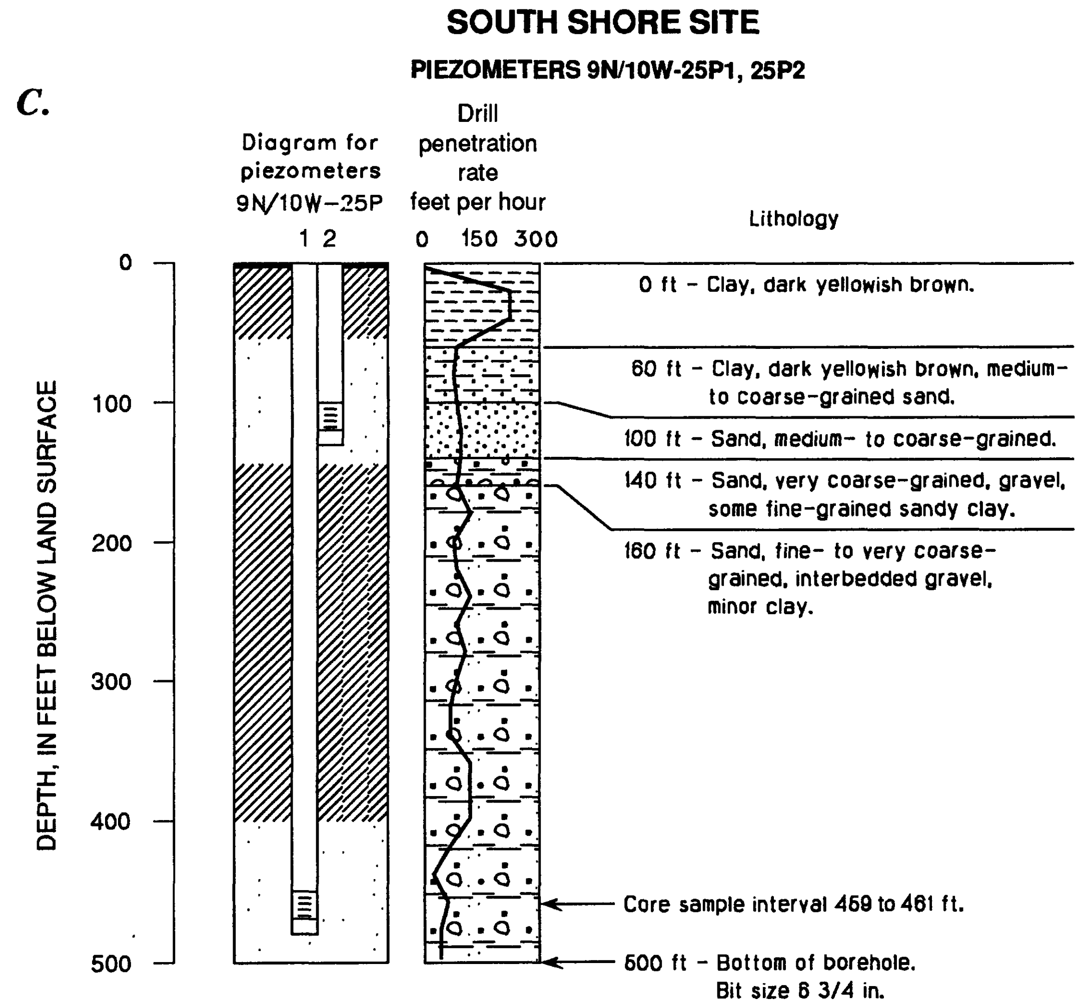


Figure 3. Drill penetration rate logs, construction diagrams, and lithologic logs for piezometers at the Buckhorn, Branch Park, and South Shore sites on Edwards Air Force Base, 1991-92--*Continued.*

SLED TRACK SITE
PIEZOMETERS 8N/10W-4R1, 4R2, 4R3, 4R4, 4R5, 4R6

A.

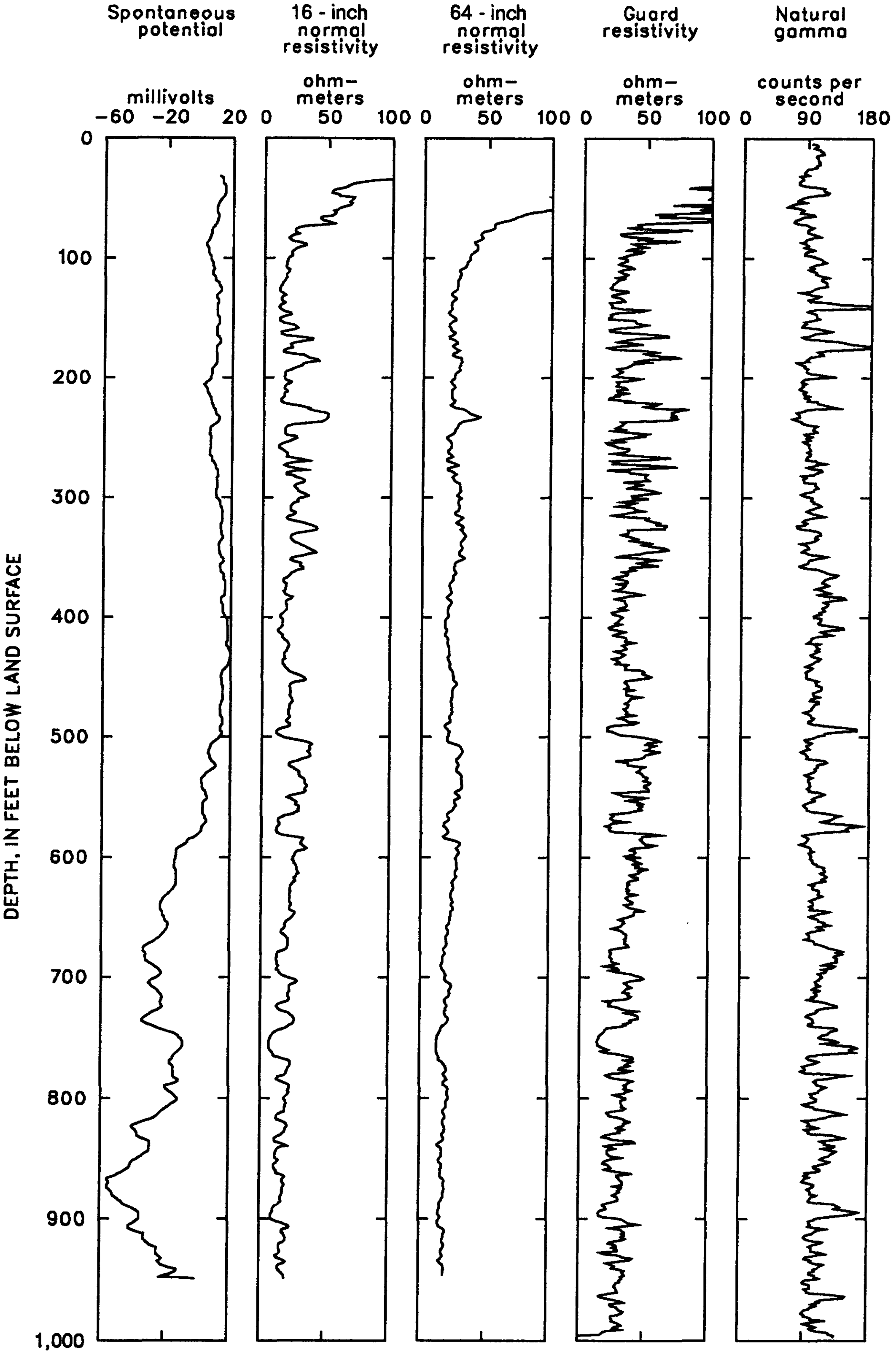
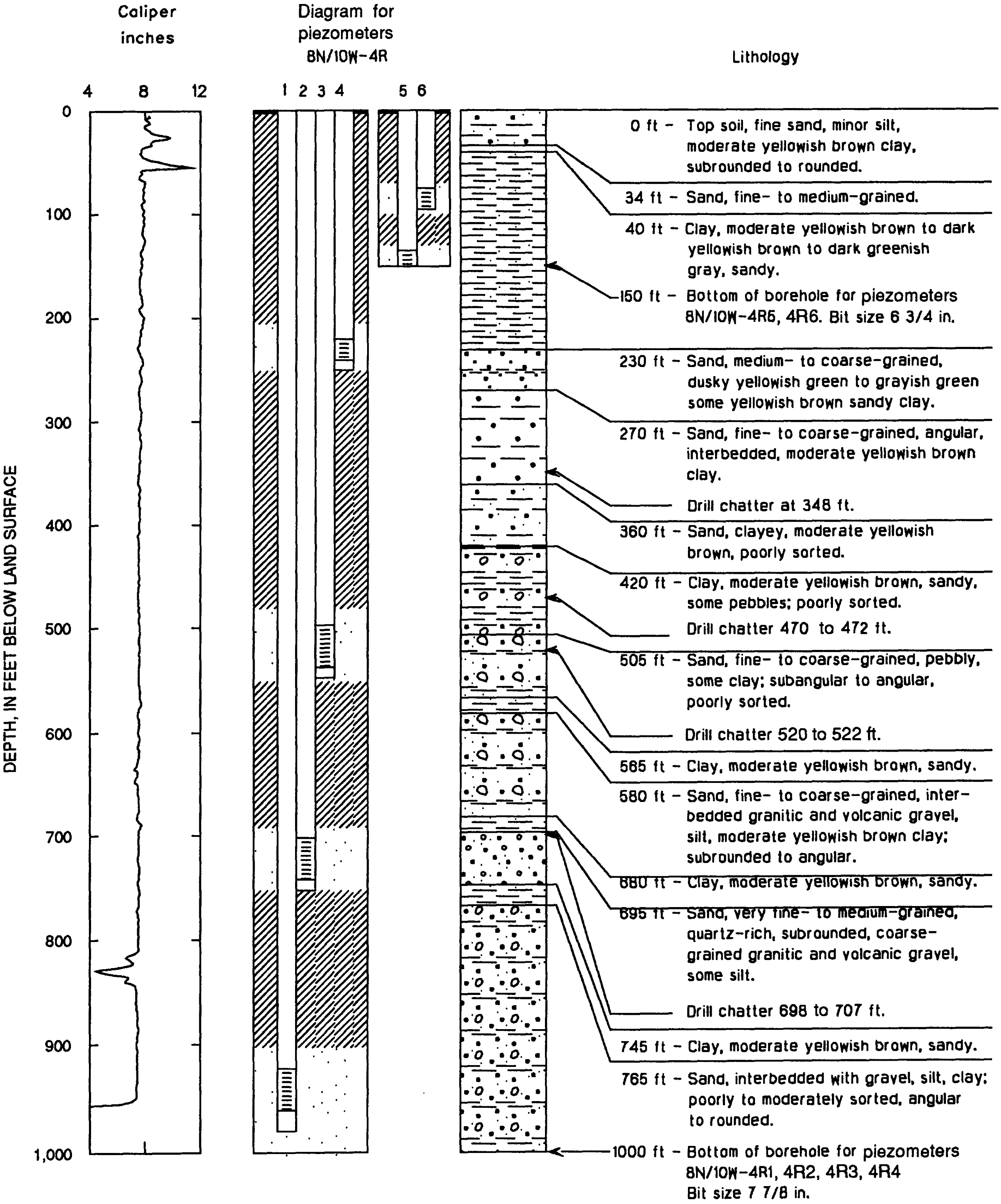


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92.

SLED TRACK SITE
PIEZOMETERS 8N/10W-4R1, 4R2, 4R3, 4R4, 4R5, 4R6



PENNINSULA SITE
PIEZOMETERS 9N/9W-9A1, 9A2, 9A3

B.

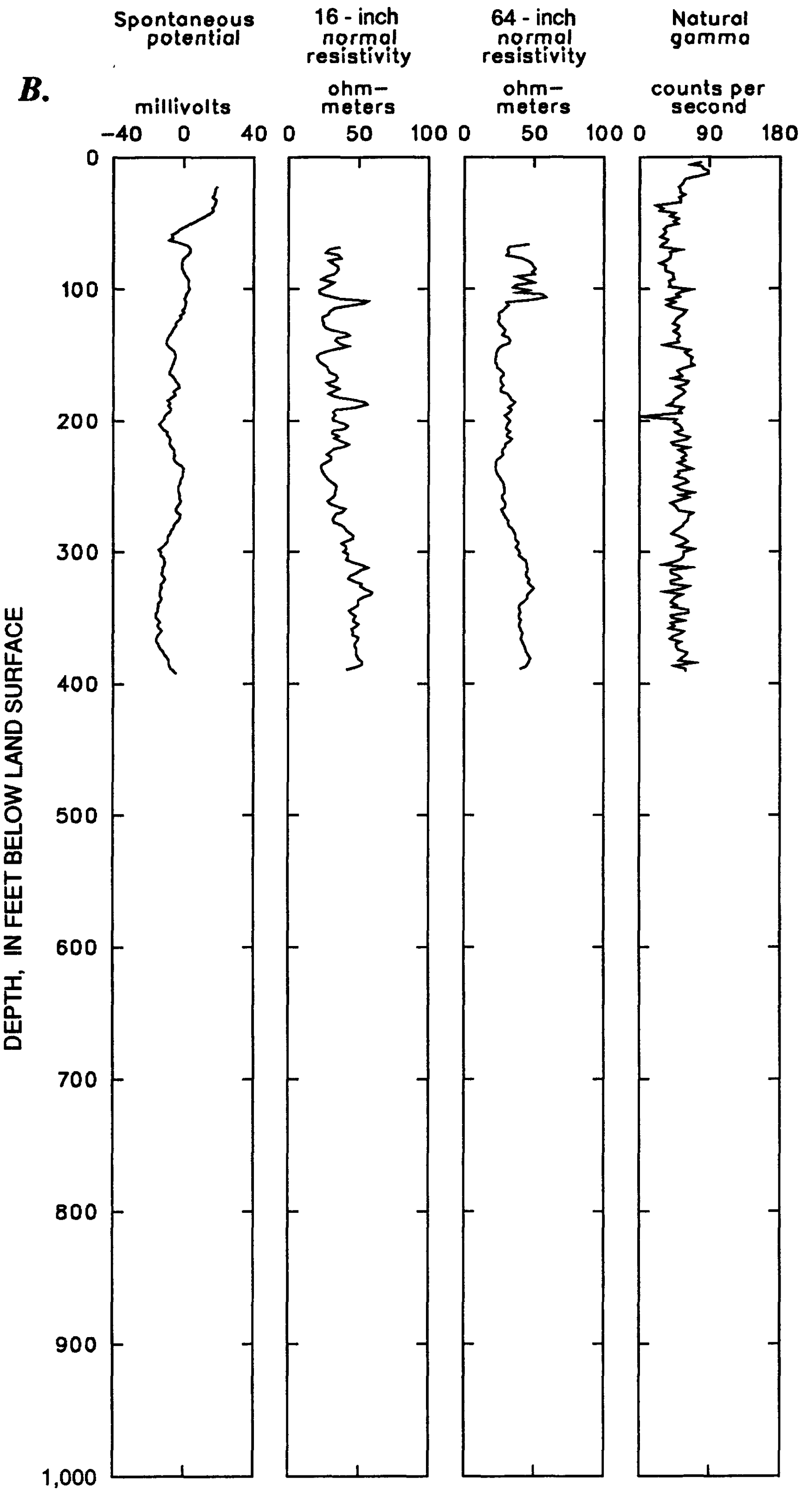
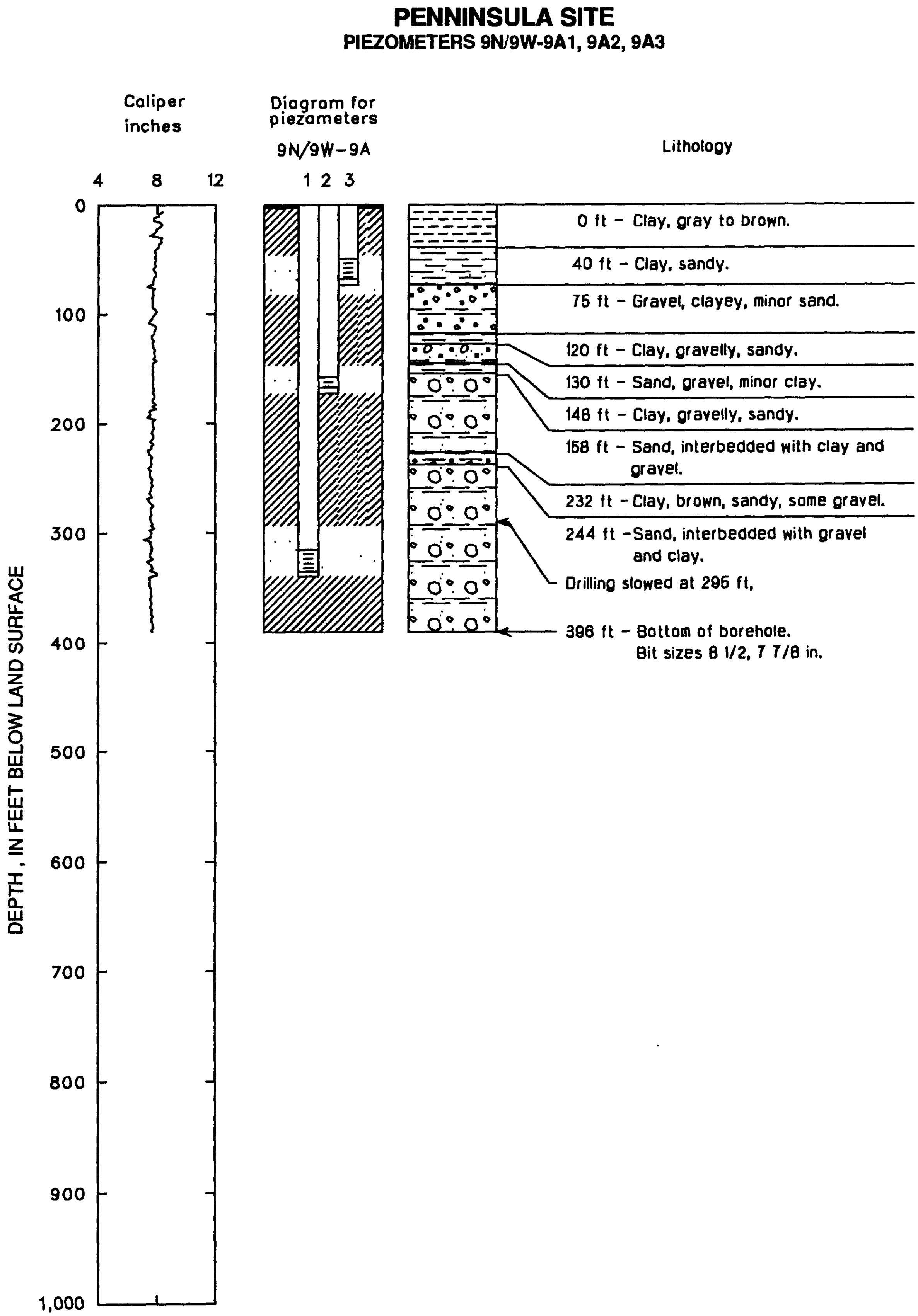


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*


PENNINSULA SITE
PIEZOMETERS 9N/9W-9A1, 9A2, 9A3
Caliper inches
4 8 12
Diagram for piezometers 9N/9W-9A
1 2 3
Lithology
DEPTH, IN FEET BELOW LAND SURFACE
0
100
200
300
400
500
600
700
800
900
1,000
0 ft - Clay, gray to brown.
40 ft - Clay, sandy.
75 ft - Gravel, clayey, minor sand.
120 ft - Clay, gravelly, sandy.
130 ft - Sand, gravel, minor clay.
148 ft - Clay, gravelly, sandy.
158 ft - Sand, interbedded with clay and gravel.
232 ft - Clay, brown, sandy, some gravel.
244 ft - Sand, interbedded with gravel and clay.
Drilling slowed at 295 ft.
396 ft - Bottom of borehole.
Bit sizes 8 1/2, 7 7/8 in.

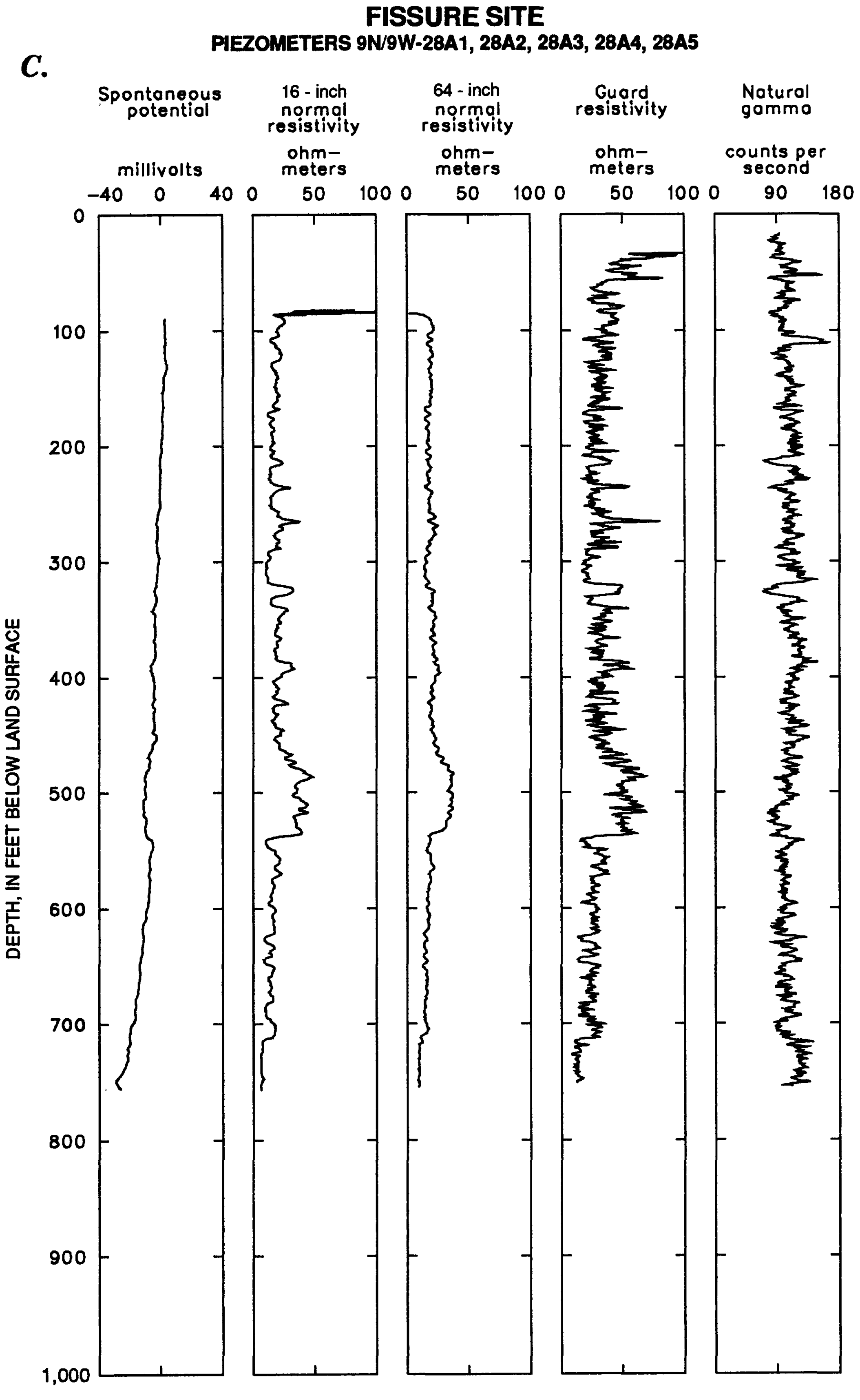
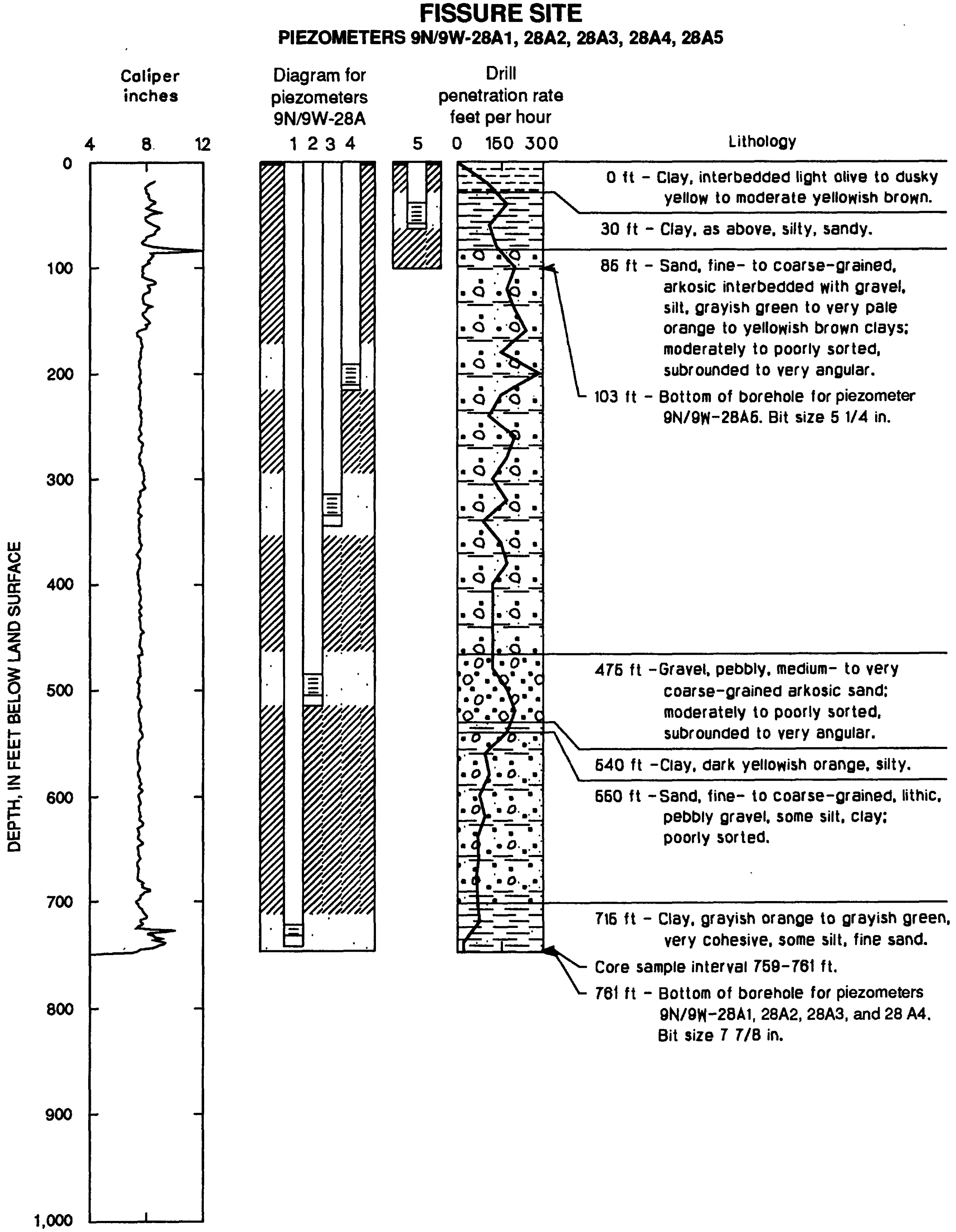


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*


FISSURE SITE
PIEZOMETERS 9N/9W-28A1, 28A2, 28A3, 28A4, 28A5
Caliper inches
4 8 12
Diagram for piezometers 9N/9W-28A
1 2 3 4
5
Drill penetration rate feet per hour
0 150 300
Lithology
DEPTH, IN FEET BELOW LAND SURFACE
0
100
200
300
400
500
600
700
800
900
1,000
0 ft - Clay, interbedded light olive to dusky yellow to moderate yellowish brown.
30 ft - Clay, as above, silty, sandy.
85 ft - Sand, fine- to coarse-grained, arkosic interbedded with gravel, silt, grayish green to very pale orange to yellowish brown clays; moderately to poorly sorted, subrounded to very angular.
103 ft - Bottom of borehole for piezometer 9N/9W-28A5. Bit size 5 1/4 in.
475 ft - Gravel, pebbly, medium- to very coarse-grained arkosic sand; moderately to poorly sorted, subrounded to very angular.
540 ft - Clay, dark yellowish orange, silty.
550 ft - Sand, fine- to coarse-grained, lithic, pebbly gravel, some silt, clay; poorly sorted.
715 ft - Clay, grayish orange to grayish green, very cohesive, some silt, fine sand.
Core sample interval 759-761 ft.
761 ft - Bottom of borehole for piezometers 9N/9W-28A1, 28A2, 28A3, and 28 A4. Bit size 7 7/8 in.

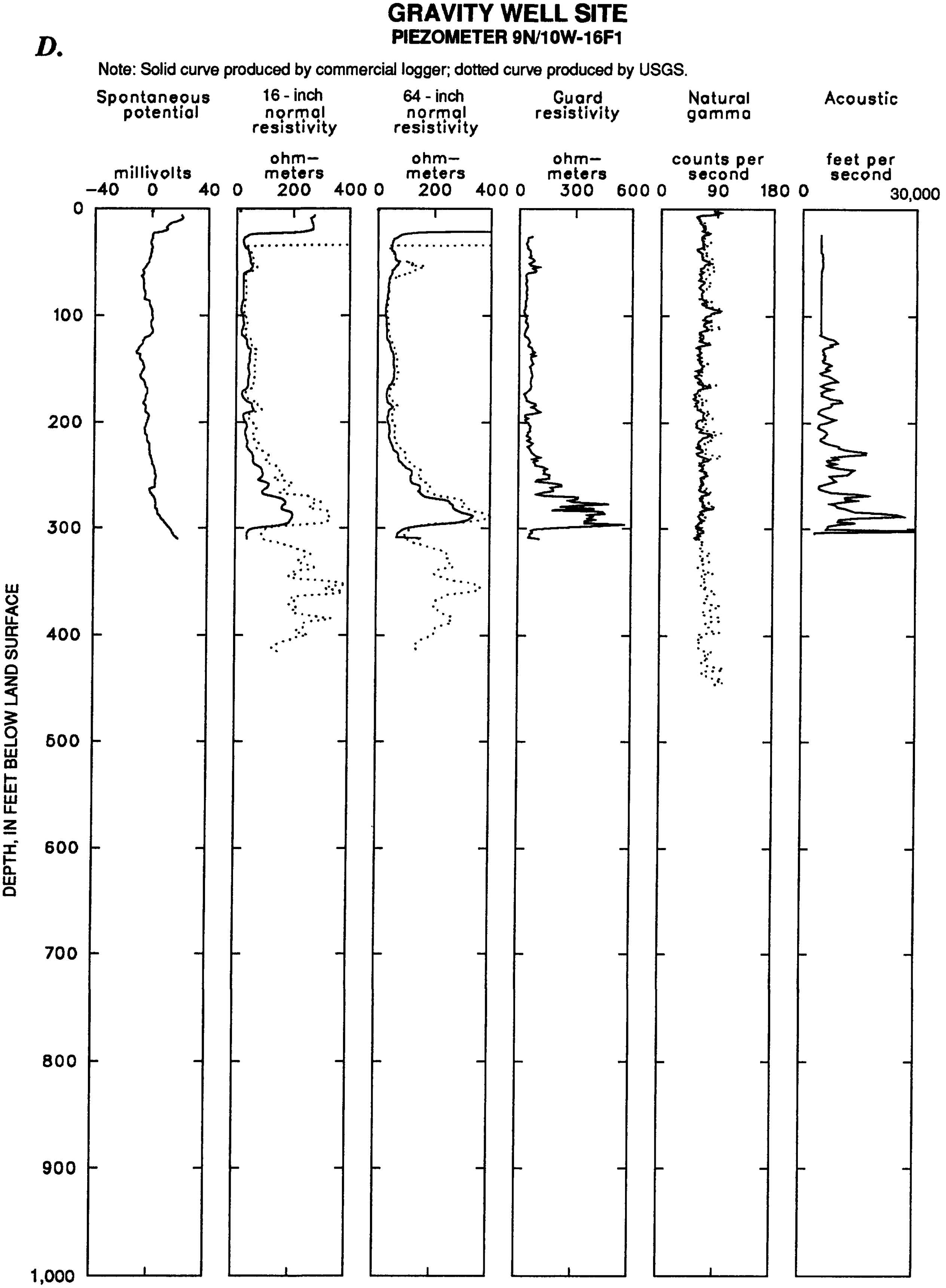
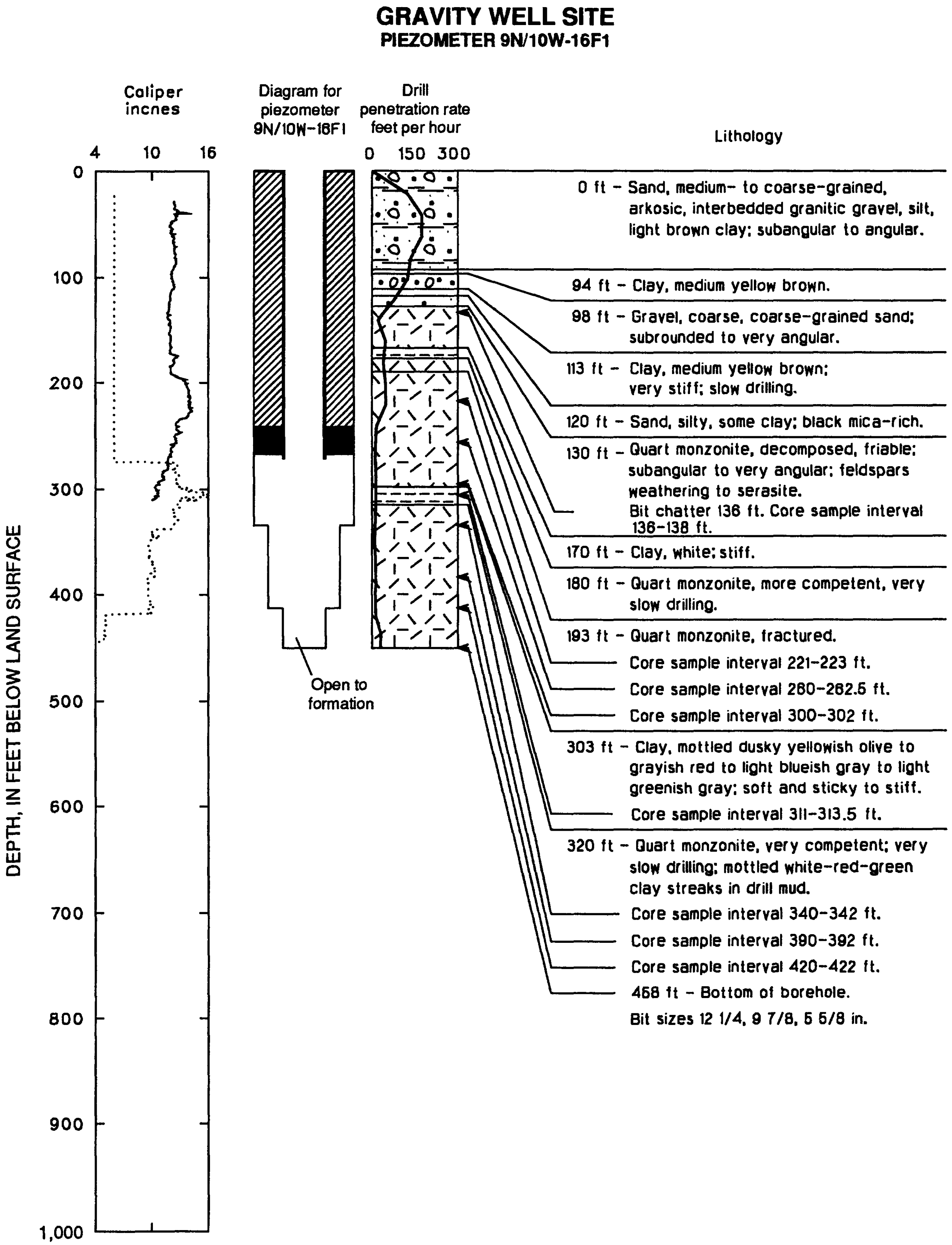


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*


GRAVITY WELL SITE
PIEZOMETER 9N/10W-16F1
Caliper incnes
4 10 16
Diagram for piezometer 9N/10W-16F1
Drill penetration rate feet per hour
0 150 300
Lithology
DEPTH, IN FEET BELOW LAND SURFACE
0
100
200
300
400
500
600
700
800
900
1,000
Open to formation
0 ft - Sand, medium- to coarse-grained, arkosic, interbedded granitic gravel, silt, light brown clay; subangular to angular.
94 ft - Clay, medium yellow brown.
98 ft - Gravel, coarse, coarse-grained sand; subrounded to very angular.
113 ft - Clay, medium yellow brown; very stiff; slow drilling.
120 ft - Sand, silty, some clay; black mica-rich.
130 ft - Quart monzonite, decomposed, friable; subangular to very angular; feldspars weathering to serasite.
Bit chatter 136 ft. Core sample interval 136-138 ft.
170 ft - Clay, white; stiff.
180 ft - Quart monzonite, more competent, very slow drilling.
193 ft - Quart monzonite, fractured.
Core sample interval 221-223 ft.
Core sample interval 260-262.5 ft.
Core sample interval 300-302 ft.
303 ft - Clay, mottled dusky yellowish olive to grayish red to light blueish gray to light greenish gray; soft and sticky to stiff.
Core sample interval 311-313.5 ft.
320 ft - Quart monzonite, very competent; very slow drilling; mottled white-red-green clay streaks in drill mud.
Core sample interval 340-342 ft.
Core sample interval 390-392 ft.
Core sample interval 420-422 ft.
458 ft - Bottom of borehole.
Bit sizes 12 1/4, 9 7/8, 5 5/8 in.

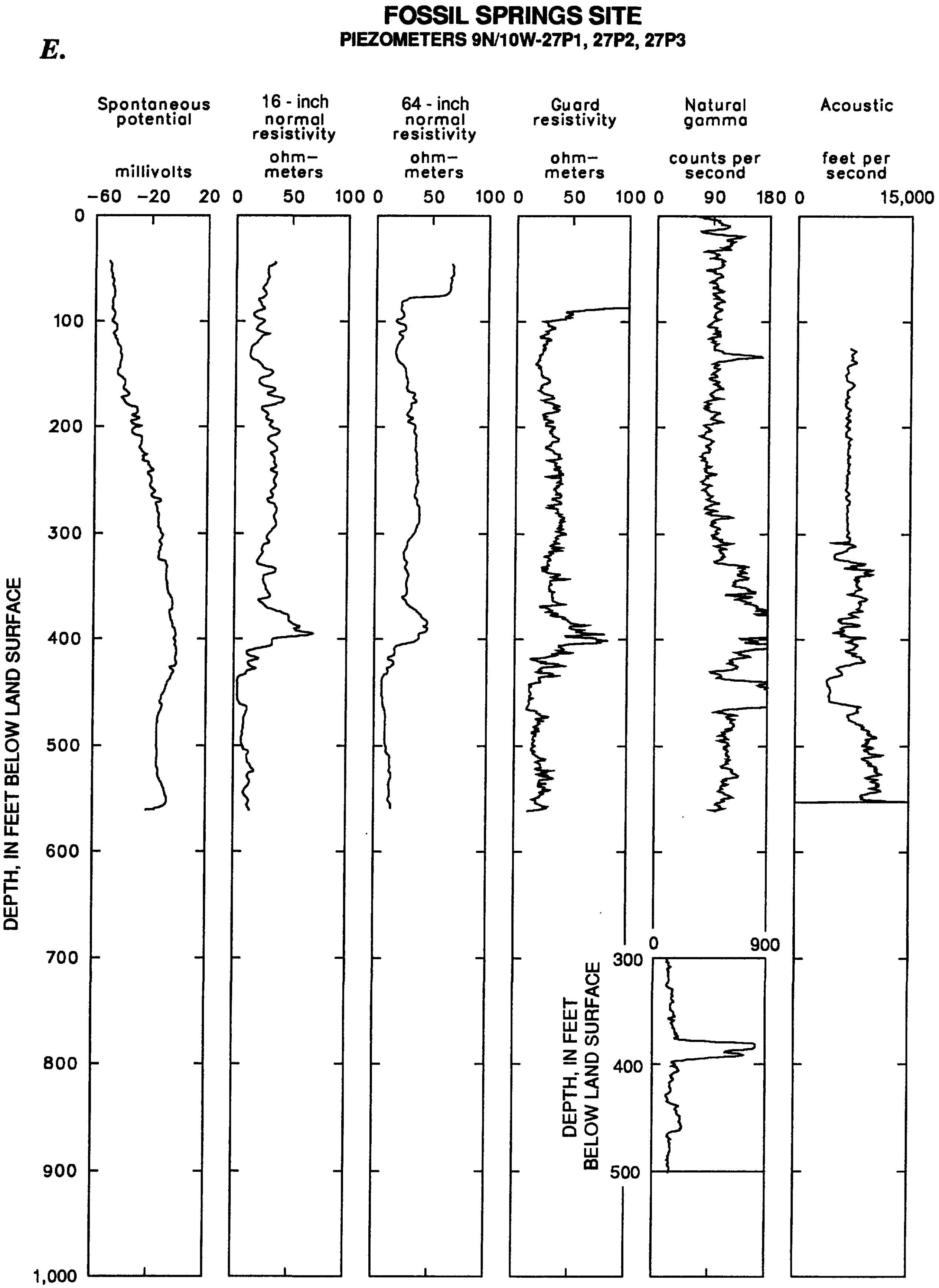
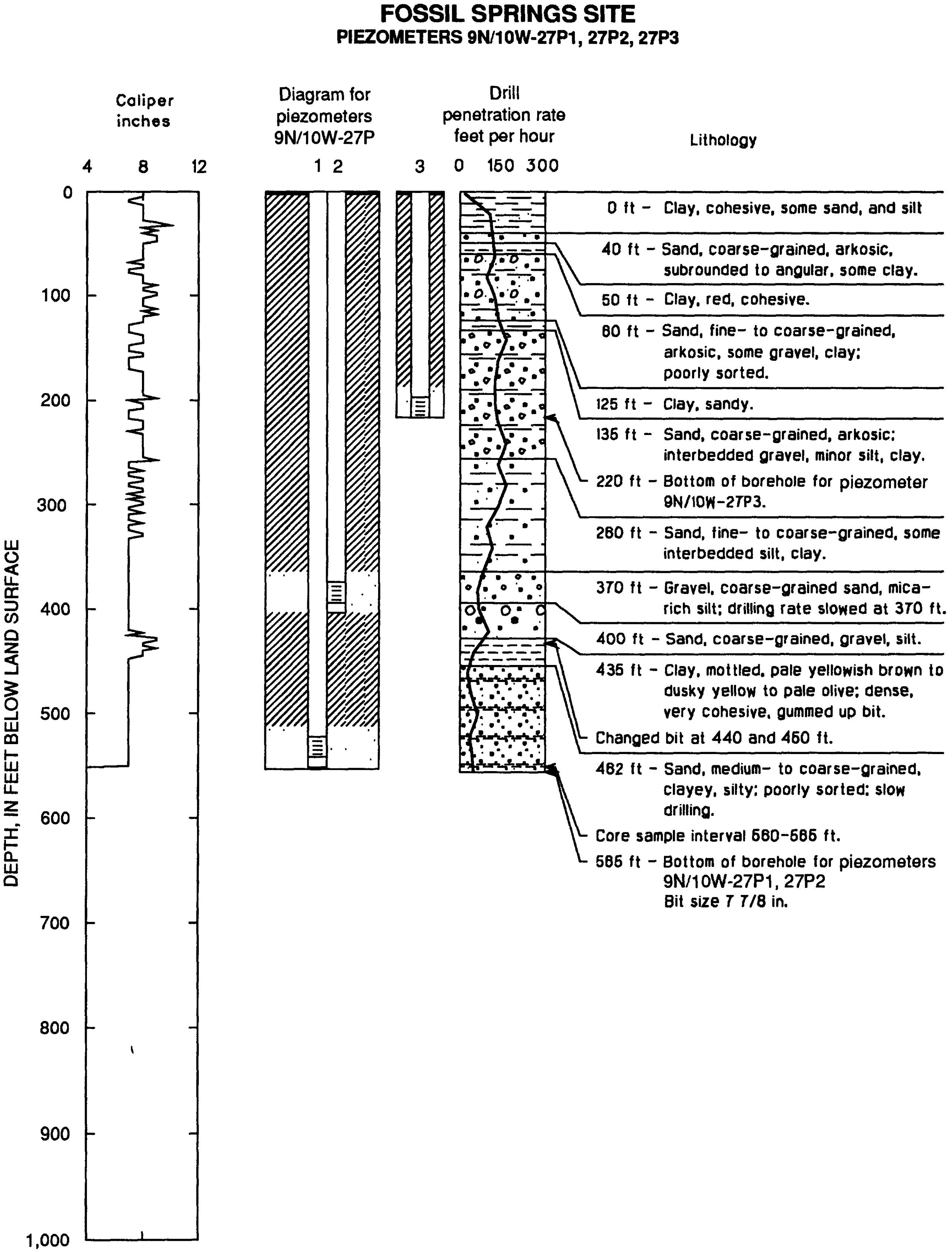


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*



FOSSIL SPRINGS SITE
PIEZOMETERS 9N/10W-27P1, 27P2, 27P3
Caliper inches
4
8
12
Diagram for piezometers 9N/10W-27P
1 2
3
Drill penetration rate feet per hour
0 150 300
Lithology
DEPTH, IN FEET BELOW LAND SURFACE
0
100
200
300
400
500
600
700
800
900
1,000
0 ft - Clay, cohesive, some sand, and silt
40 ft - Sand, coarse-grained, arkosic, subrounded to angular, some clay.
50 ft - Clay, red, cohesive.
60 ft - Sand, fine- to coarse-grained, arkosic, some gravel, clay; poorly sorted.
125 ft - Clay, sandy.
135 ft - Sand, coarse-grained, arkosic; interbedded gravel, minor silt, clay.
220 ft - Bottom of borehole for piezometer 9N/10W-27P3.
260 ft - Sand, fine- to coarse-grained, some interbedded silt, clay.
370 ft - Gravel, coarse-grained sand, mica-rich silt; drilling rate slowed at 370 ft.
400 ft - Sand, coarse-grained, gravel, silt.
435 ft - Clay, mottled, pale yellowish brown to dusky yellow to pale olive; dense, very cohesive, gummed up bit.
Changed bit at 440 and 460 ft.
462 ft - Sand, medium- to coarse-grained, clayey, silty; poorly sorted; slow drilling.
Core sample interval 560-565 ft.
565 ft - Bottom of borehole for piezometers 9N/10W-27P1, 27P2
Bit size 7 7/8 in.

HOMESTEAD SITE

PIEZOMETERS 9N/10W-28H1, 28H2, 28H3

F.

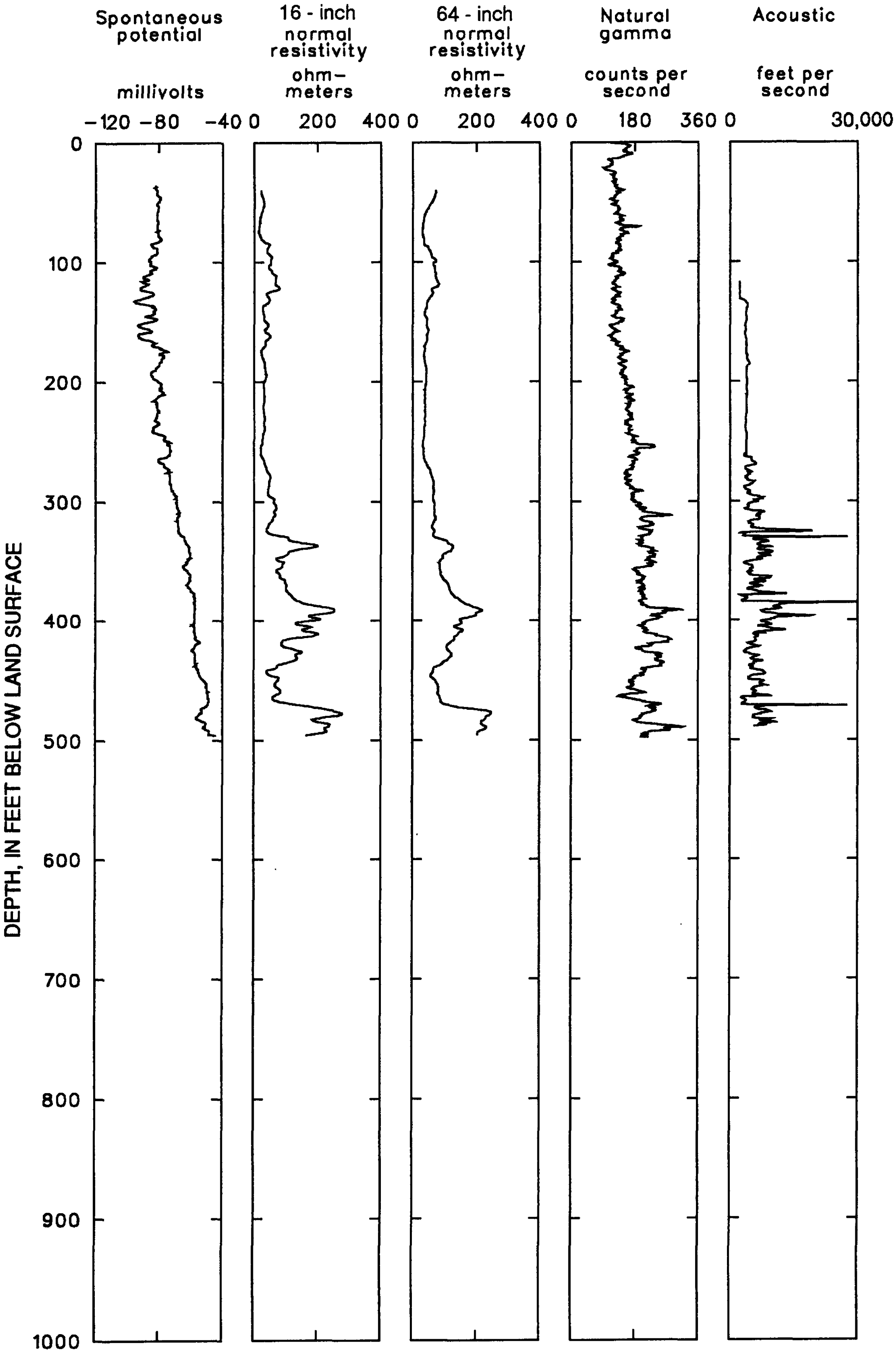
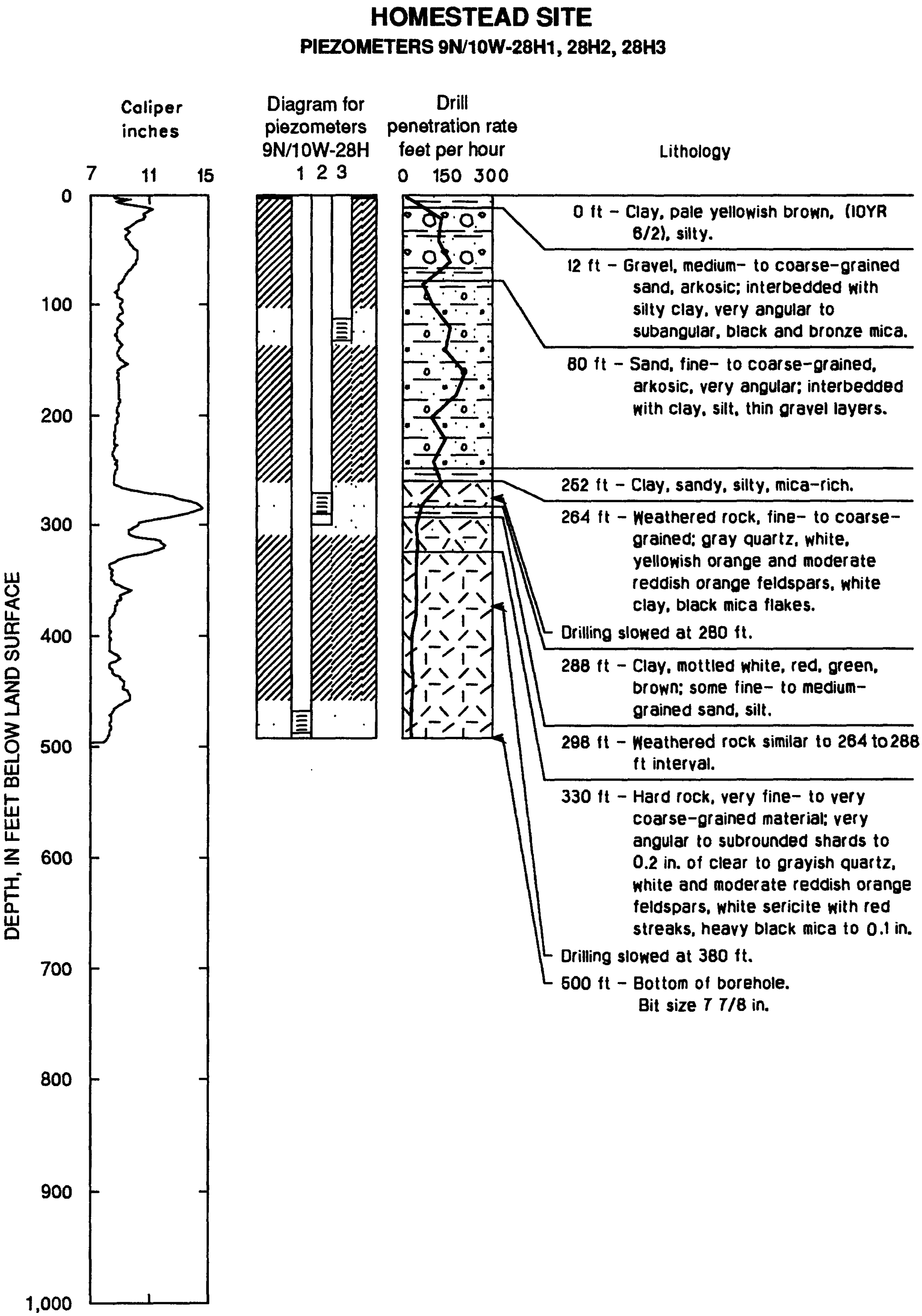


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*


HOMESTEAD SITE
PIEZOMETERS 9N/10W-28H1, 28H2, 28H3
Caliper inches
7 11 15
Diagram for piezometers 9N/10W-28H
1 2 3
Drill penetration rate feet per hour
0 150 300
Lithology
DEPTH, IN FEET BELOW LAND SURFACE
0
100
200
300
400
500
600
700
800
900
1,000
0 ft - Clay, pale yellowish brown, (10YR 6/2), silty.
12 ft - Gravel, medium- to coarse-grained sand, arkosic; interbedded with silty clay, very angular to subangular, black and bronze mica.
80 ft - Sand, fine- to coarse-grained, arkosic, very angular; interbedded with clay, silt, thin gravel layers.
252 ft - Clay, sandy, silty, mica-rich.
264 ft - Weathered rock, fine- to coarse-grained; gray quartz, white, yellowish orange and moderate reddish orange feldspars, white clay, black mica flakes.
Drilling slowed at 280 ft.
288 ft - Clay, mottled white, red, green, brown; some fine- to medium-grained sand, silt.
298 ft - Weathered rock similar to 264 to 288 ft interval.
330 ft - Hard rock, very fine- to very coarse-grained material; very angular to subrounded shards to 0.2 in. of clear to grayish quartz, white and moderate reddish orange feldspars, white sericite with red streaks, heavy black mica to 0.1 in.
Drilling slowed at 380 ft.
500 ft - Bottom of borehole. Bit size 7 7/8 in.

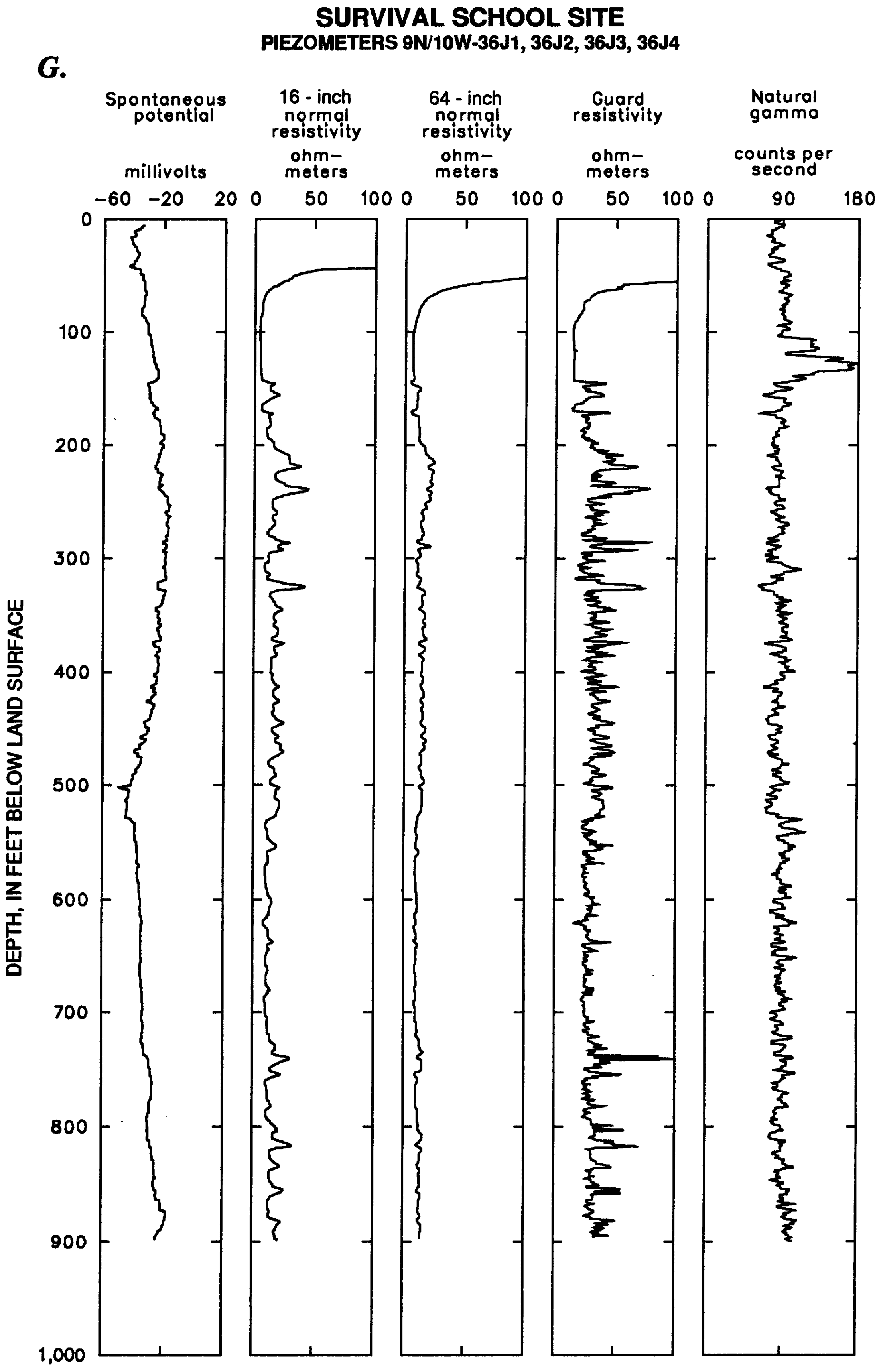
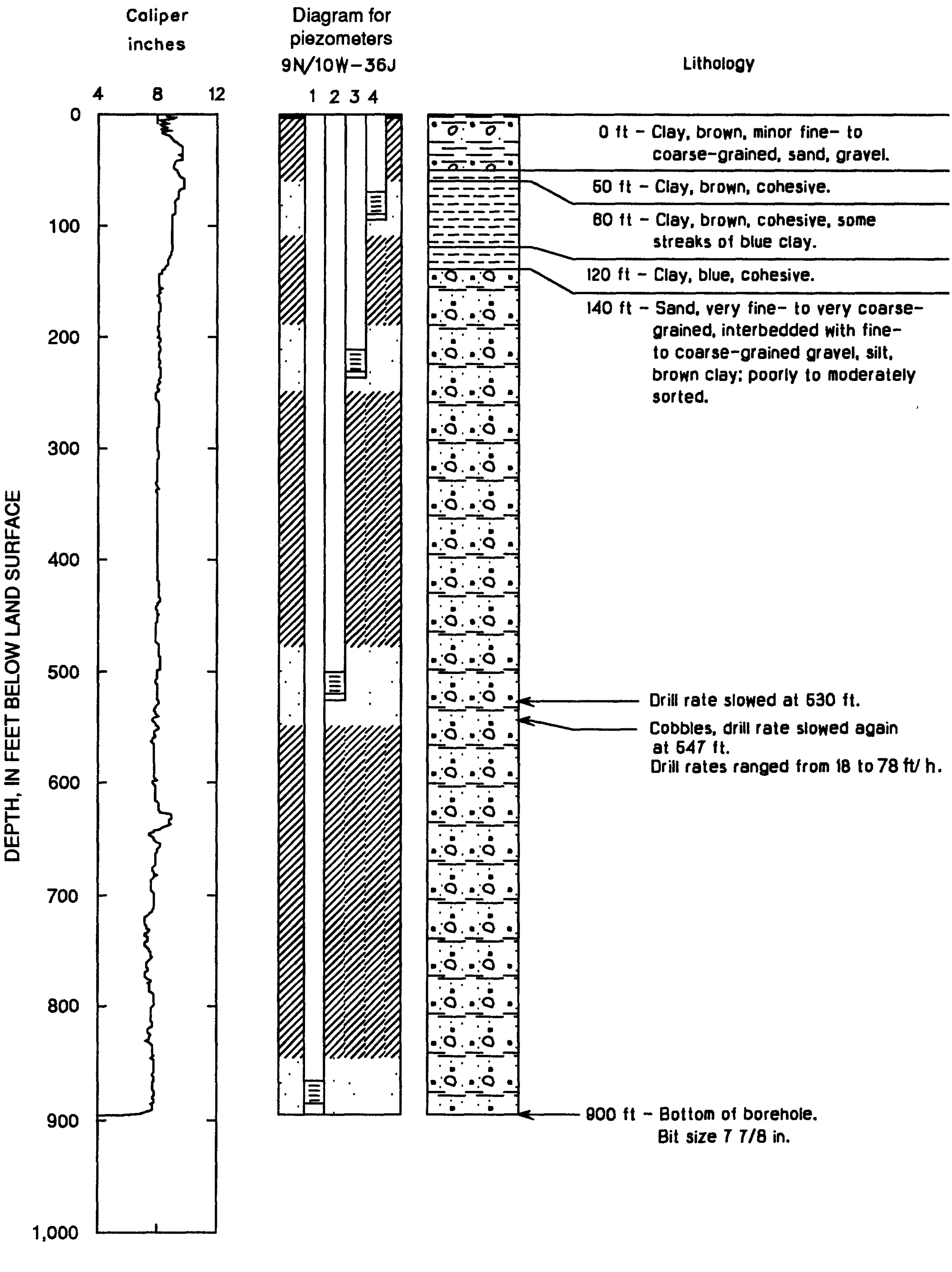


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*

SURVIVAL SCHOOL SITE
PIEZOMETERS 9N/10W-36J1, 36J2, 36J3, 36J4



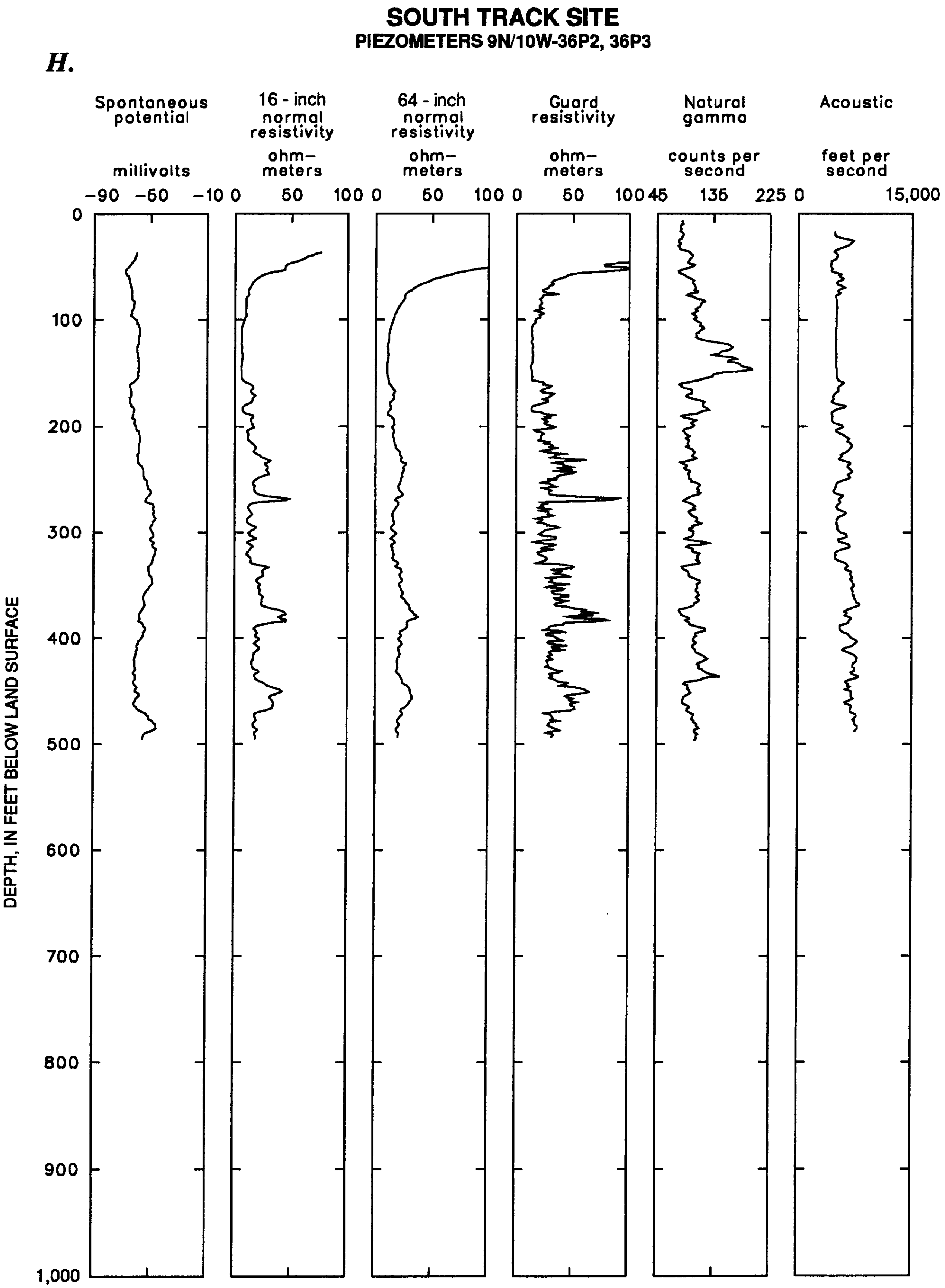
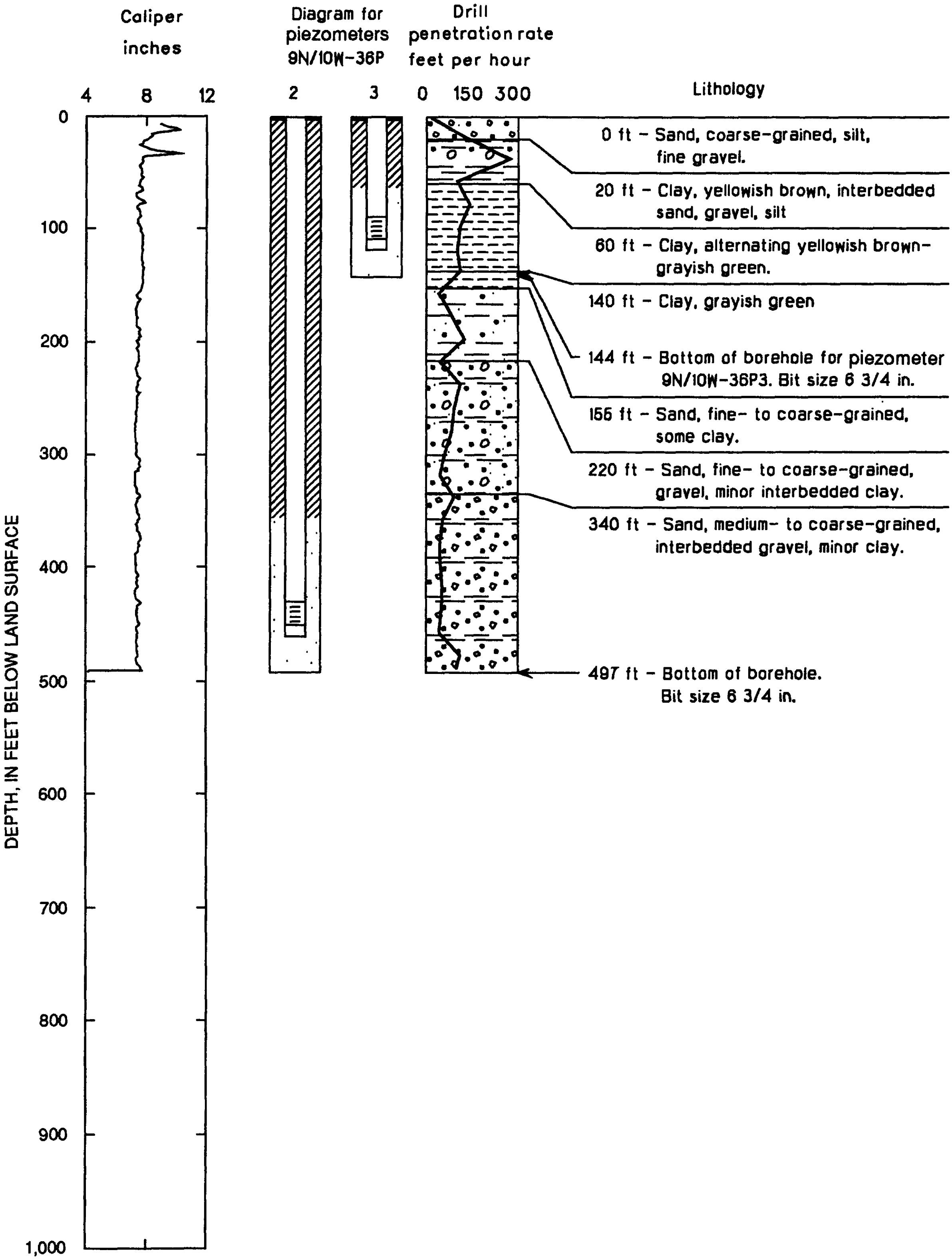


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*

SOUTH TRACK SITE
PIEZOMETERS 9N/10W-36P2, 36P3



NORTH SHORE SITE

PIEZOMETERS 10N/9W-10B1, 10B2

I.

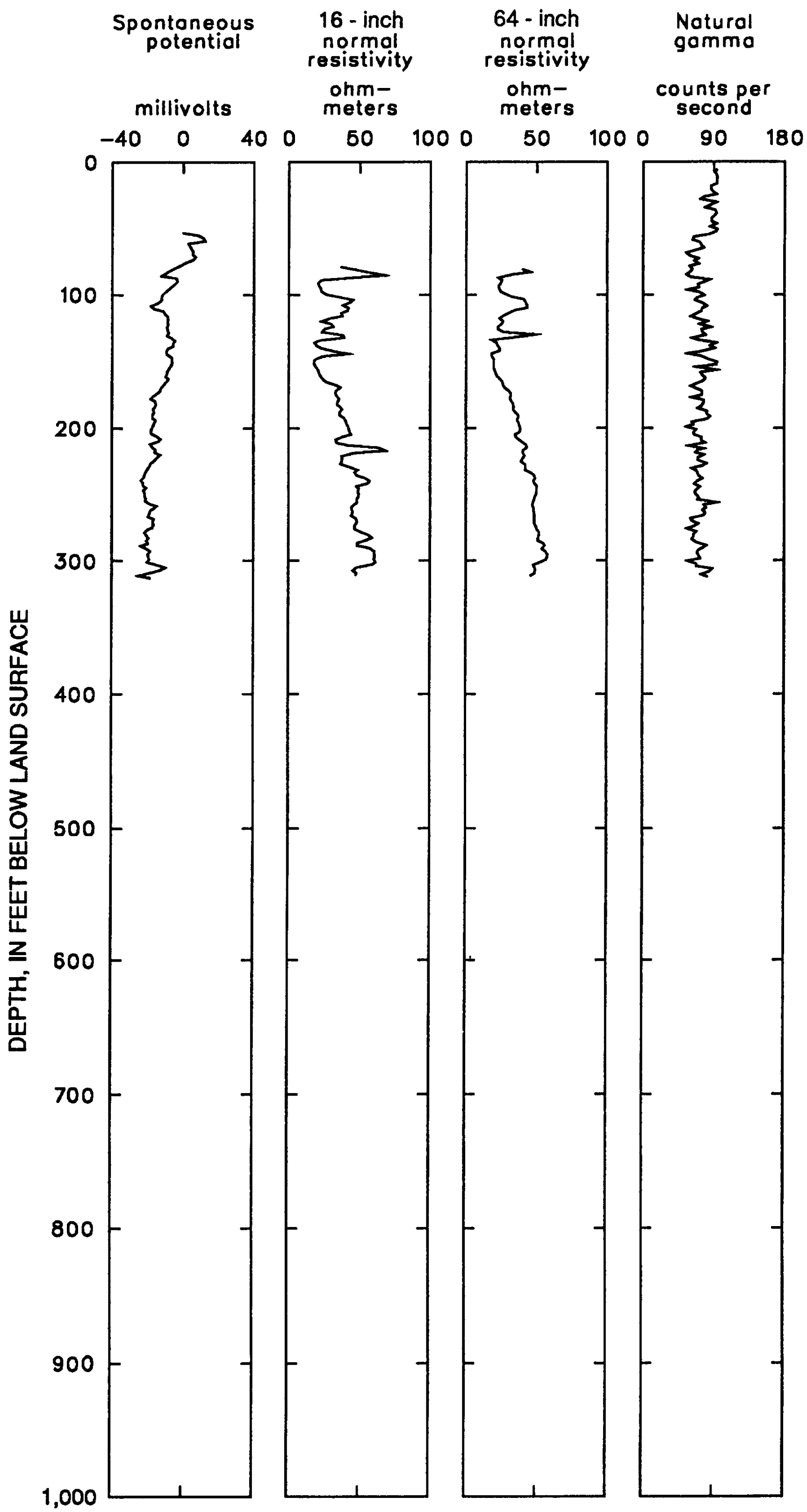
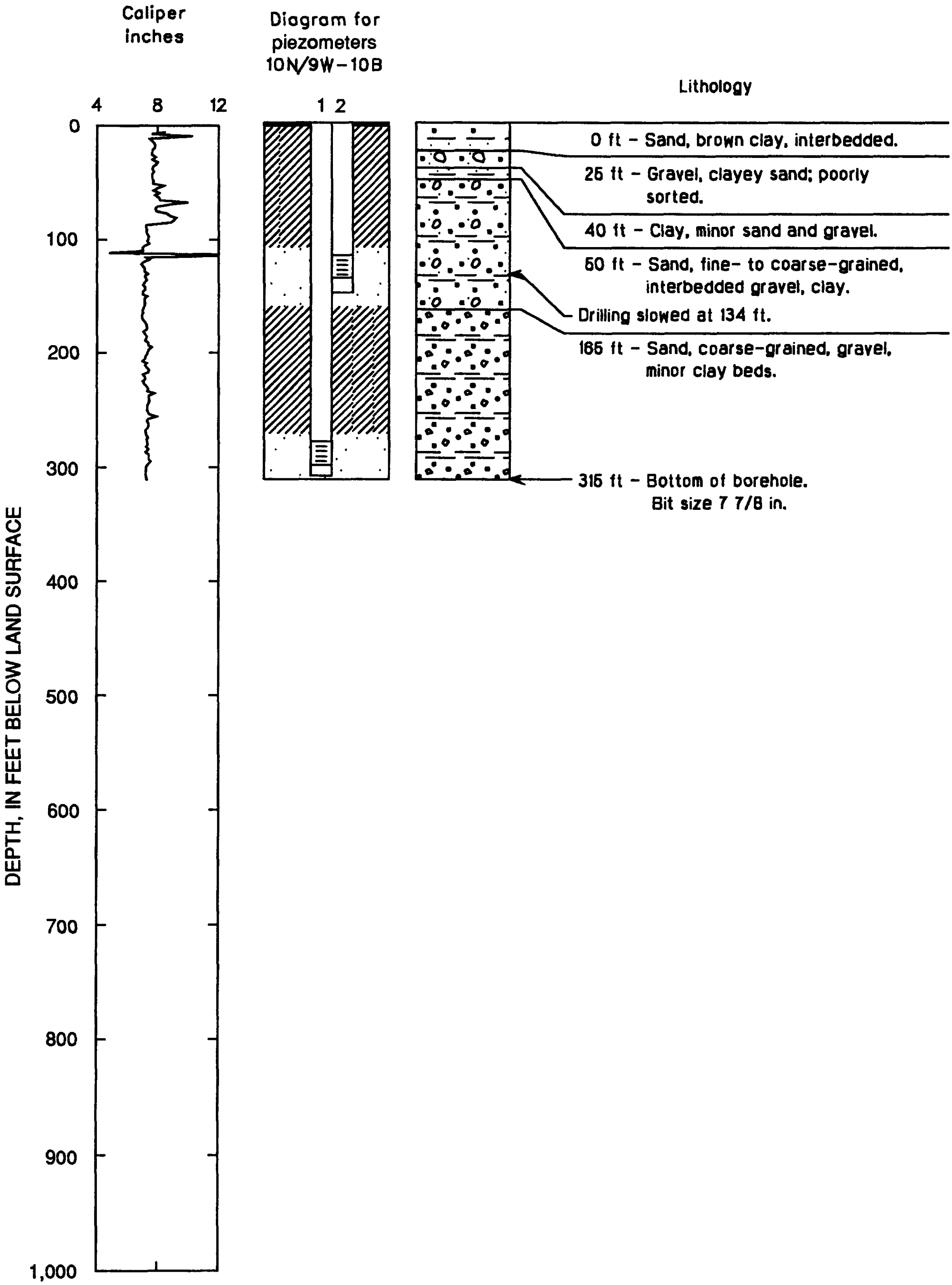


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92--*Continued.*

NORTH SHORE SITE

PIEZOMETERS 10N/9W-10B1, 10B2



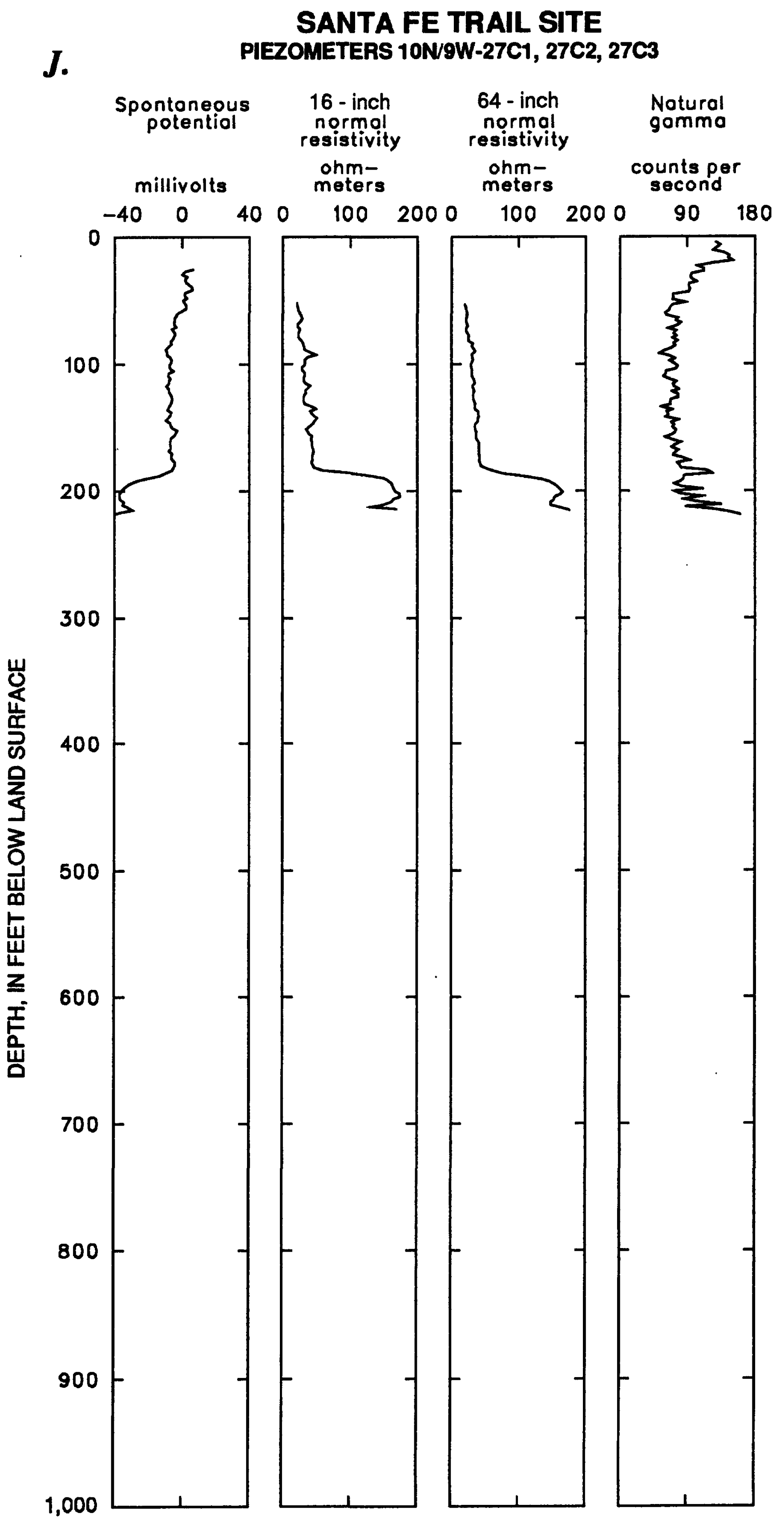


Figure 4. Borehole geophysical logs, drill penetration rate logs, construction diagrams, and lithologic logs for piezometers drilled on Edwards Air Force Base, 1991-92–*Continued.*

SANTA FE TRAIL SITE
PIEZOMETERS 10N/9W-27C1, 27C2, 27C3