DESCRIPTION OF PIEZOMETER NESTS AND WATER LEVELS IN THE RIO GRANDE VALLEY NEAR ALBUQUERQUE, BERNALILLO COUNTY, NEW MEXICO

By Scott K. Anderholm and Thomas F. Bullard

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CONVERSION FACTORS

For the convenience of readers who prefer to use the International System of units (SI), conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain SI unit
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer

Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

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

DESCRIPTION OF PIEZOMETER NESTS AND WATER LEVELS IN THE RIO GRANDE VALLEY NEAR ALBUQUERQUE, BERNALILLO COUNTY, NEW MEXICO

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ABSTRACT

Ground-water contamination in the Rio Grande valley near Albuquerque has been recognized by several authors, but prediction of the movement and fate of contamination has not been evaluated because of the poor understanding of the shallow ground-water flow system. Twenty-four piezometers were installed from mid-October 1984 to mid-January 1985 in two sections of the Rio Grande valley near Albuquerque. Each section is comprised of four piezometer nests and each nest is comprised of three piezometers completed at different depths. This report describes the piezometer nests and presents water-level data collected from the piezometers.

The piezometers were drilled using the hydraulic rotary method. Driller's logs, geophysical logs, and descriptions of well cuttings were made of a borehole at each piezometer nest. The piezometers were completed with 5 feet of 60-slot wire-wound stainless-steel well screen and flush-joint polyvinyl chloride well casing. Description of each piezometer nest consists of location; a figure showing the location, depth, altitude, and station-identification numbers of piezometers in each nest; and a driller's log, geophysical logs, and description of the well cuttings from a borehole in each piezometer nest.

Water levels were measured in each piezometer weekly from February through June 1985. During that period, water levels generally rose in the piezometers in the Rio Bravo Boulevard section but not in the Montaño Road section. Water-level altitudes in piezometers completed at different depths in a particular nest are about the same in all of the Rio Bravo Boulevard nests and in the Montaño 1 nest. In several of the piezometer nests, water-level altitudes decrease with depth, especially in the Montaño nests.

INTRODUCTION

Purpose and Scope

Ground-water contamination in the Rio Grande valley near Albuquerque has been described by several authors (Hines, 1981; McQuillan, 1982), but prediction of the movement and fate of contamination has not been evaluated because of the poor understanding of the shallow ground-water flow system. Two sections comprised of four piezometer nests per section and three piezometers per nest were installed in the Rio Grande valley near Albuquerque to collect water-level data. These data may be used to investigate the interaction of the surface-water system with the shallow ground-water flow system.

The purpose of this report is to describe the piezometer nests and present water-level data that were collected from the piezometers. This includes a description of the location and depth of each piezometer; driller's logs, geophysical logs, and descriptions of well cuttings from a borehole at each piezometer nest; and water levels measured in each piezometer.

The two sections are along Montaño Road and Rio Bravo Boulevard (fig. 1). The sections are approximately perpendicular to the Rio Grande. The piezometer nests are on right-of-way land of the New Mexico State Highway Department; Bernalillo County; City of Albuquerque; or the Middle Rio Grande Conservancy District.

Acknowledgments

Paul Meyers of the New Mexico State Highway Department; Becky Sandoval, Thomas Shafer, and Russell Givler of the City of Albuquerque; Manuel Chavez of the Middle Rio Grande Conservancy District; and David Ridgley of Bernalillo County were helpful in obtaining permission to drill piezometers on right-of-way land.

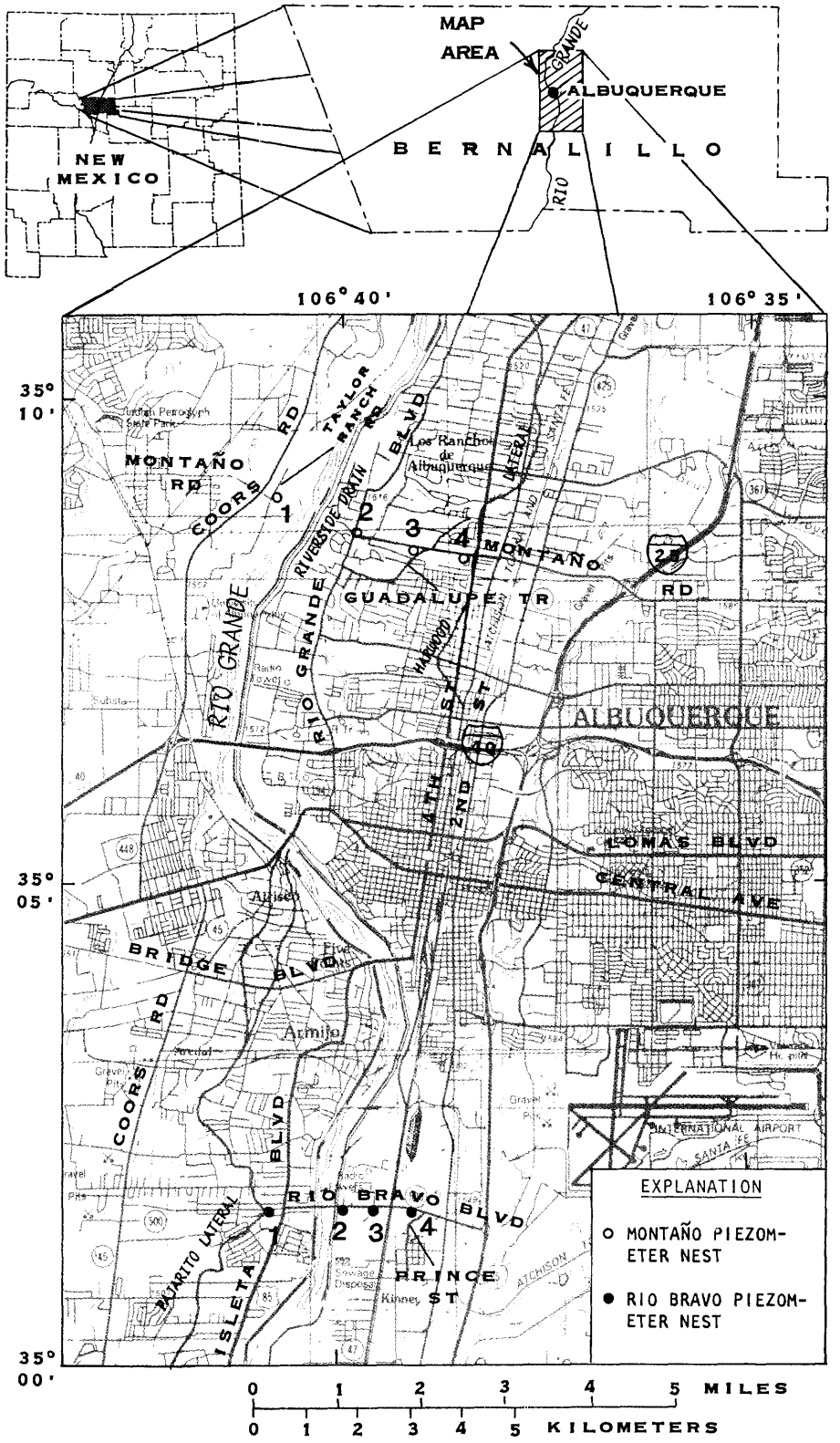

Figure 1.--Location of the piezometer nests in the Rio Grande valley near Albuquerque.

Drilling Method and Well Construction

The boreholes were drilled from mid-October 1984 to mid-January 1985 using the hydraulic rotary method. A 12.75-inch-diameter borehole was drilled for each piezometer. Samples of the material drilled were collected at 5-foot intervals during drilling of a borehole (generally the first borehole drilled) at each nest. The driller kept a log of his description of the materials drilled and the drilling rate. Geophysical logs were run on this borehole prior to installation of well casing. Geophysical logs and the driller's log were used to select permeable zones for the screened interval of the other piezometers in each nest. Red Devil drilling mud was used in the drilling of the boreholes; however, in several boreholes, drilling through clay beds resulted in thickened drilling fluids, so drilling mud was not needed after penetrating these clay beds. After reaching the total depth of each borehole, drilling fluids were circulated in the borehole and the viscosity of the drilling fluids was adjusted (generally the mud was thinned with water) to facilitate placement of the gravel pack. After the viscosity was adjusted and the borehole was logged, if necessary, the well casing and screens were installed. The well casing was 5-inch-diameter, schedule-80 flush-joint (threaded) PVC pipe. Glues or solvents were not used during installation of the casing and screens. Five feet of blank casing capped at the bottom (flush-tube extension) was installed below 5 feet of 60-slot, opening width 0.060 inch, wire-wound stainless-steel screen (fig. 2). This 5 feet of blank well casing was installed to trap sediment that passes through the gravel pack and well screen and into the well bore, thus preventing or delaying the plugging of the well screens by this material. After the casing and screens were set, the gravel pack, consisting of 1/2-inch-diameter washed rock, was emplaced in the annulus between the borehole and the casing using a tremie pipe to a level approximately 1 foot above the top of the well screen (fig. 2). Approximately 3 feet of silica sand or washed masonry sand was placed on top of the gravel pack using a tremie pipe. To prevent leakage of water along the annulus, at least 5 feet of cement grout was emplaced above the sand also using a tremie pipe. The rest of the annulus was backfilled to within 3 feet of land surface using heavy mud and fine-grained drill cuttings. A cement seal was placed at land surface to anchor the casing and seal the annulus from surface water (fig. 2). Centering devices were not used on the well casing to ensure an even gravel pack around the well screen.

Well Development

The piezometers were developed to remove drilling mud and fine-grained material in the aquifer adjacent to the screened interval. After the cement grout seals had cured, each piezometer was developed using an air compressor on the drill rig. Drill-stem or 1-inch-diameter PVC pipe was lowered to the bottom of the borehole and air was pumped down the drill stem or pipe. Specific conductance and amount of sediment in the produced water were monitored during development. Development was assumed to be completed when the specific conductance and amount of sediment in the water did not change. In several cases, water from the wells contained fine sand that possibly entered the well screen because of the lack of centering devices.

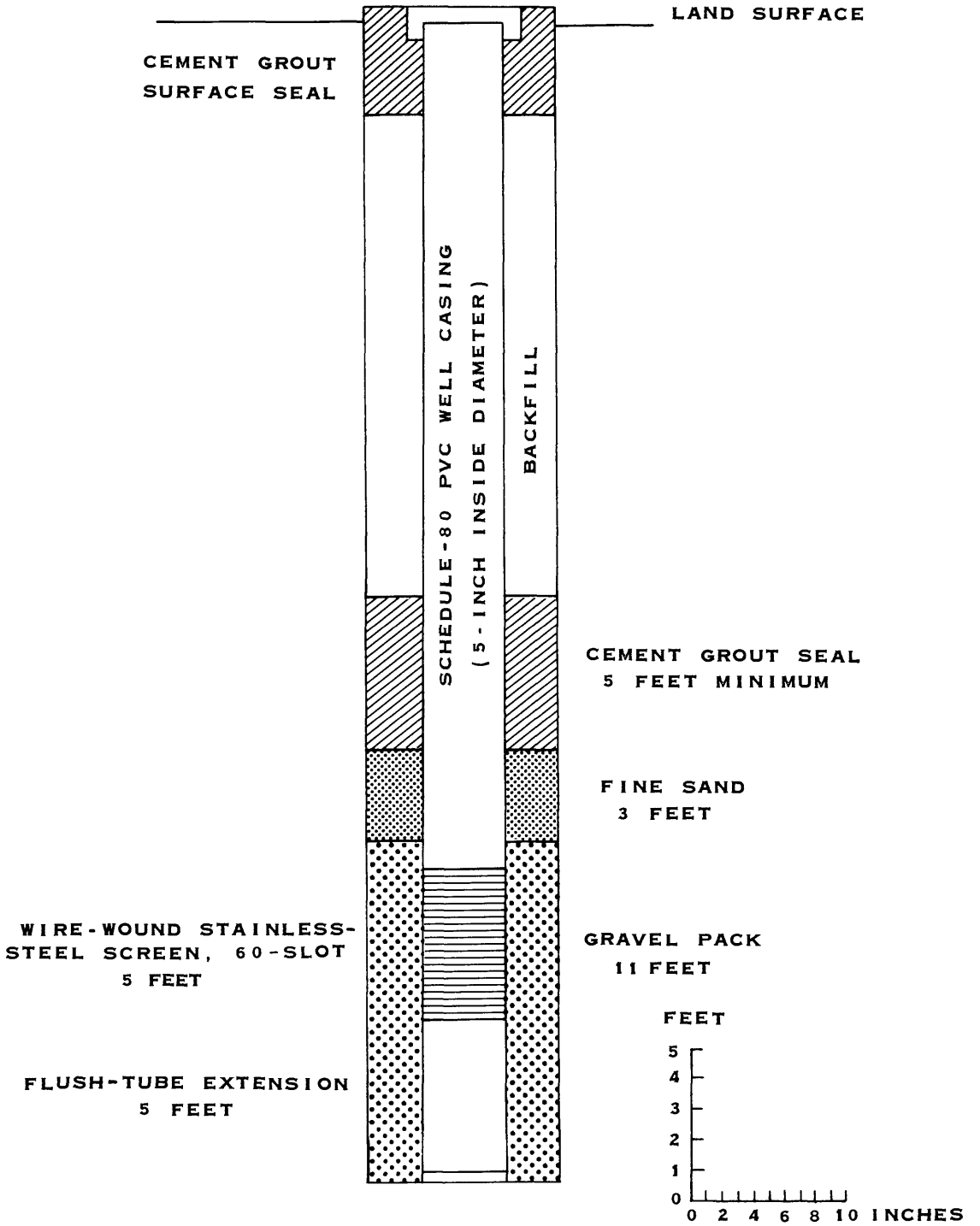

Figure 2.--Schematic of piezometer construction.

DESCRIPTION OF PIEZOMETER NESTS

The description of each piezometer nest consists of its location; a figure showing the location, depth, altitude, and station-identification number of piezometers in each nest; and a driller's log, geophysical logs, and description of the well cuttings from a borehole in each piezometer nest. The measuring-point altitude is the reference altitude from which depth to water is measured; the measuring point is the high point of the well casing and is within 1 foot of land surface. Altitudes were determined by surveying from bench marks to the measuring points. The station-identification number of each piezometer consists of the six-digit latitude, seven-digit longitude, and a two-digit sequence number. The deepest piezometer in each nest has been assigned a sequence number of 01, the mid-depth piezometer 02, and the shallowest piezometer 03.

Lithologic logs were prepared from well-cutting samples collected at 5-foot intervals of a borehole in each piezometer nest. Descriptions of well cuttings were made in the office using a 14 X magnification binocular microscope. The following properties were determined and evaluated for each borehole: (1) Dry and moist colors, (2) grain size, (3) roundness and sorting of grains, (4) distinction of rock fragment types, (5) presence of clay film and colloidal stains, and (6) reaction to 10 percent hydrochloric acid. Dry and moist colors were determined with a standard rock color chart (National Research Council, 1948). Grain-size estimates were made using grain-size images and scales. Roundness and sorting of samples were evaluated visually, using roundness and sorting images (Krumbein and Sloss, 1956; Folk, 1974). Distinction of rock fragment types was based on textural characteristics and mineralogical constituents for individual rock fragments as viewed under 14 X magnification. Reaction of 10 percent hydrochloric acid indicates the presence or absence of calcium carbonate. The degree of effervescence is based on a relative scale as described by Birkeland (1974).

Rio Bravo 1

The Rio Bravo 1 piezometer nest (fig. 1) is on the east side of the Pajarito Lateral south of Rio Bravo Boulevard (latitude 35°01'37", longitude 106°41'05"). The piezometers are oriented approximately north-south and the deepest piezometer (148.5 feet) is the southern piezometer in the nest (fig. 3). The distance between the southern and middle piezometers is 14.3 feet and the distance between the middle and northern piezometers is 21.0 feet. The driller's log is shown in figure 4 and the geophysical logs are shown in figure 5. The description of well cuttings is in table 1.

Table 1. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 1 piezometer nest

[d, dry; m, moist; mm, millimeters; $CaCO_3$, calcite; HCl, 10 percent hydrochloric acid]

RIO BRAVO 1

Lithology	Depth interval below land surface (feet)
Silty sand; pale-yellowish-brown (10YR 6/2 d), fine- to very coarse grained sand; subangular to rounded, poorly to moderately sorted; composed dominantly of rose, milky, and yellow quartz and black quartzite with lesser amounts of feldspar, volcaniclastic, sandstone, basalt, and gneissic and granitic crystalline rock fragments; very thin, discontinuous iron-oxide stains and clay films on some grains; very weak effervescence to HCl.	0 - 15
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 2/2 m), fine- to coarse-grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of scoria, mica, and gneissic rock fragments; granules and pebbles from 2 to 8 mm composed dominantly of black quartzite and rose and milky quartzite and rose and milky quartz with lesser amounts of gneissic and granitic crystalline rock fragments, scoria, pumice, sandstone, and mica; very thin clay films on some grains; very weak effervescence to HCl.	15 - 55
Gravelly sand; light-brown (5YR 6/4 d, 5YR 4/4 m), very fine to coarse-grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of clear and smokey quartz with lesser amounts of pumice, mica, and gneissic and granitic grains; granules 2 to 3 mm composed dominantly of black quartzite and quartz with lesser amounts of mica, pyroclastic, and granitic clasts; very few thin, discontinuous clay films and some iron-oxide stains on some grains; weak to moderate effervescence to HCl.	55 - 65

Table 1. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 1 piezometer nest - Concluded

RIO BRAVO 1

Lithology	Depth interval below land surface (feet)
Clayey, silty, gravelly sand; light-brown (5YR 6/4 d, 5YR 4/4 m) clay to coarse-grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of clear, rose, and smokey quartz and black quartzite with lesser amounts of mica, pumice, basalt, and granitic and metamorphic grains; pebbles up to 20 mm composed dominantly of black quartzite and quartz with lesser amounts of mica, pumice, and metamorphic and granitic clasts; increasing abundance of metamorphic clasts with depth around 80 feet; very few thick, discontinuous grain coatings with clay films and iron-oxide stains; moderate to strong effervescence to HCl; weak cementing with $CaCO_3$ and clay is apparent.	65 - 95
Clayey, silty, gravelly sand; light-brown (5YR 6/4 d, 5YR 4/4 m) clay to coarse-grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of clear, smokey, and rose quartz with lesser amounts of metamorphic and granitic clasts and pyroclastic grains; pebbles to 8 mm composed dominantly of quartz and black quartzite; few thin, discontinuous clay and iron-oxide films on grains; moderate to strong effervescence to HCl, some $CaCO_3$ coatings on grains, $CaCO_3$ nodules 1 to 2 mm.	95 - 120
Clayey, silty, gravelly sand; light-brown (5YR 6/4 d, 5YR 4/4 m) clay to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of clear and milky quartz and black quartzite with lesser amounts of mica, volcanic, metamorphic, and granitic grains; pebbles up to 15 mm composed dominantly of black quartzite and quartz; very thin, discontinuous clay films and iron-oxide stains, minor cementation of grains by iron oxide; moderate to strong effervescence to HCl increasing with depth.	120 - 148.5

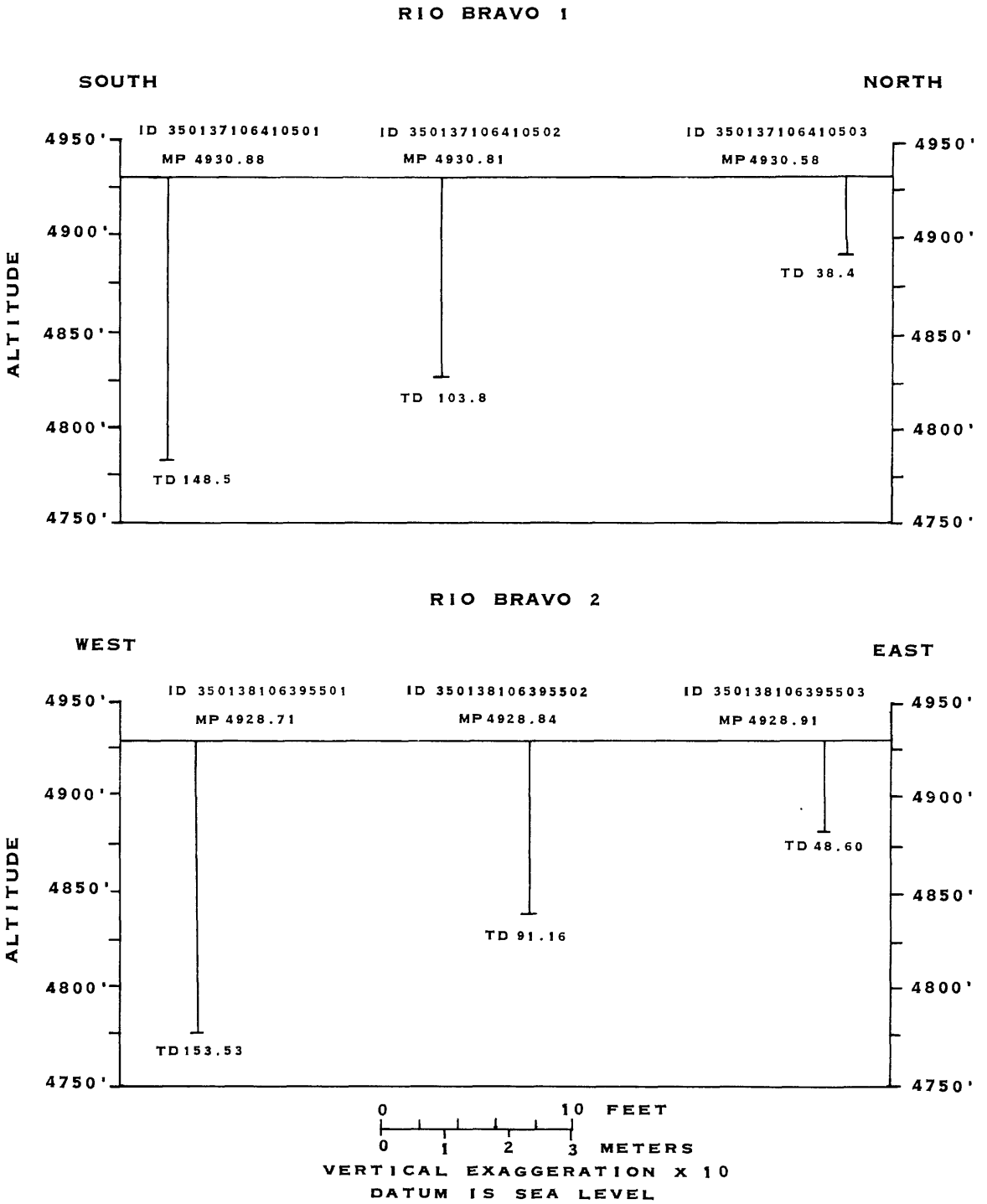

Figure 3.--Configuration of piezometers in the Rio Bravo 1 and Rio Bravo 2 piezometer nests.

RIO BRAVO 1

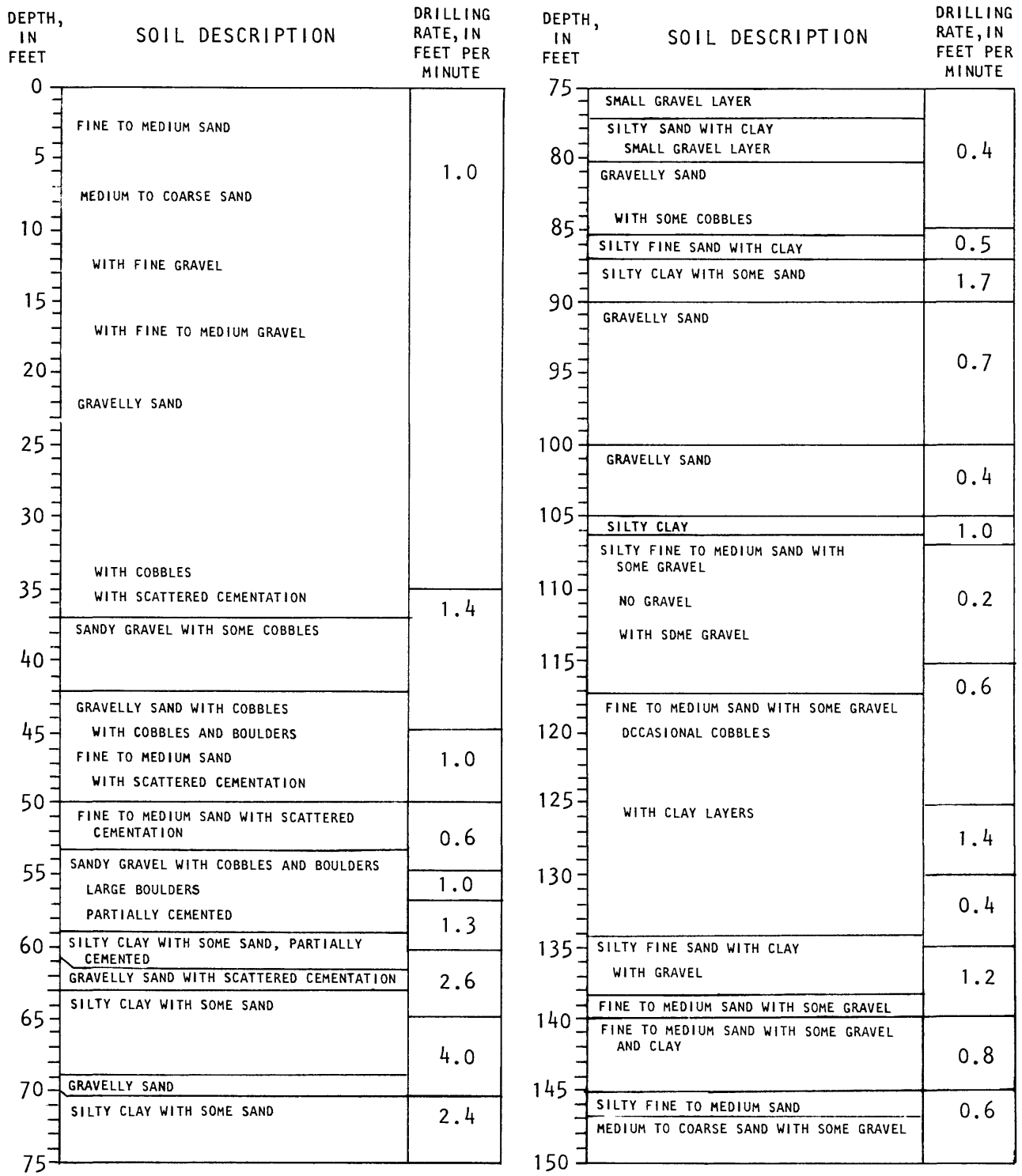

Figure 4.--Driller's log of the deepest borehole in the Rio Bravo 1 piezometer nest.

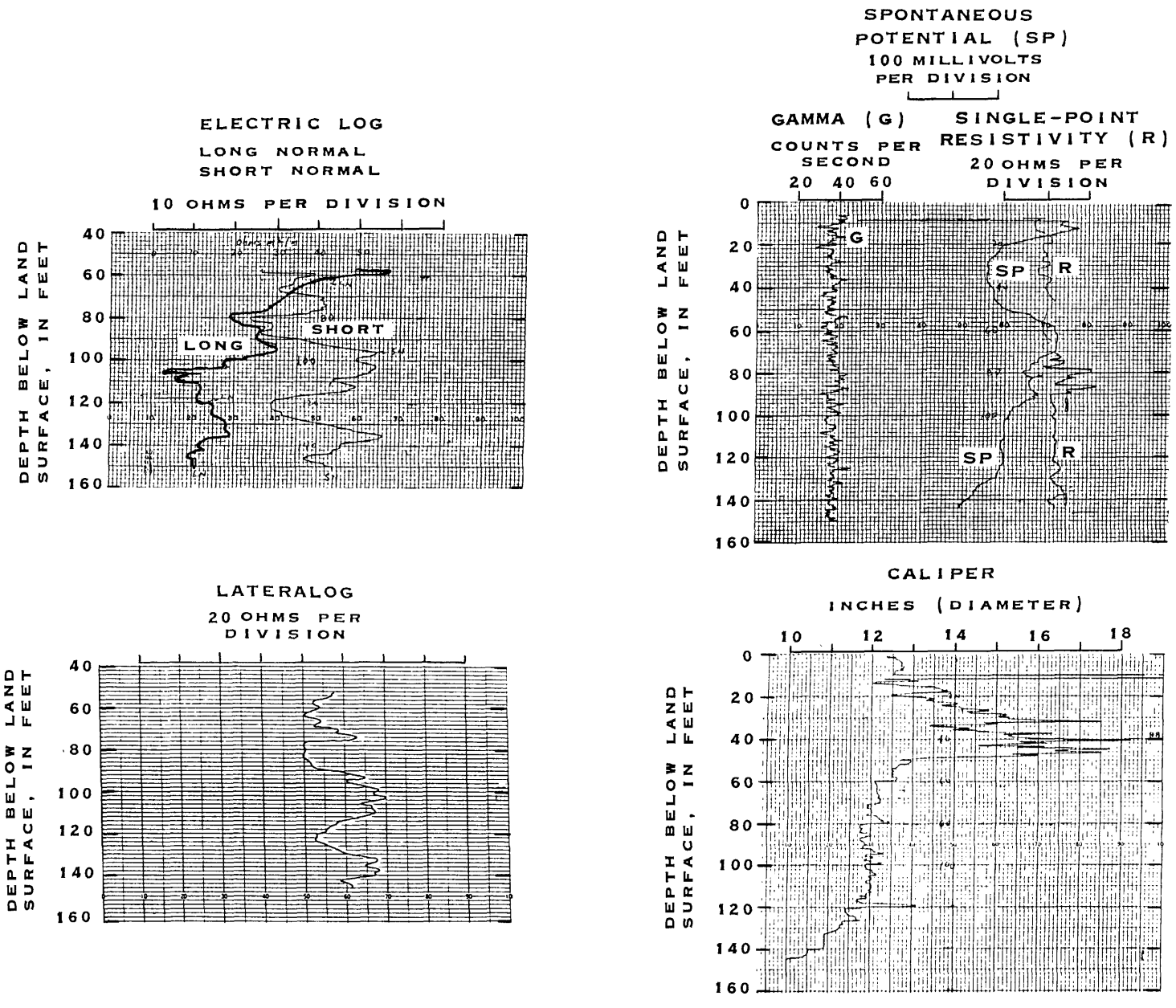

Figure 5.--Geophysical logs of the deepest borehole in the Rio Bravo 1 piezometer nest.

Rio Bravo 2

The Rio Bravo 2 piezometer nest is on the south side of Rio Bravo Boulevard (fig. 1), approximately 1,200 feet east of the east riverside drain (the Albuquerque Drain) along the Rio Grande (latitude 35°01'38", longitude 106°39'55"). The piezometers are oriented approximately east-west and the deepest piezometer (153.53 feet) is the western piezometer (fig. 3). The distance between the western and middle piezometers is 17.4 feet and the distance between the middle and eastern piezometers is 15.3 feet. The driller's log is shown in figure 6 and the geophysical logs are shown in figure 7. The description of well cuttings is in table 2.

Table 2. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 2 piezometer nest

[d, dry; m, moist; mm, millimeters; HCl, 10 percent hydrochloric acid]

RIO BRAVO 2

Lithology	Depth interval below land surface (feet)
Clayey, silty sand; pale-brown (5YR 5/2 d, 5YR 3/4 m) clay to medium- to coarse-grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of clear and milky quartz and black quartzite with lesser amounts of mica, pumice, and basalt; pebbles to 12 mm composed of black quartzite and quartz; few thin, discontinuous clay films, locally thick; strong effervescence to HCl.	0 - 35
Silty, gravelly sand; pale-yellowish-brown (10YR 6/2 d, 5YR 3/4 m) silt to coarse-grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of rose and smokey quartz and black quartzite with lesser amounts of mica and metamorphic grains; pebbles to 20 mm composed dominantly of black quartzite and quartz with lesser amounts of mica, basalt, and granitic and metamorphic clasts; few thin, discontinuous clay films and iron-oxide stains; some grain cementation by oxides; strong to violent effervescence to HCl.	35 - 80

Table 2. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 2 piezometer nest - Concluded

RIO BRAVO 2

Lithology	Depth interval below land surface (feet)
Silty, gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 5/6 m) silt to very coarse grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of smokey and clear quartz and brown and black quartzite with lesser amounts of mica and metamorphic grains; pebbles to 18 mm composed of black and brown quartzite, quartz, and granitic clasts; thin, discontinuous clay films and iron-oxide stains; strong effervescence to HCl.	80 - 115
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 5YR 5/2 m), fine- to very coarse grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of rose, milky, and smokey quartz and black quartzite with lesser amounts of mica and metamorphic grains; granules and pebbles to 5 mm composed dominantly of black quartzite and quartz; thin, discontinuous clay films and some thin iron-oxide stains; moderate to strong effervescence to HCl.	115 - 130
Silty, gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 6/4 m) silt to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and smokey quartz and black quartzite; pebbles to 8 mm composed dominantly of black quartzite and quartz with lesser amounts of mica and metamorphic and igneous clasts; thin, discontinuous clay films, some minor iron-oxide stains; moderate to strong effervescence to HCl.	130 - 153.5

RIO BRAVO 2

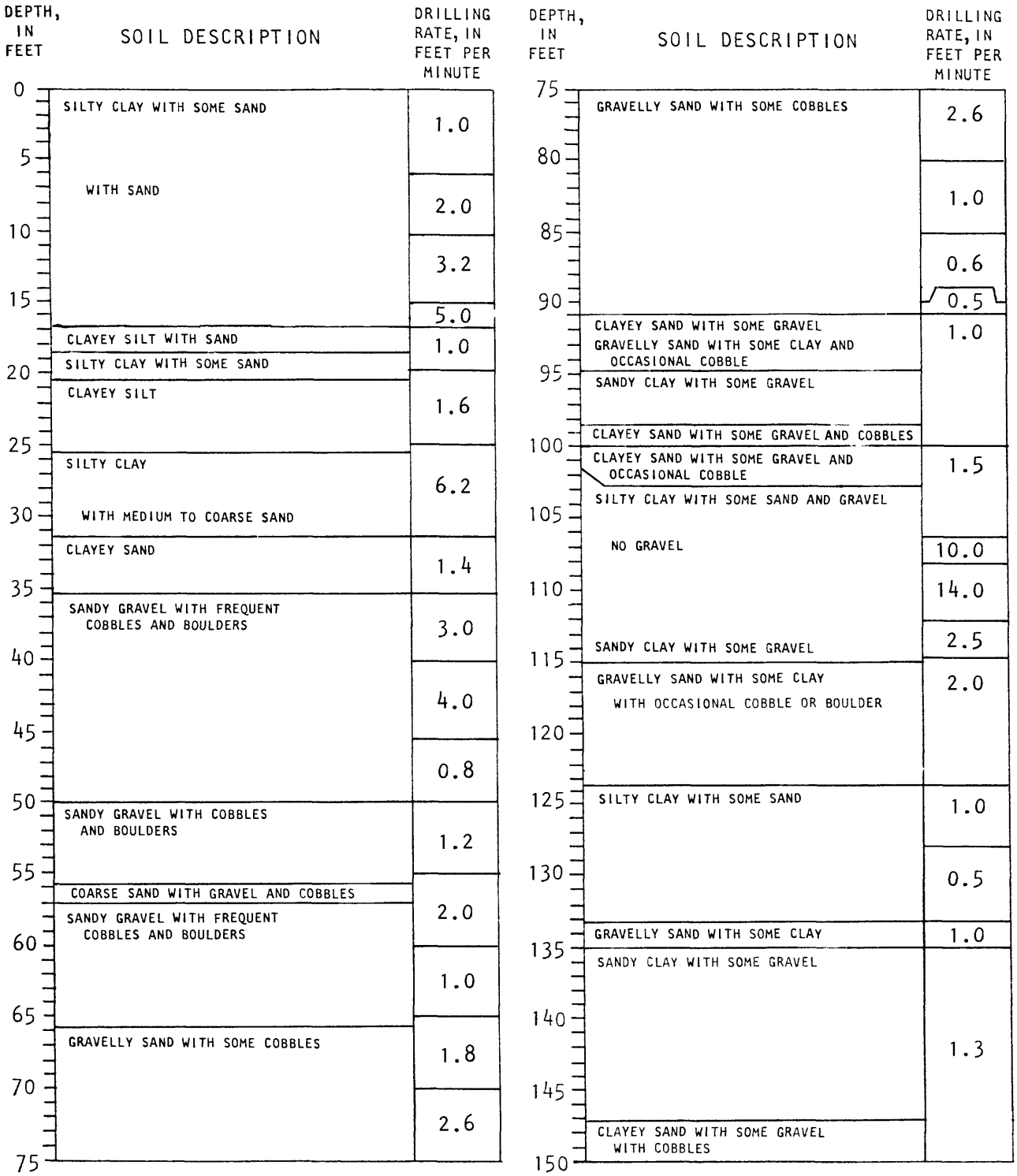

Figure 6.--Driller's log of the deepest borehole in the Rio Bravo 2 piezometer nest.

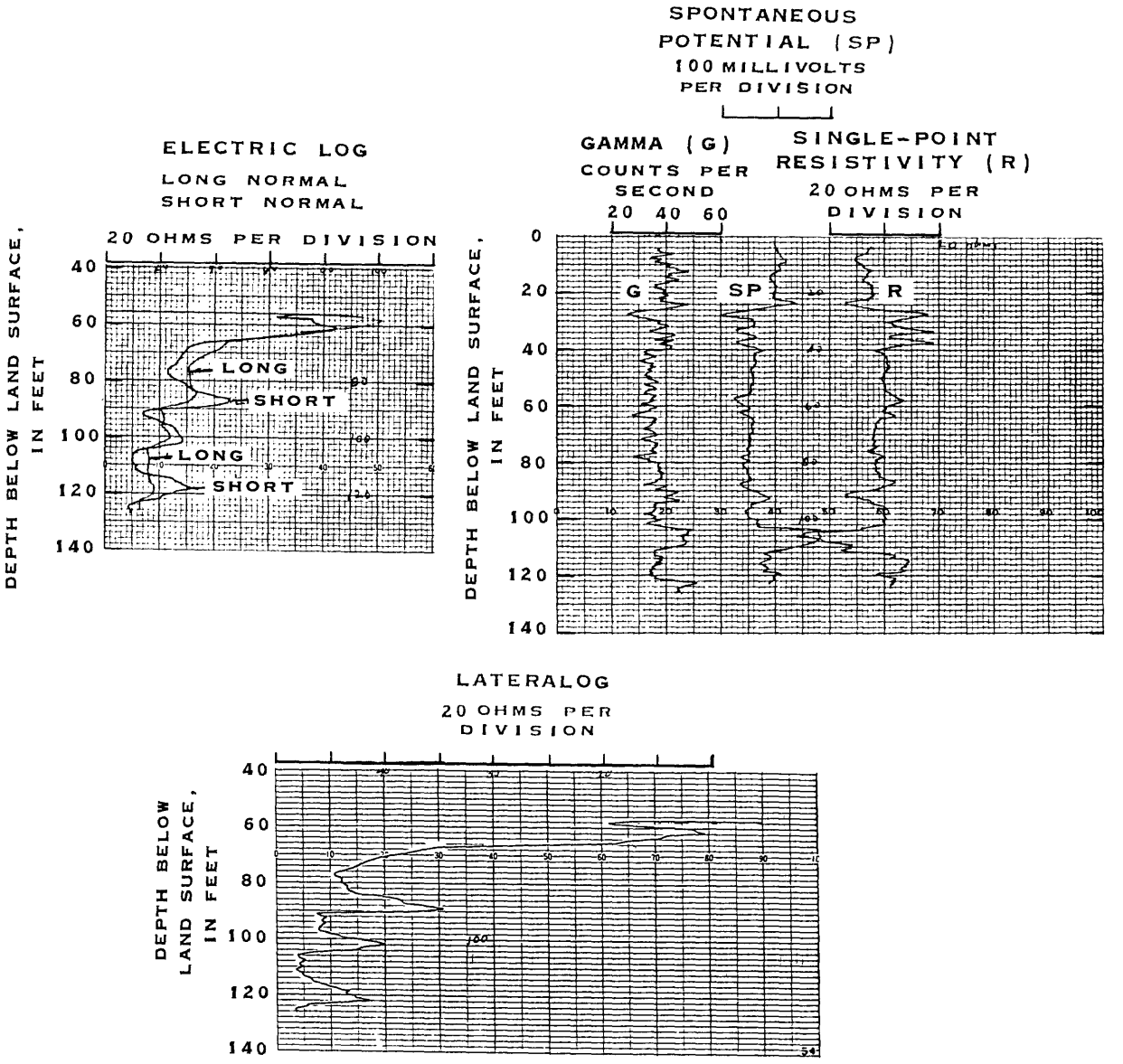

Figure 7.--Geophysical logs of the deepest borehole in the Rio Bravo 2 piezometer nest.

Rio Bravo 3

The Rio Bravo 3 piezometer nest (fig. 1) is on the south side of Rio Bravo Boulevard west of the intersection of Rio Bravo Boulevard and 2nd Street (latitude 35°01'38", longitude 106°39'32"). The piezometers are oriented approximately east-west and the deepest piezometer (148.0 feet) is the eastern piezometer (fig. 8). The distance between the eastern and middle piezometers is 15.9 feet and the distance between the middle and western piezometers is 16.0 feet. The driller's log is shown in figure 9 and the geophysical logs are shown in figure 10. The description of well cuttings is in table 3.

Table 3. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 3 piezometer nest

[d, dry; m, moist; mm, millimeters; HCl, 10 percent hydrochloric acid]

RIO BRAVO 3

Lithology	Depth interval below land surface (feet)
Clayey, silty sand; medium-light-gray (N6 d, N4 m) silt and clay to medium-grained sand; angular to subrounded, poorly sorted; composed dominantly of quartz; strong effervescence to HCl.	0 - 10
Gravelly sand; light-brownish-gray (5YR 6/2 d, 5YR 4/1 m), fine- to very coarse grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of pumice, mica/biotite, and metamorphic grains; granules to 4 mm composed dominantly of black quartzite with lesser amounts of pumice, mica, and metamorphic clasts; very few thin, discontinuous clay films and iron-oxide stains; weak to moderate effervescence to HCl.	10 - 20
Clayey, silty, gravelly sand; pale-yellowish-brown (10YR 6/2 d, 5YR 5/6 m) clay, fine silt, and medium- to coarse-grained sand; subangular to subrounded, poorly to moderately sorted; composed dominantly of rose and milky quartz with lesser amounts of pumice, mica, and volcanic glass; granules to 3 mm composed of black quartzite with some pumice; clay films and oxide stains not apparent; moderate to strong effervescence to HCl.	20 - 30

Table 3. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 3 piezometer nest - Concluded

RIO BRAVO 3

Lithology	Depth interval below land surface (feet)
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), very fine to very coarse grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of rose and smokey quartz and black quartzite with lesser amounts of pumice, mica, and metamorphic grains; pebbles to 12 mm composed dominantly of black quartzite and quartz with lesser amounts of sandstone, pumice, gneissic and igneous crytalline clasts; very few discontinuous clay films and iron-oxide stains; moderate to strong effervescence to HCl.	30 - 90
Gravelly sand; light-brown (5YR 6/4 d, 5YR 4/4 m), very fine to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and smokey quartz and black quartzite with lesser amounts of pumice, mica, and granitic clasts; pebbles to 18 mm composed dominantly of black quartzite with lesser amounts of mica, pumice, and granitic clasts; few thin, discontinuous clay films and iron-oxide stains; moderate to strong effervescence to HCl.	90 - 125
Clayey, silty, gravelly sand; yellowish-gray (5YR 8/1 d, 10YR 4/2 m) clay and silt to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of mica and granitic clasts; pebbles to 12 mm composed dominantly of black quartzite and quartz with lesser amounts of mica, pumice, and metamorphic and granitic clasts; moderate effervescence to HCl.	125 - 148

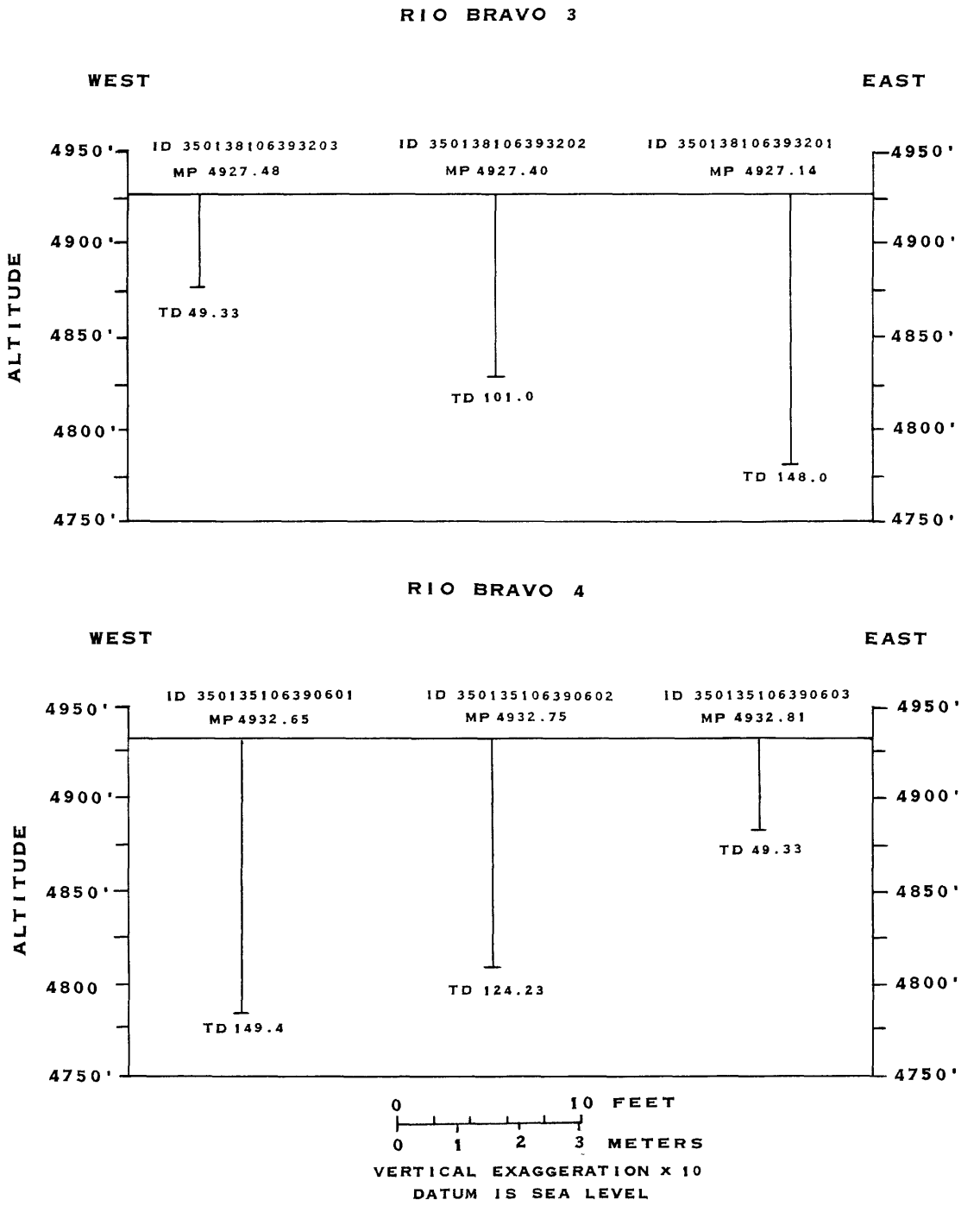

Figure 8.--Configuration of piezometers in the Rio Bravo 3 and Rio Bravo 4 piezometer nests.

RIO BRAVO 3

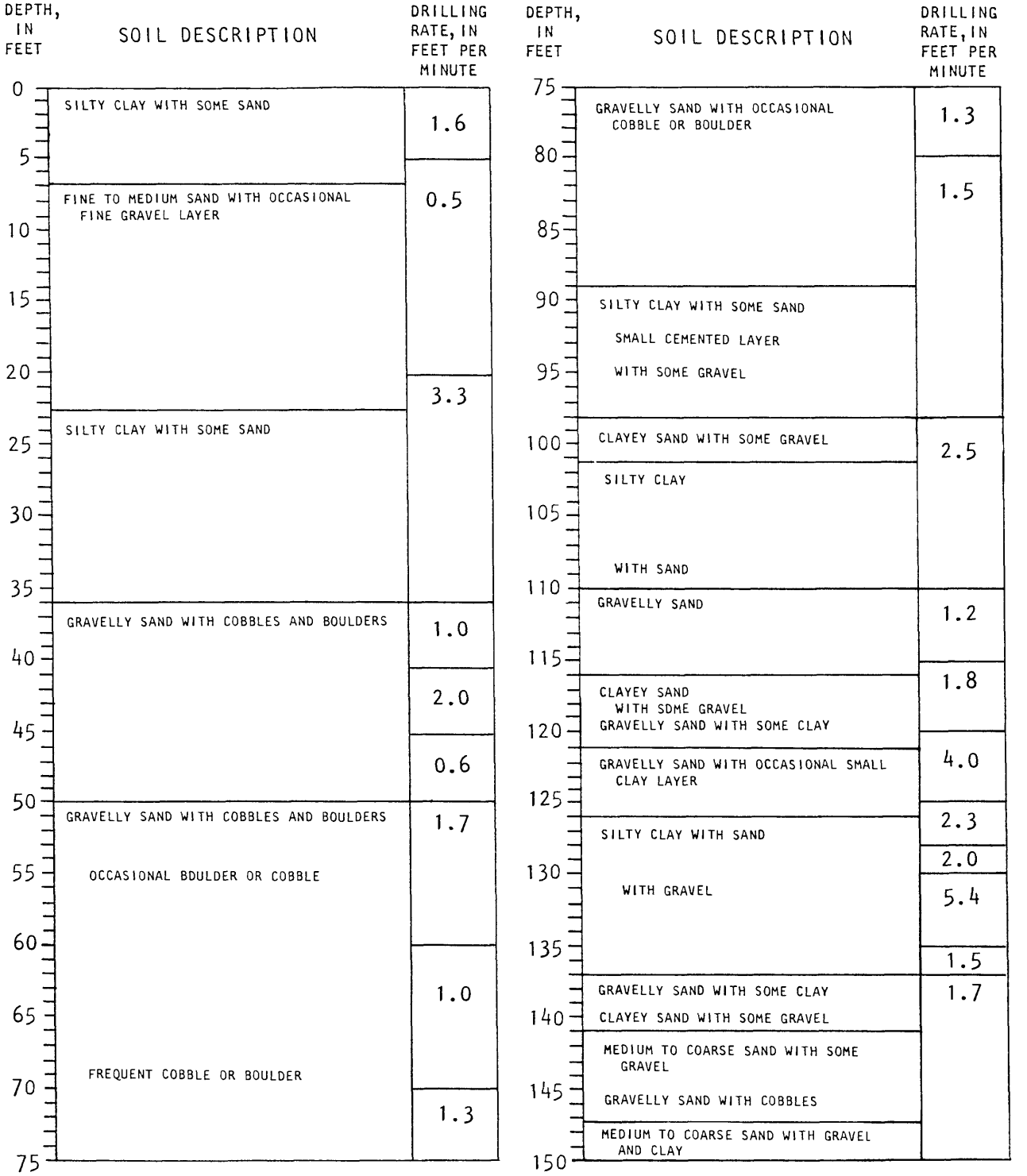

Figure 9.--Driller's log of the deepest borehole in the Rio Bravo 3 piezometer nest.

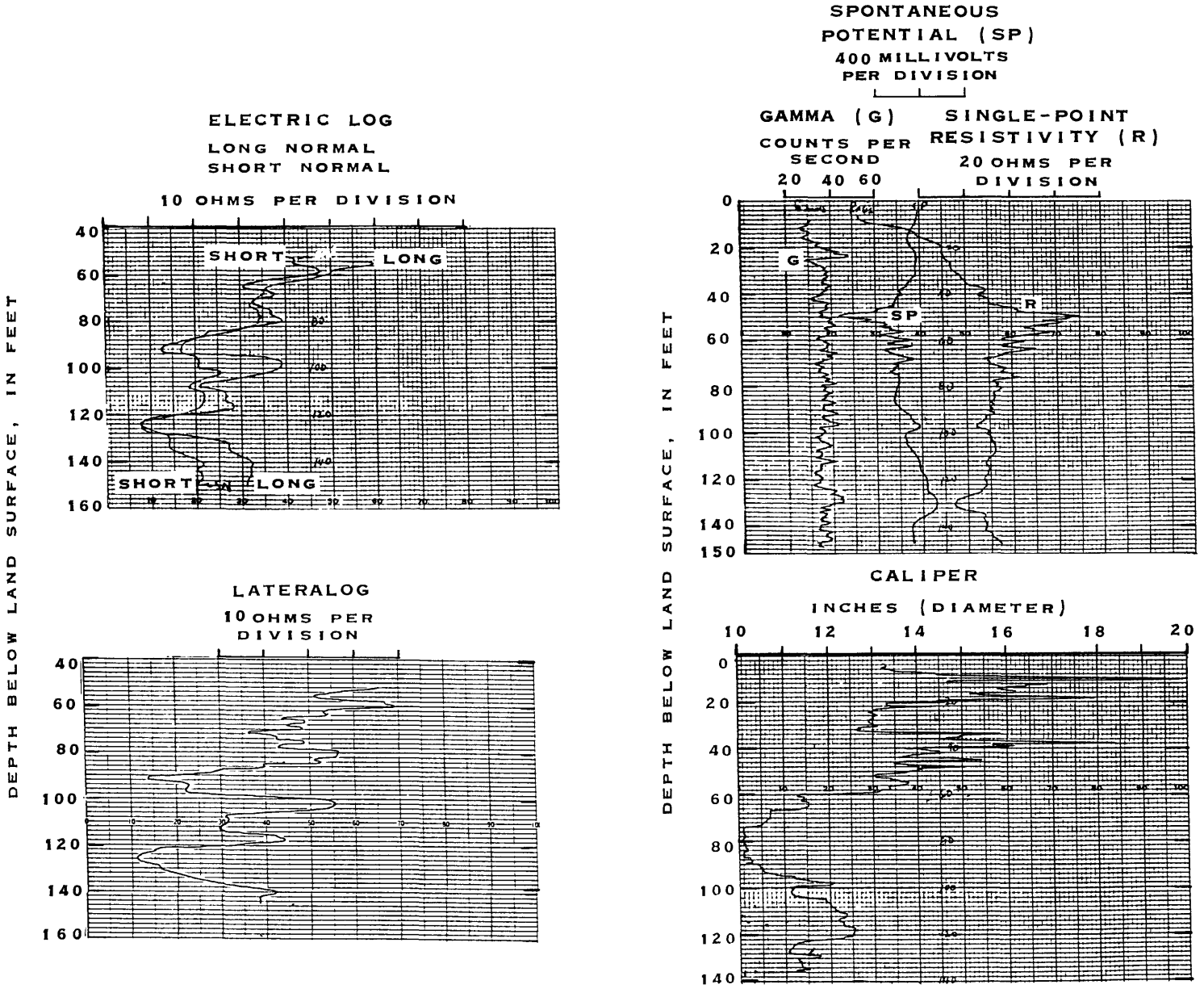

Figure 10.--Geophysical logs of the deepest borehole in the Rio Bravo 3 piezometer nest.

Rio Bravo 4

The Rio Bravo 4 piezometer nest (fig. 1) is on the south side of Rio Bravo Boulevard west of the intersection of Rio Bravo Boulevard and Prince Street (latitude 35°01'35", longitude 106°39'06"). The piezometers are oriented approximately east-west and the deepest piezometer (149.4 feet) is the western piezometer (fig. 8). The distance between the western and middle piezometers is 13.7 feet and the distance between the middle and eastern piezometers is 14.4 feet. The driller's log is shown in figure 11 and the geophysical logs are shown in figure 12. The description of well cuttings is in table 4.

Table 4. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 4 piezometer nest

[d, dry; m, moist; mm, millimeters; HCl, 10 percent hydrochloric acid]

RIO BRAVO 4

Lithology	Depth interval below land surface (feet)
Clayey, silty, gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 5/2 m) clay, silt, and fine- to coarse-grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite; pebbles to 5 mm composed dominantly of black quartzite; very thin, discontinuous clay films; moderate to strong effervescence to HCl.	0 - 15
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with minor amount of mica; pebbles to 8 mm composed dominantly of black quartzite and quartz with lesser amounts of mica, sandstone, and volcanic clasts; few thin, discontinuous clay films; moderate to strong effervescence to HCl.	15 - 40

Table 4. Lithologic description of well cuttings from the deepest borehole in the Rio Bravo 4 piezometer nest - Concluded

RIO BRAVO 4

Lithology	Depth interval below land surface (feet)
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 5YR 5/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of biotite and metamorphic clasts; pebbles to 23 mm composed dominantly of black quartzite and quartz with lesser amounts of mica and gneissic and granitic clasts; few very thin, discontinuous clay films and iron-oxide stains; moderate to strong effervescence to HCl.	40 - 70
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of biotite, pumice, and volcanic, metamorphic, and granitic clasts; pebbles to 10 mm composed dominantly of black quartzite and quartz with lesser amounts of mica and metamorphic, plutonic, and volcanic clasts; some mollusk shells from 105 to 110 feet; very few thin, discontinuous clay films and iron-oxide stains; moderate to strong effervescence to HCl.	70 - 130
Silty, gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m) silt and fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of metamorphic grains; pebbles to 8 mm composed dominantly of black quartzite and quartz; shell material at 135 feet; very few thin, discontinuous clay films, some minor grain cementation by iron oxides; strong effervescence to HCl.	130 - 149.4

RIO BRAVO 4

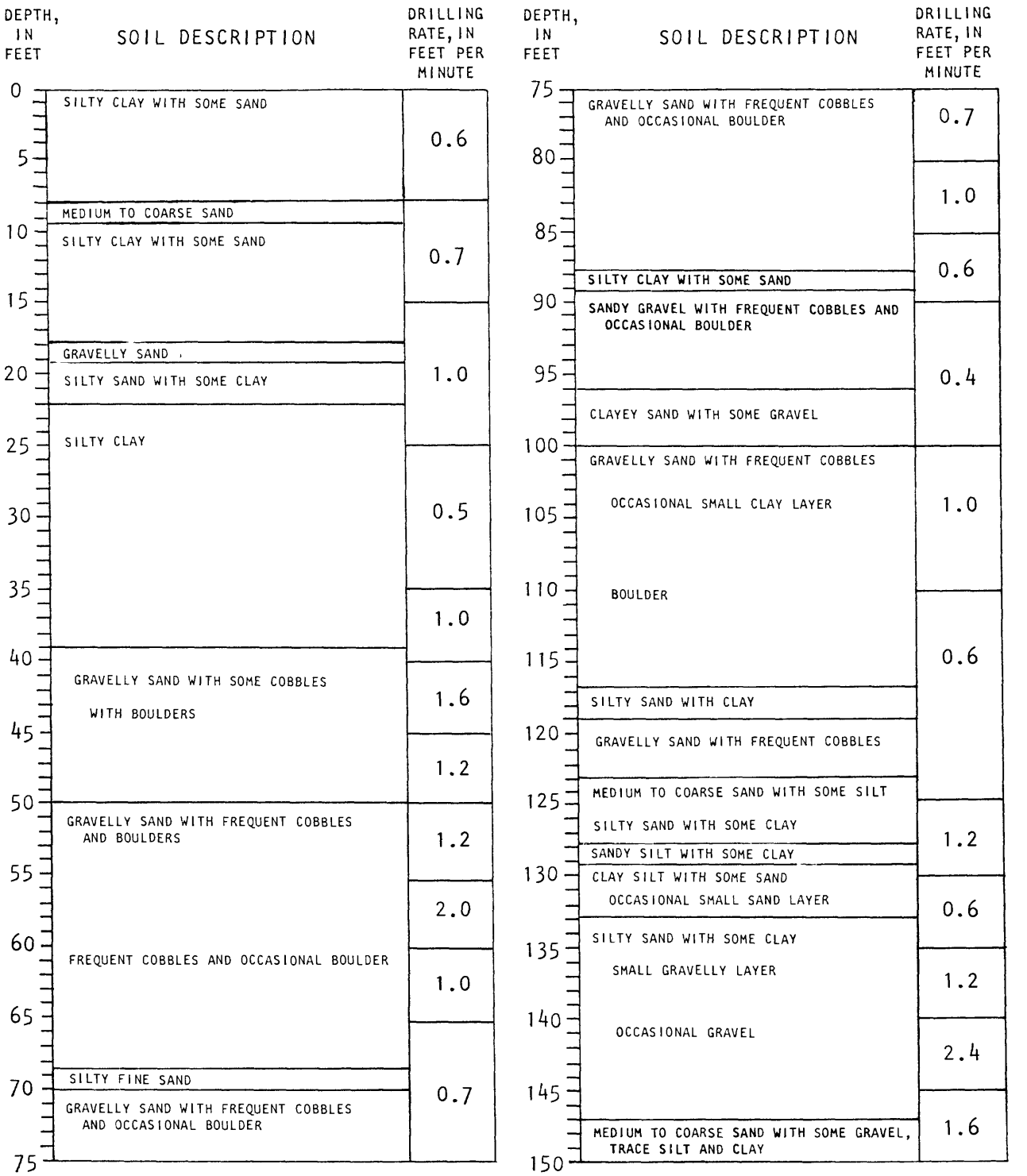

Figure 11.--Driller's log of the deepest borehole in the Rio Bravo 4 piezometer nest.

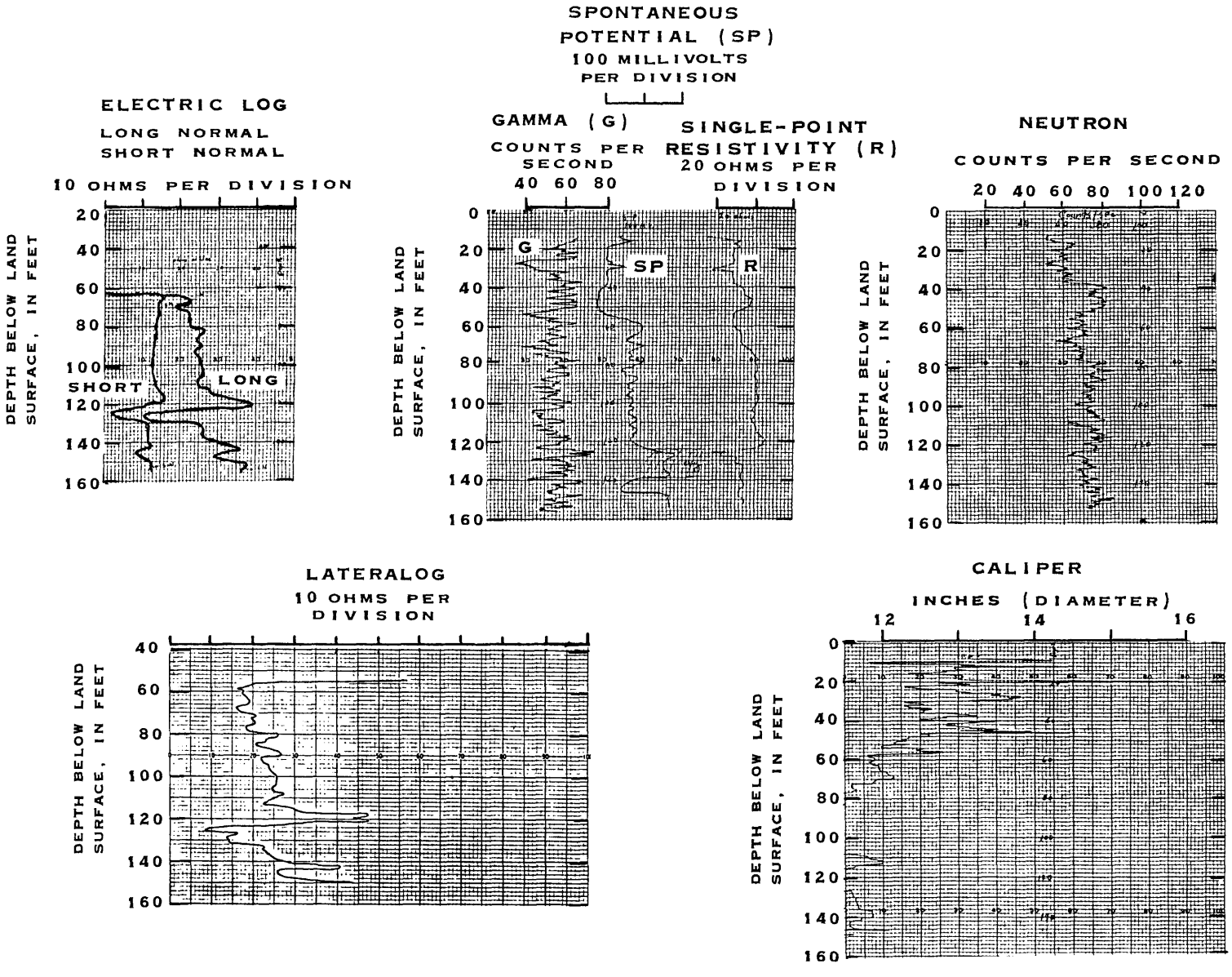

Figure 12.--Geophysical logs of the deepest borehole in the Rio Bravo 4 piezometer nest.

Montaño 1

The Montaño 1 piezometer nest (fig. 1) is on the north side of Montaño Road east of the intersection of Montaño Road and Taylor Ranch Road (latitude 35°08'54", longitude 106°40'37"). The piezometers are oriented approximately east-west and the deepest piezometer (152.0 feet) is the eastern piezometer (fig. 13). The distance between the eastern and middle piezometers is 15.3 feet and the distance between the middle and western piezometers is 15.6 feet. The driller's log is shown in figure 14 and the geophysical logs are shown in figure 15. The description of well cuttings is in table 5.

Table 5. Lithologic description of well cuttings from the deepest borehole in the Montaño 1 piezometer nest

[d, dry; m, moist; mm, millimeters; $CaCO_3$, calcite; HCl, 10 percent hydrochloric acid]

MONTAÑO 1

Lithology	Depth interval below land surface (feet)
Silty sand; light-brown (5YR 6/4 d, 5YR 5/2 m) silt and fine- to coarse-grained sand; subangular to well rounded, poorly to moderately sorted; composed dominantly of clear, rose, and smokey quartz with lesser amounts of mica; thin, colloidal stains on some grains; moderate effervescence to HCl.	0 - 10
Sandy gravel; light-brown (5YR 6/4 d, 5YR 4/4 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of milky, clear, and smokey quartz, black quartzite, and basalt with lesser amounts of mica and granitic grains; pebbles to 5 mm composed dominantly of black quartzite and pumice with lesser amounts of metamorphic and igneous clasts; very thin, discontinuous clay films and colloidal stains; moderate effervescence to HCl.	10 - 15
Clayey, sandy gravel; light-brown (5YR 6/4 d, 5YR 4/4-5/2 m) clay and fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of pumice, volcanic glass, and basalt; very thin, discontinuous clay films and colloidal iron-oxide stains; moderate to strong effervescence to HCl; some weak cementation of grains by $CaCO_3$, $CaCO_3$ nodules 2 to 4 mm.	15 - 25

Table 5. Lithologic description of well cuttings from the deepest borehole in the Montaño 1 piezometer nest - Continued

MONTAÑO 1

Lithology	Depth interval below land surface (feet)
Sandy gravel; light-brown (5YR 6/4 d, 5YR 5/2 m), fine- to coarse-grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of smokey, rose, and milky quartz and black quartzite with lesser amounts of mica and basalt; pebbles to 15 mm composed dominantly of black quartzite and volcanic clasts (basalt, andesite) with lesser amounts of quartz, metamorphic clasts, pumice, volcanic glass, and volcanics; moderate to strong effervescence to HCl.	25 - 50
Sandy gravel; light-brown to pale-yellowish-brown (5YR 6/4 to 10YR 6/2 d, 5YR 5/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of basalt, pumice, perlite, mica, feldspar, and metamorphic clasts; granules to 4 mm composed of basalt, andesite, and quartzite; very few thin, discontinuous clay films and colloidal oxide stains; weak to moderate effervescence to HCl.	50 - 55
Sandy gravel; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of mica, feldspar, pumice, basalt, and metamorphic grains; pebbles to 7 mm composed dominantly of black quartzite and quartz with lesser amounts of basalt, sandstone, granite, and metamorphic clasts; few very thin, discontinuous clay films; moderate to strong effervescence to HCl.	55 - 80

Table 5. Lithologic description of well cuttings from the deepest borehole in the Montaño 1 piezometer nest - Concluded

MONTAÑO 1

Lithology	Depth interval below land surface (feet)
Silty, clayey, gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 4/4 m), clayey silt to very coarse grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of mica and feldspar; pebbles to 8 mm composed dominantly of black quartzite and quartz; few thin, discontinuous clay films and minor iron-oxide stains and minor cementation of grains; strong effervescence to HCl, $CaCO_3$ nodules to 3 mm.	80 - 95
Gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 6/5-4/2 m), fine- to coarse-grained sand; subangular to subrounded, poorly to moderately sorted; composed dominantly of clear, smokey, rose, and milky quartz with lesser amounts of black quartzite, pumice, mica, basalt, and andesite clasts; pebbles to 15 mm composed dominantly of black quartzite and quartz with lesser amounts of basalt and metamorphic clasts; few thin, discontinuous clay films and iron-oxide coatings; strong effervescence to HCl.	95 - 120
Gravelly sand; grayish-orange-pink (5YR 7/2 d, 5YR 5/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of yellow, rose, and milky quartz and black quartzite with lesser amounts of mica, feldspar, felsic volcanics; pebbles to 5 mm composed of black quartzite and quartz; few very thin, discontinuous clay films and iron-oxide stains; moderate to strong effervescence to HCl.	120 - 152

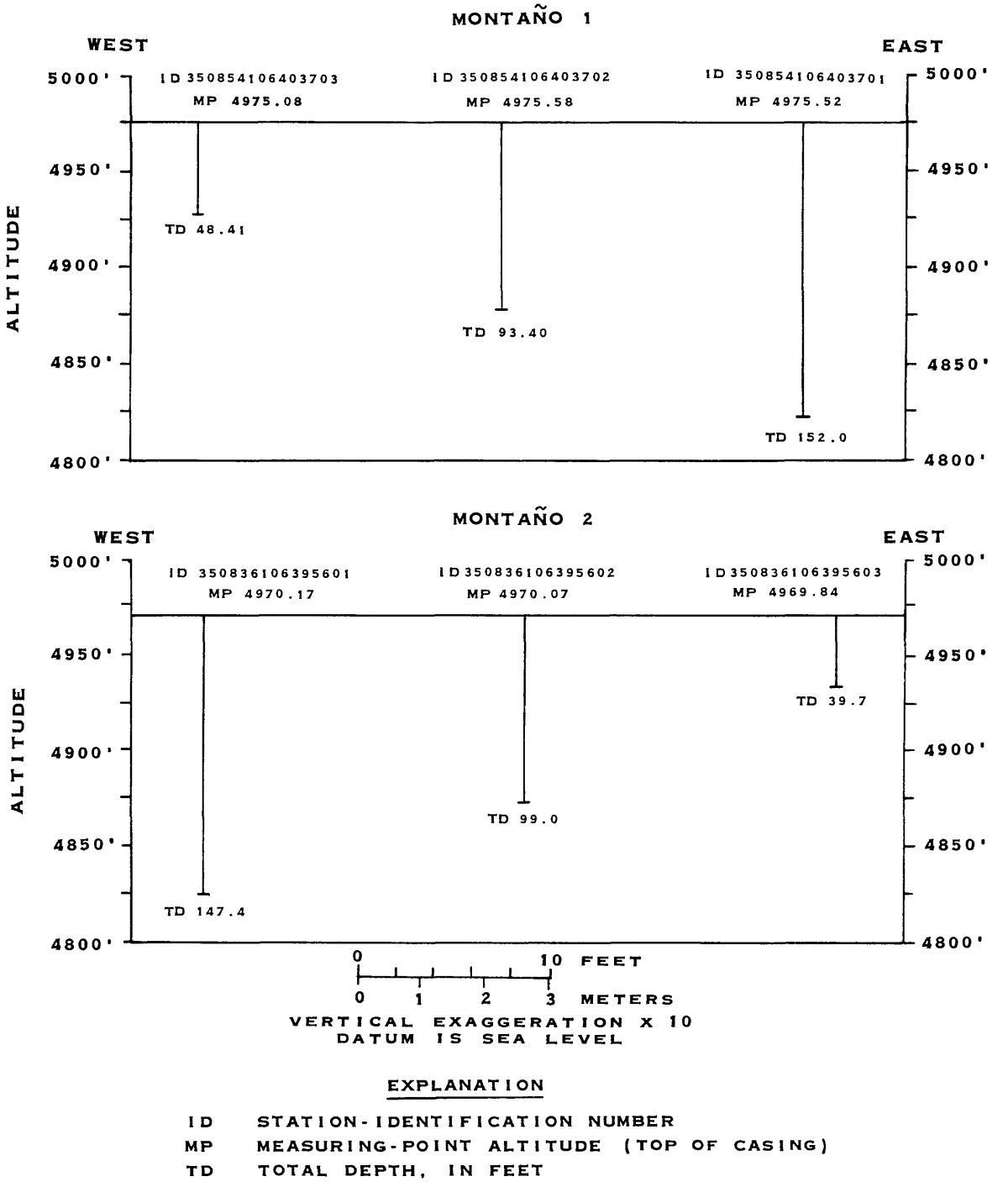

Figure 13.--Configuration of piezometers in the Montaño 1 and Montaño 2 piezometer nests.

MONTAÑO 1

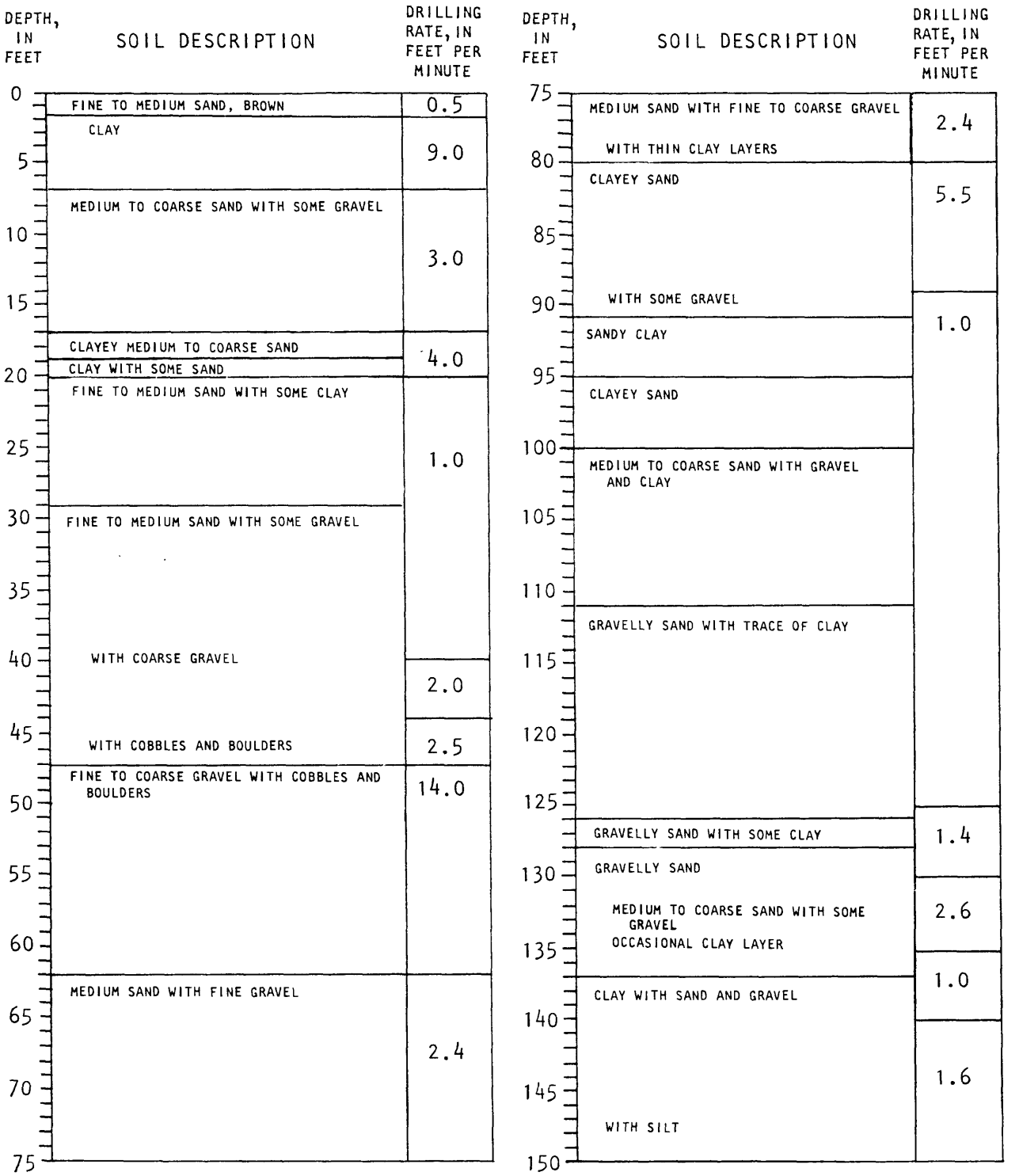

Figure 14.--Driller's log of the deepest borehole in the Montaño 1 piezometer nest.

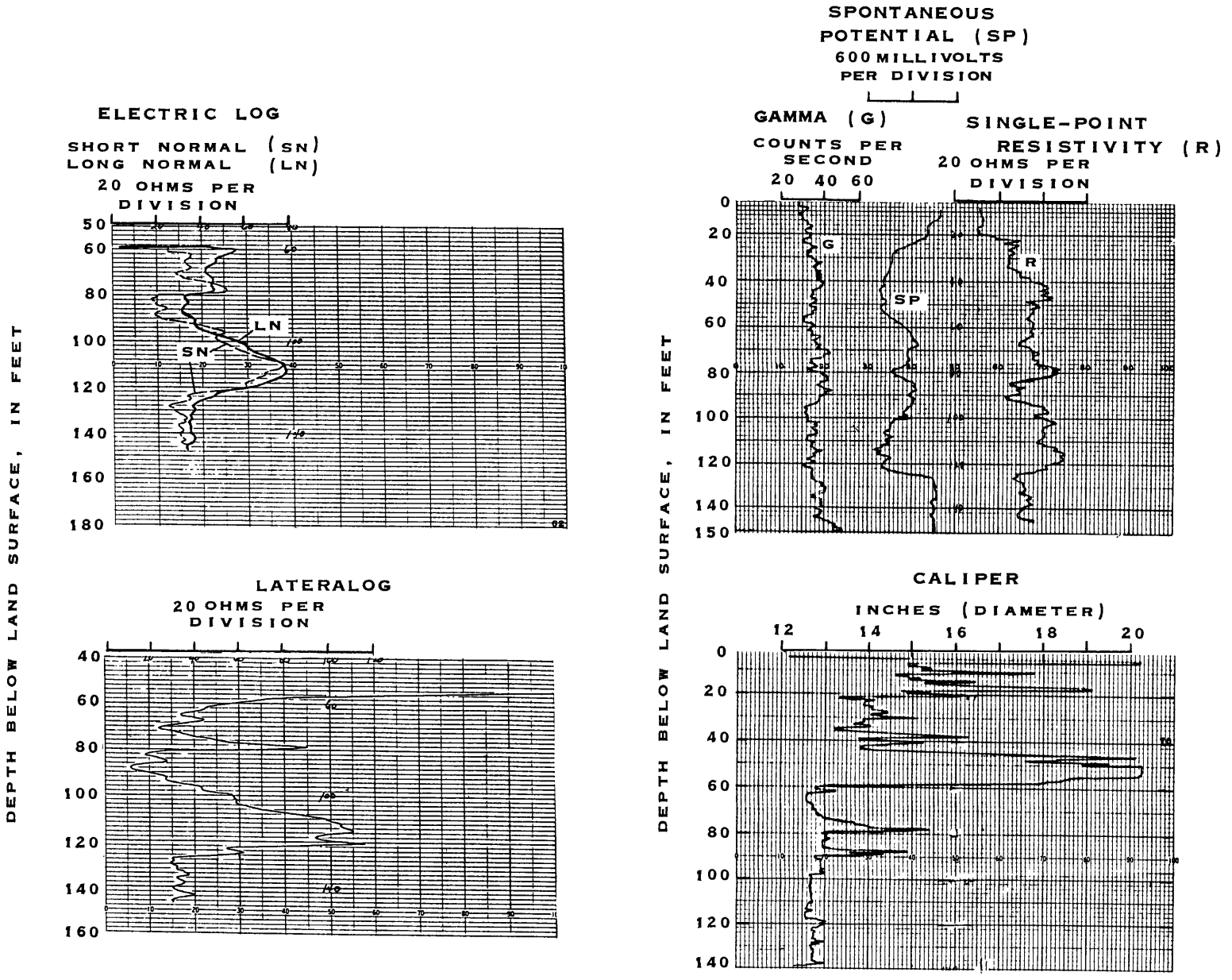

Figure 15.--Geophysical logs of the deepest borehole in the Montaño 1 piezometer nest.

Montaño 2

The Montaño 2 piezometer nest (fig. 1) is on the north side of Montaño Road east of the intersection of Montaño Road and Rio Grande Boulevard (latitude 35°08'36", longitude 106°39'56"). The piezometers are oriented approximately east-west and the deepest piezometer (147.4 feet) is the western piezometer (fig. 13). The distance between the western and middle piezometers is 16.8 feet and the distance between the middle and eastern piezometers is 16.1 feet. The driller's log is shown in figure 16 and the geophysical logs are shown in figure 17. The description of well cuttings is in table 6.

Table 6. Lithologic description of well cuttings from the deepest borehole in the Montaño 2 piezometer nest

[d, dry; m, moist; mm, millimeters; $CaCO_3$, calcite; HCl, 10 percent hydrochloric acid]

MONTAÑO 2

Lithology	Depth interval below land surface (feet)
Clayey, silty, gravelly sand; grayish-orange-pink to pale-brown (5YR 7/2 to 5YR 5/2 d, 5YR 3/2 m) clay and silt to fine-grained sand; angular to rounded, moderately sorted; composed dominantly of quartz and black quartzite with some mica present; pebbles to 5 mm composed of quartzite and volcanic and plutonic clasts; strong effervescence to HCl, $CaCO_3$ nodules to 2 mm.	0 - 10
Gravelly sand; pale-brown (5YR 5/2 d, 5YR 2/2 m), fine- to coarse-grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of smokey, rose, and milky quartz and black quartzite with lesser amounts of basalt, obsidian, pumice, mica, and granitic and metamorphic grains; granules to 4 mm composed of black quartzite, basalt, and quartz; few very thin, discontinuous clay films; weak to moderate effervescence to HCl.	10 - 40
Sandy gravel; pale-brown (5YR 5/2 d, 5YR 3/2 m), very fine to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of clear, rose, milky, and smokey quartz and black quartzite with lesser amounts of mica, feldspar, pumice, and granitic and metamorphic grains; pebbles to 6 mm composed dominantly of black and brown quartzite and rose quartz with lesser amounts of sandstone, basalt, metamorphic, and granitic clasts; minor iron-oxide stains on grains; weak effervescence to HCl.	40 - 80

Table 6. Lithologic description of well cuttings from the deepest borehole in the Montaño 2 piezometer nest - Concluded

MONTAÑO 2

Lithology	Depth interval below land surface (feet)
Gravelly sand; light-brown (5YR 6/4 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of feldspar, basalt, metamorphic, and plutonic fragments; granules to 4 mm composed dominantly of black quartzite, basalt, and quartz with lesser amounts of granitic and metamorphic fragments; few thin, discontinuous clay films and minor iron-oxide stains on grains; moderate to strong effervescence to HCl.	80 - 95
Sandy gravel; brownish-gray (5YR 4/1 d, 5YR 3/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and black quartzite with lesser amounts of feldspar, mica, metamorphic, and volcanic fragments; pebbles to 12 mm composed dominantly of black and brown quartzite, quartz, and basalt with lesser amounts of sandstone, metamorphic, granitic, and andesitic clasts; few very thin, discontinuous clay films and minor iron-oxide stains; moderate to strong effervescence to HCl.	95 - 120
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), very fine to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of clear, rose, yellow, and milky quartz and black quartzite with lesser amounts of feldspar, mica, granitic, and metamorphic grains; pebbles to 10 mm composed dominantly of black quartzite and quartz with lesser amounts of metamorphic, granitic, andesitic, and sandstone clasts; minor iron-oxide stains; moderate to strong effervescence to HCl.	120 - 147.4

MONTAÑO 2

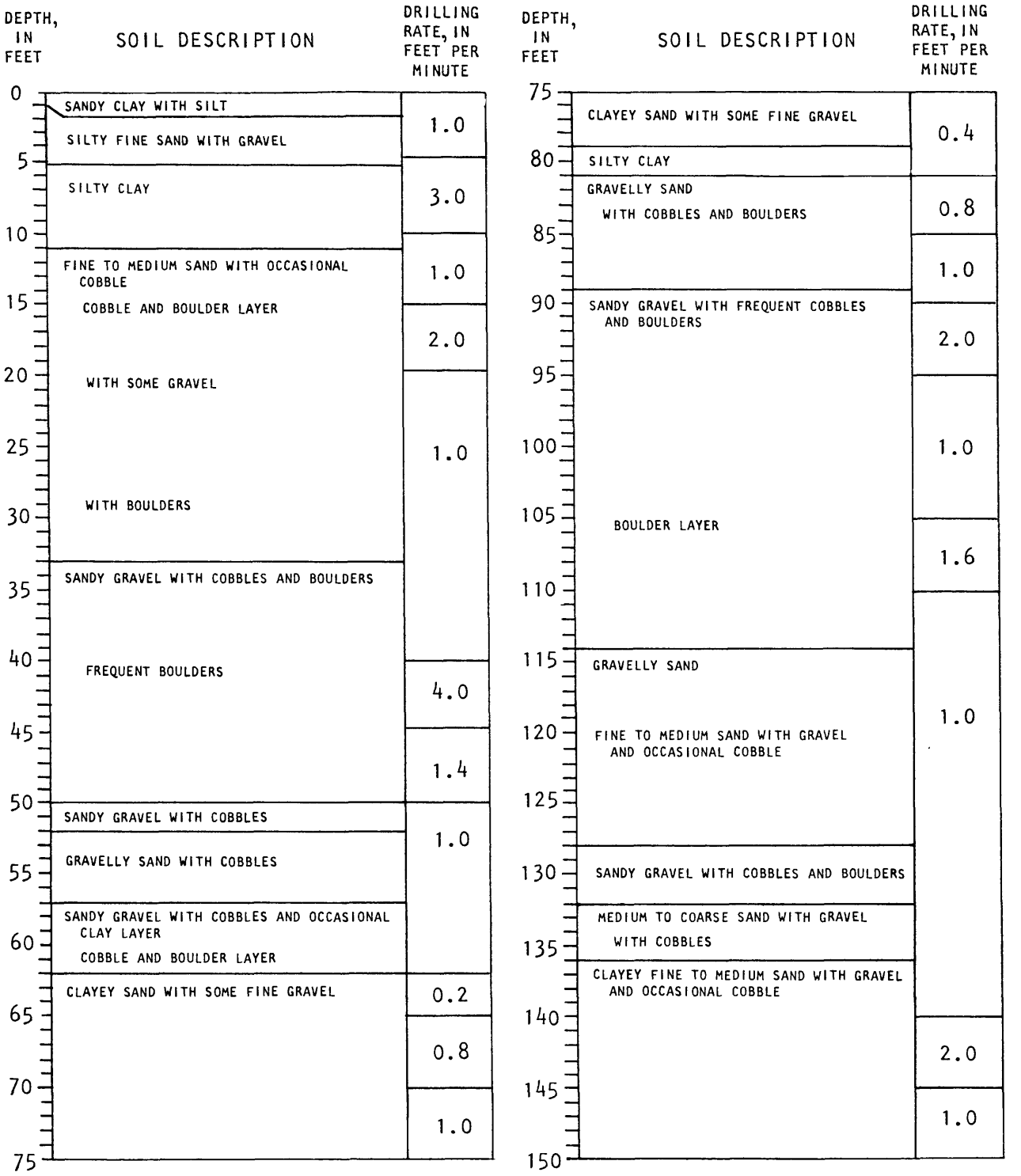

Figure 16.--Driller's log of the deepest borehole in the Montaño 2 piezometer nest.

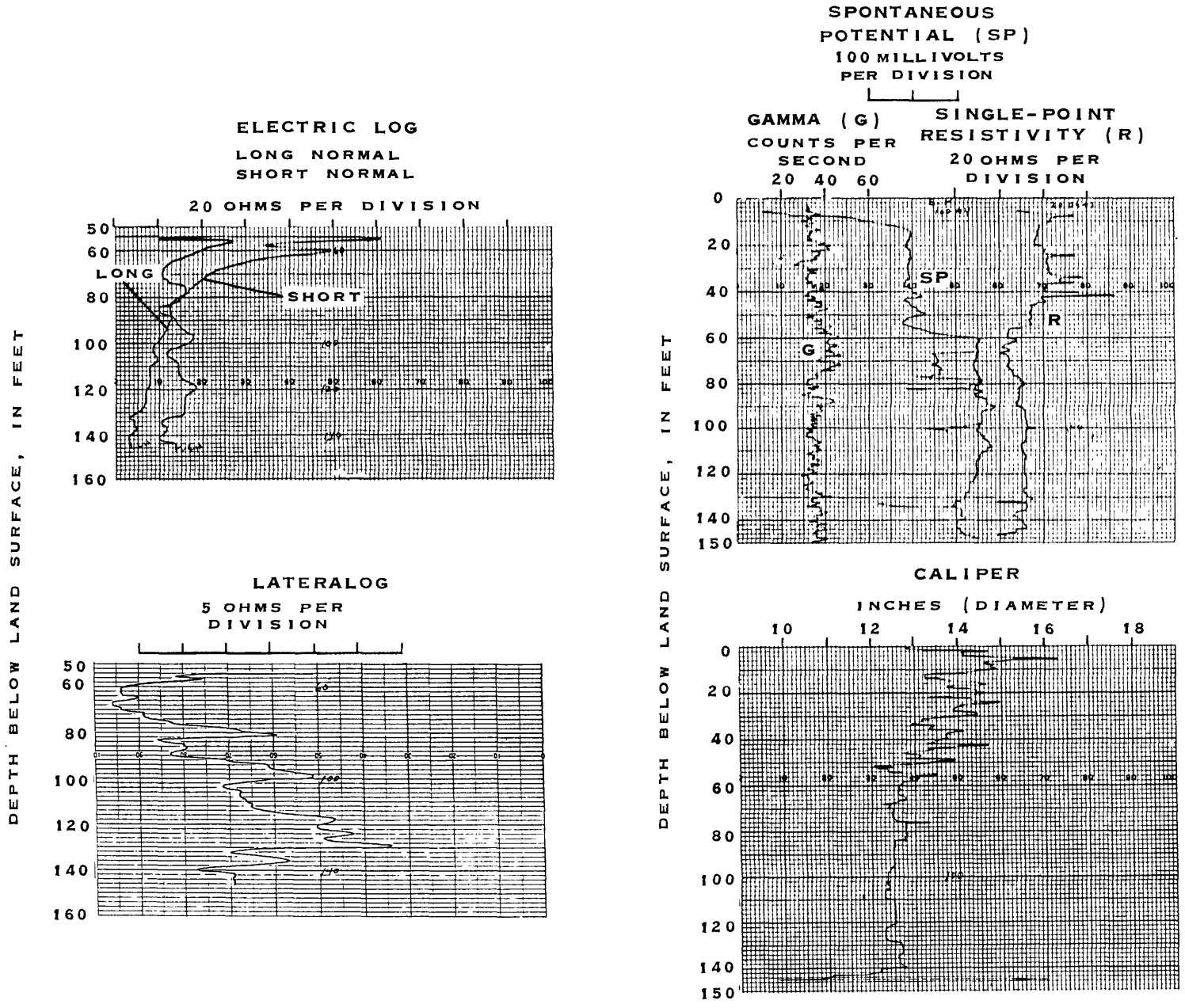

Figure 17.--Geophysical logs of the deepest borehole in the Montaño 2 piezometer nest.

Montaño 3

The Montaño 3 piezometer nest (fig. 1) is on the south side of Montaño Road approximately 900 feet west of the intersection of Montaño Road and Guadalupe Trail (latitude 35°08'27", longitude 106°39'13"). The piezometers are oriented approximately east-west and the deepest piezometer (149.8 feet) is the middle piezometer (fig. 18). The distance between the western and middle piezometers is 17.3 feet and the distance between the middle and eastern piezometers is 21.1 feet. The driller's log is shown in figure 19 and the geophysical logs are shown in figure 20. The description of well cuttings is in table 7.

Table 7. Lithologic description of well cuttings from the deepest borehole in the Montaño 3 piezometer nest

[d, dry; m, moist; mm, millimeters; $CaCO_3$, calcite; HCl, 10 percent hydrochloric acid]

MONTAÑO 3

Lithology	Depth interval below land surface (feet)
Clayey, silty sand; grayish-orange-pink (5YR 7/2 d, 5YR 5/2 m) silt and clay to medium-grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of quartz and quartzite; strong effervescence to HCl, $CaCO_3$ nodules to 2 mm.	0 - 15
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 5YR 5/2) silt to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of mica, feldspar, pumice, basalt, and metamorphic grains; pebbles to 5 mm composed dominantly of black quartzite and quartz with lesser amounts of metamorphic, sandstone, and basalt clasts; strong effervescence to HCl, $CaCO_3$ coats some clasts, cements some grains, and as nodules to 2 mm.	15 - 45

Table 7. Lithologic description of well cuttings from the deepest borehole in the Montaño 3 piezometer nest - Concluded

MONTAÑO 3

Lithology	Depth interval below land surface (feet)
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of mica, pumice, metamorphic, and plutonic grains; pebbles to 8 mm composed dominantly of black and brown quartzite and quartz with lesser amounts of sandstone, granitic, and metamorphic clasts; few thin, discontinuous clay films and colloidal iron-oxide stains; moderate to strong effervescence to HCl.	45 - 85
Silty, clayey, gravelly sand; pale-yellowish-brown (10YR 7/2 d, 10YR 5/2 m) silt and clay to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of mica, feldspar, metamorphic, and volcanic fragments; pebbles to 15 mm composed dominantly of black and brown quartzite and quartz with lesser amounts of sandstone, metamorphic, and granitic clasts; few colloidal iron-oxide stains; strong effervescence to HCl, $CaCO_3$ nodules 1 to 2 mm.	85 - 135
Gravelly sand; light-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of metamorphic and granitic grains; pebbles to 12 mm composed dominantly of black quartzite with lesser amounts of quartz and granitic clasts; very few thin, discontinuous clay films and iron-oxide stains; strong to violent effervescence to HCl.	135 - 149.8

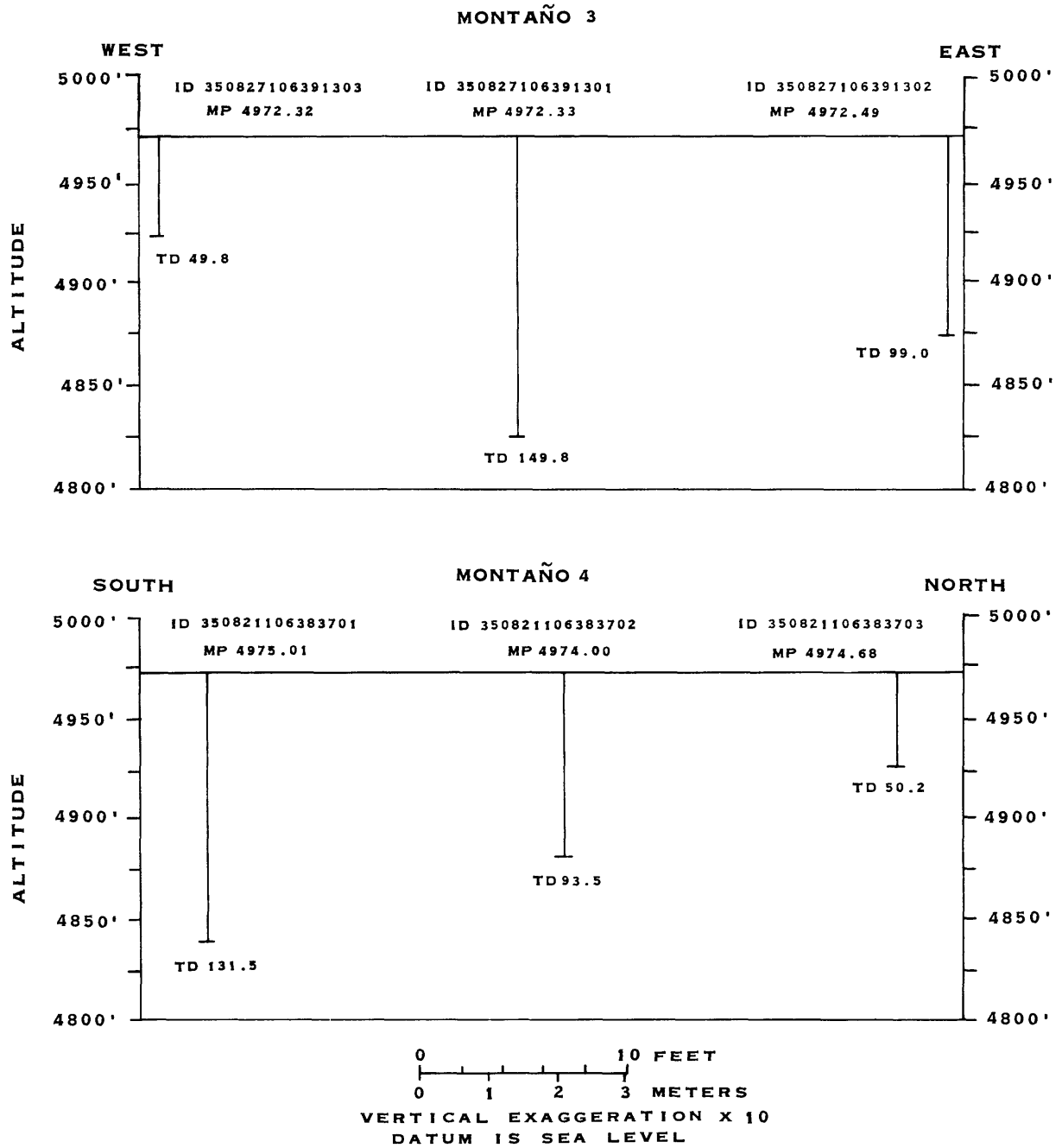

Figure 18.--Configuration of piezometers in the Montaño 3 and Montaño 4 piezometer nests.

MONTAÑO 3

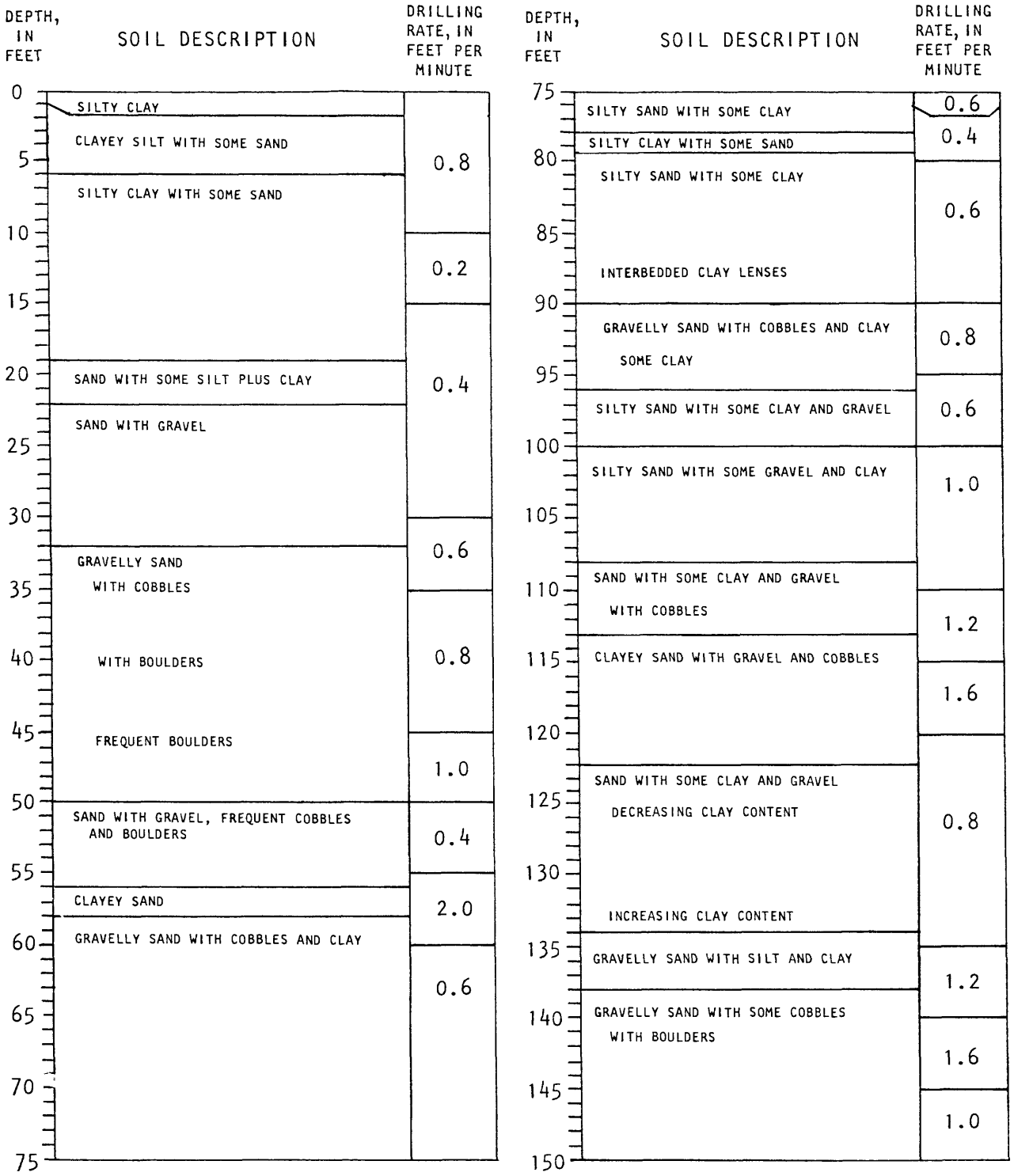

Figure 19.--Driller's log of the deepest borehole in the Montaño 3 piezometer nest.

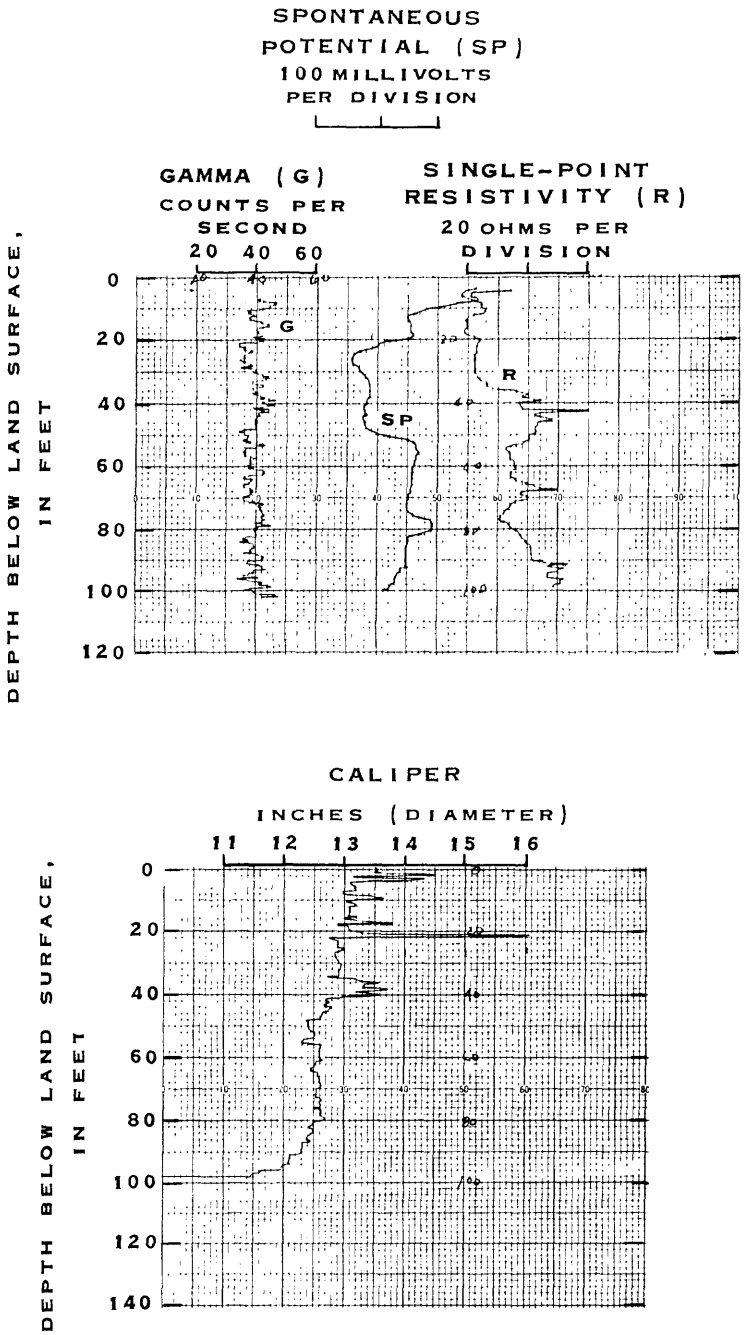

Figure 20.--Geophysical logs of the intermediate-depth borehole in the Montaño 3 piezometer nest.

Montaño 4

The Montaño 4 piezometer nest (fig. 1) is on the south side of Montaño Road and on the west side of the Harwood Lateral (latitude 35°08'21", longitude 106°38'37"). The piezometers are oriented approximately north-south and the deepest piezometer (131.5 feet) is the southern piezometer (fig. 18). The distance between the southern and middle piezometers is 17.5 feet and the distance between the middle and northern piezometers is 16.4 feet. The driller's log is shown in figure 21 and the geophysical logs are shown in figure 22. The description of well cuttings is in table 8.

Table 8. Lithologic description of well cuttings from the deepest borehole in the Montaño 4 piezometer nest

[d, dry; m, moist; mm, millimeters; $CaCO_3$, calcite; HCl, 10 percent hydrochloric acid]

MONTAÑO 4

Lithology	Depth interval below land surface (feet)
Clayey, silty sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m) silt and clay to very fine grained sand; angular to subrounded, poorly to moderately sorted; composed dominantly of quartz with lesser amounts of mica and quartzite; strong effervescence to HCl, $CaCO_3$ nodules to 2 mm.	0 - 10
Gravelly sand; dark-yellowish-brown (10YR 6/2 d, 5YR 3/4 m), fine- to very coarse grained sand; angular to rounded, poorly to moderately sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of mica, feldspar, pumice, granitic, and metamorphic grains; granules to 4 mm composed dominantly of black quartzite and quartz with lesser amounts of metamorphic and granitic clasts; few very thin, discontinuous clay films; moderate to strong effervescence to HCl.	10 - 25
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to rounded, poorly to well sorted; composed dominantly of rose and milky quartz and black quartzite with lesser amounts of mica, feldspar, basalt, and metamorphic grains; pebbles to 5 mm composed dominantly of black quartzite and quartz with lesser amounts of metamorphic, granitic, basalt, and volcanic clasts; minor iron-oxide stains and cementation; weak to moderate effervescence to HCl.	25 - 55

Table 8. Lithologic description of well cuttings from the deepest borehole in the Montaño 4 piezometer nest - Concluded

MONTAÑO 4

Lithology	Depth interval below land surface (feet)
Gravelly sand; pale-yellowish-brown (10YR 6/2 d, 10YR 4/2 m), fine- to very coarse grained sand; angular to well rounded, poorly to moderately sorted; composed dominantly of rose, milky, and smokey quartz and black quartzite with lesser amounts of mica, feldspar, basalt, granitic, metamorphic, and sandstone grains; pebbles to 10 mm composed dominantly of black quartzite and quartz with lesser amounts of basalt, sandstone, granitic, metamorphic, and volcanic clasts; few very thin, discontinuous clay films and some iron-oxide stains; moderate to strong effervescence to HCl.	55 - 131.5

MONTAÑO 4

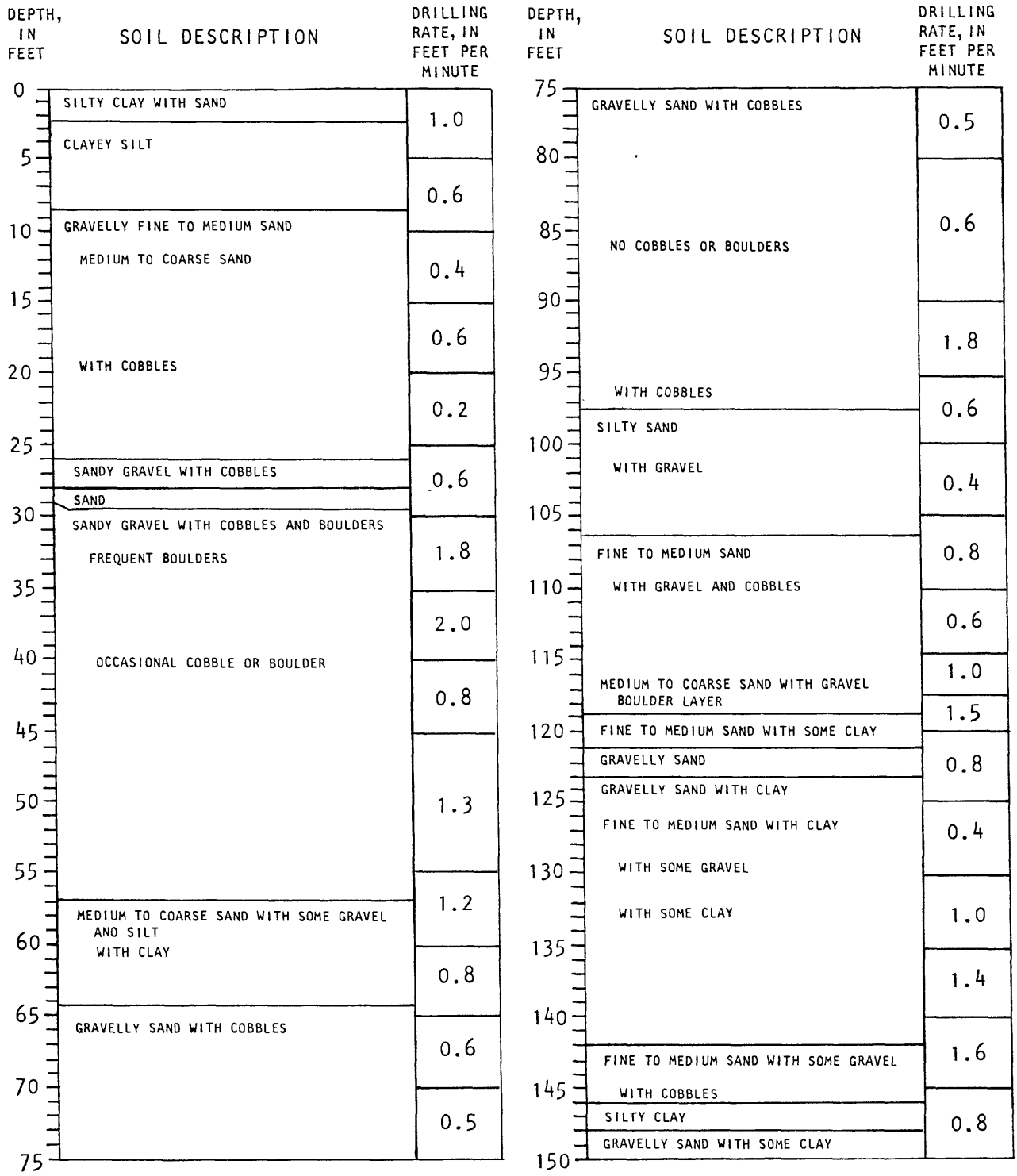

Figure 21.--Driller's log of the deepest borehole in the Montaño 4 piezometer nest.

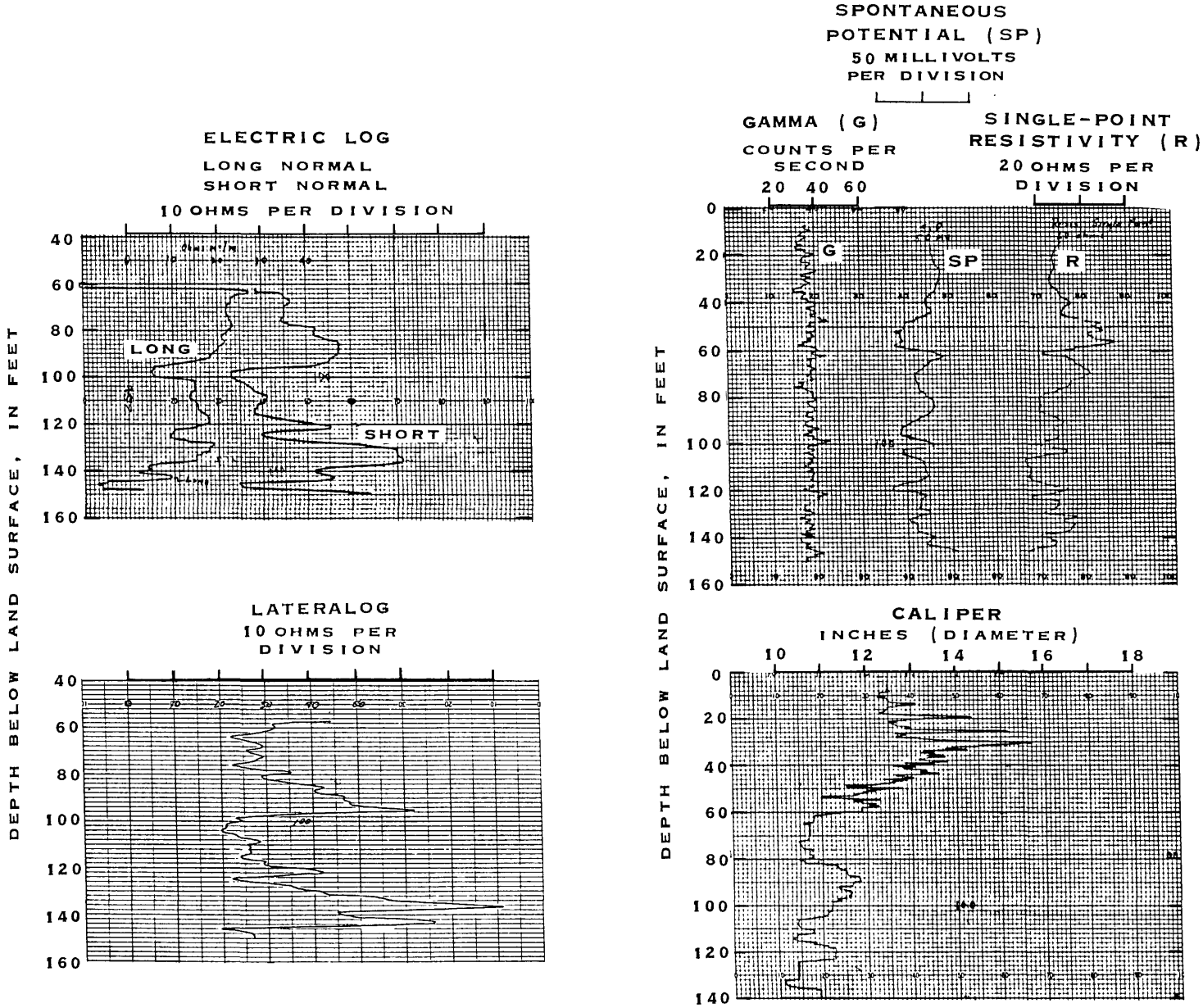

Figure 22.--Geophysical logs of the deepest borehole in the Montaño 4 piezometer nest.

WATER-LEVEL DATA

Water levels were measured in the piezometers at approximately 1-week intervals from February through June 1985. Water-level hydrographs of the data collected from each piezometer are shown in figures 23 through 26. Water levels generally rose in piezometers in the Rio Bravo section. This general rise in water levels did not occur in piezometers in the Montaño Road section. Water-level altitudes in piezometers completed at different depths in a particular nest are about the same in the Rio Bravo piezometer nests and Montaño 1 nest. In several of the piezometer nests, water levels generally decrease with depth, especially in the Montaño nests (figs. 25 and 26).

Hydrologic sections of the Rio Bravo and Montaño piezometer nests are shown in figures 27 and 28. Water levels in piezometers screened at approximately the same altitude are at approximately the same altitude in the Rio Bravo section (fig. 27). In the Montaño section, water levels in wells screened at approximately the same altitude generally are lower in the eastern piezometers (Montaño 3 and 4) than in the western piezometers (Montaño 1 and 2) (fig. 28).

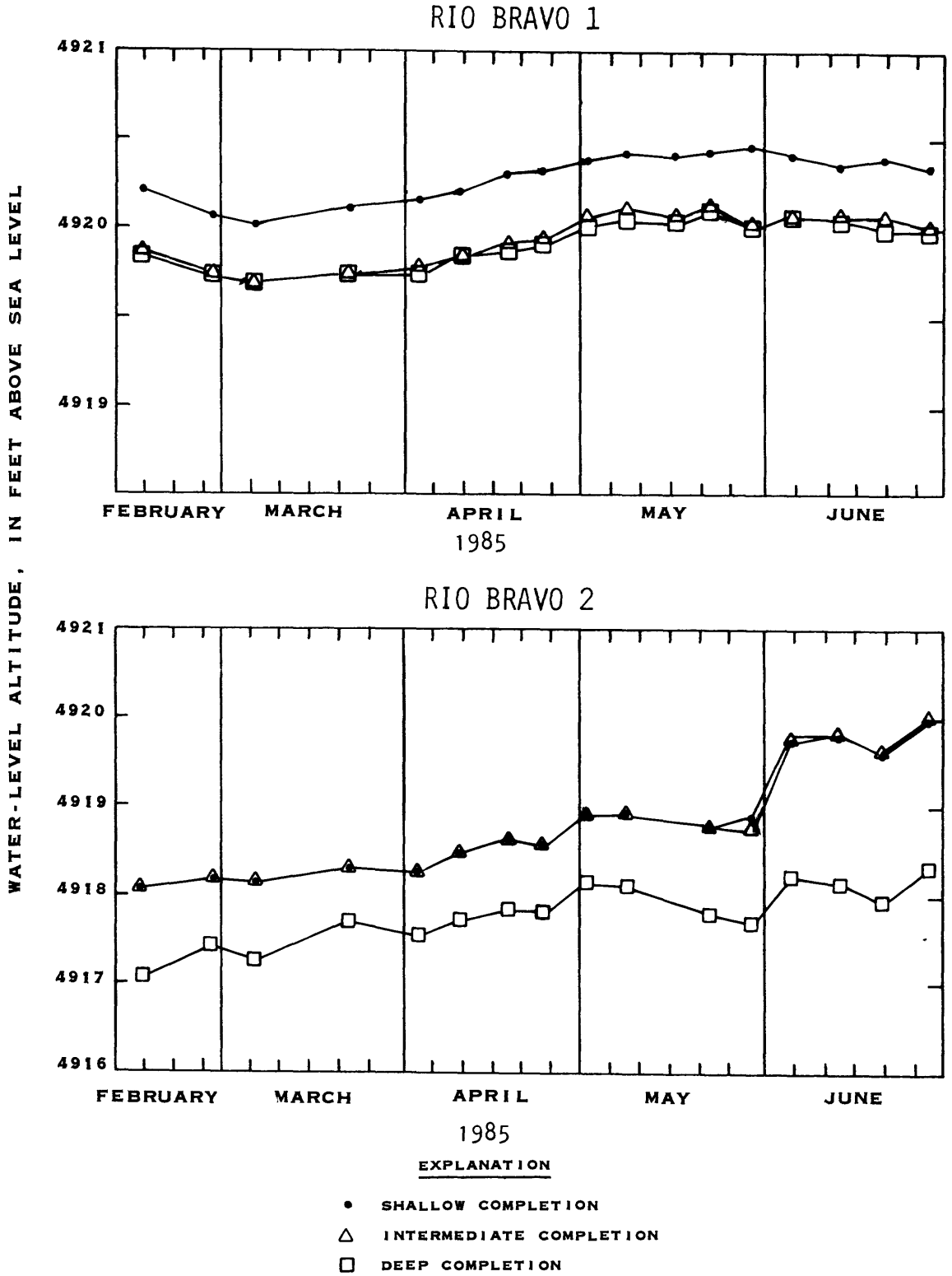

Figure 23.--Water-level hydrographs of the Rio Bravo 1 and Rio Bravo 2 piezometer nests.

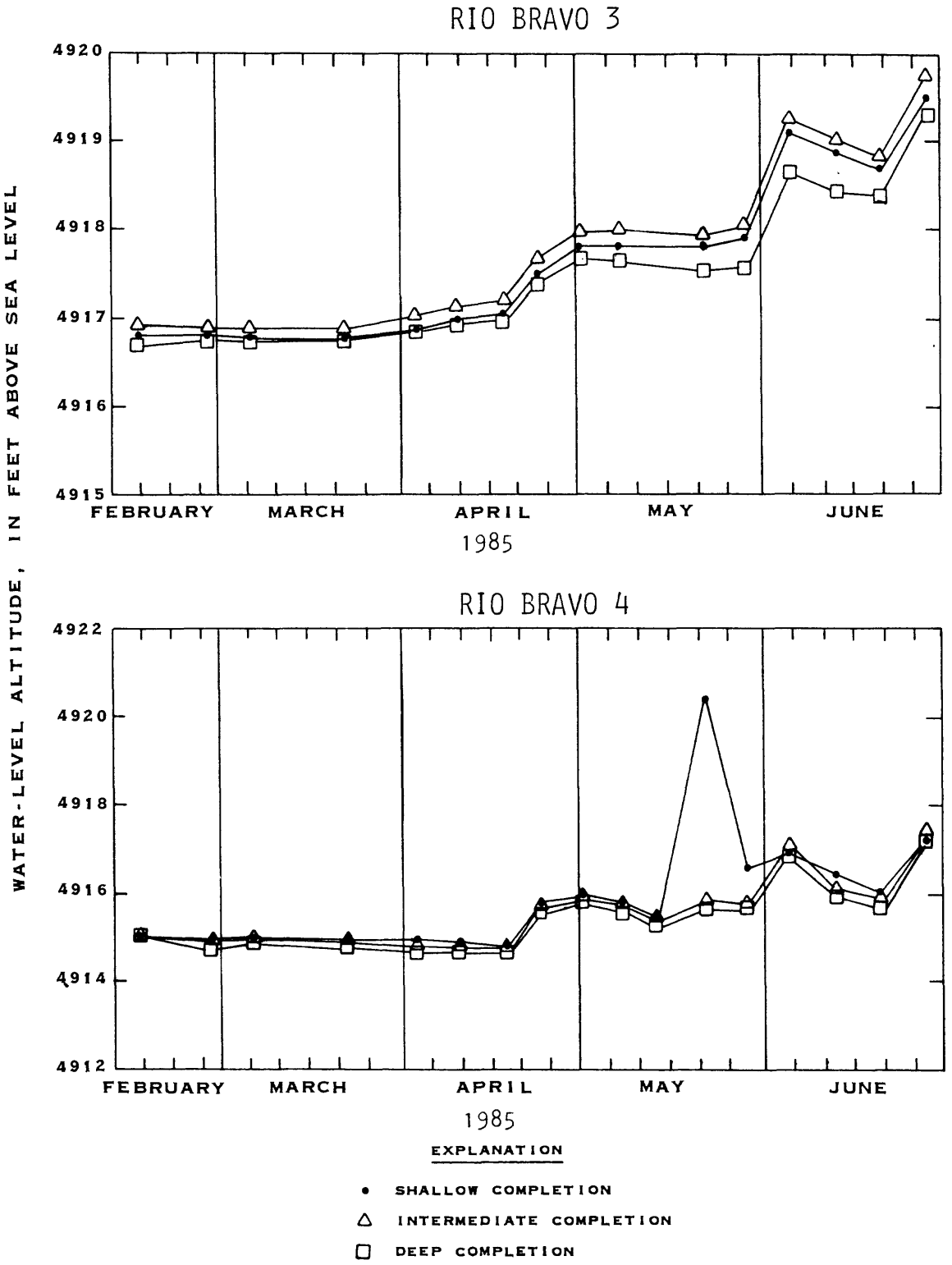

Figure 24.--Water-level hydrographs of the Rio Bravo 3 and Rio Bravo 4 piezometer nests.

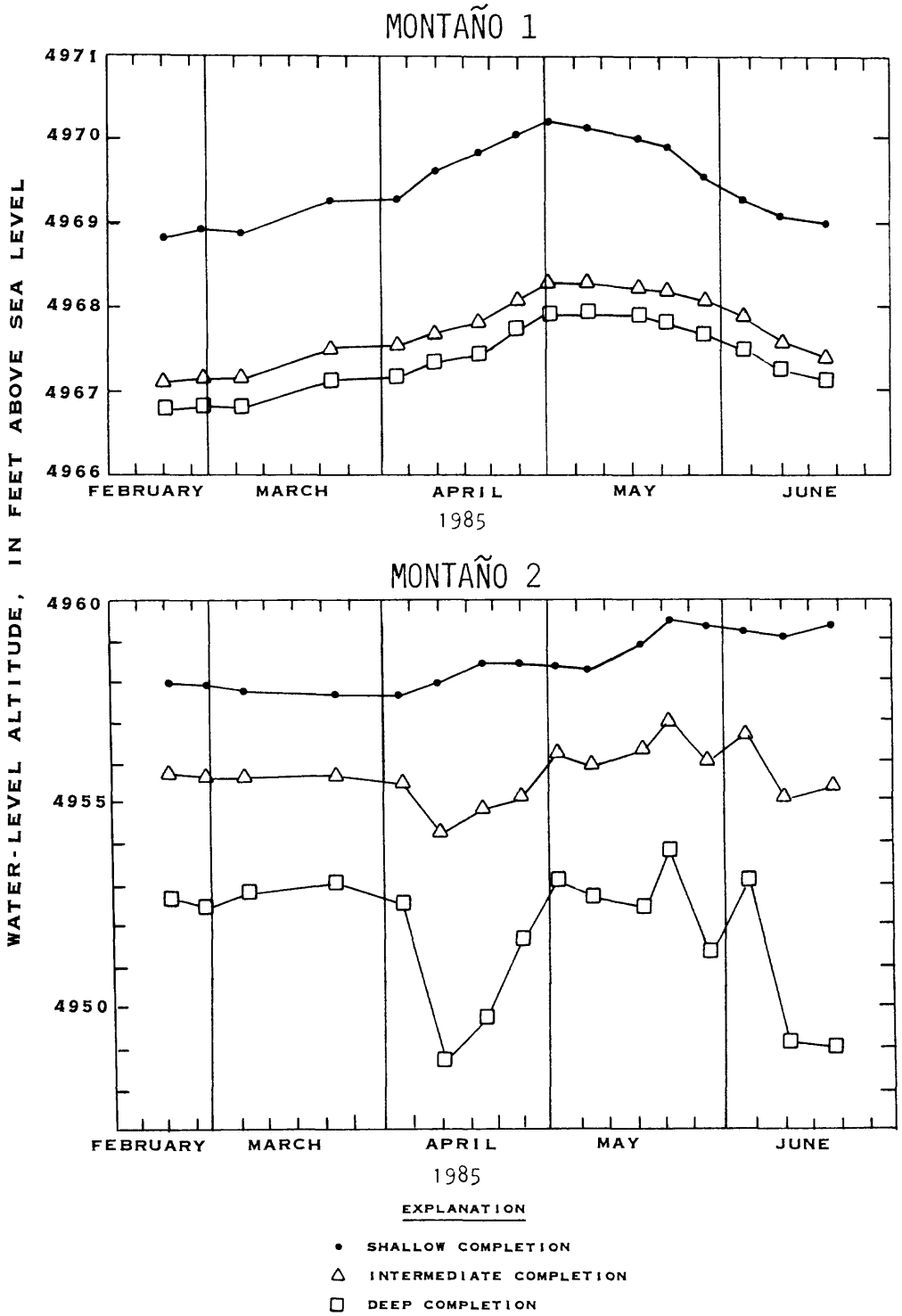

Figure 25.--Water-level hydrographs of the Montaño 1 and Montaño 2 piezometer nests.

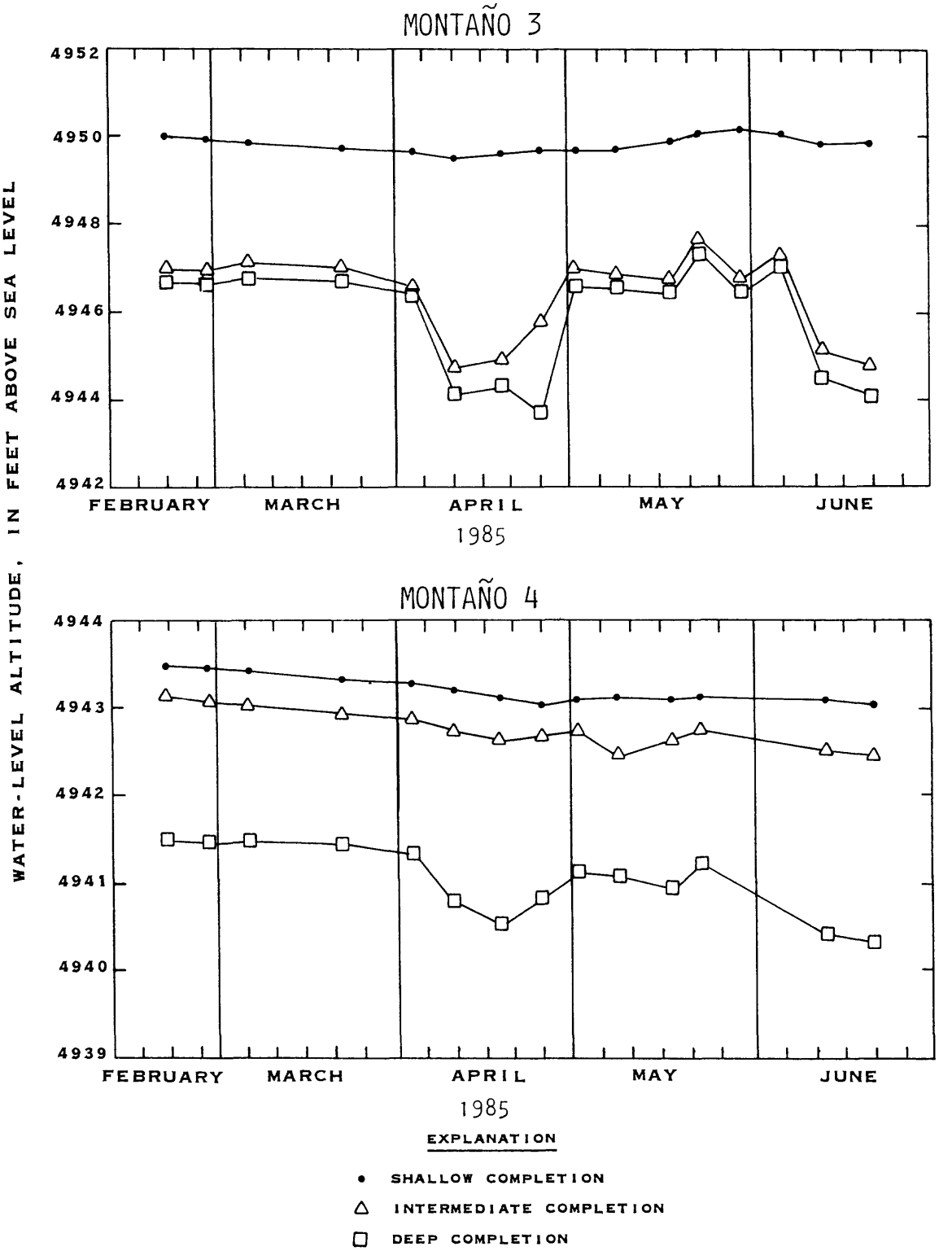

Figure 26.--Water-level hydrographs of the Montaño 3 and Montaño 4 piezometer nests.

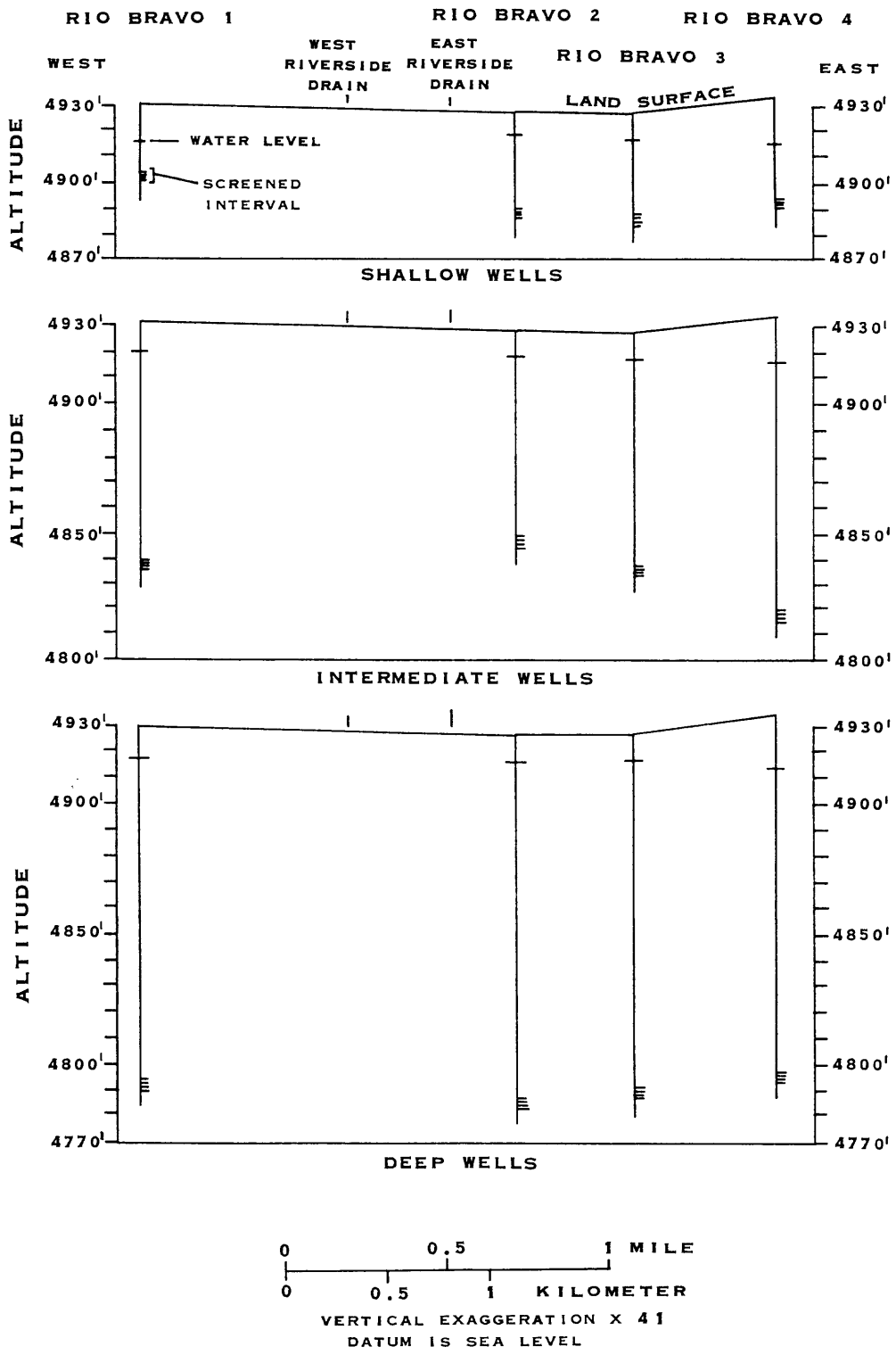

Figure 27.--Hydrologic sections of the Rio Bravo piezometers, January 15, 1985.

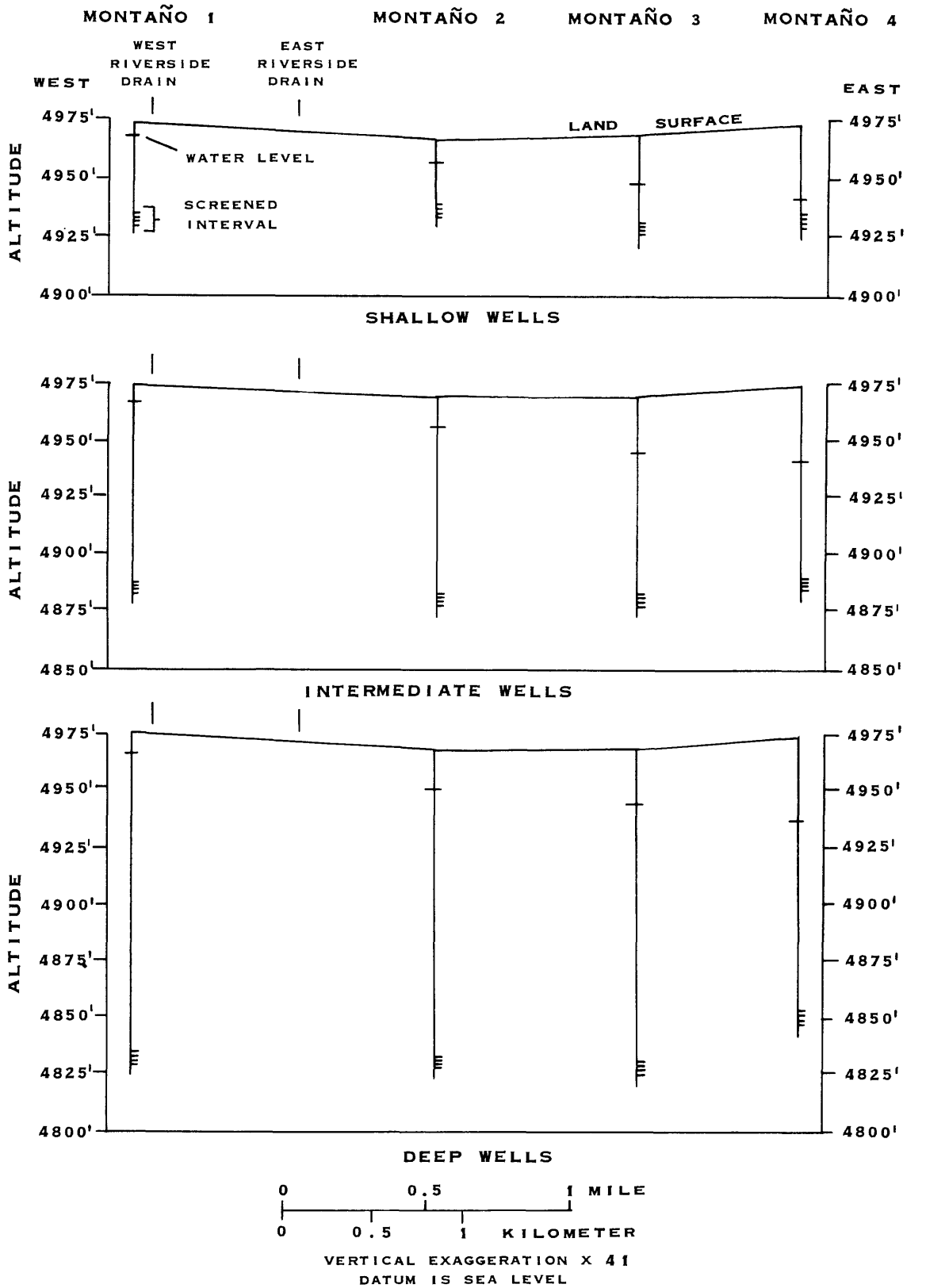

Figure 28.--Hydrologic sections of the Montaño piezometers, January 20, 1985.

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