DATA FOR GROUND-WATER TEST HOLE NEAR BUTTE CITY,

CENTRAL VALLEY AQUIFER PROJECT,

CALIFORNIA

By James J. French, R. W. Page, G. L. Bertoldi, and R. P. Fogelman

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CONVERSION FACTORS

In this report some measurements are given in inch-pound units and some laboratory data are reported in metric units. Conversion factors from inch-pound units to International System of Units are given below. To convert from International System of Units to inch-pound units, multiply by the reciprocal of the conversion shown.

Multiply	By	To obtain
acres	0.4047	hm^2 (square hectometers)
ft (feet)	0.3048	m (meters)
ft/d (feet per day)	0.00243	mD (millidarcies)
ft^2 (square feet)	0.0929	m^2 (square meters)
ft^2/yr (square feet per year)	0.0929	m^2/a (square meters per annum)
gal/min (gallons per minute)	0.00006309	m^3/s (cubic meters per second)
inches	25.4	mm (millimeters)
lb/in^2 (pounds per square inch)	703.1	kg/m^2 (kilograms per square meter)
lb/ft^2 (pounds per square foot)	4.881	kg/m^2 (kilograms per square meter)
lb/ft^3 (pounds per cubic foot)	16.02	kg/m^3 (kilograms per cubic meter)
mi (miles)	1.609	km (kilometers)
ton/d (tons per day)	0.9072	Mg/d (megagrams per day)
ton/acre-ft (tons per acre foot)	735.7	Mg/hm^3 (megagrams per cubic hectometer)

Temperature is reported in degrees Celsius (°C). Degrees Celsius are converted to degrees Fahrenheit (°F) by using the formula:

$$\text{Temp }^{\circ}F = 1.8 \text{ temp }^{\circ}C + 32$$

Abbreviations:
cm (centimeters)
°C/km (degrees Celsius per kilometer)
μg/L or UG/L (micrograms per liter)
mg/L or MG/L (milligrams per liter)
pCi/L (picocuries per liter)
W/(mK) (Watt per meter Kelvin)

ALTITUDE DATUM

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.

TRADE NAMES

The use of brand, firm, or trade names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

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CENTRAL VALLEY AQUIFER PROJECT, CALIFORNIA

By James J. French, R. W. Page, G. L. Bertoldi, and R. P. Fogelman

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ABSTRACT

This report provides preliminary data for the second of seven test holes drilled as a part of the Central Valley Aquifer Project, which is part of the National Regional Aquifer Systems Analysis Program. The test hole was drilled in the SW¼NE¼ sec. 32, T. 19 N., R. 1 W., Glenn County, Calif., about one-half mile south of the town of Butte City. Drilled to a depth of 1,432 feet below land surface, the hole is cased to a depth of 82 feet and equipped with three piezometer tubes to depths of 592 feet, 968 feet, and 1,330 feet. A 5-foot well screen is at the bottom of each piezometer. Each screened interval has a cement plug above and below it to isolate it from other parts of the aquifer, and the well bore is filled between the plugs with sediment.

Nine cores and 49 sidewall cores were recovered. Laboratory tests were made for mineralogy, hydraulic conductivity, porosity, consolidation, grain-size distribution, Atterberg limits, X-ray diffraction, and chemical quality of water. Geophysical and thermal gradient logs were made.

The hole is sampled periodically for chemical analysis and measured for water level in the three tapped zones.

This report presents methods used to obtain field samples, laboratory procedures, and the data obtained.

INTRODUCTION

The ground-water test hole near Butte City (19N/1W-32G) (fig. 1) was the second test hole drilled as part of the Central Valley Aquifer Project (CVAP). CVAP, as a part of the National Regional Aquifer Systems Analysis program, will evaluate the entire Central Valley (fig. 2) for its optimum ground-water potential. In the Sacramento Valley, the northern part of the Central Valley, geologic and hydrologic data below a depth of a few hundred feet are scarce. Most water wells in the Sacramento Valley are less than 300 feet deep (Olmsted and Davis, 1961, p. 137), but the potentially usable aquifer may extend to a depth of 2,500 feet (Bertoldi, 1979, p. 13).

The test hole was drilled and piezometer tubes were installed to provide data on confining beds, hydraulic conductivity, hydraulic connection between permeable units, chemical quality of the water, thermal gradient, mineral composition, and head differentials. The data are given in this report and include descriptions of rock cuttings coming out of the borehole, drill cores, sidewall cores, and geophysical logs. Also included are laboratory reports on mineralogy, hydraulic conductivity, porosity, consolidation, grain-size distribution, Atterberg limits, X-ray diffraction, thermal gradient, and chemical quality of water. In a few instances, the reporting laboratory's measuring units or definitions have been changed to conform to U.S. Geological Survey usage.

The site near Butte City was selected because it overlies one of the thicker sections of continental deposits near the structural axis of the Sacramento Valley (Page, 1974, figs. 2 and 3), and because virtually no data are available in this area with regard to water levels and water quality in the deep subsurface.

WELL-NUMBERING SYSTEM

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well 19N/1W-32G, the first two segments designate the township (T. 19 N.) and the range (R. 1 W.); the third number gives the section (sec. 32); and the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram. A final digit is a serial number for wells in each 40-acre subdivision (19N/1W-32G1).

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

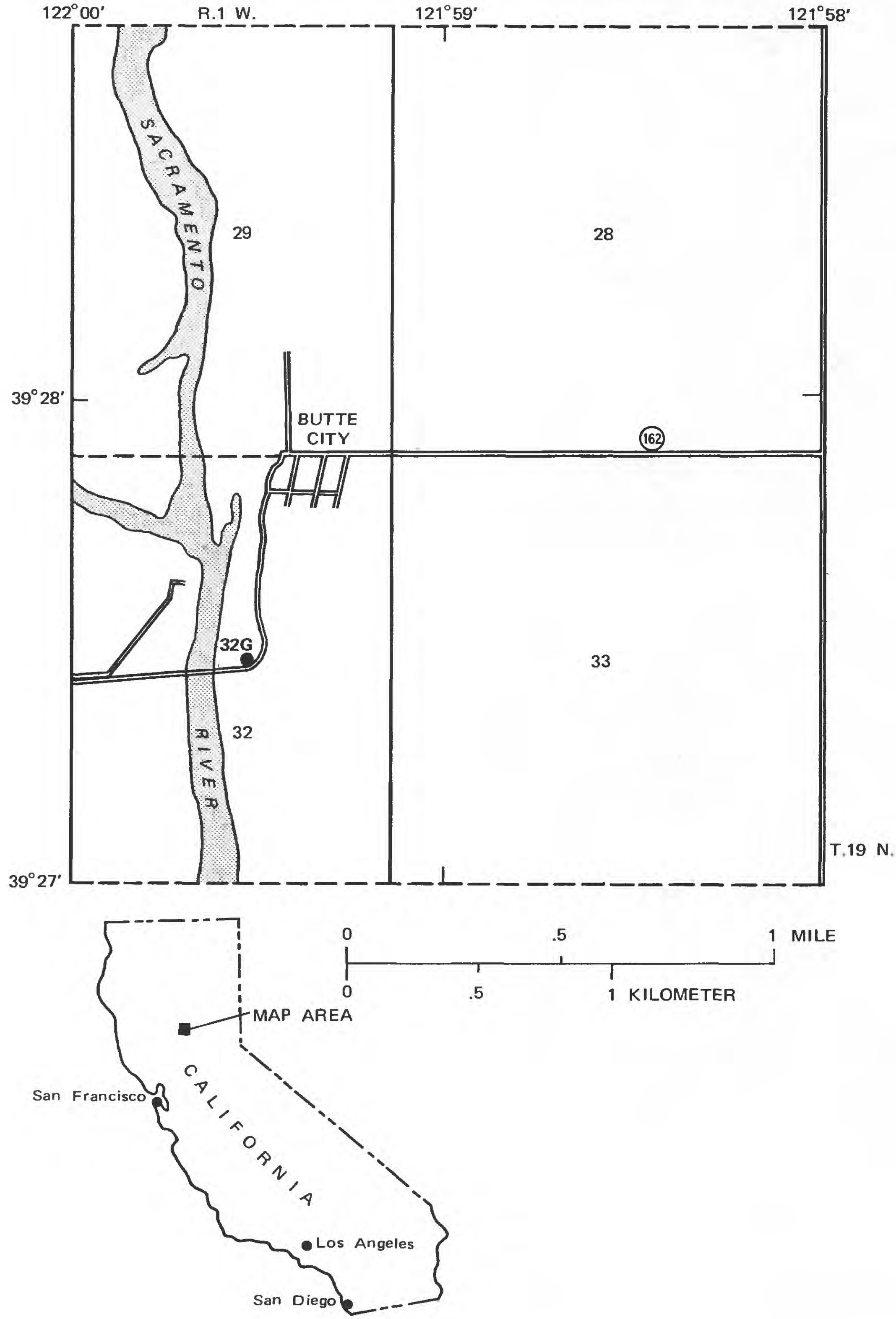

FIGURE 1.— Index map.

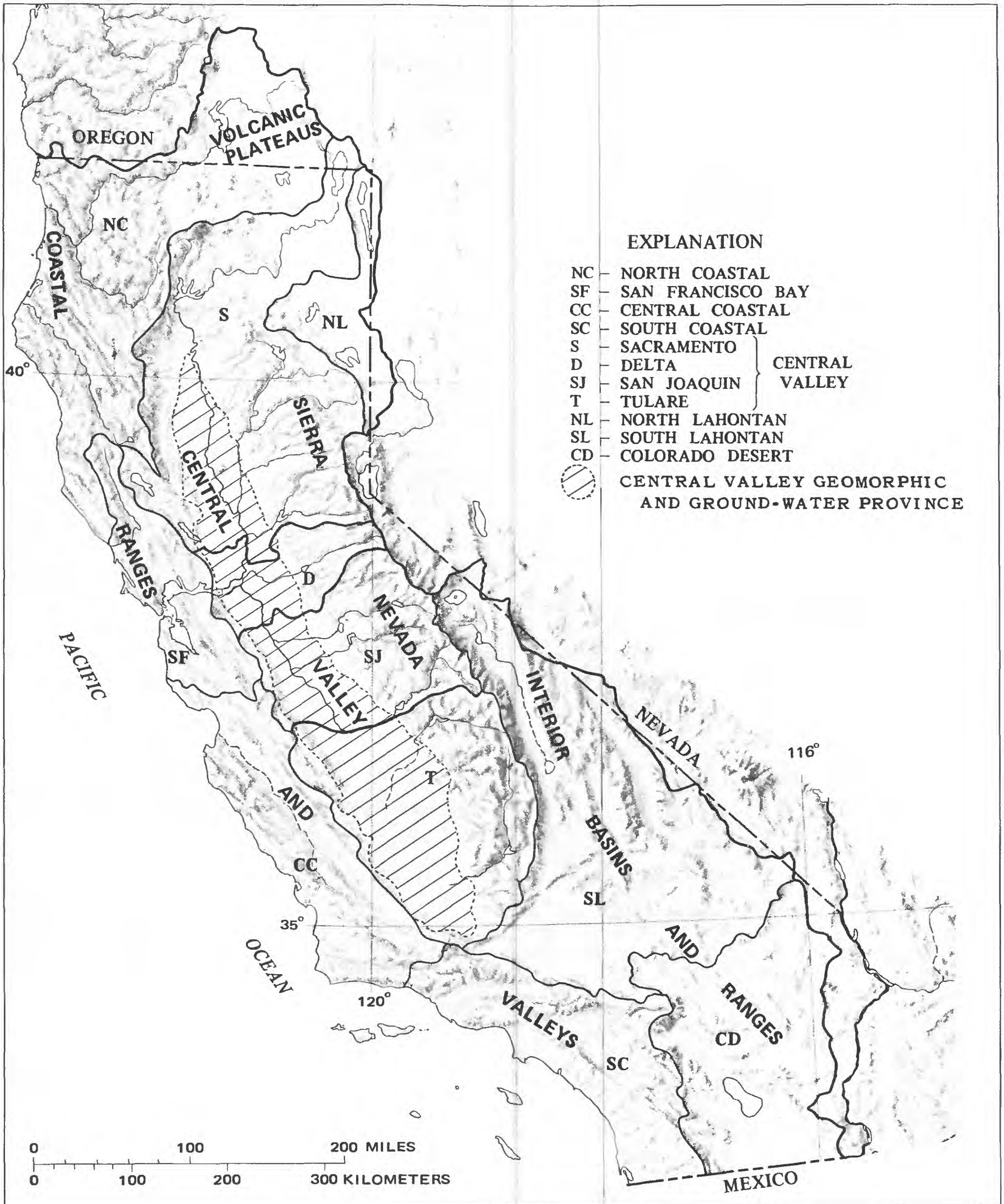

FIGURE 2. – Subregions and landforms of the California Region. (Modified from Thomas and Phoenix, 1976, p. E3).

PHYSICAL DESCRIPTION OF THE TEST HOLE

The test hole was started in alluvium August 8, 1979, and bottomed at 1,432 feet in clay and silt September 15, 1979. It was drilled by a mud-rotary rig using roller cone bits. Bit sizes used were 20 inches to a depth of 190 feet, 13-3/8 inches to 900 feet, 12-1/4 inches to 1,350 feet, and 9-7/8 inches to bottom. The test hole is cased with 16-inch-diameter cemented steel casing from land surface to 82-foot depth (fig. 3).

Three 4-inch-diameter steel piezometers were installed at depths of 592 (G3), 968 (G2), and 1,330 (G1) feet. The bottom 5 feet of each piezometer is screened to provide access to the aquifer. Each screened interval has a cement plug above and below it to isolate it from other parts of the aquifer. The top of casings above land surface are: G1, 1.11 feet; G2, 1.10 feet; and G3, 1.09 feet.

The test hole was finished with a 7-foot-square concrete slab surrounding the hole, and a 6-foot-square sheet-metal shelter built over it (fig. 4).

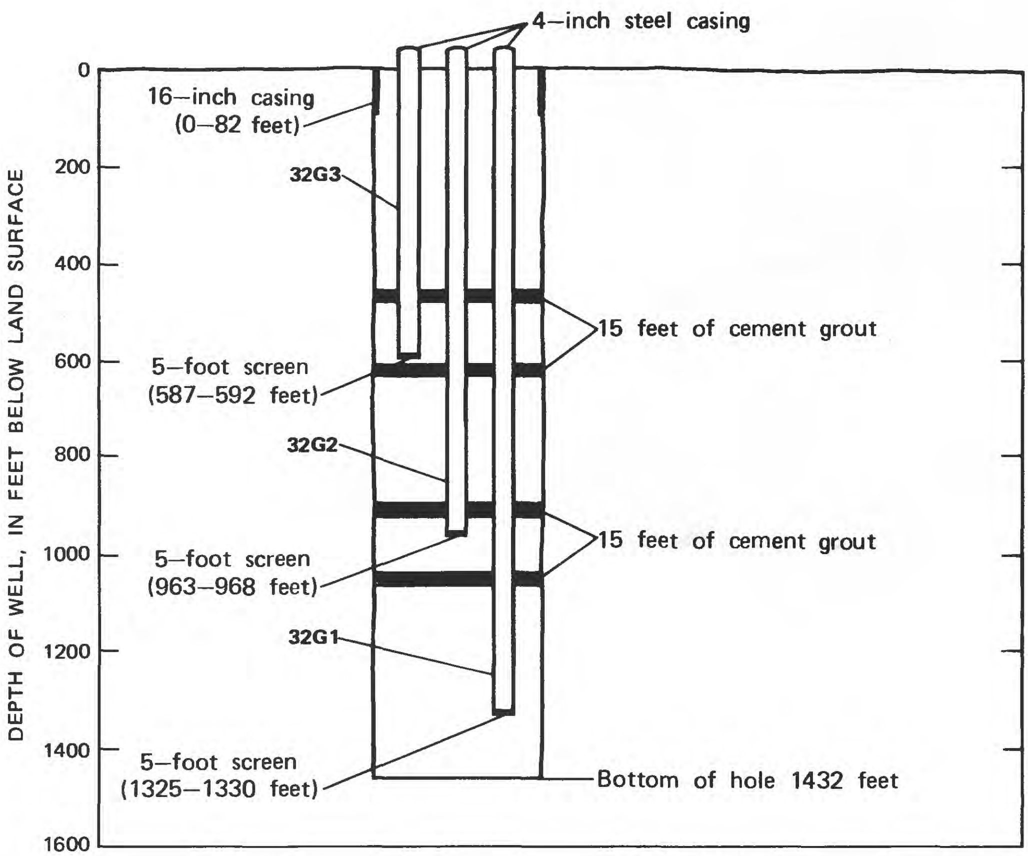

FIGURE 3. — Diagram of construction of test hole near Butte City.

FIGURE 4. — Test-hole shelter.

CUTTINGS AND CORE DESCRIPTIONS

The descriptions given in table 1 are for the depth interval indicated, from top to bottom, unless only a single depth is given. The single depths indicate that the description is for that depth only, not an interval. The log was constructed from all available data, including cuttings, cores, and geophysical logs. All depths are from land-surface altitude, which is 87.40 feet above the National Geodetic Vertical Datum of 1929.

During the drilling of the test hole, rock cuttings from the borehole were continuously monitored and collected at frequent intervals. In addition, nine drill cores were taken and 49 sidewall cores were recovered. The cores are to be stored in the California Well Sample Repository in Bakersfield, Calif.

The elements of a sample description are sediment type and texture, color, sorting, rounding, and cementation. Any or all these elements, plus any pertinent comments, were used by the geologist at the drill site to describe each interval.

Color descriptions follow the Rock Color Chart of the Geological Society of America (Goddard and others, 1948). This color chart has color chips for comparison with the samples and each chip is designated with a code. The code consists of a color name and an alphanumeric system which describes hue, value, and chroma. An example of this code is: light-olive-gray 5Y5/2, where the color name is defined by hue (5Y), value (5), and chroma (2).

Texture descriptions follow the National Research Council (1947) classification of grain size (table 2).

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G

Test hole 19N/1W-32G. Altitude of land surface 87.40 feet. Drilled by Water Development Corp. in 1979. Screens at 587-592 feet (G3); 963-968 feet (G2); 1,325-1,330 feet (G1).

Depth (feet) From	To	Description
CUTTINGS		
0	20	Top soil, clay, and some organic material.
20	60	Clay, silt, sand, fine to very coarse, and gravel, very fine, overall light-olive-brown 5Y5/6 to light-olive-gray 5Y5/2 with some moderate-yellowish-brown 10YR5/4 and olive-gray 5Y3/2. Small amounts of plant material and some nodules.
	30	Clay, silty, sandy, and some gravel and nodules. Silty clay, overall light-olive-brown 5Y5/6, sand, coarse, and gravel, very fine, subangular, low to medium sphericity, 60 percent dark grains, 40 percent light grains. Nodules light-olive-brown 5Y5/6, with streaks, brownish-black 5YR2/1.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
	40	Clay, silty, with some sand and nodules. Clay, light-olive-gray 5Y5/2 with some olive-black 5Y2/1, nodules light-olive-brown 5Y5/6 with some brownish-black 5YR2/1 speckling; sand, coarse to very coarse, sub-angular to subrounded, medium to high sphericity, mostly light grains, some dark grains.
	50	Sand, some silt and gravel.
	60	Clay, silty, with some nodules; clay, moderate-yellowish-brown 10YR5/4 to light-olive-brown 5Y5/6.
60	70	Clay, some silt; clay, moderate-yellowish-brown 5Y5/6.
	70	Silt, clayey, light-olive-brown 5Y5/6.
70	82	Sand, clayey and silty, and some gravel, fine, light-olive-brown 5Y5/6.
82	105	Sand, medium to very coarse, small amounts of clay, olive-gray 5Y3/2.
105	114	Clay and silt, dark-yellowish-brown 10YR4/2, some plant material and black N1 seeds(?) up to 0.04 in. in diameter.
114	127	Gravel, very fine to medium, and sand, coarse to very coarse, with some silt and volcanic ash(?). Gravel and sand 70 percent dark-greenish-gray 5GY4/1 and dark-yellowish-brown 10YR4/2 to grayish-brown 5YR3/2 and grayish-black N2, 30 percent white N9 and yellowish-gray 5Y8/1 to light-olive-brown 5Y5/6, angular to rounded, moderately sorted, low to high shpericity; ash(?) and silt, dark-yellowish-brown 10YR2/2.
SIDEWALL CORE NO. 49		
--	114	Gravel, fine to medium, and sand, fine to very coarse, overall moderate-yellowish-brown 10YR5/4 to dark-yellowish-brown 10YR4/2, angular to subangular, low to medium sphericity; gravel mostly dark grains (moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2, some grayish-black N2), some light grains (yellowish-gray 5Y8/1); sand, overall dark-yellowish-brown 10YR4/2.
SIDEWALL CORE NO. 48		
--	126	Sand, fine to coarse, some very coarse, and gravel, fine, olive-gray 5Y3/2, mostly dark grains, dark-yellowish-brown 10YR4/2 and grayish-olive 10Y4/2 to grayish-brown 5YR3/2 and black N1 (speckled with light color), angular to rounded, low to medium sphericity.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
127	158	Silt, clayey, and some sand and gravel. Silt, dark-yellowish-brown 10YR4/2 to moderate-olive-brown 5Y4/4. Sand, fine to coarse, grayish-olive 10Y4/2 to dusky-yellowish-brown 10YR2/2, very dusky-red 10R2/2 and black N1, some light grains (white N9, yellowish-gray 5Y8/1 to light-gray N7, and moderate-yellowish-brown 10YR5/4). Gravel, very fine to medium, mostly dark grains, grayish 10Y4/2 to dusky-yellowish-brown 10YR2/2, angular to rounded, low sphericity.
158	159	Gravel, fine to very fine, sand, very fine to very coarse, silty sand, and some silt; gravel, mostly dark grains (dark-yellowish-brown 10YR4/2 to dark-reddish-brown 10R3/4, olive-gray 5Y3/2 and black N1), angular to rounded, low to medium sphericity. Silt and sand, light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4.
SIDEWALL CORE NO. 47		
--	159	Sand, very fine to coarse, silty, and gravel, very fine to medium. Sand, overall olive-gray 5Y3/2, gravel and sand, 50 percent dark grains (dark-yellowish-brown 10YR4/2, dusky-yellow-green 5GY5/2, and dark-greenish-gray 5GY4/1 to dark-reddish-brown 10R3/4 and black N1), and 50 percent light grains (white N9 to light-olive-gray 5Y6/1), subangular to subrounded, low to medium sphericity.
CUTTINGS		
159	169	Gravel, fine to very fine, sand, very fine to very coarse, some silt, light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4.
SIDEWALL CORE NO. 46		
--	169	Sand, very fine to coarse, and some gravel, fine. Sand, finer grains, overall light-olive-brown 5Y5/6, angular to subrounded, low sphericity, coarser grains 50 percent dark-reddish-brown 10R3/4 to greenish-black 5G2/1 and 50 percent light-olive-gray N7 to yellowish-gray 5Y8/1; gravel, angular to subrounded, low sphericity.
CUTTINGS		
169	170	Sand, very fine to coarse, and silt, some gravel, fine, overall light-olive-brown 5Y5/6.
170	182	Clay and silt, overall light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4.

Depth (feet) From	To	Description
182	187	Sand, fine to very coarse, and gravel, fine to medium, some silt and clay. Sand, 75 percent moderate-brown 5YR4/4 and olive-gray 5Y4/1 to grayish-olive-green 5GY3/2 and grayish-black N2, 25 percent white N9, pinkish-gray 5YR8/1 to greenish-gray 5GY6/1, angular to rounded, low to medium sphericity; gravel, similar to sand; silt, clayey, overall moderate-olive-brown 5Y4/4.
187	208	Silt, clayey, some sand, fine, moderate-olive-brown 5Y4/4 and moderate-brown 5YR4/4 to grayish-olive 10Y4/2 and dark-greenish-gray 5GT4/1.
208	243	Sand, fine to coarse, gravel, fine to medium, some silt; sand and gravel, 60 percent dark grains (moderate-brown 5YR4/4, dark-yellowish-brown 10YR4/2, olive-gray and grayish-black N2), and 40 percent light grains (white N9, yellowish-gray 5Y8/1 to pale-olive 10Y6/2 and pinkish-gray 5YR8/1). Silt and sand, overall grayish-olive 10Y4/2; sand, angular to subrounded, low to medium sphericity.
243	262	Clay and silt, some sand and gravel. Silty clay and fine sand, grayish-olive 10Y4/2; sand, medium to very coarse, and gravel, 60 percent dark grains (grayish-olive 10Y4/2, olive-gray 5Y3/2, dark-gray N3), 40 percent light grains (white N9, grayish-yellow 5Y8/4, dusky-yellow 5Y6/4, pale-olive 10Y6/2), poor sorting, angular to subrounded, low to medium sphericity, some plant material including black N1 seeds up to 0.04 in. in diameter.
SIDEWALL CORE NO. 45		
--	254	Silt, clayey, grayish-olive 10Y4/2.
CUTTINGS		
262	302	Clay and silt, some sand, very fine to medium, grayish-olive 10Y4/2, some plant material including black N1 seeds to 0.04 in. in diameter.
302	306	Sand, very fine to very coarse, gravel, very fine to fine, and some silt, clayey, overall grayish-olive 10Y4/2 to olive-gray 5Y3/2; coarse sand and gravel, 70 percent dark grains (moderate-brown 5YR3/4, black N1 to medium-gray N4, gray-olive-green 5Y4/1), 30 percent light grains (white N9, pale-olive 10Y6/2, dusky-yellow-green 5GY5/2, green-gray 5GY6/1, moderate-brown 10YR5/4), angular to rounded, poor sorting, low to medium sphericity, some plant material including black N1 seeds(?).
SIDEWALL CORE NO. 44		
--	306	Sand, very fine to fine, overall grayish-olive 10Y4/2 to olive-gray 5Y3/2.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
306	335	Sand, very fine to very coarse, gravel, very fine to fine, and some silt, clayey, overall grayish-olive 10Y4/2 to olive-gray 5Y3/2.
335	347	Clay, silt, sand, very fine to fine, and gravel, very fine, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 43		
--	347	Silt, clayey with sand, very fine to fine, grayish-olive 10Y4/2.
CUTTINGS		
347	372	Clay, silt, sand, very fine to fine, and gravel, very fine, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 42		
--	372	Sand, very fine to fine, overall olive-gray 5Y3/2 to olive-black 5Y2/1.
CUTTINGS		
372	401	Clay, silt, sand, very fine to fine, and some gravel, very fine, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 41		
--	401	Silt, clayey, dark-greenish-gray 5GY4/1 to grayish-olive 10Y4/2.
CUTTINGS		
401	412	Clay, silt, sand, very fine to fine, and some gravel, very fine, grayish-olive 10Y4/2, some plant material.
412	432	Sand, coarse, and gravel, fine, 70 percent dark grains (moderate-brown 5YR4/4, dark-yellowish-brown 10YR4/2 and medium-dark-gray N4 to grayish-black N2), 30 percent light grains (white N9 to light-olive-gray 5Y6/1, pale-green 10G6/2 and medium-gray N5), subangular to subrounded, medium sphericity, some plant material.
432	472	Clay, silt, and sand, very fine, grayish-olive 10Y4/2.
SIDEWALL CORE NO. 40		
--	472	Silt, clayey, grayish-olive 10Y4/2 to dark-greenish-gray 5GY4/1.

Depth (feet) From	To	Description
CUTTINGS		
472	490	Clay, silt, and sand, very fine, grayish-olive 10Y4/2.
490	493	Sand, fine to very coarse, and gravel, some silt, overall grayish-olive 10Y4/2 to olive-gray 5Y4/1. Sand, coarse to very coarse and gravel, 70 percent dark grains (dark-greenish-gray 5G4/1 and moderate-brown 5YR3/4 to black N1) and 30 percent light grains (white N9, yellowish-gray 5Y8/1 and light-gray N7 to light-olive-brown 5Y5/6, subangular to subrounded, poor sorting, medium sphericity, some plant material.
SIDEWALL CORE NO. 39		
--	493	Sand, very fine to fine, silty, olive-gray 5Y4/1 to light-olive-brown 5Y5/6.
CUTTINGS		
493	510	Clay, silt, and sand, very fine, grayish-olive 10Y4/2.
510	556	Clay, silt, and sand, very fine, grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4, bedded, some plant material.
SIDEWALL CORE NO. 38		
--	556	Silt, clayey, overall light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4.
CUTTINGS		
556	558	Clay, silt, and sand, very fine, grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4, bedded, some plant material.
558	569	Sand, very fine to very coarse, and gravel, silty, overall moderate-olive-gray 5Y4/4 to grayish-olive 10Y4/2; coarse sand and gravel, 65 percent dark grains (black N1 to medium-dark-gray N4, dark-greenish-gray 5GY4/1, olive-gray 5Y3/1, gray-olive 10Y4/2 and blackish-red 5R2/2), and 35 percent light grains (white N9 to light-gray N7, yellowish-gray 5Y8/1, yellowish-gray 5Y7/2 and moderate-yellowish-brown 10YR5/4), angular to subrounded, low to medium sphericity, some plant material.
SIDEWALL CORE NO. 37		
--	569	Sand, fine to medium, some coarse to very coarse, overall olive-gray 5Y3/2, subangular to subrounded. Rock fragments, mostly dark-gray N3, aphanitic, quartz throughout, some feldspar(?).
CUTTINGS		
569	584	Sand, very fine to coarse, and gravel, silty, moderate-olive-gray 5Y4/4 to grayish-olive 10Y4/2, some plant material.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
SIDEWALL CORE NO. 36		
--	584	Sand, fine to coarse, overall olive-gray 5Y3/2 to light-olive-gray 5Y5/2.
CUTTINGS		
584	596	Sand, very fine to very coarse, and gravel, silty, moderate-olive-gray 5Y4/4 to grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 35		
--	596	Sand, fine to medium, some coarse, overall color between olive-gray 5Y4/1 and dark-greenish-gray 5GY4/1. Rock fragments mostly dark-gray N3, aphanitic, quartz throughout.
CUTTINGS		
596	605	Sand, very fine to very coarse, and gravel, silty, moderate-olive-gray 5Y4/4 to grayish-olive 10Y4/2, some plant material.
605	624	Clay and silt, grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4 to dusky-yellow-green 5GY5/2.
SIDEWALL CORE NO. 34		
--	624	Silt and clay, dusky-yellow-green 5GY5/2.
CUTTINGS		
624	628	Clay and silt, grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4 to dusky-yellow-green 5GY5/2.
628	644	Sand, fine to very coarse, and gravel, very fine to fine, overall olive-gray 5Y3/2, subangular to rounded, low sphericity. Grains similar to zone 558-569.
SIDEWALL CORE NO. 33		
--	644	Sand, very fine to very coarse, very fine to medium, overall olive-gray 5Y3/2, coarse to very coarse, mostly dark-gray N3.
CUTTINGS		
644	645	Sand, fine to very coarse, and gravel, very fine to fine, olive-gray 5Y3/2, similar to zone 558-605.
645	660	Clay, silt, and sand, very fine, bedded. Clay, yellowish-gray 5Y7/2 to dark-greenish-gray 5GY4/1; silt and fine sand, pale-olive 10Y6/2 to grayish-olive 10Y4/2. Some plant material with black seeds(?).
SIDEWALL CORE NO. 32		
--	660	Clay, yellowish-gray 5Y7/2 to grayish-olive 10Y4/2, and streaks of pale-greenish-yellow 10Y8/2, effervescent in dilute hydrochloric acid.

Depth (feet) From	To	Description
CUTTINGS		
660	683	Clay, silt, and sand, very fine, bedded. Clay, yellowish-gray 5Y7/2 to dark-greenish-gray 5GY4/1; silt and fine sand, pale-olive 10Y6/2 to grayish-olive 10Y4/2, some plant material with black seeds(?).
CORE NO. 1		680-683 ft. Recovered 2.1 ft.
680.0	680.75	Gravel and sand, silty, clayey. Gravel, fine to coarse, grayish-olive 10Y4/2 to greenish-black 5G2/1, some grayish-black grains N2, and light grains, white N9 to light-gray N7, subangular to rounded, medium sphericity. Silt, clayey, and sand, fine, overall grayish-olive 10Y4/2 to olive-gray 5Y3/2. Contact abrupt, horizontal. NOTE: Gravel and sand probably caved from above; none indicated on induction log.
680.75	680.9	Clay, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2. Oxidized(?) zones on outside and in cracks, clay becomes moderate-brown 5YR4/4, consolidated. Contact abrupt, horizontal.
680.9	681.6	Clay, slightly silty and sandy, consolidated at top, overall dusky-yellow-green 5GY5/2 to grayish-olive 10Y4/2; sand, very fine to medium. Contact abrupt, domed.
681.6	682.0	Clay and silt, overall grayish-olive 10Y4/2. Contact fairly abrupt, domed.
682.0	682.1	Clay and silt, overall light-olive-gray 5Y5/2 to grayish-olive 10Y4/2.
CUTTINGS		
683	693	Clay, silt, and sand, very fine, bedded. Clay, yellowish-gray 5Y7/2 to dark-greenish-gray 5G4/1; silt and fine sand, pale-olive 10Y6/2 to grayish-olive 10Y4/2, some plant material.
693	705	Sand, coarse, to gravel, fine, overall olive-gray 5Y3/2 to dusky-yellowish-green 10GY3/2, 75 percent dark grains (dark-greenish-gray 5G4/1, dark-yellowish-brown 10YR4/2, dark-gray N3 to grayish-black N2, some very dusky-red 10R2/2), 25 percent light grains (light-gray N6, white N9, and yellowish-gray 5Y7/2); subangular to subrounded, medium sphericity; minor amount of clay, silty, moderate-olive-brown 5Y4/4 and some sand, fine to medium.
705	714	Clay, silt, and some sand, very fine to fine, and ash(?). Silt, clay, and ash(?), light-olive-gray 5Y5/2; clay, greenish-gray 5G6/1.
SIDEWALL CORE NO. 31		
--	714	Sand, very fine to fine, light-olive-gray to olive-gray 5Y3/2.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
714	728	Clay, silt, and some sand, very fine to fine, and ash(?). Silt, clay, and ash(?) light-olive-gray 5Y5/2; clay, greenish-gray 5G6/1.
728	730	Sand, coarse, to gravel, fine, 70 percent dark grains (grayish-green 10G4/2, dark-yellowish-brown 10Y4/2, dark-gray N3 to black N1), 30 percent light grains (white N9, yellowish-gray 5Y7/2 to moderate-yellowish-brown 10YR5/4), subangular to subrounded, medium sphericity.
CORE NO. 2		730-735 ft. Recovered 0.4 ft.
730.0	730.4	Clay, silty, sandy, gravel, very fine to coarse, mostly dark grains (moderate-olive-brown 5Y4/4 to greenish-black 5G2/1, and some black N1), some light grains (white N9 to yellowish-gray 5Y8/1), subangular to rounded, low sphericity. NOTE: Most of sample may be from above.
CUTTINGS		
730	732	Sand, coarse, to gravel, fine, as in 728-730 ft.
732	744	Clay, sand, very fine and some silt, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 30		
--	744	Clay, silty and sandy, light-olive-gray 5Y5/2.
CUTTINGS		
744	758	Clay, sand, very fine, some gravel and silt, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 29		
--	758	Clay, silty, some sand, very fine to fine with a few very coarse grains, overall dusky-yellow-green 5GY5/2.
CUTTINGS		
758	772	Clay, sand, very fine, and some silt, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
CORE NO. 3		772-775 ft. Recovered 2.0 ft.
772.0	774.0	Clay, silty, and sandy, and gravel. Clay overall grayish-olive 10Y4/2; sand, very fine to medium, a few coarse grains; gravel, very fine to medium, subangular to subrounded, medium sphericity. NOTE: Gravel and coarse sand probably caved from above; none indicated on induction log.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
775	782	Clay, sand, very fine, and some silt, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
782	784	Clay, locally silty, grayish-olive 10Y4/2 to olive-gray 5Y3/2 or greenish-black 5GY2/1; minor amount of very fine sand, some plant material.
SIDEWALL CORE NO. 28		
--	784	Silt, clayey, and sand, very fine, grayish-olive 10Y4/2 to olive-gray 5Y3/2.
CUTTINGS		
784	797	Clay, silty, some sand, very fine, grayish-olive 10Y4/2 to olive-gray 5Y3/2 or greenish-black 5GY2/1.
SIDEWALL CORE NO. 27		
--	797	Clay, greenish-olive 10Y4/2.
CUTTINGS		
797	817	Clay, silty, some sand, very fine, grayish-olive 10Y4/2 to olive-gray 5Y3/2, some plant material.
817	820	Silt, clayey, some sand, very fine to fine, grayish-olive 10Y4/2, some plant material.
CORE NO. 4		820-823 ft. Recovered 1.7 ft.
820.0	820.35	Gravel, very fine to medium, and sand, medium to very coarse, with silt and clay, overall grayish-olive 10Y4/2; coarse sand and gravel, mostly dark grains (moderate-olive-brown 5Y4/4, greenish-black 5G2/1, some black N1), some light grains (white N9, yellowish-gray 5Y8/1), subangular to rounded, low to medium sphericity. Contact abrupt, horizontal. NOTE: Gravel and coarse to very coarse sand probably caved from above.
820.35	820.9	Clay, silty, sandy, grayish-olive 10Y4/2, with many small linear cavities (left by decayed vascular plants ?) with light-olive-brown 5Y5/6 to dark-yellowish-brown 10YR4/2 color around edges; sand, very fine to medium; consolidated. Contact abrupt, horizontal.
820.9	821.1	Clay, silty, sand, very fine to coarse, grayish-olive 10Y4/2, hard; outer 0.5 inch of core soft, grayish-olive 10Y4/2 to pale-olive 10Y6/2. Contact gradual, horizontal.
821.1	821.7	Clay, silty, sandy, grayish-olive 10Y4/2; sand, very fine to medium.

Depth (feet) From	To	Description
CUTTINGS		
823	836	Silt, clayey, some sand, very fine to fine, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 26		
--	836	Silt, clayey, grayish-blue 10Y4/2.
CUTTINGS		
836	847	Silt, clayey, some sand, very fine to fine, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 25		
	847	Clay, pale-olive 10Y6/2 to light-olive-gray 5Y5/2.
CUTTINGS		
847	852	Silt, clayey, some sand, very fine to fine, grayish-olive 10Y4/2, some plant material.
852	858	Silt, clayey, grayish-olive 10Y4/2 to olive-gray 5Y3/2.
858	875	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2 or olive-gray 5Y3/2.
CORE NO. 5		875-878 ft. Partial recovery.
--	875	Silt, clayey, sandy, very fine, some coarse, grayish-olive 10Y4/2 to dark-bluish-gray 5B4/1, consolidated.
CUTTINGS		
878	884	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2 or olive-gray 5Y3/2.
SIDEWALL CORE NO. 24		
--	884	Clay, grayish-olive 10Y4/2 to dark-greenish-gray 5GY4/1.
CUTTINGS		
884	914	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2 or olive-gray 5Y3/2.
SIDEWALL CORE NO. 23		
--	914	Clay, sandy, overall grayish-olive 10Y4/2 to dark-greenish-gray 5GY4/1; sand, very fine to fine, a few coarse grains, mostly dark, angular to subangular, medium sphericity.
CUTTINGS		
914	924	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2 or olive-gray 5Y3/2.
SIDEWALL CORE NO. 22		
--	924	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
924	950	Clay, silty, grayish-olive 10Y4/2 to light-olive-gray 5Y5/2 or olive-gray 5Y3/2.
950	951	Silt and clay, sandy, some gravel, overall grayish-olive 10Y4/2 to light-olive-brown 5Y5/6 or moderate-olive-brown 5Y4/4; sand, mostly very fine to fine, a few very coarse grains; gravel very fine to fine, 70 percent dark, 30 percent light, subangular to subrounded, medium sphericity.
CORE NO. 6		951-954 ft. Recovered 1.0 ft.
951.0	951.45	Clay, silty, with sand, very fine to very coarse, and gravel, very fine. Clay, silt, and fine sand, overall grayish-olive 10Y4/2; coarse sand and gravel, 70 percent dark grains (olive-gray 5Y3/2, olive-black 5Y2/1, and blackish-red 5R2/2), 30 percent light grains (very light-gray N8, pale-olive 10Y6/2 and pale-blue 5B6/2), subangular to subrounded, medium sphericity. NOTE: Sand, coarse, and gravel probably from above, none indicated on induction log.
951.45	951.75	Clay, silty and sandy, and one pebble, overall grayish-olive 10Y4/2 with some light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4 or moderate-brown 5YR3/4; sand, very fine to fine. One pebble, very coarse (0.2 in.), olive-gray 5Y3/2 interior and brownish exterior, subangular to subrounded. Contact fairly abrupt, horizontal.
951.75	951.85	Clay, grayish-olive 10Y4/2, light-olive-gray 5Y5/2, bedded. Beds 0.10 in. thick. Contact fairly abrupt, horizontal.
951.85	952.0	Similar to 951.0-951.45.
CUTTINGS		
954	957	Silt and clay, sandy, some gravel, overall grayish-olive 10Y4/2 to light-olive-brown 5Y5/6 or moderate-olive-brown 5Y4/4.
SIDEWALL CORE NO. 21		
--	957	Sand, very fine to fine, olive-gray 5Y3/2 to grayish-olive-green 5GY3/2.
CUTTINGS		
957	968	Silt and clay, sandy, some gravel, overall grayish-olive 10Y4/2 to light-olive-brown 5Y5/6 or moderate-olive-brown 5Y4/4.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
968	983	Sand, fine to very coarse, and some gravel, fine, overall grayish-olive-green 5GY3/2. Coarser grains 70 percent dark grains, 30 percent light grains, subangular to subrounded, medium sphericity.
983	984	Clay, silty, grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 20		
--	984	Clay, silty, grayish-olive 10Y4/2 to olive-gray 5Y3/2.
CUTTINGS		
984	992	Clay, silty, grayish-olive 10Y4/2, some plant material.
992	997	Sand, very fine to very coarse, silty, overall grayish-olive 10Y4/2 to olive-gray 5Y3/2; coarser sand 75 percent dark grains, 25 percent light grains, angular to subangular, low to medium sphericity, some plant material.
997	1,000	Clay and silt, grayish-olive 10Y4/2 to olive-gray 5Y3/2, some plant material.
SIDEWALL CORE NO. 19		
--	1,000	Clay, grayish-olive-green 5GY3/2 to grayish-olive 10Y4/2.
CUTTINGS		
1,000	1,022	Clay and silt, grayish-olive 10Y4/2 to olive-gray 5Y3/2, some plant material.
CORE NO. 7		1,022-1,025 ft. Recovered 1.7 ft.
1,022.0	1,022.6	Clay, sandy, and some gravel, overall grayish-olive 10Y4/2 to light-olive-gray 5Y5/2. Sand, mostly very fine to fine, occasional medium to coarse grains and gravel, very fine to fine, 90 percent dark grains, 10 percent light grains, angular to subangular, medium sphericity.
1,022.6	1,022.8	Clay, with some sand, very fine to fine, and gravel, overall light-olive-gray 5Y5/2. Gravel, very fine to medium, 70 percent dark grains, 30 percent light grains, angular to rounded, medium sphericity.
1,022.8	1,022.9	Gravel and clay with some very fine sand, overall light-olive-gray 5Y5/2 to olive-gray 5Y4/1. Gravel, very fine to coarse, 90 percent dark grains, 10 percent light grains, subangular to rounded, medium sphericity. Contact abrupt, horizontal.
1,022.9	1,023.4	Clay, silty, sandy, some gravel, light-olive-gray 5Y5/2 to olive-gray 5Y4/1.
1,023.4	1,023.7	Clay, silty, overall medium-brown 5YR4/1 to light-olive-gray 5Y5/2, with some organic material.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
1,025	1,043	Clay and silt, grayish-olive 10Y4/2 to olive-gray 5Y3/2, some plant material.
SIDEWALL CORE NO. 18		
--	1,043	Sand, very fine to fine, silty, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2.
CUTTINGS		
1,043	1,052	Clay and silt, grayish-olive 10Y4/2 to olive-gray 5Y3/2, some plant material.
1,052	1,066	Sand, fine to very coarse, overall grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4.
SIDEWALL CORE NO. 17		
	1,066	Sand, medium to very coarse, overall olive-gray 5Y3/2. 60 percent dark grains, 40 percent light grains, subrounded to rounded, fair to good sorting, high sphericity.
CUTTINGS		
1,066	1,072	Sand, very fine to fine, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2.
1,072	1,087	Clay, silt and sand, very fine, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
CORE NO. 8		1,087-1,090 ft. Recovered 2.0 ft.
1,087.0	1,087.17	Sand, coarse to very coarse, and gravel, overall light-olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4. NOTE: Probably caved from above; none indicated on induction log.
1,087.17	1,087.23	Clay with gravel, very fine to fine, overall color grayish-olive 10Y4/2 to moderate-olive-brown 5Y4/4. Gravel, 60 percent dark grains, 40 percent light grains, subrounded to rounded, medium sphericity. Contact fairly abrupt, horizontal.
1,087.23	1,087.4	Clay with some sand, very fine to very coarse, and gravel, overall light-olive-gray 5Y5/2; coarse sand and gravel, very fine to medium, 70 percent dark grains, 30 percent light grains, subangular to subrounded, medium sphericity. Contact abrupt, horizontal.
1,087.4	1,087.52	Clay with some gravel, overall color grayish-olive 10Y4/2; gravel, very fine to medium, 90 percent dark grains, 10 percent light grains, subangular to subrounded, medium sphericity. Contact abrupt, horizontal.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
1,087.52	1,088.55	Clay, some sand, very fine to fine, and gravel, overall light-olive-gray 5Y5/2; gravel, very fine to fine, 70 percent dark grains, 30 percent light grains, subrounded, high sphericity.
		Contact abrupt, horizontal.
1,088.55	1,088.8	Clay, some gravel, overall moderate-olive-brown 5Y4/4. Gravel, very fine to coarse, 60 percent dark grains, 40 percent light grains, subangular to subrounded, medium sphericity.
		Contact abrupt, horizontal.
1,088.8	1,089.0	Clay, sandy, fine, and silty, overall grayish-olive 10Y4/2; somewhat consolidated.
CUTTINGS		
1,090	1,098	Clay, silt, and sand, very fine, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 16		
--	1,098	Clay, silty, and sandy, very fine, dusky-yellow-green 5GY5/2 to grayish-olive-green 5GY3/2.
CUTTINGS		
1,098	1,125	Clay, silt, and sand, very fine, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
SIDEWALL CORE NO. 15		
--	1,125	Clay, dusky-yellow-green 5GY5/2, with small streaks of pale-red 5R6/2 and light-bluish-gray 5B7/1.
CUTTINGS		
1,125	1,135	Clay, silt, and sand, very fine, light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some plant material.
1,135	1,146	Sand, fine to coarse, and gravel, some clay, overall light-olive-gray 5Y5/2 to grayish-olive 10Y4/2; gravel, very fine to coarse, subrounded, medium sphericity.
CORE NO. 9		1,146-1,149 ft. Recovered 1.9 ft.
1,146	1,146.2	Clay with some gravel and minor amount of sand, very fine to fine, overall light-olive-gray 5Y5/2; gravel, very fine to fine, 40 percent dark grains, 60 percent light grains, subangular, medium sphericity.
		Contact abrupt, horizontal.
1,146.2	1,146.45	Gravel, very fine to coarse, some clay, overall light-olive-gray 5Y5/2, 40 percent dark grains, 60 percent light grains, subrounded, medium sphericity.
		Contact fairly abrupt.

Depth (feet) From	To	Description
1,146.45	1,146.75	Gravel, very fine to coarse, some clay, overall light-olive-gray 5Y5/2 to olive-gray 5Y3/2, 70 percent dark grains, 30 percent light grains, subrounded, medium sphericity.
1,146.75	1,147.3	Gravel and clay, overall greenish-gray 5G6/1. Gravel, very fine to medium with occasional coarse grain, 60 percent dark grains, 30 percent light grains, subrounded, high sphericity. Contact diffuse.
1,147.3	1,147.5	Gravel, clay, silt and sand, very fine, overall 5Y5/2. Gravel, very fine to coarse, 80 percent dark grains, 20 percent light grains, angular, medium sphericity. Contact diffuse.
1,147.5	1,147.9	Gravel, clay, silt, and sand, very fine, overall grayish-olive 10Y4/2 to olive-gray 5Y4/1; gravel 100 percent dark (black N1 to dark-gray N4, and moderate-brown 5YR4/4), rounded, medium sphericity.
CUTTINGS		
1,149	1,170	Clay, silty, light-olive-gray 5Y5/2 to moderate olive-brown 5Y4/4, some plant material.
SIDEWALL CORE NO. 14		
--	1,170	Clay, silty and sandy, light-olive-gray 5Y5/2.
CUTTINGS		
1,170	1,178	Clay, silty, light-olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4, some plant material.
1,178	1,182	Sand, very fine to coarse, some clay and silt, overall light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some organic material.
SIDEWALL CORE NO. 13		
--	1,182	Sand, medium, some silt, overall light-olive-brown 5Y5/6 to moderate-olive-brown 5Y4/4, subangular to subrounded.
CUTTINGS		
1,182	1,185	Sand, very fine to coarse, some clay and silt, overall light-olive-gray 5Y5/2 to grayish-olive 10Y4/2, some organic material.
1,185	1,193	Clay, silt and sand, very fine, overall olive-gray 5Y4/1 to grayish-olive-green 5GY3/2, some plant material.
SIDEWALL CORE NO. 12		
--	1,193	Silt, dusky-yellow-green 5GY5/2.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
1,193	1,202	Clay, silt, some sand, very fine, overall olive-gray 5Y4/1 to grayish-olive-green 5GY3/2, some plant material.
1,202	1,258	Sand, very fine to coarse, some silt, overall olive-gray 5Y3/2 or light-olive-gray 5Y5/2 to grayish-olive 10Y4/2; coarse sand, 60 percent dark grains, 40 percent light grains, subangular, medium to high sphericity, some plant material.
SIDEWALL CORE NO. 11		
--	1,258	Sand, very fine to fine, overall dusky-yellowish-brown 10YR2/2.
CUTTINGS		
1,258	1,262	Clay, silt, and sand, very fine to fine, overall dark-yellowish-brown 10YR4/2 to grayish-brown 5YR3/2, some organic material.
SIDEWALL CORE NO. 10		
--	1,262	Silt, brownish-black 5YR2/1 to olive-black 5Y2/1.
CUTTINGS		
1,262	1,272	Clay, silt, some sand, very fine to fine, dark-yellowish-brown 10YR4/2 to grayish-brown 5Y3/2, some organic material.
1,272	1,283	Sand, very fine to medium, and silt, olive-gray 5Y4/1 to light-olive-gray 5Y5/2, some plant material.
SIDEWALL CORE NO. 9		
--	1,283	Sand, very fine, silt, brownish-black 5YR2/1 to dusky-yellowish-brown 10YR2/2.
CUTTINGS		
1,283	1,300	Sand, very fine to medium, and silt, olive-gray 5Y4/1 to light-olive-gray 5Y5/2, some plant material.
1,300	1,307	Clay and silt, olive-gray 5Y4/1 to brownish-gray 5YR4/1.
SIDEWALL CORE NO. 8		
--	1,307	Clay and silt, brownish-gray 5YR4/1 to olive-gray 5Y4/1 or dark-yellowish-brown 10YR4/2.
CUTTINGS		
1,307	1,312	Clay and silt, olive-gray 5Y4/1 to brownish-gray 5YR4/1.
1,312	1,329	Sand, very fine to fine, dark-yellowish-brown 10YR4/2 to olive-gray 5Y4/1.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
SIDEWALL CORE NO. 7		
--	1,329	Sand, very fine to fine, olive-gray 5Y4/1 to olive-black 5Y2/1.
CUTTINGS		
1,329	1,342	Sand, very fine to fine, dark-yellowish-brown 10YR4/2 to olive-gray 5Y4/1.
1,342	1,343	Clay and silt, light-olive-gray 5Y5/2 to olive-black 5Y2/1, some plant material.
SIDEWALL CORE NO. 6		
--	1,343	Silt, light-olive-gray 5Y5/2 to dark-yellowish-brown 10YR4/2.
CUTTINGS		
1,343	1,355	Silt, clay, some sand, very fine, olive-gray 5Y4/1 to dark-yellowish-brown 10YR4/2.
SIDEWALL CORE NO. 5		
--	1,355	Sand, very fine to fine, olive-gray 5Y4/1 to olive-black 5Y2/1.
CUTTINGS		
1,355	1,362	Clay and silt, olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4.
SIDEWALL CORE NO. 4		
--	1,362	Silt, olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4.
CUTTINGS		
1,362	1,372	Silt and clay, some sand, very fine to fine, light-olive-gray 5Y5/2 to moderate-olive-brown 5Y4/4.
1,372	1,374	Clay and silt, moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2.
SIDEWALL CORE NO. 3		
--	1,374	Silt, light-olive-gray 5Y5/2.
CUTTINGS		
1,374	1,382	Clay and silt, some sand, very fine to fine, light-olive-brown 5Y4/4 to olive-gray 5Y3/2.
1,382	1,394	Clay and silt, light-olive-brown 5Y4/4 to olive-gray 5Y3/2.
SIDEWALL CORE NO. 2		
--	1,394	Silt and clay, moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2.

TABLE 1. - Log of test hole near Butte City, 19N/1W-32G--Continued

Depth (feet) From	To	Description
CUTTINGS		
1,394	1,413	Clay, some silt, light-olive-brown 5Y4/4 to olive-gray 5Y3/2.
1,413	1,418	Clay and silt, moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2.
SIDEWALL CORE NO. 1		
--	1,418	Silt, moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2.
CUTTINGS		
1,418	1,432	Clay and silt, moderate-olive-brown 5Y4/4 to olive-gray 5Y3/2.
TOTAL DEPTH 1,432 ft.		

TABLE 2. - Grain-size classification

[From National Research Council, 1947]

Name	Grade limits (diameter in inches)	
Very coarse gravel	2.5-	1.3
Coarse gravel	1.3-	.6
Medium gravel	.6-	.3
Fine gravel	.3-	.16
Very fine gravel	.16-	.08
Very coarse sand	.08-	.04
Coarse sand	.04-	.02
Medium sand	.02-	.01
Fine sand	.01-	.005
Very fine sand	.005-	.0025
Silt	.0025-	.0002
Clay	<.0002-	

GEOPHYSICAL LOGS

Geophysical logs (pl. 1) made in the test hole by Schlumberger Well Services include dual induction-spherically focused electric, compensated neutron, formation density, caliper, gamma, porosity index (percentage sandstone matrix), bulk density, spontaneous potential, resistivity, and conductivity.

Induction-electric logging devices induce a current into the rock at the borehole and record the resistivity (reciprocal of conductivity). Because the contrast between borehole mud and formation water in a freshwater system is commonly large, this device is focused to minimize the influence of the borehole mud and the lithology above and below the focused interval.

The dual-induction log (pl. 1, log A) of the test hole included a deep induction log, in ohms per square meter per meter; a spherically focused log, in ohms per square meter per meter; a conductivity log, in millimhos per meter; and a spontaneous potential log, in millivolts.

Neutron logging devices continuously emit neutrons into the rock around the borehole. The neutrons collide with the nuclei of the formation material, losing some of their energy with each collision. The greatest energy loss occurs when the neutron strikes a hydrogen nucleus; thus neutron logging is primarily a function of the hydrogen content of the rocks and their fluid. The compensated neutron log minimizes the influence of the borehole.

The compensated neutron-formation density log (pl. 1, log B) of the test hole included a caliper log, in inches; a gamma log, in API units[1]; compensated neutron porosity, in percent; and bulk density, in grams per cubic centimeter.

The formation density log is obtained by emitting medium-energy gamma rays into the formation. These rays act as high-velocity particles which collide with electrons in the formation. The rays lose some energy with each collision. The scattered gamma rays reach the detector and are counted as an indication of formation density. The greater the density of the formation the fewer counts in the detector, so that what is actually measured is the number of electrons per cubic centimeter.

MINERAL ANALYSES

Mineral analyses were made on seven samples by N. C. Janke, consulting geologist of Sacramento, Calif. (table 3). Identification of minerals was done using methods and classification from Deer, Howie, and Zussman (1966) and Winchell (1951). Janke found 36 minerals or mineral series (table 4), and also submitted a table of gravel-particle lithologies (table 5).

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[1]API units are standard units for nuclear logs established by the American Petroleum Institute (1959) based on the use of a permanent calibration facility.

EXPLANATION OF TABLE 3

Sample depth: Depth or depth interval of sample, in feet below land surface. "Core" indicates that the sample was taken from a device that cores as the hole is being drilled; "sidewall" indicates that the sample was taken from a device that cores the side of the borehole.

Sample texture and intervals analyzed: Sample texture is indicated by the percentages of weights retained on five sieve sizes c/m/f/vf/p: coarse (+35) mesh, medium (-35, +60) mesh, fine (-60, +120) mesh, very fine (-120, +230) mesh, pan (-230) mesh. The coarse, c (+35) mesh material is overstated in most instances as it is, at least in part, composed of cuttings, not loose grains; the pan material, p (-230) mesh, is composed, in large part, of drilling mud.

The size intervals chosen for analysis--medium sand, m (-35, +60) mesh, and fine sand, f(-60, +120) mesh--are common to most rocks and sediments, and contain mineral sizes most easily identified under the microscope, thus minimizing error. Heavy-mineral suites characteristic of sediment types also tend to fall within these ranges.

Particle types as percent of interval analyzed: The first listing of particle types is based on whole-field counts ($150 \leqq N$) of the monomineralic grains and composite particles, polycrystalline grains or rock fragments (L), or both, found in the light fraction--specific gravity (s.g.) $\leqq 2.9$. An approximation to equal-sized grains was made by weighting the counts.

K-Feldspar: Potassium or potash feldspar.
P: Plagioclase with anorthite less than 34 percent (An < 34 pct.) and with anorthite greater than 34 percent (An > 34 pct.).
Quartz - Monocrystalline and polycrystalline: Quartz, chalcedony, and chert.
Lithic fragments: Rock fragments not identified as to rock type; many include interstitial plagioclase.
Light opaques: Usually composed of a mass, often semiporous, of hematite and goethite. They are alteration products of hornblende and pyroxene monocrystals or polycrystals.
Volcanic glass: Glass identified as being of volcanic origin.
Calcite: A common mineral, but found only in traces in sampled intervals.

Mean ratio Q:F:L: Ratio of quartz (Q) to total feldspar (F) - potash and plagioclase, to lithic fragments (L).

Percentage of heavy minerals, specific gravity > 2.9: Percentage of heavy minerals in sample. Opaques, as a percentage of the heavy minerals--magnetic and non-magnetic: Opaque, heavy minerals classified as magnetic or non-magnetic; they are indicated as a percentage of the heavy-mineral fraction only.

Detail of other non-opaque heavy minerals: Non-opaque heavy minerals as a percentage of the heavy-mineral fraction only. Includes orthopyroxene (opx) and clinopyroxene (cpx).

BH and GH are used to classify very fine-grained masses with mixed indices of refraction. BH includes the classes CIIB + CIII + sideromelane + possible small amounts of CIA or CIB, and CIIA; dark green, greenish-brown, brown, red-brown, orange-brown refractions. And GH includes CIA, CIB + CIIA + possible sideromelane or palagonite, or both; slightly brownish-green, green, yellowish-green, pale green, white, colorless, very-pale brown, as indicated in the table below.

<u>Heavy minerals (specific gravity > 2.9)</u>:

Common colors in oblique reflected light	Fine-grained designation[1] and approximate index of refraction, N	Usual constituents, others are possible
White, yellowish, pale-gray, brownish	CIA N, high	Leucoxene, other titanium minerals, clay, and often goethite (see CIII below).
Smooth, often waxy, white, colorless, green, pale-green, yellow, yellowish-green, often mottled	CIB $1.63 \leqq N$ to a maximum of 1.8	Sausserite containing variable amounts of albite, clinozoisite, epidote, zoisite, and occasionally pyrophyllite and paragonite.
Blue-green	CIIA $N < 1.68$ usual, may be to 1.76	Uralite (fibrous amphibole such as actinolite) talc, epidote, or zoisite, and possibly quartz.
Dark-green, brownish-green	CIIB $1.6 < N < 1.7+$	Amphiboles, calcite, chlorite, plagioclase, pumpellyite.
Colorless to brownish	Sideromelane $N \leqq 1.6$	Basic glass, often microlitic, sometimes partially altered to palagonite, commonly with calcite, chlorite, and zeolites.
Green, greenish-brown, brown to red-brown or orange brown	CIII $1.7 \leqq N$	Bowlingite (green to greenish-brown) and Iddingsite (brown and red mixtures). Minerals include variable amounts of: goethite, hematite, chlorites, and other phyllosilicates, and may include leucoxene.
Brick-red	Hematite $2.9 \leqq N$	Particles identified as hematite may only be coated, and this is even more likely for goethite. The indices of both of these
Yellowish-brown	Goethite $2.3 \leqq N$	minerals are very difficult to obtain in rapid counting of detrital aggregates; thus classification is based on color.

[1]Particles are not monomineralic or are mostly glass.

TABLE 3. - Mineral analyses

Sample depth (ft)	114 (sidewall)		306 (sidewall)		569 (sidewall)	
Sample texture c/m/f/vf/p	76/11/6/4/2		0/4/31/36/29		34/36/19/6/5	
Intervals analyzed	m	f	m	f	m	f
Particle types as percent of interval analyzed						
K - Feldspar	22	23	35	24	31	39
P: Plagioclase An < 34 pct. (± 4 pct.)	44	46	33	39	29	17
Plagioclase An > 34 pct. (± 4 pct.)	14	11	9	17	11	23
Quartz - monocrystalline and polycrystalline	4	10	12	6	10	5
Lithic fragments	14	6	8	8	11	5
Light opaques	-	-	-	-	-	-
Volcanic glass	1	1	1	2	3	5
Calcite	-	-	-	-	-	-
Others	-	1	1	1	2	1
Mean ratio Q:F:L	4:83:13	11:83:6	12:80:8	6:86:8	11:78:11	5:90:5
Pct. heavy minerals s.g. > 2.9	1	2	2	3	3	5
Opaques[1] (as a pct. of the heavy minerals)						
Magnetic	5	14	9	7	6	9
Non-magnetic	1	1	-	-	2	2

Detail of other non-opaque heavy minerals	114	306	569
Very abundant 24-50 pct.	[a]Opx [b]Epidote-clinozoisite	GH	BH
Abundant 10-24 pct.			[c]Opx GH [d]Cpx
Common 4-10 pct.	GH [c]Lithic fragments	BH Cordierite [a]Hornblende	Green hornblende
Sparse 1-4 pct.	[d]Cpx	Clinozoisite Zoisite Andalusite [b]Chlorite Aegirine-augite Glaucophane Diopside-hedenbergite Epidote	Actinolite-tremolite [e]Epidote Brown hornblende Hematite
Rare or doubtful < 1 pct.	Ilmenite-chromite [e]Hornblende Hematite Oxy-hornblende	Gedrite Hypersthene Pigeonite Margarite Oxy-hornblende Spinel	Oxy-hornblende Sphene
Comments or special characteristics	[a]Bronzite-hypersthene [b]Green epidote predominates over colorless clinozoisite [c]Almost entirely tuff, occasionally metamorphics and argillite [d]Augite,rarely diopside [e]Green and brown	[a]Almost all green [b]Some may be manganese chlorites [c]Hypersthene and a few enstatite [d]Auguite-ferroaugite, some aegirine-augite possible [e]Includes clinozoisite	

[1]The magnetic opaques are removed from the 'm' and 'f' fractions with a hand magnet of about 650 Gauss. This material is then counted for non-opaque contaminants, and corrected for these.

TABLE 3. - Mineral analyses--Continued

Sample depth (ft)	644 (sidewall)		758 (sidewall)		952 (core)	
Sample texture c/m/f/vf/p	17/9/21/35/17					
Intervals analyzed	m	f	m	f	m	f
Particle types as percent of interval analyzed						
K - Feldspar	27	32	25	20	8	4
P: Plagioclase An < 34 pct. (± 4 pct.)	28	12	22	30	60	47
Plagioclase An > 34 pct. (± 4 pct.)	13	31	14	23	9	28
Quartz - monocrystalline and polycrystalline	13	8	11	10	11	5
Lithic fragments	13	11	18	8	8	7
Light opaques	-	-	-	-	-	-
Volcanic glass	1	3	1	2	3	3
Calcite	-	-	trace	trace	trace	trace
Others	2	1	5	2	1	2
Mean ratio Q:F:L	13:74:13	8:81:11	11:71:18	10:82:8	11:81:8	5:88:7
Pct. heavy minerals s.g. > 2.9	3	2	4	6	1	4
Opaques[1] (as a pct. of the heavy minerals)						
Magnetic	9	12	15	20	11	16
Non-magnetic	7	7	7	7	22	22

Detail of other non-opaque heavy minerals		644 (sidewall)	758 (sidewall)	952 (core)
Very abundant	24-50 pct.	[a]Hypersthene-enstatite		[a]Opx
Abundant	10-24 pct.	Aegirine-augite BH	GH [d]Cpx [e]Opx BH	[b]Cpx Pyrite [c]Hornblende
Common	4-10 pct.	[b]Hornblende Hematite GH [c]Cpx	[f]Hornblende Anthophyllite-gedrite Tremolite	BH Hematite GH
Sparse	1- 4 pct.	Actinolite Sideromelane	Hematite Olivine Pyrite Ilmenite or chromite Leucoxene	[d]Other Amphiboles Chlorite
Rare or doubtful	< 1 pct.	Brookite		
Comments or special characteristics		[a]At least 1/3 are enstatite [b]Green hornblende predominate over brown [c]Augite-ferroaugite and diopside [d]Diopside-hedenbergite, augite, and a small amount of aegirine [e]Varieties between enstatite and ferrohypersthene [f]Green, brown, and some very altered.	One odd egg-shaped, very smooth "grain." Looks like an oolite, but is probably not.	[a]Hypersthene [b]Augite-ferroaugite predominate. Some aegirine augite and diopside-hedenbergite [c]Mostly green [d]Includes anthophyllite-gedrite, actinolite-tremolite varieties

[1]The magnetic opaques are removed from the 'm' and 'f' fractions with a hand magnet of about 650 Gauss. This material is then counted for non-opaque contaminants, and corrected for these.

TABLE 3. - Mineral analyses--Continued

Sample depth (ft)	1258 (sidewall)			
Sample texture c/m/f/vf/p	32/25/16/14/13			
Intervals analyzed	m	f		
Particle types as percent of interval analyzed				
K - Feldspar	12	5		
P: Plagioclase An < 34 pct. (± 4 pct.)	31	29		
Plagioclase An > 34 pct. (± 4 pct.)	18	33		
Quartz - monocrystalline and polycrystalline	6	8		
Lithic fragments	27	19		
Light opaques	-	-		
Volcanic glass	trace	trace		
Calcite	-	-		
Others	2	2		
Mean ratio Q:F:L	6:67:27	8:73:19		
Pct. heavy minerals s.g. > 2.9	4	5		
Opaques[1] (as a pct. of the heavy minerals)				
Magnetic	24	34		
Non-magnetic	-	-		
Detail of other non-opaque heavy minerals				
Very abundant 24-50 pct.	BH			
Abundant 10-24 pct.	[a]Cpx [b]Hornblende GH [c]Opx			
Common 4-10 pct.	Clinozoisite-epidote			
Sparse 1- 4 pct.	Actinolite-tremolite			
Rare or doubtful < 1 pct.	Hematite FO - Olivine Devitrified glass Allanite ?			
Comments or special characteristics	[a]Augite-ferroaugite predominates, but cannot always be differentiated from diopside-hedenbergite [b]Mostly green hornblende [c]Hypersthene, often euhedral, predominates			

[1]The magnetic opaques are removed from the 'm' and 'f' fractions with a hand magnet of about 650 Gauss. This material is then counted for non-opaque contaminants, and corrected for these.

TABLE 4. - Summary alphabetical list of minerals identified in samples

[The word "series" in parentheses after mineral name indicates that several varieties within the series were found]

Actinolite-tremolite (series)
Aegirine-augite and Aegirine-acmite
Allanite
Amphiboles (Clino-, undifferentiated)
Andalusite
Anthophyllite-gedrite (series)
Augite-ferroaugite (series)

Basic glass (not sideromelane)
Bronzite-ferrohypersthene (series)
Brookite

Chlorite (incl. oxy-chlorite and undifferentiated varieties)
Chromite
Clinozoisite
Cordierite

Diopside-hedenbergite (series)

Enstatite-bronzite (series)
Epidote

Gedrite
Glaucophane

Hematite (some specular)
Hornblende (green, brown and oxy-varieties)
Hypersthene

Ilmenite

Leucoxene

Margarite

Olivine

Pigeonite
Plagoclase (series)
Potash feldspar (undifferentiated)
Pumpellyite
Pyrite

Sideromelane
Sphene
Spinel

Tremolite

Zoisite

TABLE 5. - Gravel-particle lithologies from selected depths

Lithic type	Percent
Depth, 120 feet. Size range (mesh numbers, +10)	
Quartz-mica tectonite	5.0
Hornblende schist, some including metaquartzite	43.0
Granulite	4.0
Quartz-amphibolite	2.0
Quartz-mica-feldspar	6.0
Metagraywacke	9.0
Metaquartzite	9.0
Argillite	7.0
Tuff	[1]2.0
Vein quartz	13.0
No indeterminate particles	
Depth, 750 feet. Size range (mesh numbers, + 8)	
Quartz-mica tectonite	5.0
Schist	2.0
Slate and augen slate	4.5
Metasiltstone and metagraywacke	5.0
Quartz-mica-feldspar aggregate	5.0
Greenstone (metabasalt)	4.0
Black metabasalt	4.5
Metavolcanic (otherwise indeterminate)	4.0
Silty sandstone	1.0
Argillite shale	31.0
Chert	1.0
Silty sandstone (possibly a metasediment)	1.0
Welded tuff (otherwise indeterminate)	3.0
Welded rhyolite tuff	2.0
Basalt[2]	10.0
Pyroclastics	1.0
Volcanic-hypabyssal (mid-range composition)	1.5
Volcanic-hypabyssal (otherwise indeterminate)	2.0
Hypabyssal (*ca.* diabase)	1.0
Leucocrate-plutonic (granitic texture)	1.0
Hydrothermal quartz[3]	9.0
Indeterminate particles - a total of 1.5 percent	1.5

See footnotes at end of table.

TABLE 5. - Gravel-particle lithologies from selected depths--Continued

Lithic type	Percent
Depth, 951 feet. Size range (mesh numbers, +10)	
Quartz-mica-tectonite	8.5
Slate	3.7
Phyllite	5.4
Quartzite (metaquartzite)	7.6
Metasandstone (similar to jaspar and some are quartz veined)	13.1
Metagraywacke	4.2
Schist[4]	21.3
Granulite (includes quartz-mica-feldspar types with occasional foliation)	3.7
Gneiss (with augen structure)	10.0
Metavolcanic conglomerate	0.8
Metavolcanic (acid to intermediate)	15.2
Metavolcanic (otherwise indeterminate)	0.8
Sedimentary	1.2
Hypabyssal (acid to intermediate dike rock)	1.5
Hypabyssal (near gabbro composition)	1.5
Vein quartz	1.5
No indeterminate particles	

[1]Extremely friable, large sampling loss.
[2]Most are diagenetically altered and could be considered slightly metamorphosed.
[3]Often with remnants of metamorphic rocks.
[4]Schistose material is 1/3 or more of the particle, otherwise it is classified as hydrothermal (vein quartz in this case).

X-RAY DIFFRACTION

X-ray diffraction is the phenomenon of the apparent bending of X-rays passing near opaque objects. The diffraction depends on the crystal structure of the object. A single crystal produces a diffraction pattern of spots called a Laue pattern, and a powdered substance produces a pattern of rings called an X-ray powder pattern. From the X-ray diffraction pattern of a substance, the crystal structure and the unit cell dimension can be determined.

Eleven samples of fine-grained material were submitted to Technology of Materials, Santa Barbara, Calif. Of special interest was the identification and quantification of various clay minerals in the samples. Twenty-two X-ray diffraction charts and five electron micrographs of clay minerals were included in their report (written commun., 1980), part of which is paraphrased here.

> Both the diffraction charts and the separation studies indicate that a relationship exists between clay content and sample depth. The clay content runs between 20 percent for the upper samples to less than 10 percent for the lower levels. It is possible that alteration has occurred at the lower levels causing deterioration of the clay fraction and some of the feldspar as well, forming an amorphous allophane. This phase, of course, would not show up on the diffraction patterns except as it dilutes the other phases. This would also account for the low intensity of some of the deep level samples such as XRD Chart 7861.
>
> The fine fractions of an upper and deep level sample was studied by transmission electron microscopy (TEM). The so-called kaolinite phase was found to be mostly the clay type, halloysite. This phase gives an identical X-ray diffraction pattern to kaolinite; however, it can be differentiated morphologically by the TEM studies. TEM number 1 shows a cluster of short tubular structures which are definitely halloysite. Very few particles which appear as definitely kaolinite particles were found in either of the samples studied. A micrograph of a sample from the 1,193-foot level showed kaolinite plates to be present; however, they were not well formed. Halloysite was found to coexist with the kaolinite in the sample. Both samples show the poorly formed flakes of illite to be present, along with blocky particles which represent fines of alphaquartz and feldspar.
>
> A few minor peaks were present in some of the patterns which could not be matched to mineral phases, due to incompleteness of the patterns. The 14 Å peak in the 478-foot sample appears to be a chlorite mineral in the light fraction. No measurable amount of montmorillonite clays were found in any of the samples; however, some mixed layers (montmorillonite-chlorite) may be present as minor constituents (less than 5 percent).

The X-ray diffraction charts and micrographs are on file with the report in the Sacramento District office of the Survey. X-ray diffraction data are summarized in table 6.

TABLE 6. - Summary of X-ray diffraction data

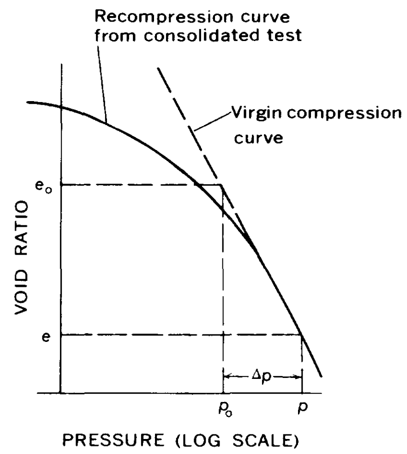
Sample depth (feet)	XRD[2] No.	α-Quartz (percent)	Feld-spar (percent)	Amor-phous	Kaolin-ite (percent)	Illite (percent)	Other crystalline phases
260	7851	35-45	25-35	--	15-20	5-10	Trace (unidentified)
353	7852	40	15-20	--	10-15	([1])	Trace (minor)
407	7853	35-40	20-25	--	10-15	2-5	Trace (minor)
478	7854	35-40	25-30	--	10-15	5-10	5-10 percent Chlorite
562	7855	10-20	15-25	Major	5-15	2-5	
630	7856	20-25	15-20	Intermediate	5-15	2-10	Trace (unidentified)
930	7857	15-20	10-15	Intermediate	10-15	5-10	
984	7858	5-15	5-10	Major	10-15	1-5	Trace (unidentified)
1,098	7859	5-10	5-10	Major	5-10	1-5	
1,193	7860	5-15	5-10	Major	5-10	1-5	Trace (minor)
1,390	7861	5-10	2-5	Major	2-5	2-5	

[1]Not determined
[2]XRD, x-ray diffraction data sample

CONSOLIDATION TESTS

Consolidation tests were made on nine samples by J. H. Kleinfelder and Associates, geotechnical consultants, Sacramento, Calif. Table 7 shows values for dry unit weight, moisture content, Atterberg limits, specific gravity, initial void ratio, porosity, coefficient of consolidation, estimated applied stress, vertical hydraulic conductivity, compression index, and recompression index. Definition of the elements in table 7, as well as a description of the laboratory methods, are found in Johnson, Moston, and Morris (1968, p. 10-18).

Consolidation of a soil is that gradual process which involves simultaneously a slow escape of water, a gradual compression, and a gradual pressure adjustment (Taylor, 1948, p. 212). As beds of sediment are deposited layer on layer through geologic time, each layer is compressed by the layers above it. The layers attain a state of consolidation in equilibrium with the superimposed load. The layer is then called normally consolidated. In a normally consolidated layer, density will increase with depth of overburden and the void ratio will decrease. The relation between specific gravity increase and void ratio decrease is approximately an extended straight line (virgin compression curve) on a semilogarithm graph (fig. 5). Figure 5 also shows the method for determining the compression index and the graphical explanation of the void ratio curves (Johnson and others, 1968).



The virgin compression curve or the field consolidation curve, for clayey soils, appears on a semilogarithmic diagram as a straight line as shown at left. This line can be represented by the equation

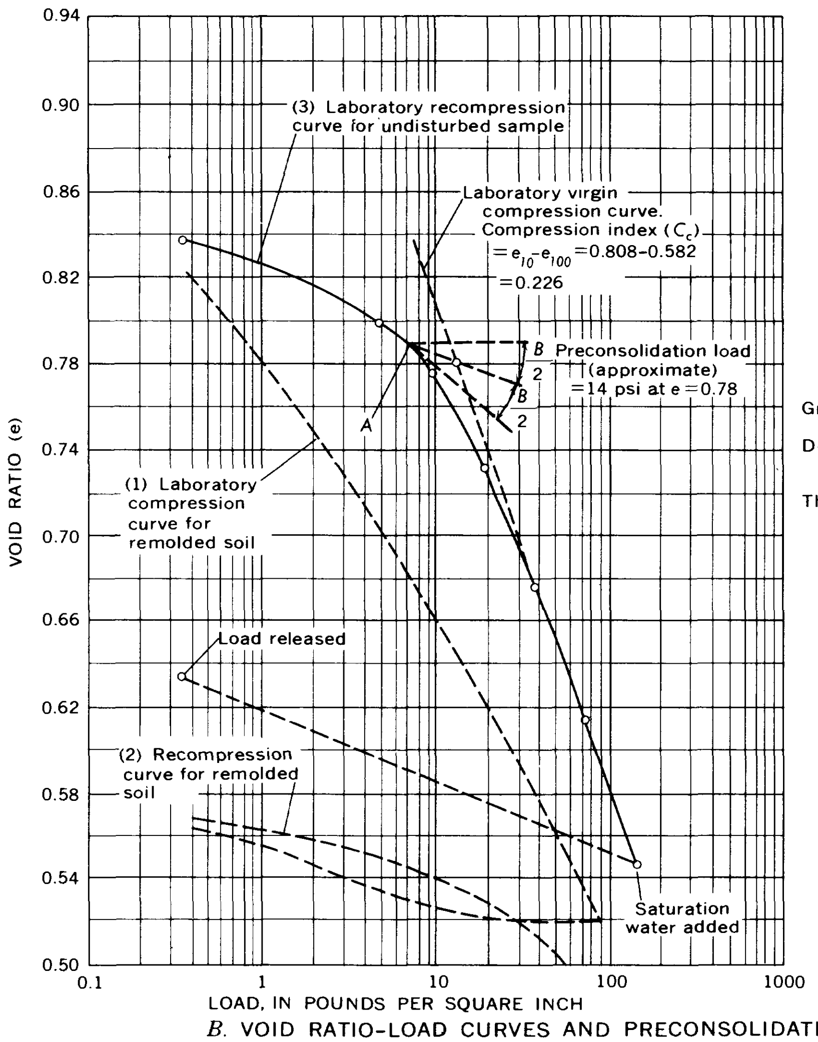
$$e = e_o - C_c \log_{10} \frac{P_o + \Delta p}{P_o}$$

in which C_c (dimensionless) is the compression index

The virgin compression curve is established by extending the straight-line part of the recompression curve. By selecting two points (e_o, p_o) and (e, p) and substituting in the above equation, C_c can be determined

$$C_c = \frac{e_o - e}{\log_{10} \frac{P_o + \Delta p}{P_o}}$$

A. METHOD OF DETERMINING THE COMPRESSION INDEX (C_c)



Graphical determination of preconsolidation load:

Draw tangent and horizontal line to point of maximum curvature (*A*)

The point of intersection between virgin compression curve and line bisecting angle *B*, is preconsolidation load and void ratio

B. VOID RATIO-LOAD CURVES AND PRECONSOLIDATION LOAD

FIGURE 5. – Void ratio-load curve, compression index, and preconsolidation load. (After Johnson, Moston, and Morris, 1968.)

TABLE 7. - Data from

Sample depth (ft)	Dry unit weight (lb/ft^3)	Moisture content (percent of dry weight)	Atterberg limits		Specific gravity	Initial void ratio (e)	Porosity (percent)
			Liquid	Plastic			
681	82	33.5	41	24	2.61	0.981	49
730	70	46.2	49	29	2.65	1.36	58
774	Disturbed	22.8	60	34	2.71	--	--
821	103	23.7	37	15	2.64	.596	37
875	108	20.8	36	22	2.67	.545	35
951	100	26.0	49	24	2.65	.662	40
1,023	86	33.5	55	22	2.62	.894	47
1,087+	123	14.8	51	29	2.61	.322	24
1,146	Disturbed	22.1	43	24	2.65	--	--

[1]Calculated at load generally larger than that of overburden.

ATTERBERG LIMITS

The moisture content in a clay determines the consistency of the clay. As water content increases the clay changes consistency from a solid state through a plastic state to a semiliquid state. The limits of these three states are arbitrarily fixed by a standardized testing procedure and are called Atterberg limits (Atterberg, 1911). The moisture content, in percentage of dry weight, at the transition from the semiliquid state to the plastic state is called the liquid limit, at the transition from the plastic state to the semisolid state is called the plastic limit, and at the transition from the semisolid state to the solid state is called the shrinkage limit. A decrease in volume of the clay takes place as the water content decreases. In some extreme cases of ground-water overdraft this shrinkage could cause land subsidence. Atterberg limits for nine core samples are given in table 7.

HYDRAULIC CONDUCTIVITY AND POROSITY ANALYSIS

Analyses were made on five sidewall cores by Core Laboratories, Inc. Sidewall cores were obtained by shooting a 2-inch long, 5/8-inch-diameter cylinder horizontally into the side of the borehole. In the laboratory the cores obtained are oriented in the testing apparatus so that the results indicate horizontal, not vertical, hydraulic conductivity. Test results are shown in table 8.

consolidation tests

Coefficient[1] of consolidation (ft^2/yr)	Estimated applied-stress overburden (lb/in^2)	Calculated vertical hydraulic conductivity (ft/d)	Compression index	Recompression index
--	--	--	0.626	0.014
--	--	--	.608	.059
--	--	--	--	--
457	375	7.8×10^{-5}	.293	.026
73.8	400	1.2×10^{-5}	.278	.016
--	--	--	.392	.033
59.7	465	9.1×10^{-6}	.730	.087
--	--	--	.383	.097
--	--	--	--	--

TABLE 8. - Hydraulic conductivity and porosity data

Depth (feet)	Hydraulic conductivity (feet per day)	Porosity (percent)
493	0.01	35.1
957	1.3	36.0
1,066	2.9	34.1
1,182	.2	25.3
1,414	.002	41.7

GRAIN-SIZE DISTRIBUTION

Mechanical analyses of grain-size distribution were made on nine samples by J. H. Kleinfelder and Associates, geotechnical consultants, Sacramento, Calif. (fig. 6). The procedure used was American Society for Testing Materials designation D 422 (American Society for Testing and Materials, 1980).

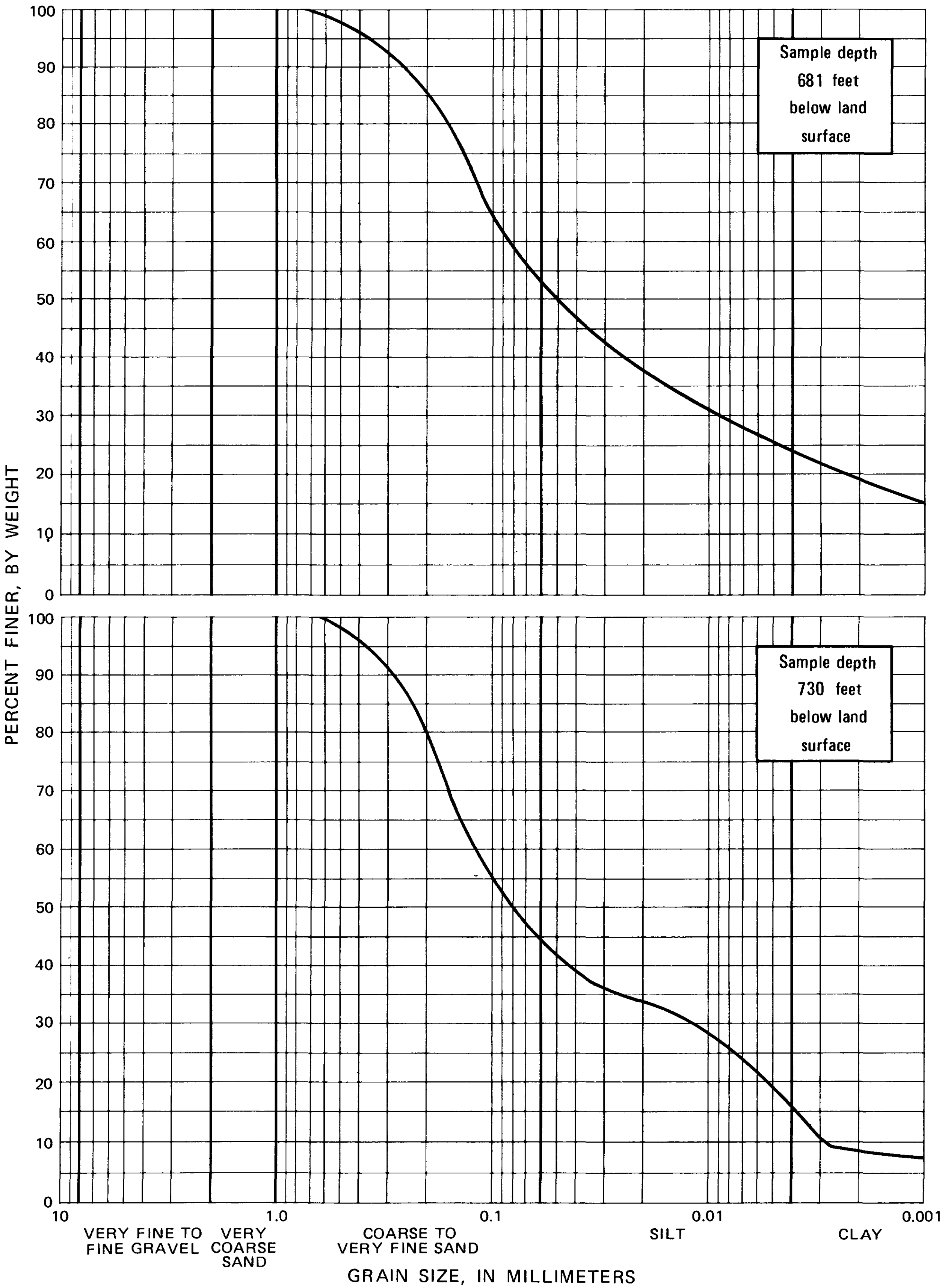


FIGURE 6. – Graphs of grain-size distribution.

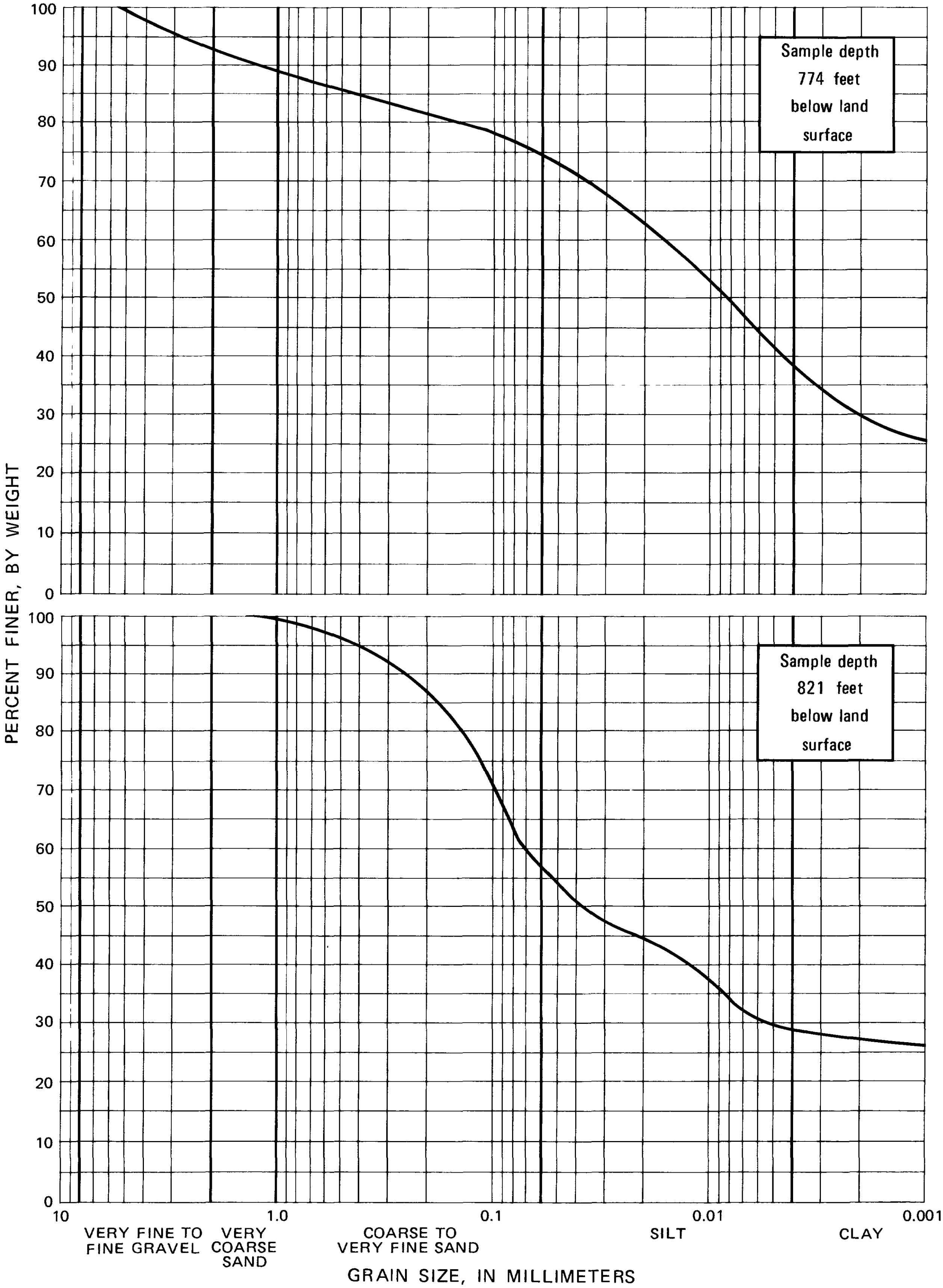


FIGURE 6. – Continued.

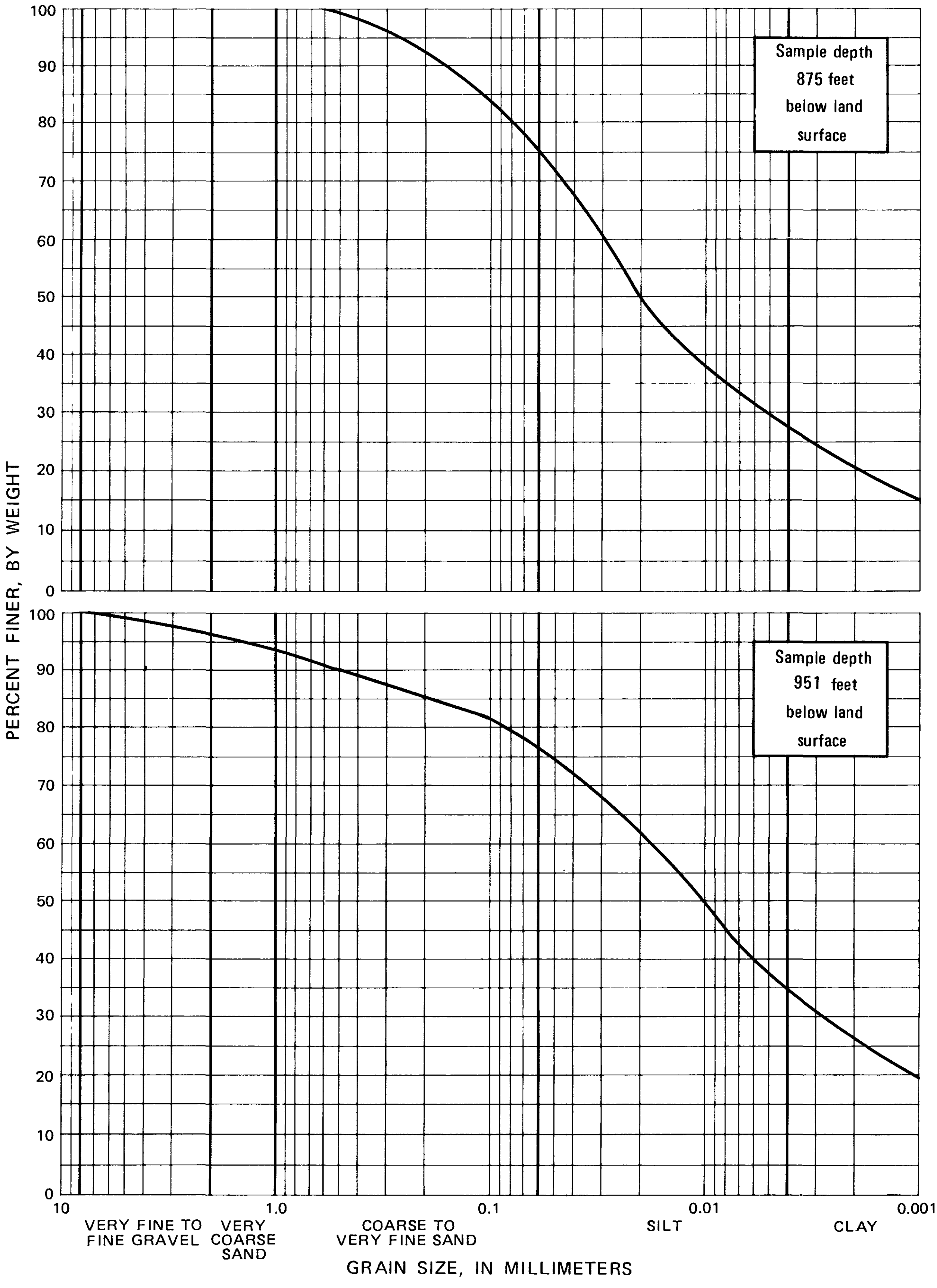


FIGURE 6. – Continued.

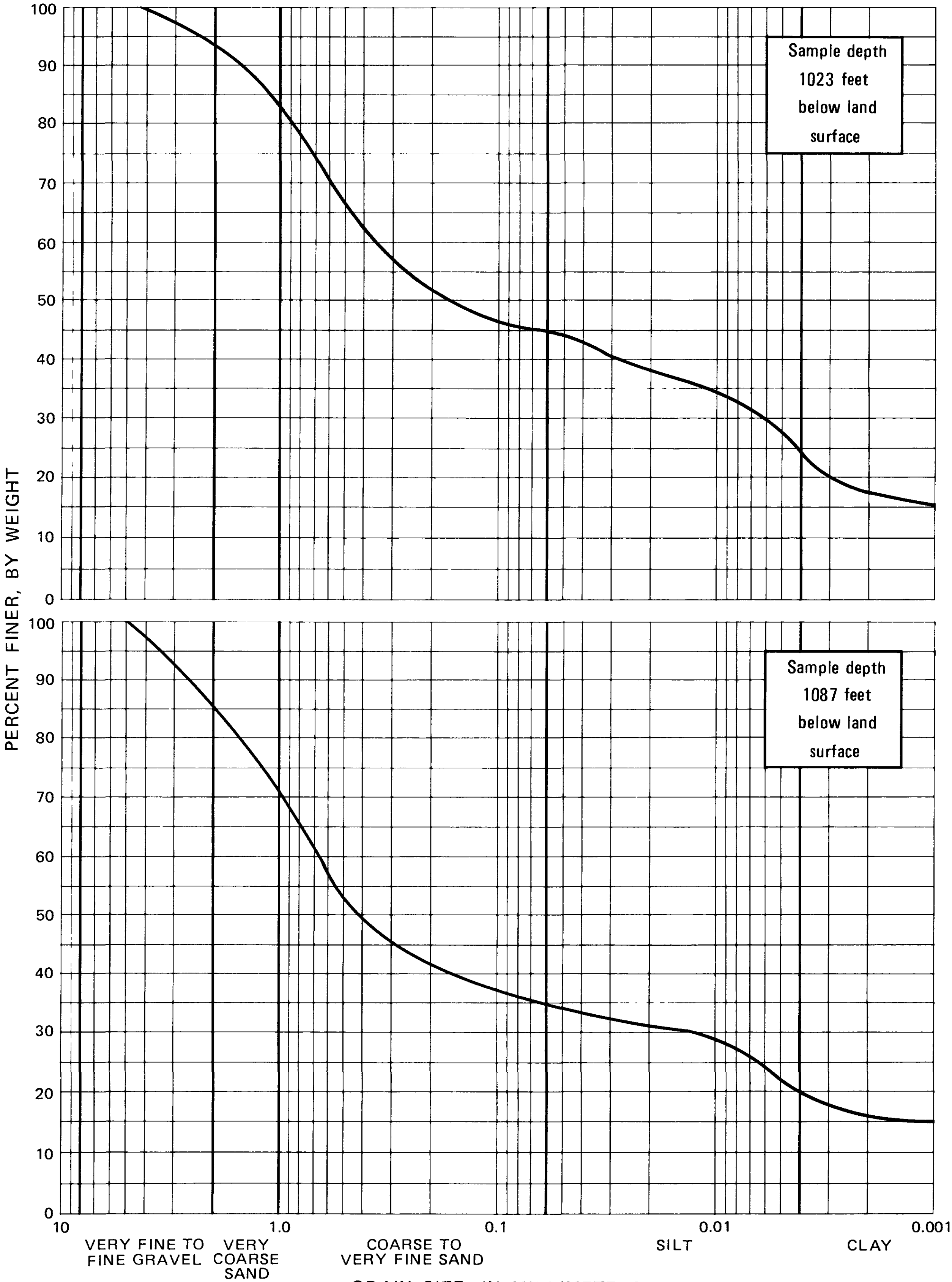


FIGURE 6. – Continued.

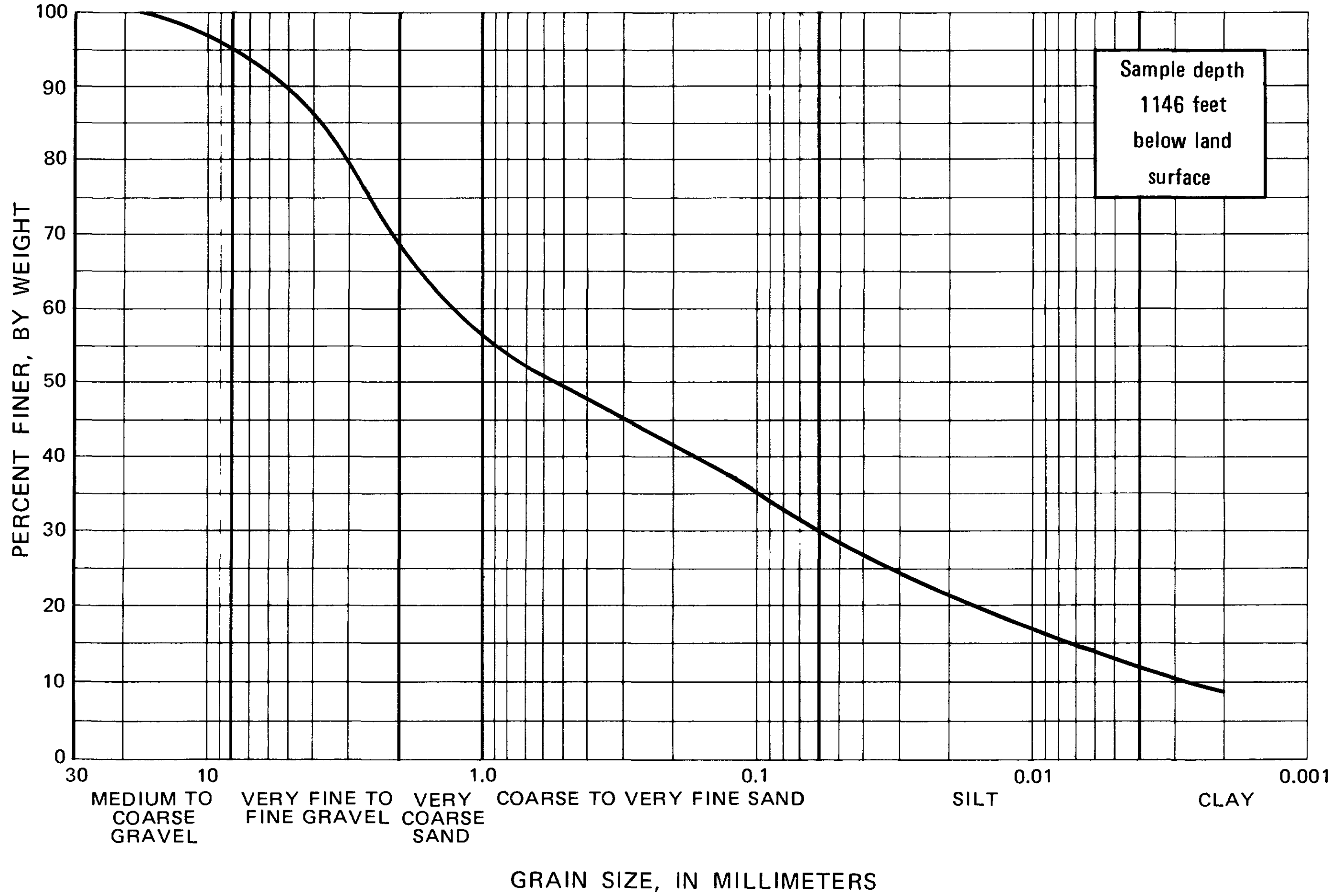


FIGURE 6. – Continued.

THERMAL GRADIENT LOG

A graphic log of the thermal gradient was run by the Geological Survey's Office of Earthquake Studies, Branch of Tectonophysics (fig. 7). The thermal gradient was 24.0°C/km and at a depth of 1,007 feet the temperature was 21.5°C. Projected from the thermal gradient through the zero depth axis the top-hole temperature was estimated to be 14.2°C. A possible interpretation of the top-hole gradient reversal shown on the log is that water is moving upward from about the 200-foot depth (T. H. Moses, Jr., U.S. Geological Survey, oral commun., 1979).

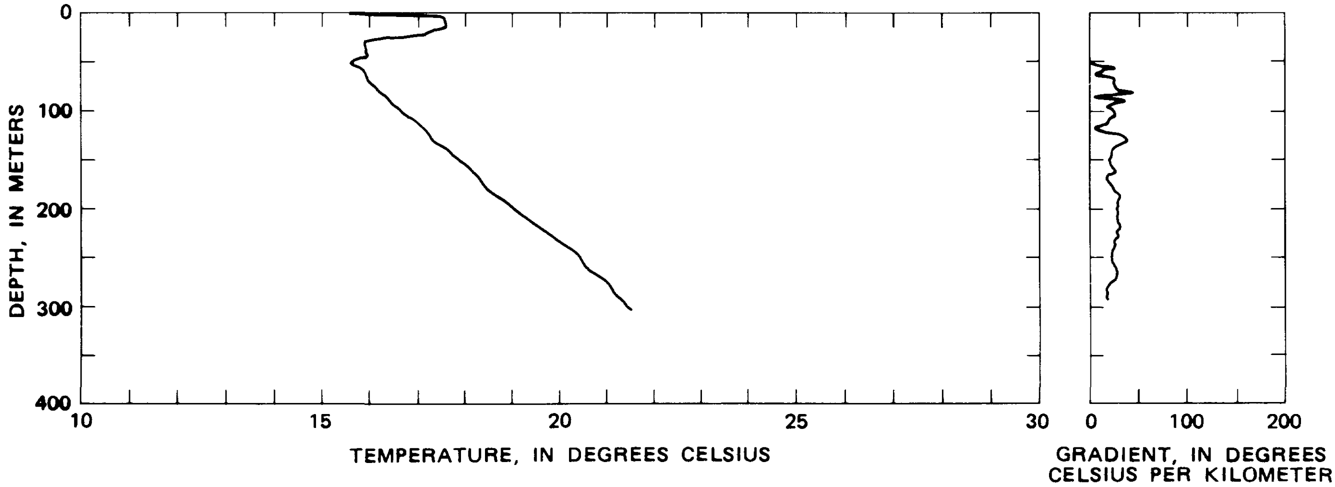


FIGURE 7.– Thermal gradient log.

CHEMICAL ANALYSES OF WATER

The chemical characteristics of the water in the three depth zones opposite the perforated intervals were obtained from water samples collected by submersible pump. In each instance a quantity of water equal to the volume of the casing was pumped out at least once before a sample was collected. For example, the deep zone (G1) was pumped at the rate of 10 gal/min for 6 hours, the middle zone (G2) for 4 hours, and the shallow zone (G3) for 2 hours. During these times the values for specific conductance and temperature stabilized.

Specific conductance, pH, temperature, and alkalinity were recorded at the field site. After completing field determinations, the remaining part of the sample was split. Samples that required filtering were filtered using a 0.1-micrometer membrane. Samples to be analyzed for nutrients were chilled immediately after filtering by packing in ice. All samples were refrigerated until packed for shipping to the U.S. Geological Survey Central Laboratory in Denver, Colo.

Chemical analyses are given in table 9. Figures 8 and 9 show the chemical differences in the water samples. Figure 8 shows plots of the ionic analyses of five samples and is a water-type classification as described by Piper (1944). Figure 9 is a classification of irrigation water based on sodium and salinity hazards according to the U.S. Salinity Laboratory Staff (1954). The water from the deep zone, 1,325-1,330 ft (G1), is a sodium-chloride type with a dissolved-solids concentration of about 550 mg/L. The sodium hazard ranged from medium to high, and the salinity hazard is high. The water from the middle zone, 963-968 ft (G2), is a sodium-chloride type with a dissolved-solids concentration of about 350 mg/L. The sodium hazard is medium, and the salinity hazard is medium. The water from the shallow zone, 587-592 ft (G3), is a sodium-bicarbonate type with a dissolved-solids concentration of about 270 mg/L. The sodium hazard is low, and the salinity hazard is medium.

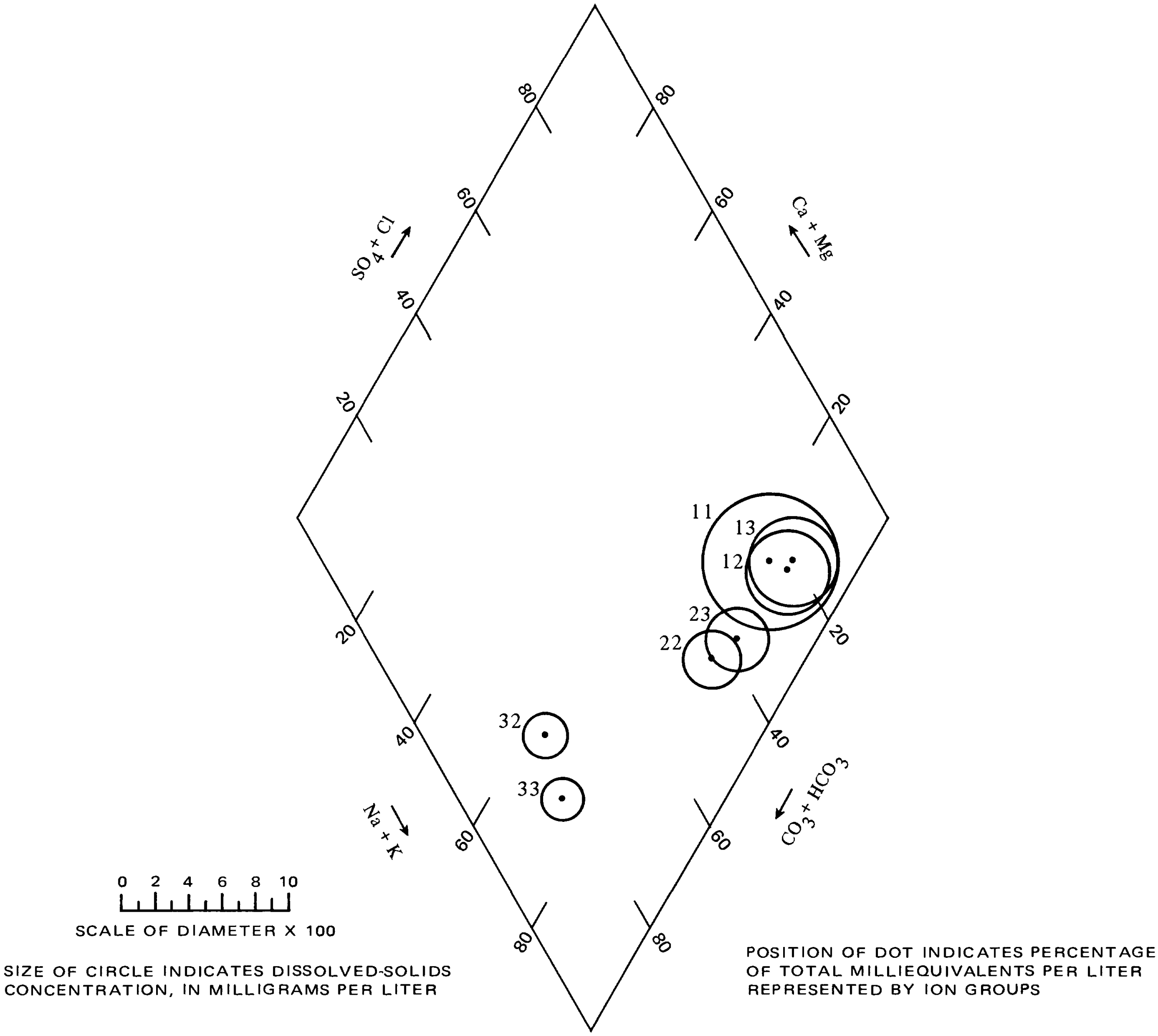
TABLE 9. - Water-quality analyses

STATION NUMBER	LOCAL IDENT-I-FIER	DATE OF SAMPLE	DEPTH OF WELL, TOTAL (FEET)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)
392730121593001	019N001W32G01M	79-09-16	1333	--	--	--	100	0	30
		79-11-16	1333	936	--	21.5	49	0	15
		80-04-18	1333	886	8.0	19.0	49	0	15
392730121593002	019N001W32G02M	79-11-16	968	627	--	20.5	41	0	12
		80-04-18	968	571	7.8	19.0	38	0	11
392730121593003	019N001W32G03M	79-11-16	595	372	--	19.5	81	0	25
		80-04-18	595	344	8.4	18.5	51	0	16

LOCAL IDENT-I-FIER	DATE OF SAMPLE	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	PERCENT SODIUM	SODIUM AD-SORP-TION RATIO	POTAS-SIUM, DIS-SOLVED (MG/L AS K)	ALKA-LINITY FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	FLUO-RIDE, DIS-SOLVED (MG/L AS F)
019N001W32G01M	79-09-16	6.0	250	84	11	4.9	150	28	330	.2
	79-11-16	2.8	160	87	10	3.5	92	3.4	230	.3
	80-04-18	2.8	170	88	11	2.6	86	.6	240	.3
019N001W32G02M	79-11-16	2.6	110	84	7.8	3.2	120	3.6	110	.2
	80-04-18	2.5	120	86	8.8	2.5	110	.3	130	.2
019N001W32G03M	79-11-16	4.4	62	61	3.1	3.7	170	12	22	.2
	80-04-18	2.7	58	69	3.7	3.8	150	1.8	22	.2

LOCAL IDENT-I-FIER	DATE OF SAMPLE	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N)	ALUM-INUM, DIS-SOLVED (UG/L AS AL)	ARSENIC DIS-SOLVED (UG/L AS AS)	BARIUM, DIS-SOLVED (UG/L AS BA)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)
019N001W32G01M	79-09-16	44	821	784	.05	--	--	--	270	--
	79-11-16	55	501	526	.12	--	--	--	240	--
	80-04-18	53	544	537	.02	20	2	300	260	1
019N001W32G02M	79-11-16	26	336	340	.02	--	--	--	180	--
	80-04-18	27	359	360	.02	--	--	--	200	--
019N001W32G03M	79-11-16	44	278	276	.03	--	--	--	150	--
	80-04-18	41	266	236	.02	--	--	--	150	--

LOCAL IDENT-I-FIER	DATE OF SAMPLE	CHRO-MIUM, DIS-SOLVED (UG/L AS CR)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)	MERCURY DIS-SOLVED (UG/L AS HG)	MOLYB-DENUM, DIS-SOLVED (UG/L AS MO)	SELE-NIUM, DIS-SOLVED (UG/L AS SE)	SILVER, DIS-SOLVED (UG/L AS AG)	ZINC, DIS-SOLVED (UG/L AS ZN)
019N001W32G01M	79-09-16	--	--	--	--	--	--	--	--	--
	79-11-16	--	--	--	--	--	--	--	--	--
	80-04-18	0	0	260	0	.1	23	0	0	<3
019N001W32G02M	79-11-16	--	--	--	--	--	--	--	--	--
	80-04-18	--	--	<10	--	--	--	--	--	--
019N001W32G03M	79-11-16	--	--	--	--	--	--	--	--	--
	80-04-18	--	--	<10	--	--	--	--	--	--



PERCENTAGE REACTING VALUES

SAMPLE NO	TUBE NO	DATE	DISSOLVED SOLIDS (mg/L)	DEPTH (feet)
11	32G1	9–79	821	1330
12	32G1	11–79	501	1330
22	32G2	11–79	336	968
32	32G3	11–79	278	592
13	32G1	4–80	544	1330
23	32G2	4–80	359	968
33	32G3	4–80	266	592

FIGURE 8. – Water-analysis diagram.

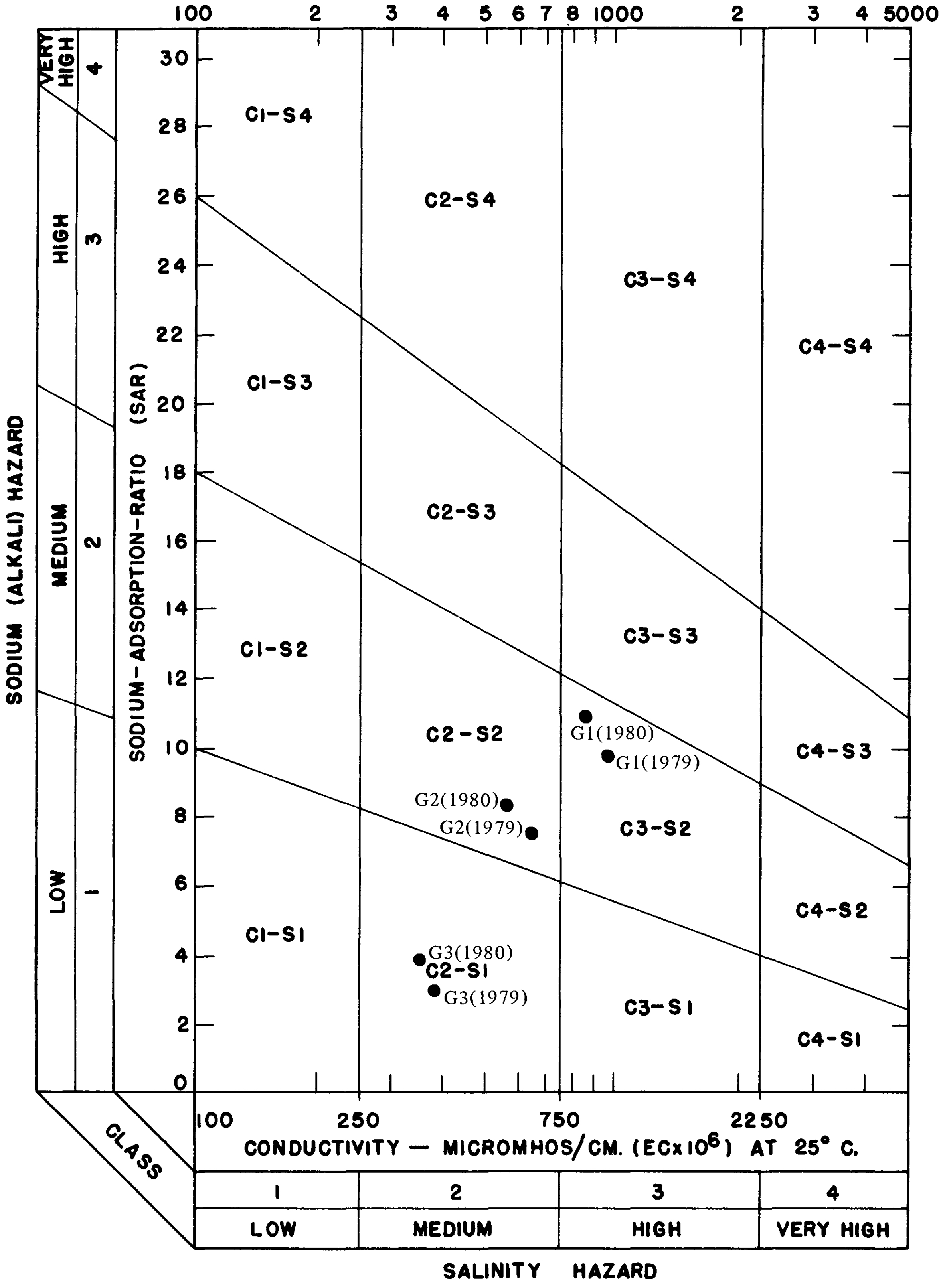


FIGURE 9. – Diagram for the classification of irrigation waters.

Water levels in three piezometers were measured periodically (table 10) and monitored continually by recorder. The top of each casing is the measuring point. The hydrographs (figs. 10-12) show the fluctuation of water levels in each zone.

TABLE 10. - Records of depth to water

[Altitude of land surface is 87.40 feet above National Geodetic Vertical Datum of 1929. Measuring point is top of casing above land surface: G1, 1.11 feet, G2, 1.10 feet, and G3, 1.09 feet above land surface]

Date	Depth to water, in feet above(+) or below land surface		
	G1 depth 1,333 feet	G2 depth 968 feet	G3 depth 595 feet
Nov. 15, 1979	8.03	10.79	17.81
Nov. 26	5.31	10.58	17.46
Nov. 28	4.65	10.61	17.07
Dec. 12	4.63	10.36	16.81
Dec. 28	4.02	9.73	16.32
Jan. 29, 1980	3.55	9.05	12.64
Feb. 28	2.37	6.79	10.40
Mar. 20	2.8	7.50	10.09
Apr. 18	2.31	7.07	13.15
May 15	2.11	7.94	16.41
June 19	2.39	8.93	18.16
July 9	2.78	9.83	20.26
July 30	3.18	10.67	21.59
Aug. 26	3.89	11.60	22.19
Sept. 10		11.80	
Sept. 22	4.36	11.58	19.17
Oct. 16	4.39	10.88	17.45
Nov. 13	4.24	10.45	17.46
Dec. 16	4.01	10.11	16.46
Jan. 15, 1981	3.81	9.69	16.01
Feb. 12	3.34	9.05	14.34
Mar. 12	2.88	8.38	13.82
Apr. 9	2.45	7.99	13.27
May 5	2.19	7.86	16.96
June 2	2.31	9.32	18.72
July 6	2.92	10.53	21.86

TABLE 10. - Records of depth to water--Continued

Date	Depth to water, in feet above(+) or below land surface		
	G1 depth 1,333 feet	G2 depth 968 feet	G3 depth 595 feet
July 31	3.53	11.39	22.45
Aug. 31	4.05	11.90	21.95
Oct. 1	4.51	11.59	18.52
Oct. 30	4.38	10.58	17.13
Dec. 3	3.49	9.39	15.11
Jan. 6, 1982	2.36	7.49	11.15
Feb. 3	2.51	7.44	10.97
Mar. 4	1.82	6.62	10.23
Apr. 5	1.12	5.83	10.61
May 4	1.07	6.10	10.69
June 3	.98	6.97	16.44
July 1	1.34	7.95	18.87
July 30	1.80	9.01	20.44
Aug. 27	2.29	10.01	21.54
Sept. 30	2.82	10.08	17.10
Nov. 1	2.62	8.99	15.94
Dec. 2	2.07	8.10	14.43
Dec. 29	1.74	7.45	12.58
Jan. 31, 1983	+.06	4.60	9.96
Mar. 8	+.53	3.89	6.94
Apr. 1	+.41	4.12	6.98
May 3	+.40	4.42	9.56

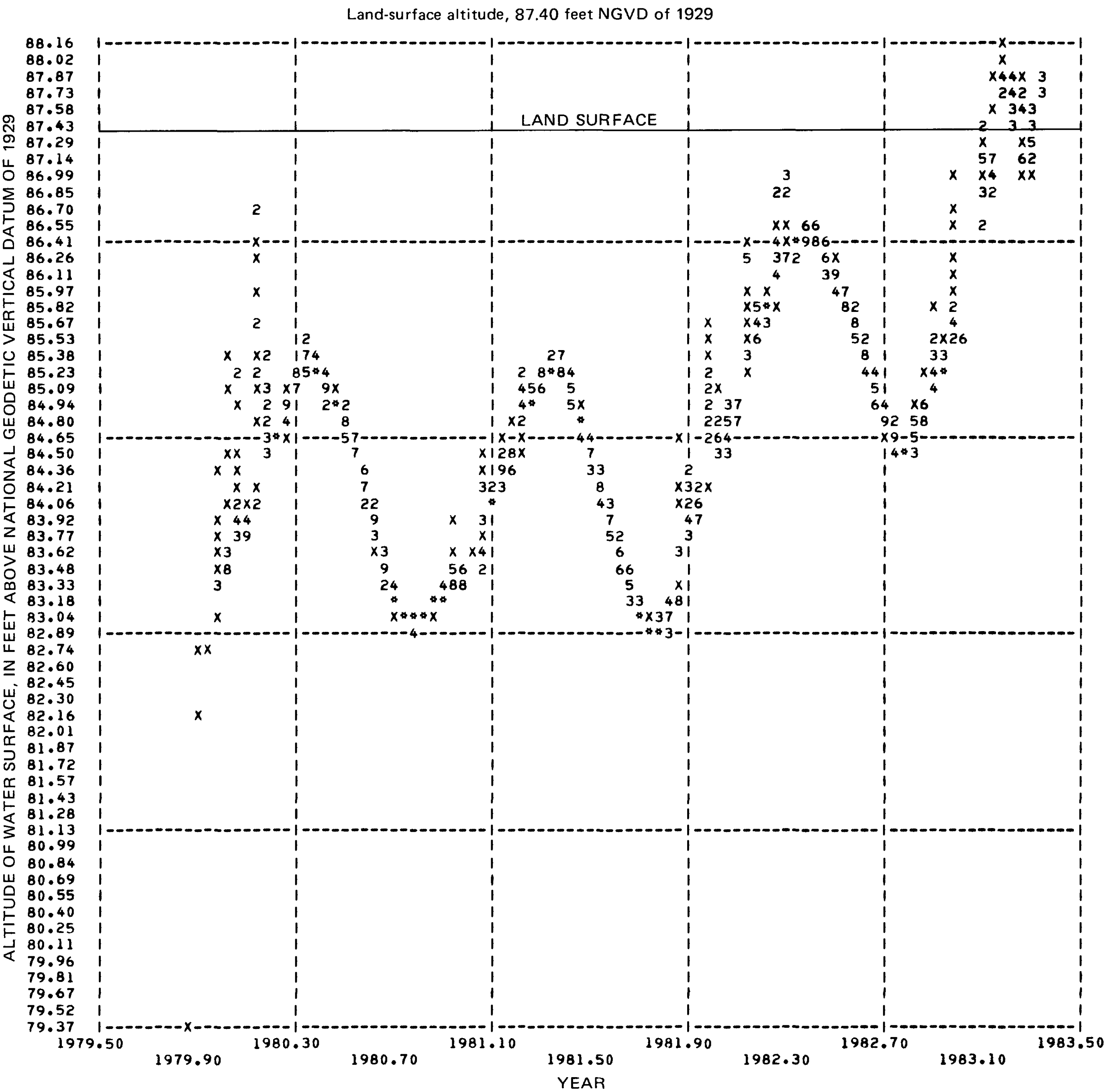


FIGURE 10. – Hydrograph of well 19N/1W–32G1 near Butte City, California. (Explanation of plot: X is used for a single Y–X plot point, numbers 2 to 9 are used for overprinted Y–X plot values, and * is used for more than 9 values.)

Land-surface altitude, 87.40 feet NGVD of 1929

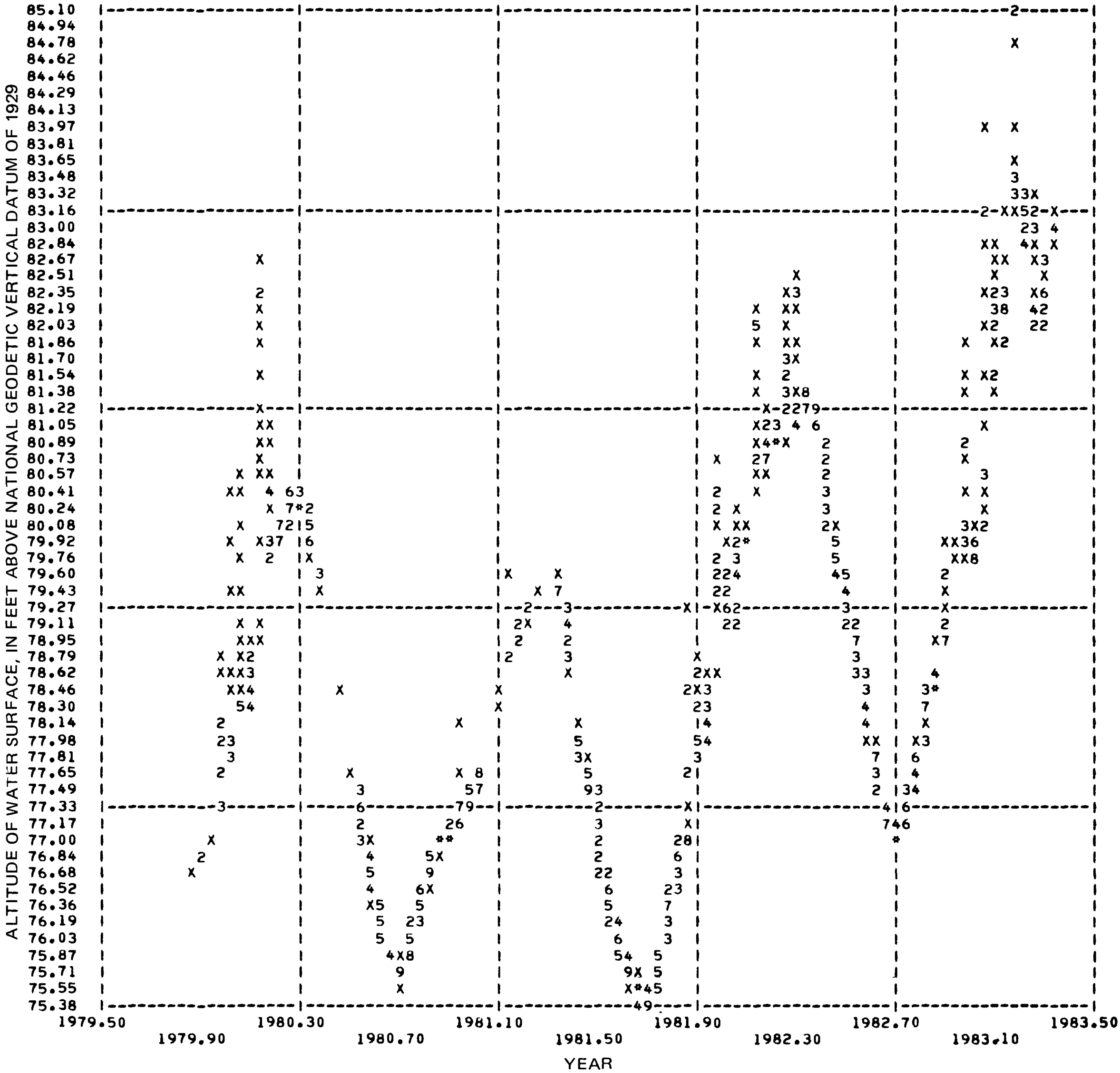


FIGURE 11. – Hydrograph of well 19N/1W–32G2 near Butte City, California. (Explanation of plot: X is used for a single Y–X plot point, numbers 2 to 9 are used for overprinted Y–X plot values, and * is used for more than 9 values.)

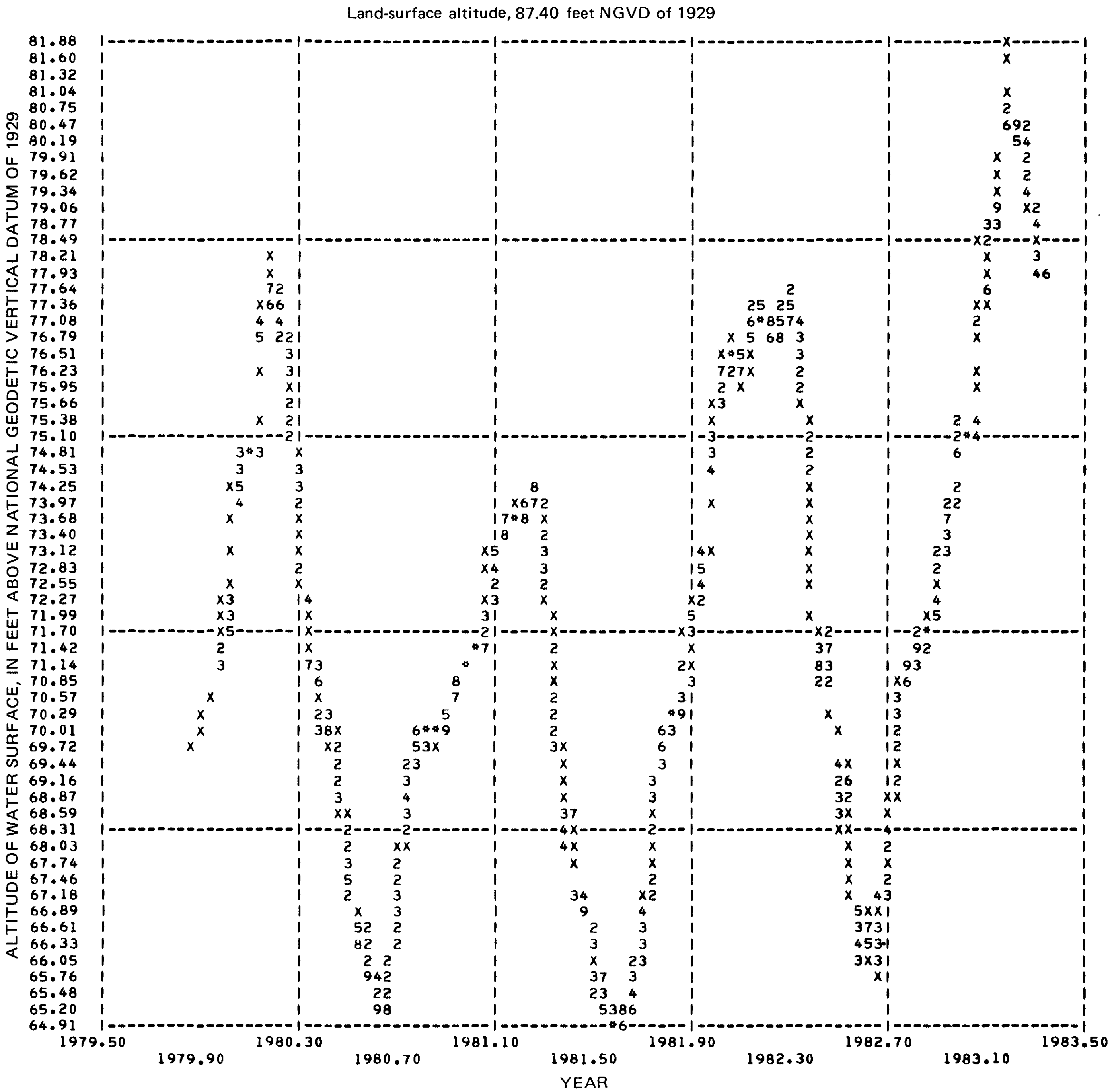


FIGURE 12. – Hydrograph of well 19N/1W–32G3 near Butte City, California. (Explanation of plot: X is used for a single Y–X plot point, numbers 2 to 9 are used for overprinted Y–X plot values, and * is used for more than 9 values.)

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