GROUND-WATER RESOURCES IN LAJAS VALLEY, PUERTO RICO

By Robert P. Graves

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CONVERSION FACTORS

For the convenience of readers who prefer to use Metric Units, the following conversion factors may be used:

Multiply inch-pound units	by	To obtain metric units
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09294	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per day (m^3/d)
	Temperature	
degrees Fahrenheit (°F)	°C = 5/9 x (°F-32)	degrees Celsius (°C)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter [(L/s)/m]
	Transmissivity	
square foot per day (ft^2/d)	0.09290	square meter per day (m^2/d)

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ABSTRACT

The principal aquifer in the Lajas Valley is a nonhomogeneous, anisotropic confined aquifer consisting of alluvial deposits of Quaternary age. The altitude of the potentiometric surface of the Lajas Valley alluvial aquifer ranges from more than 50 feet above mean sea level near its northern and southern boundary to about 12 feet above mean sea level in the central part of the valley. Values of aquifer transmissivity range from 670 to 8,020 square feet per day; the storage coefficient of the aquifer is approximately 0.00093. Yields in the alluvial aquifer commonly range from 5 to 300 gallons per minute. Water-quality analyses of ground water in the alluvial aquifer indicated that, at several sites, the U.S. Environmental Protection Agency drinking water standards for iron, manganese, chloride and dissolved solids were exceeded. Elevated chloride concentrations in excess of 5,000 milligrams per liter were measured in water samples from several wells.

Consolidated clastic and carbonate strata of Cretaceous and Tertiary age underlie the alluvial aquifer. Well yields for two test holes drilled into this rock were about 200 gallons per minute. Chloride concentrations in ground water in this strata ranged from 100 to 2,100 milligrams per liter.

INTRODUCTION

The Lajas Valley in southwestern Puerto Rico (fig. 1) is a large (about 32,500 acres), flat lowland, which is being considered for agricultural and industrial development by the Department of Agriculture of Puerto Rico (DAPR) and the Puerto Rico Industrial Development Company (PRIDCO). Historically, ground water in the Lajas Valley has been under-utilized because of its elevated chloride concentration. Fresh ground water is known to occur in the recharge areas; but brackish water is reported to be present throughout much of the alluvial aquifer that underlies the valley (Anderson, 1977). Anderson further reported that the analyses of ground water collected from selected test holes indicated that chloride concentration decreased with depth. The depth of these test holes was less than 200 feet. It was suspected that fresh ground water occurred in Cretaceous and Tertiary limestone deposits, which were believed to underlie alluvial deposits of Quaternary age in the Lajas Valley.

The principal source of freshwater in the valley is an aqueduct from Lago Loco, which supplies approximately 4,600 acre-ft/mo (acre-feet per month) of water to the valley (fig. 1). Planned development of a rice industry by DAPR and new industrial development by PRIDCO

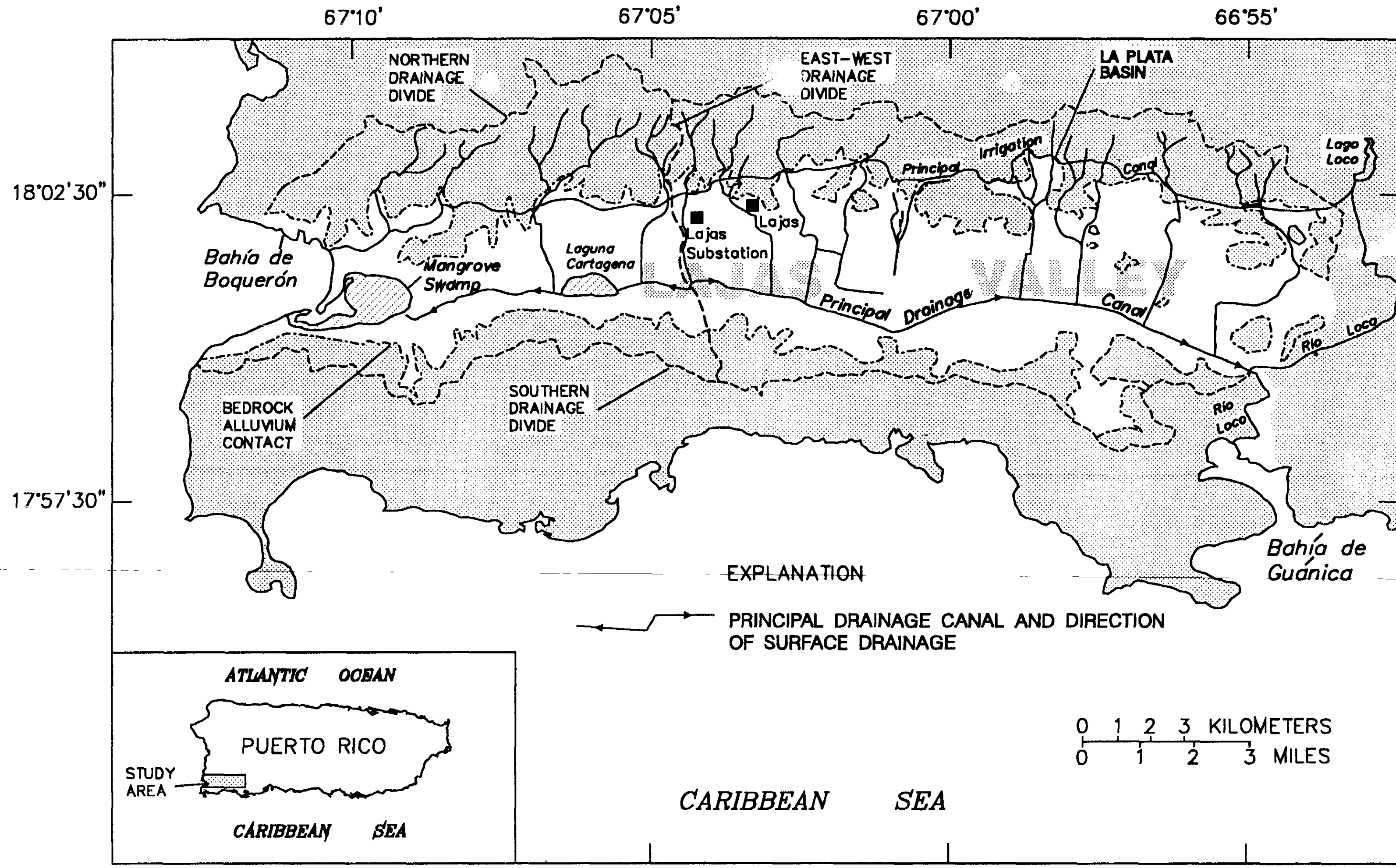


Figure 1.--Location of the Lajas Valley and important hydrologic features.

will require approximately 6,000 and 3,200 acre-ft/mo of water, respectively. Because the surface-water resources in the Lajas Valley are not adequate to meet the projected water demand, fresh ground-water supplies are needed to supplement the surface-water supply.

Purpose and Scope

This report summarizes the results of a three-year cooperative investigation initiated in 1983 between the U.S. Geological Survey, DAPR, and PRIDCO. The objectives of this study are to:

1. Assess the ground-water resources of the alluvial deposits in the Lajas Valley in terms of its occurrence, availability, and chemistry.
2. Determine if fresh ground water occurs in the limestone deposits underlying the Lajas Valley.

The objectives of the investigation were addressed by first evaluating results of all previous hydrologic studies of the area. After the available data were compiled, a data-collection program was initiated in 1984 to provide additional hydrologic information. This program included an inventory of information on well specifications, water levels, well yield, drawdown, and water quality. To determine the occurrence of ground water in the alluvial deposits, batteries of test wells were installed at three sites to depths ranging from 1 to 247 feet below land surface. Additional wells were drilled to help define the potentiometric surface of the alluvial aquifer. To provide a better understanding of the geohydrologic character of the alluvial aquifer and the hydrologic relation between the alluvial aquifer and the suspected underlying limestone deposits, two test wells were drilled to depths of 636 and 856 feet. These test wells were drilled using the dual tube method; a technique that permits the collection of continuous geologic cores, hydrologic data (aquifer yield, head change, and change in aquifer characteristics), and water-quality data as the well is drilled.

A continuous recorder was used to monitor ground-water level fluctuations in the alluvial aquifer in the central portion of the valley. An aquifer test was conducted to determine the transmissivity and storage properties of the alluvial aquifer.

Water samples were collected periodically at the different well batteries to study the change in chloride concentration with depth. Additional water-quality samples from selected wells were collected and analyzed for major cations and anions and the trace elements of iron, manganese, barium, and aluminum.

The location of wells used in this investigation are shown in figure 2. Information on these wells is given in the appendix of this report. The well numbers in figure 2 and in the appendix apply

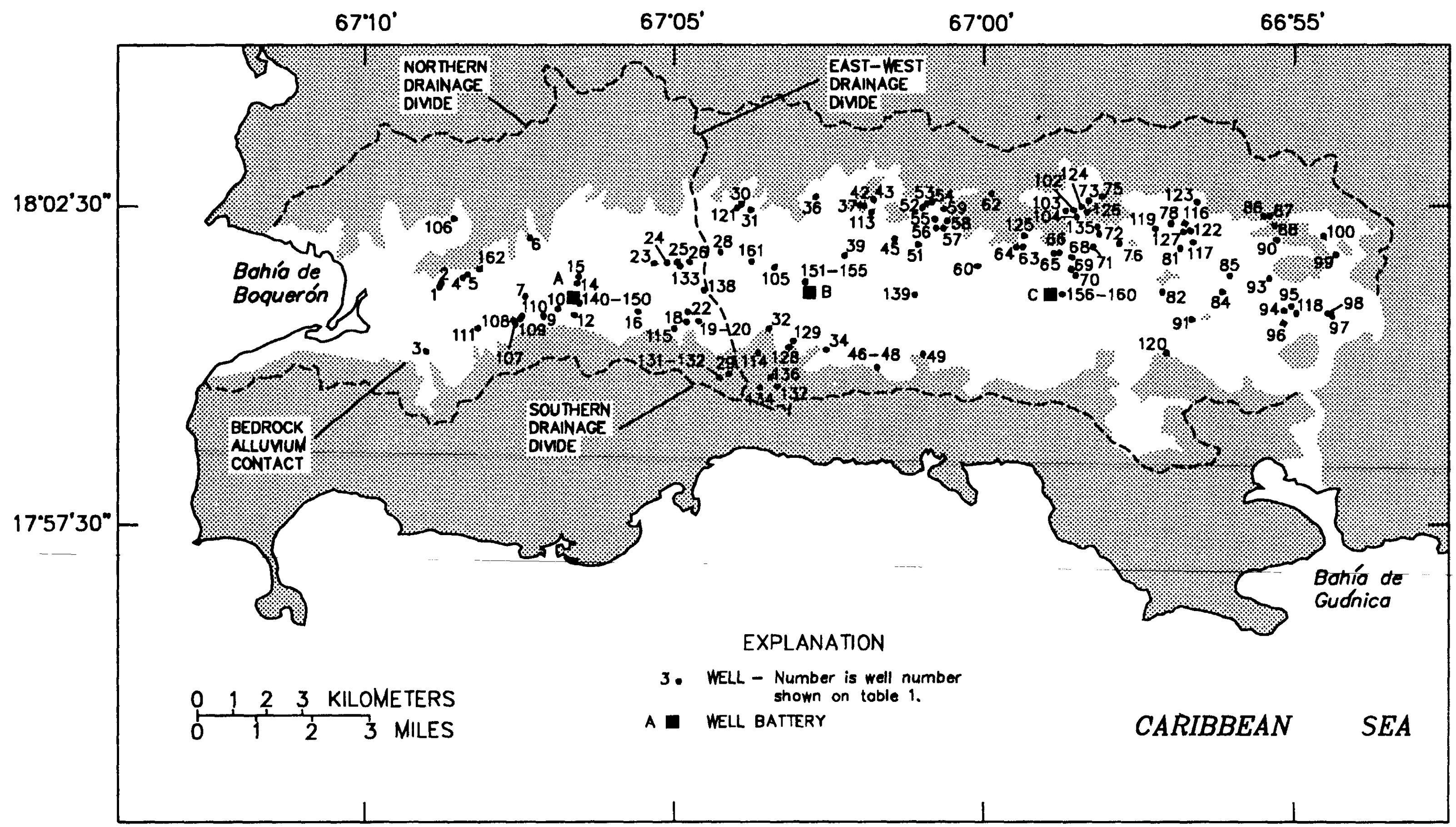


Figure 2.--Location of the inventoried wells and well batteries in the Lajas Valley.

only to this report; however, site identification numbers presented in the appendix conform with the established U.S. Geological Survey Ground-Water Site Inventory well numbering scheme.

Acknowledgments

The author gratefully acknowledges the individuals who provided assistance and cooperation throughout the project. Special acknowledgment is extended to private landowners José B. Ramírez-Acosta, Miguel Carlo, Johnny González, Olmar C. López, and Rafael Salcedo-Rivera, and to the University of Puerto Rico Agricultural Experimental Station, Lajas, for allowing the installation of test wells on their property. Appreciation is also extended to Aquaculture Enterprises, Inc. for the hydrologic data they provided and for their assistance in conducting an aquifer test at their facility.

GENERAL FEATURES

Landforms and Drainage

The Lajas Valley is located in the extreme southwestern corner of Puerto Rico (fig. 1). The valley, which is oriented along an east-west axis, is 18 miles long and ranges from 1 to 3 miles wide. The valley is open at both ends, draining into Río Loco and Bahía de Guánica to the east, and Bahía de Boquerón to the west. Foothills on the north and south sides of the valley rise to a maximum altitude of 980 and 820 feet above mean sea level, respectively. The altitude of the central valley floor varies from sea level near Bahía de Boquerón to approximately 43 feet above mean sea level along the east-west drainage divide that is located 6.5 miles east of Bahía de Boquerón. North and south of the central valley floor, the land surface rises to altitudes of as much as 164 feet above mean sea level at the base of the bordering foothills. Natural streams that flow out of the foothills into the Lajas Valley are small and ephemeral (fig. 1). Following heavy rains, flow from these streams disappears in the alluvial deposits of the Lajas Valley (Anderson, 1977).

Man-induced surface-water flow and drainage also is evident in the Lajas Valley. A 23 mile long gravity-fed irrigation canal extends westward from Lago Loco to Bahía de Boquerón along the base of the northern foothills (fig. 1). A series of drainage canals have been constructed within the valley. The main drainage canal runs east-west along the southern edge of the valley with direction of flow being controlled by the central inner valley drainage divide. Surface-water bodies within the Lajas Valley includes Laguna Cartagena and a mangrove swamp near Bahía de Boquerón (fig. 1).

Climate

The climate in Lajas Valley is classified as moist to dry subhumid tropical (Jones and Pico, 1955). The mean annual air temperature recorded by the National Oceanic and Atmospheric Administration (NOAA) at the Lajas Substation is 77 degrees Fahrenheit (U.S. Department of Commerce, 1986) (fig. 1). Average annual rainfall at the Lajas Substation is 43 inches. Two seasons occur within the Lajas Valley, a dry season that extends from January to March, and a wet season from August through November (fig. 3). Average annual pan evaporation reported by NOAA between 1982 and 1986 for the Lajas Substation is 60 inches a year.

Geology

Metamorphic, igneous (plutonic and volcanic), and sedimentary rocks that crop out and underlie the study area range from Late Jurassic to Quaternary age (Volckmann, 1984a, b, c, and d) (fig. 4). For hydrogeologic purposes, igneous rock is considered to be the basement underlying the Lajas Valley.

Cores collected from test wells 161 and 162 indicate that igneous rock underlies the valley at a depth of 540 to 875 feet below land surface, respectively. Lithologic descriptions for these two deep wells are presented in figures 5 and 6. Consolidated clastic and carbonate strata (referred to in this report as sedimentary rock) of Cretaceous and Tertiary age overlie the igneous rock. The sedimentary rock is about 850 feet thick in well 162 and about 364 feet thick in well 161 (fig. 7). This sedimentary rock is the limestone described by Anderson (1977). Unconsolidated alluvial deposits of Quaternary age, which are characterized by silt, clay, and lenses of sand, overlie the consolidated sedimentary rock. The thickness of the alluvial deposits exceeds 210 feet in the eastern end of the valley (fig. 7). Alluvial fan deposits of sand and gravel are found near the northern and southern edge of the valley and grade into the silt and clay deposits of the central valley (Volckmann, 1984a, b, and c).

GROUND-WATER RESOURCES

Occurrence of Ground Water

The principal aquifer discussed in this report is a nonhomogenous, anisotropic confined aquifer comprised of alluvial deposits of Quaternary age (fig. 7). The upper confining unit of the aquifer consists of clay deposits. Locally, at the base of the foothills in the alluvial fan deposits near the northern and southern edge of the valley, ground water can occur under water-table conditions (Anderson, 1977).

The alluvial deposits are in hydraulic connection with the underlying sedimentary rock of Cretaceous and Tertiary age, but, because of the difference in rock type, significant differences

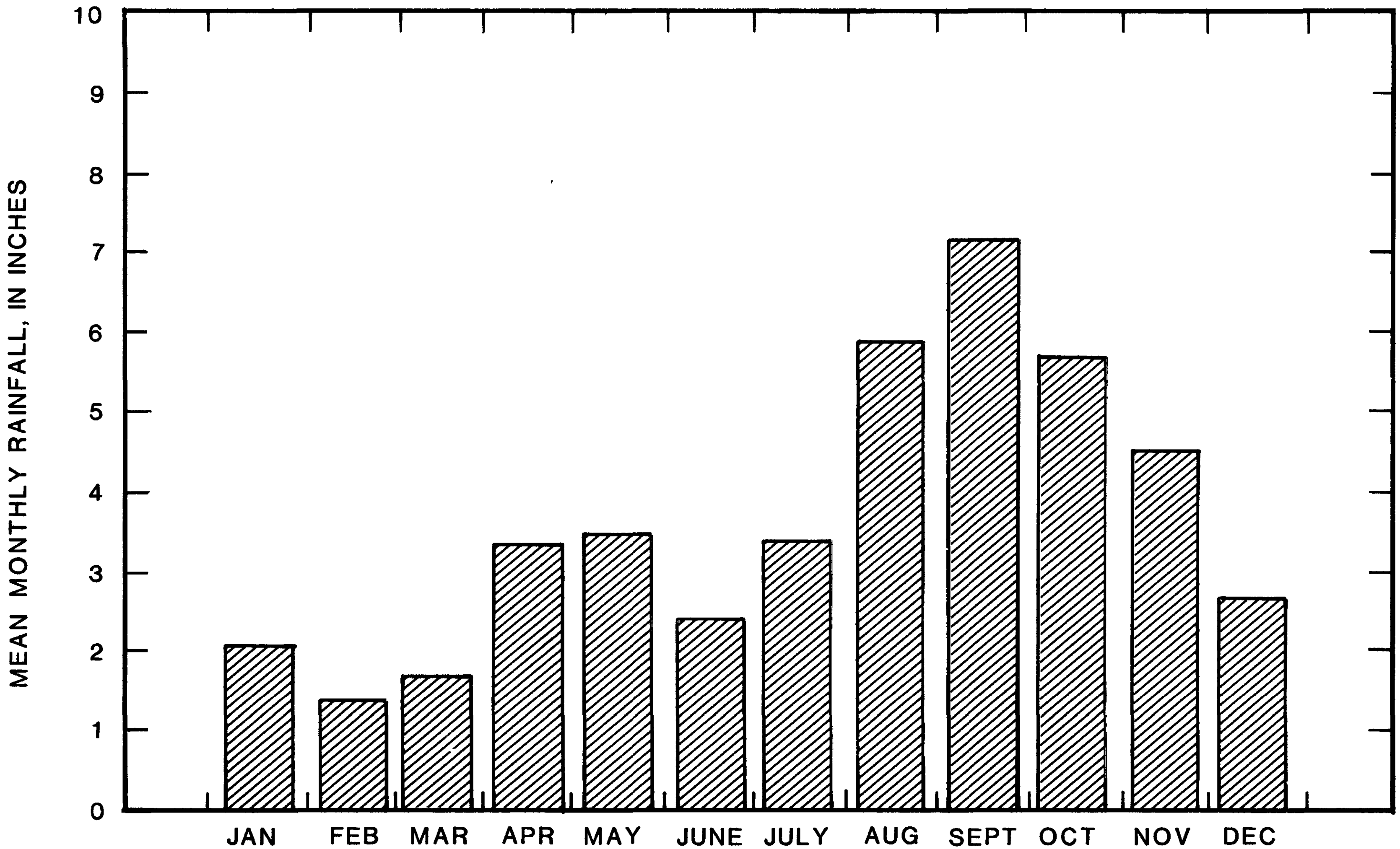
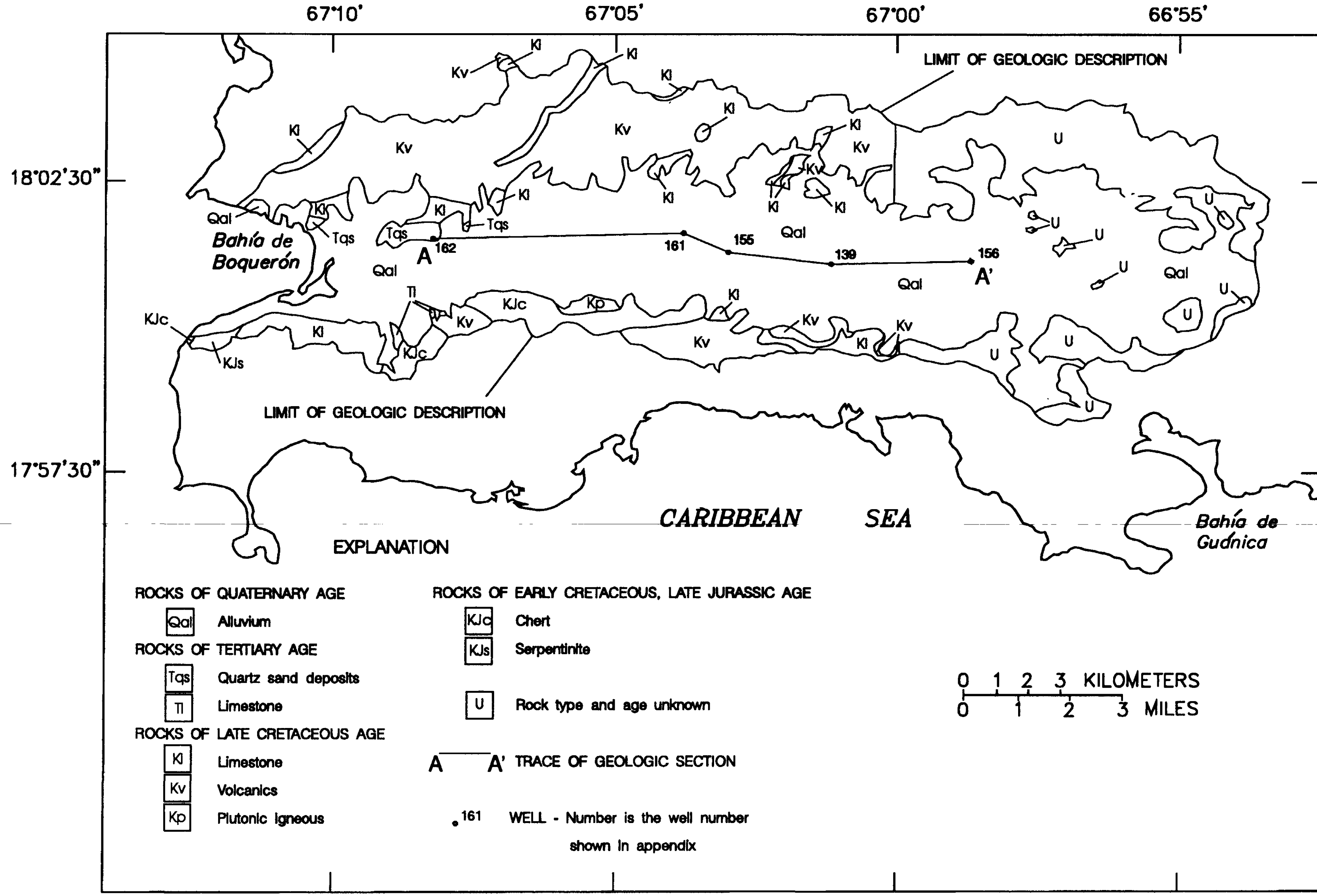


Figure 3.--Mean monthly rainfall for Lajas Substation, 1966 - 1986. (Data from U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1986)


67°10'
67°05'
67°00'
66°55'
18°02'30"
17°57'30"
LIMIT OF GEOLOGIC DESCRIPTION
Bahía de Boquerón
Bahía de Guánica
CARIBBEAN SEA
A
A'
162
161
155
139
156
Qal
Tqs
Tl
Kl
Kv
Kp
KJc
KJs
U
0 1 2 3 KILOMETERS
0 1 2 3 MILES
EXPLANATION
ROCKS OF QUATERNARY AGE
Qal Alluvium
ROCKS OF TERTIARY AGE
Tqs Quartz sand deposits
Tl Limestone
ROCKS OF LATE CRETACEOUS AGE
Kl Limestone
Kv Volcanics
Kp Plutonic igneous
ROCKS OF EARLY CRETACEOUS, LATE JURASSIC AGE
KJc Chert
KJs Serpentinite
U Rock type and age unknown
A A' TRACE OF GEOLOGIC SECTION
161 WELL - Number is the well number shown in appendix

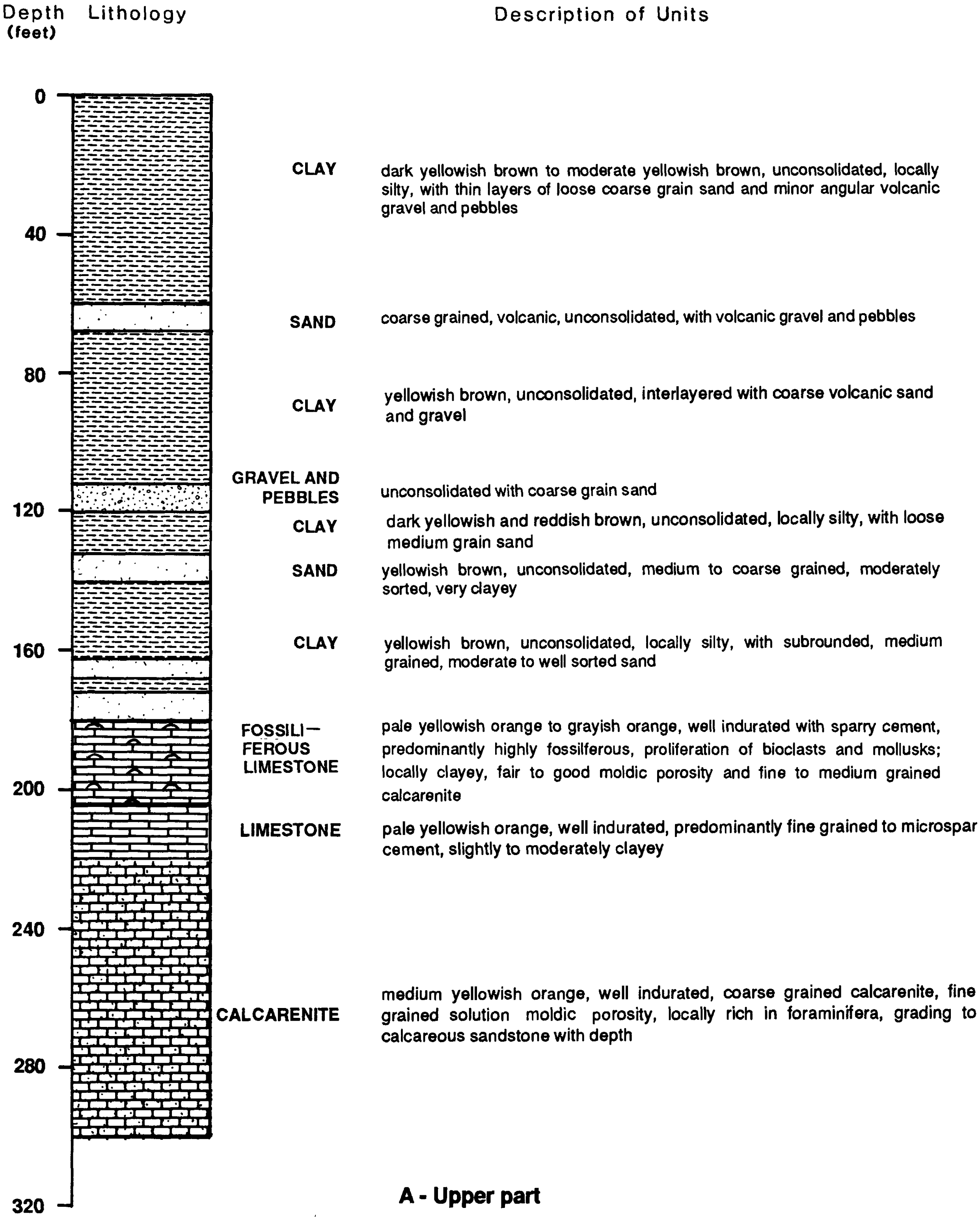
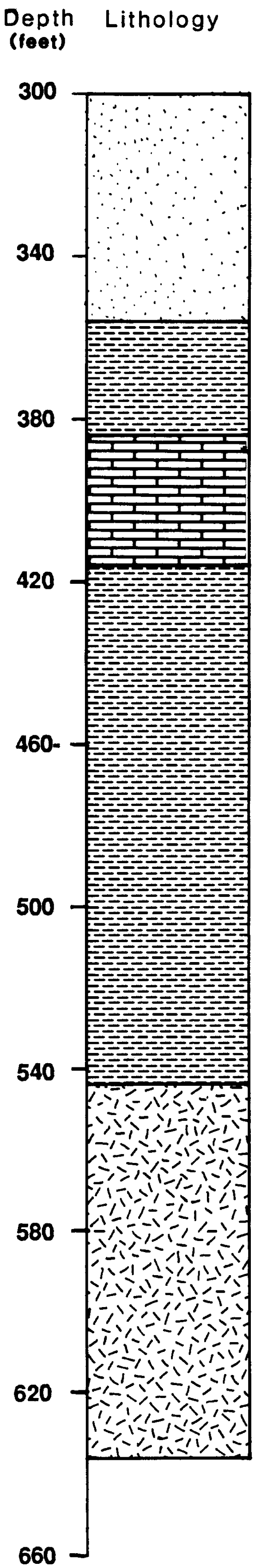


Figure 5.--Stratigraphic section for well 161, upper part (A) and lower part (B).



Description of Units

SANDSTONE medium to coarse grained, moderately to well indurated, minor lenses of loose sand, locally fossiliferous

CLAYSTONE greenish gray, moderately to well indurated, with limestone angular clasts, calcareous, locally with coarse grained quartzose sandstone, minor silt, minor organic structure (lignite?)

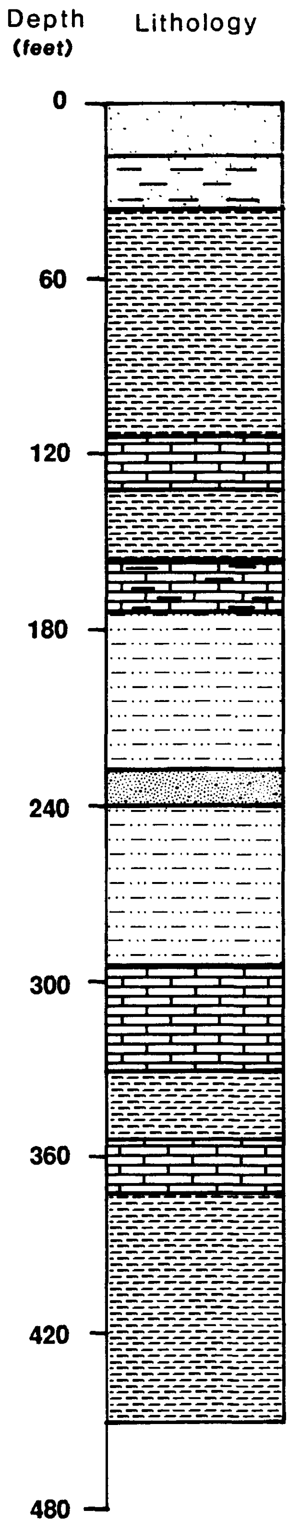
LIMESTONE dark gray, dusky brown, highly bioclastic, wackestone to packstone, locally with coral reef debris, locally with spar cement, locally fine to coarse grained porosity, grading to and interbedded with claystone

CLAYSTONE dark greenish gray, locally moderately indurated, with silty fine grained sand lenses, and dark gray biosparite, highly bioclastic wackestone to packstone limestone

IGNEOUS ROCK dark reddish to purplish brown, with green vesicles, with very fine crystalline to aphanitic texture

B - Lower part

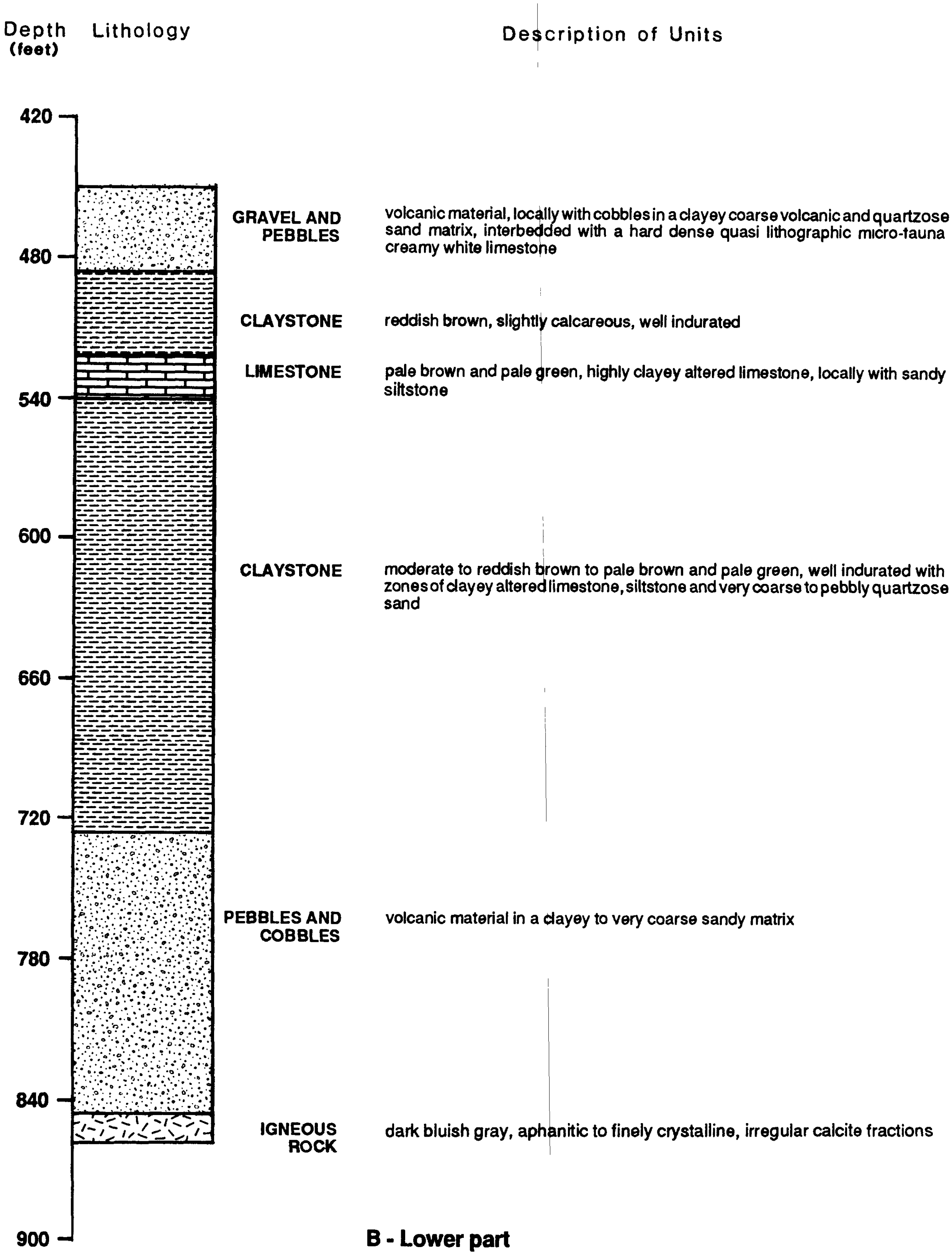
Figure 5.--Stratigraphic section for well 161 - continued.



Unit	Description of Units
QUARTZ SAND DEPOSITS	reddish orange, medium to coarse grained, moderate to good sorting, poorly consolidated, with clay and minor volcanic pebbles
CLAYEY SANDSTONE	predominantly brownish red, medium to coarsed grained, well indurated
CLAYSTONE	brownish yellow to purple, well indurated, moderately to strongly calcareous, interbedded with silt, sand, gravel, pebbles, and yellowish brown, well indurated, moderately calcareous and terrigenious, sandy limestone
LIMESTONE	creamy white to pale green, well indurated, with biosparite (microfauna) locally with coarse sand and pebbles
CLAYSTONE	dark brown to orange brown, silty, well indurated
ARGILLACEOUS LIMESTONE	creamy white, pale green, well indurated, grading to strongly calcareous well indurated claystone, locally silty
SILTSTONE	moderate brown clayey, strongly calcareous, well indurated, locally with sand and pebbles and interbedded claystone
GRAVEL AND PEBBLES	coarse volcanic material in quartzose fraction sand matrix
SILTSTONE	pale to moderate yellowish brown, clayey, well indurated, locally strongly calcareous, locally sandy, with spare patches of clayey altered limestone
LIMESTONE	dense quasi-lithographic, locally strongly calcareous, highly clayey
CLAYSTONE	reddish brown silty, well indurated, lenses of altered clayey limestone
LIMESTONE	pale creamy brown, white mottled, silty, clayey, highly altered, with carbonacious microfauna
CLAYSTONE	reddish brown, well indurated with isolated altered clayey limestone, locally strongly calcareous and silty

A - Upper part

Figure 6.--Stratigraphic section for well 162, upper part (A) and lower part (B).



B - Lower part

Figure 6.--Stratigraphic section for well 162 - continued.

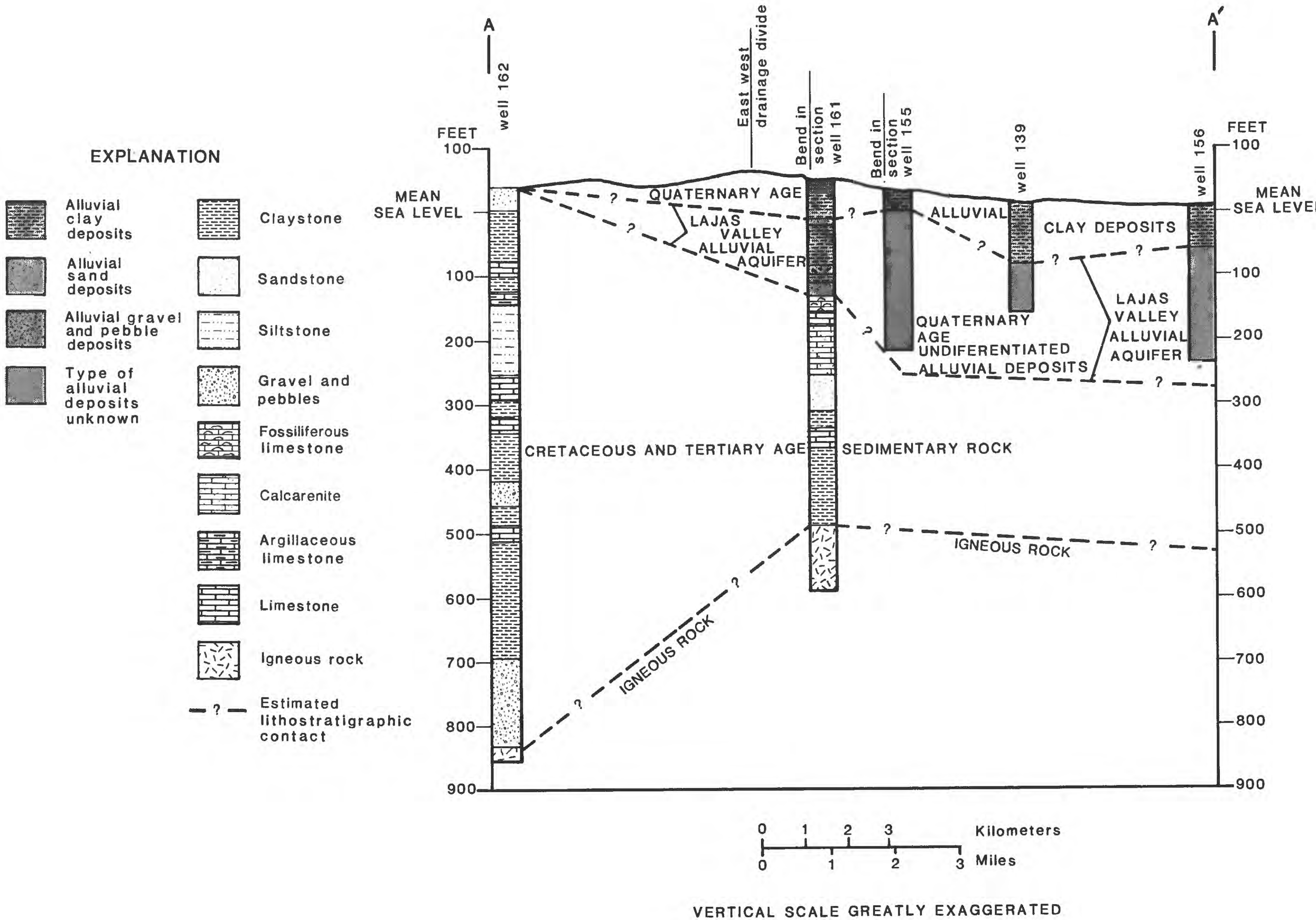


Figure 7.--Generalized hydrogeologic section of the Lajas Valley. (See figure 4 for location)

exist between the hydraulic characteristics of the alluvial deposits and the consolidated sedimentary rock. Because of this, the sedimentary rock could be considered a distinct aquifer. Geohydrologic data for the sedimentary rock deposits in Lajas Valley are available for only two deep test wells. Therefore, in this report, the discussions of the Lajas Valley aquifer are of the alluvial deposits. Only where sufficient data were collected is reference made to the occurrence, availability, and quality of the water in the sedimentary rock.

There are few data showing the thickness of the alluvial aquifer or its upper clay confining unit throughout the valley. Test-hole drilling indicate that the base of the aquifer occurs at depths greater than 210 feet in the eastern part of the valley. Cores collected from well 162 indicated that the alluvial deposits pinch out laterally, exposing the sedimentary rock at land surface. Cuttings and cores collected while drilling, and the depth below land surface that ground water was first encountered, indicated that the top of the Lajas Valley alluvial aquifer ranged from 27 to about 90 feet below land surface (fig. 7, table 1).

Movement of Ground Water

The movement of water within the aquifer is complex. Water levels in wells completed at discrete zones within the alluvial deposits at the three batteries of test wells indicated a downward vertical- flow component at these sites (fig. 8). Elsewhere in the valley, it was difficult to document a vertical-flow component because most privately owned wells have been screened throughout the entire well bore. Water levels in these and other wells that are open to a substantial section of the aquifer, represent a composite head. Therefore, vertical and horizontal ground-water flow patterns in most of the study area are discussed in general terms only. It should be noted that these two flow components can vary greatly depending on the part of the aquifer being evaluated.

Data collected from wells 161 and 162 indicated that there was no significant difference between heads in the sedimentary rock and those in lower parts of the alluvial deposits. Therefore, even though some wells in the Lajas Valley were drilled into the sedimentary rock, the water levels in these wells were considered representative of water levels in the alluvial deposits.

The downward vertical ground-water gradient documented at each well battery (fig. 8) may be due to the nonhomogeneous nature of the alluvial material. Cores collected from well 161 indicated that coarse-grain sand lenses interlayered with silty-clay occurred near the base of the alluvial deposits (fig. 5). The coarse-grain sand lenses had a much higher hydraulic conductivity than shallower alluvial deposits, and wells screened in these sands tended to have larger yields. The lower heads near the base of the aquifer may be the result of pumping from wells screened in the deeper alluvial deposits.

Table 1.--*Depth to the first water-bearing zone in test holes and static water level in cased wells*
[units - NA, data not available: +, indicates water level above land surface]

Well number (appendix)	Depth of test hole (feet)	Depth to first water-bearing zone [1] (feet)	Depth to static water level in tightly cased well (feet)
138	212	137-138	21.00
139	172	87-92	0.50
151	25	NA	5.00
152	40	27	3.00
153	50	27	3.00
154	110	27	3.00
155	247	27	25.00
156	247	52-57	1.50
157	101	52	+2.78
158	59	52	+2.80
159	47	47	+2.81

[1] Test holes drilled with augers: depth to first water-bearing zone during drilling determined from changes in auger speed and visual inspection of sample cuttings. Depth to first water could be in error plus or minus 5 feet.

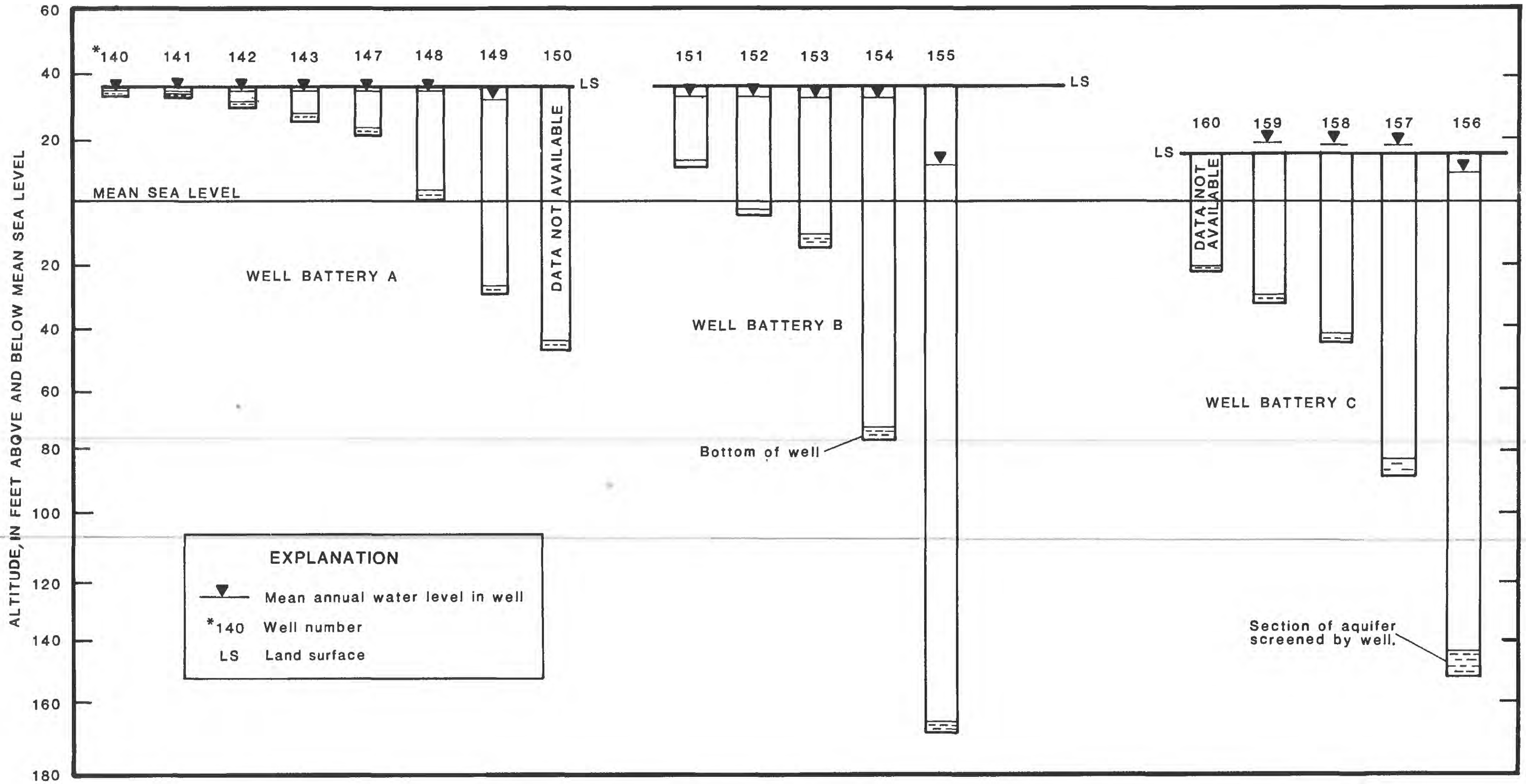


Figure 8.-- Mean annual water levels at well batteries A, B, and C, Lajas Valley, 1986

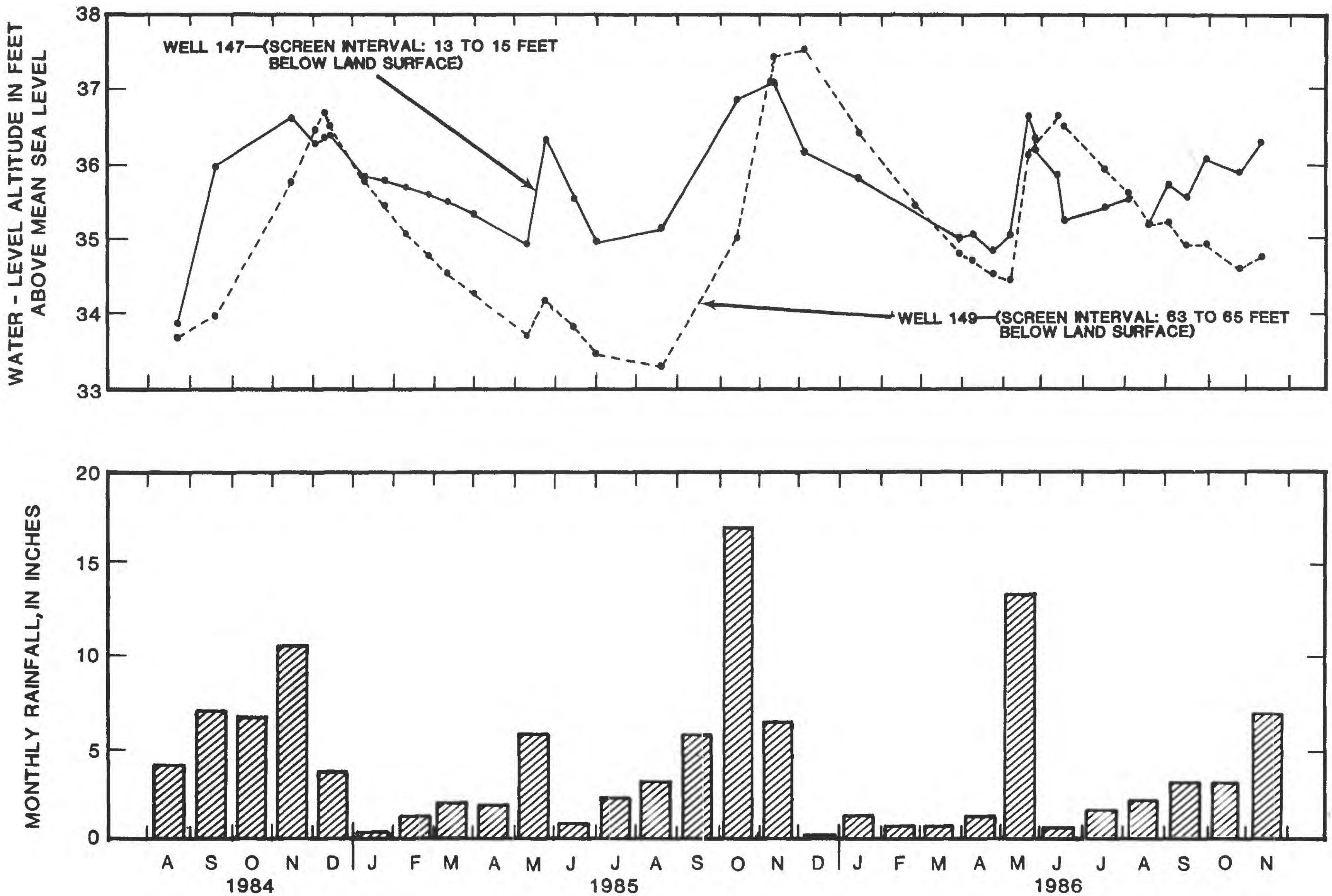


Figure 9.--Water - level altitude in wells 147 and 149 at well battery A, and monthly rainfall at Lajas Substation, August 1984 through November 1986.

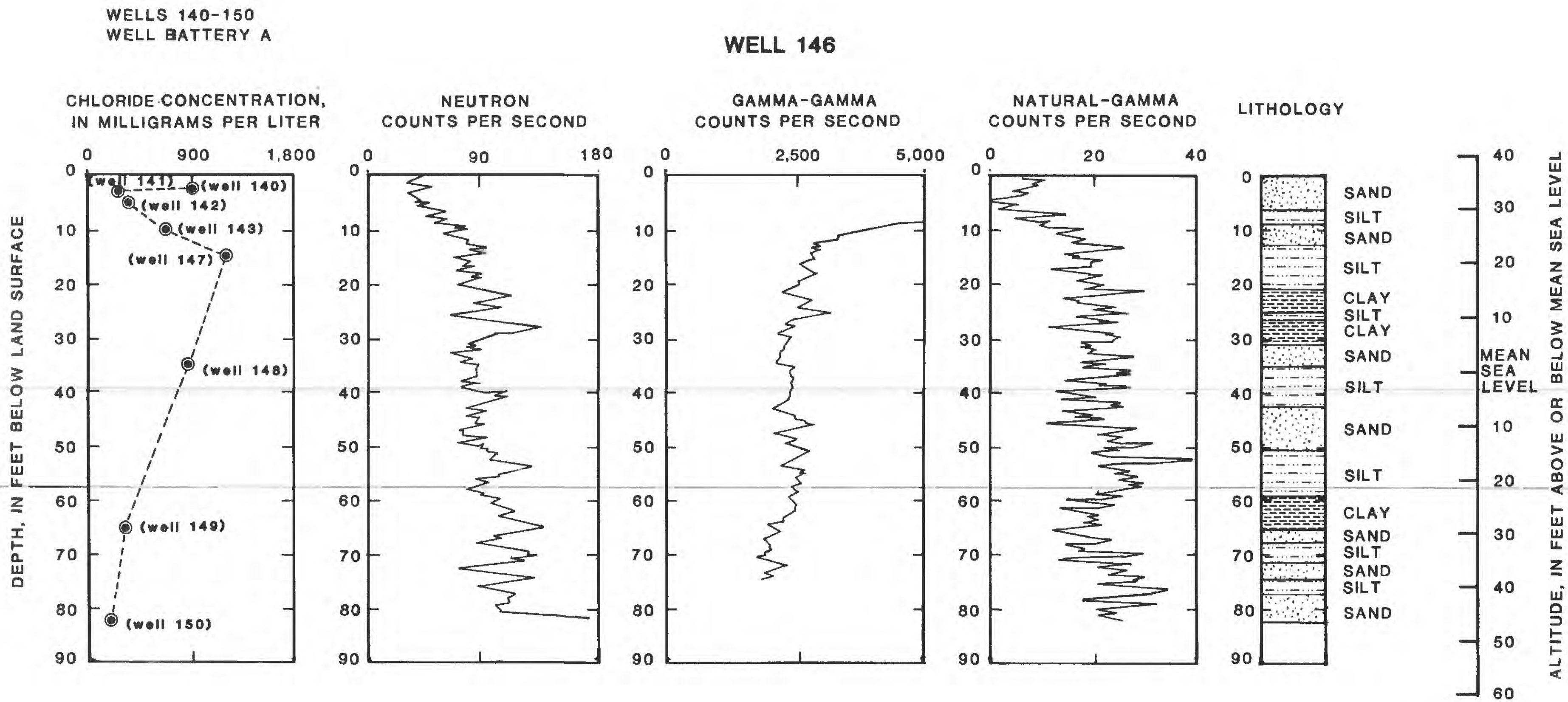


Figure 10.--Lithology and geophysical logs for well 146 and chloride concentration in selected wells at well battery A.

A seasonal reversal in the downward ground-water flow was documented at well battery A (fig. 9). This reversal of vertical gradient coincides with periods of heavy rainfall. The driller's log and borehole geophysical data (well 146, well battery A, fig. 10) indicated that well 149 was screened in a sandy material, and well 147 was screened in a much shallower silty clay. If there was good hydraulic connection between the sand lenses and the coarse-grain alluvial fan material, then, during heavy rainfall events, recharge may occur more rapidly in the permeable sand lenses than in the silty-clay material.

The altitude of the potentiometric surface of the Lajas Valley alluvial aquifer is more than 50 feet above mean sea level in the northern and southern parts of the valley, about 12 feet above mean sea level in the central part of the valley, and is approximately at sea level near Bahía de Boquerón (fig. 11). The principle direction of horizontal ground-water flow is from the foothills toward the center of the valley and then either east to the Bahía de Guánica or west to Bahía de Boquerón.

Although long-term fluctuations in the potentiometric surface of the Lajas Valley aquifer cannot be evaluated because of the lack of historical data, seasonal fluctuations in the potentiometric surface are evident (fig. 12). Water-level data collected from 1981 to 1986 indicated that generally heads begin to decline in December or January and reach a low in June, July, or August. Recovery of the potentiometric surface usually begins in September. The greatest seasonal change in head in well 105 during the 5-year period from 1982 to 1986 was 2 feet. The maximum change in head in well 149 during a 2.5-year period, from 1984 to 1986 was approximately 4.5 feet (fig. 9).

The Lajas Valley aquifer is recharged by streamflow and rainfall. Anderson (1977) estimated the annual recharge to the aquifer to be about 2 inches. Most of this recharge occurs through the coarse grain alluvial fan deposits that lie near the edge of the alluvial valley. In the central part of the valley, recharge from rainfall is limited by the less permeable clays near the surface of the alluvial deposits.

Discharge of ground water can occur through pumpage, evapotranspiration, and subsurface seepage. Subsurface seepage occurs at Laguna Cartagena, along the extensive drainage canal system, and at the mangrove swamp at Boquerón (Anderson, 1977). Subsurface seepage also occurs in the form of base flow to Bahía de Boquerón in the western part of the valley and Río Loco and Bahía de Guánica in the eastern part of the valley.

Availability of Ground Water

Ground-water availability is a function of the ability of an aquifer to transmit, store, and release water to wells. Transmissivity is a measure of the aquifer's ability to transmit water and is a product of the aquifer's hydraulic conductivity and the aquifer thickness. The storage coefficient

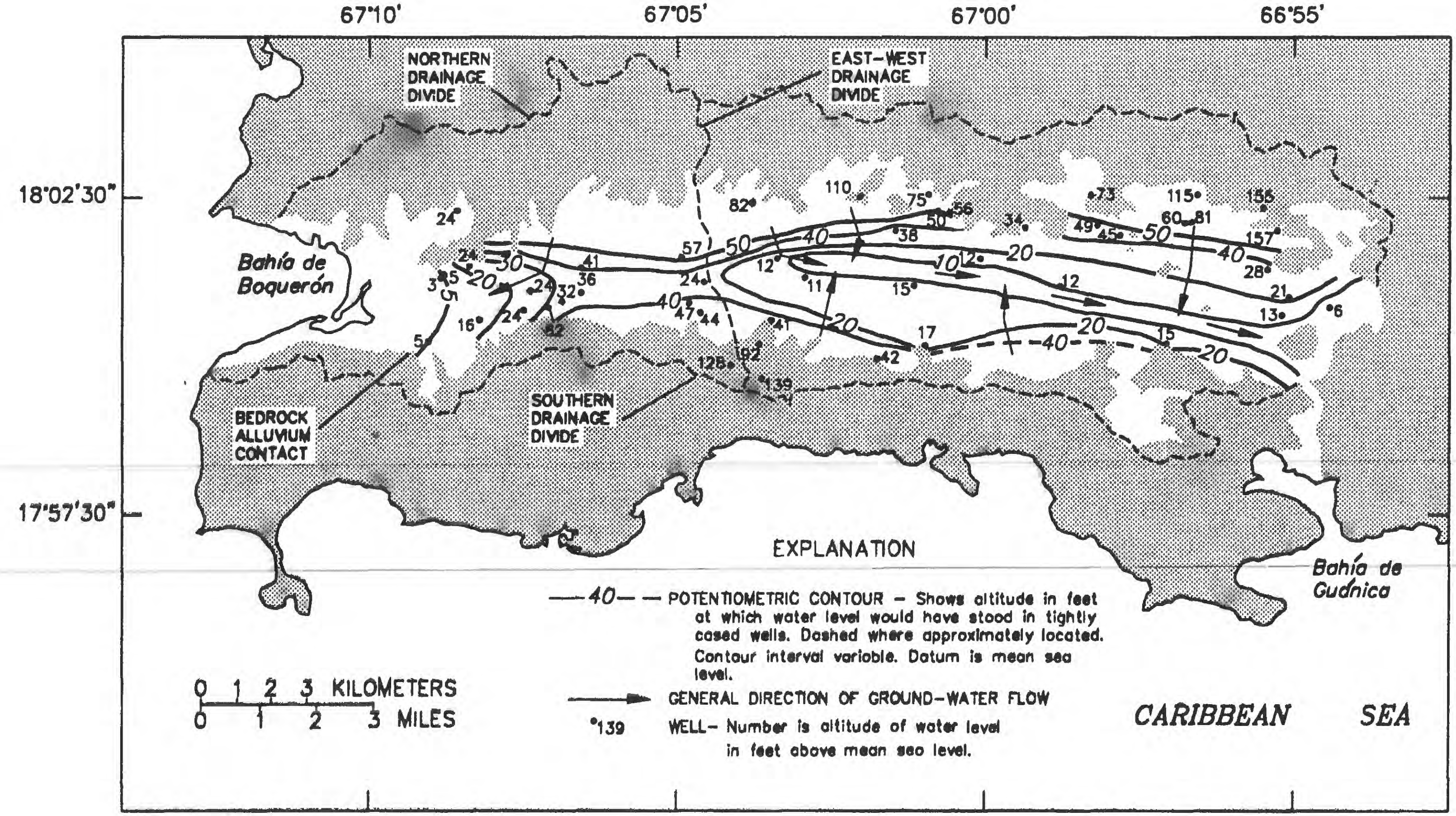


Figure 11.--Potentiometric surface of the Lajas Valley alluvial aquifer, March 1986.

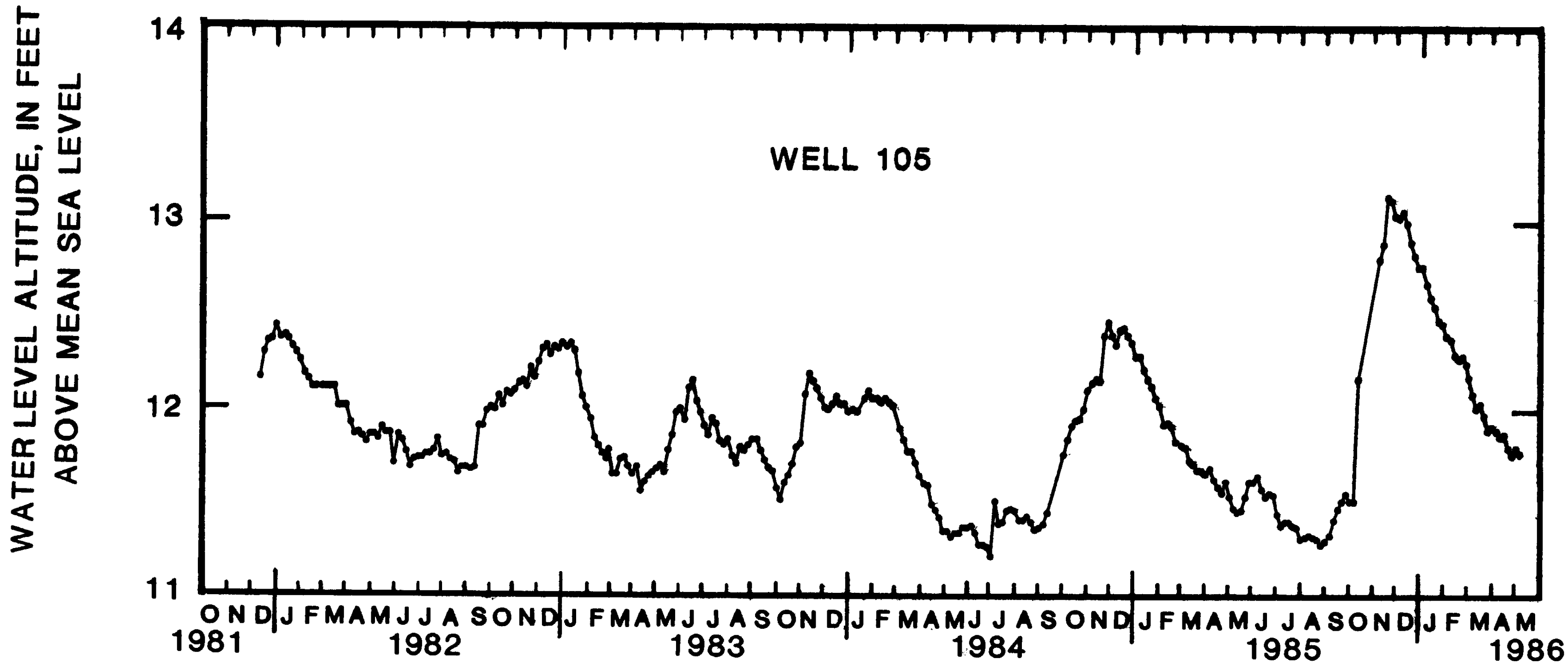


Figure 12.--Weekly water levels in well 105, December 1981 to May 1986.

is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The mathematical definitions of these hydraulic characteristics are beyond the scope of this investigation, but are presented in Lohman (1979).

Hydraulic characteristics of the aquifer were determined from an aquifer test conducted at well 73, and specific capacity estimates for selected wells throughout the valley. The aquifer test was conducted in the La Plata basin area of the Lajas Valley (fig. 1). Based on the results of this test, the transmissivity of the aquifer was estimated at 7,500 ft^2/d (feet squared per day) and the storage coefficient of the aquifer was estimated at 0.00093. Transmissivity values calculated from ten specific-capacity tests ranged from 670 to 8,020 ft^2/d (table 2).

Pumpage data for wells throughout the study area indicated that well yields ranged from 5 to 674 gal/min (gallons per minute) (appendix). Based on measurements in wells 161 and 162, well yields in the sedimentary rock ranged from 50 to 200 gal/min. Wells in the alluvial material commonly yielded 30 to 100 gal/min along the southern edge of the valley and 5 to 200 gal/min in the central part of the valley. Wells screened in the alluvial fan deposits on the northern side of the valley yielded as much as 300 gal/min. Where these alluvial fan deposits are in hydraulic connection with the underlying sedimentary rock, reported yields were as high as 674 gal/min. Wells drilled near the town of Lajas and in the La Plata basin were reported to yield 500 and 674 gal/min respectively.

Ground-Water Use

In 1986 ground-water use in the Lajas Valley was estimated to be 2.95 Mgal/d (million gallons per day) (table 3). Only 38 of the 160 wells inventoried in the study area were in use in 1986 (appendix). Of the 38 wells in use, only three were municipal wells. The remainder of the wells in use were used for irrigation, watering livestock, or domestic purposes. Many of the inventoried wells had been abandoned because of high chloride concentrations.

Ground-Water Quality

The suitability of ground water for domestic, agricultural, or industrial use is dependent upon its dissolved mineral content. Much of the dissolved mineral content of ground water is derived from the soil and rocks through which the water passes. The mineral content of ground water also reflects the extent to which saline water in the aquifer has been diluted by freshwater recharge.

Samples were collected from 20 wells in the Lajas Valley and analyzed for principal cations and anions, iron, manganese, barium, and aluminum. The results of these analyses are given in table 4. Water samples from 19 of these wells had dissolved solids or chloride concentrations that exceeded the recommended U.S. Environmental Protection Agency (EPA) drinking water standards

Table 2.--*Transmissivity of the alluvial aquifer estimated from specific capacity data (estimates based on method described by Meyer, 1963)*
[units - (gal/min)/ft, gallons per minute per foot of drawdown; ft^2/d, feet squared per day]

Well number (appendix)	Specific capacity [(gal/min)/ft]	Transmissivity (ft^2/d)
30	6	1,740
31	20	7,350
36	25	8,020
45	8	2,406
53	5	1,340
71	5	1,340
100	7	2,005
102	2	670
103	3	935
105	3	935

Table 3.--*Estimated ground-water use in Lajas Valley, 1986*

Type of use	Number of wells	Estimated water use (million gallons per day)
Agricultural	24	2.00
Domestic	11	0.16
Municipal	3	0.79
Total	38	2.95

Table 4.--*Chemical analyses of ground water in Lajas Valley*

[units - mg/L, milligrams per liter]

Well number (appendix)	Date of sampling	Depth of well sampled (feet)	Type of casing	Silica dissolved (mg/L as Si)	Calcium dissolved (mg/L as Ca)	Magnesium dissolved (mg/L as Mg)	Sodium dissolved (mg/L as Na)	Potassium dissolved (mg/L as K)	Alkalinity field (mg/L as (CaCO3)	Sulfate dissolved (mg/L as SO4)	Chloride dissolved (mg/L as Cl)	Fluoride dissolved (mg/L as F)	Nitrate dissolved (mg/L as NO3)
012	06-19-86	2	OPEN HOLE	25	10	9.4	42	4.0	51	19	57	0.3	4.50
034	06-20-86	80	STEEL	35	120	98.0	400	2.4	426	190	640	0.8	27.00
036	06-20-86	111	STEEL	44	94	44.0	51	0.6	379	97	42	0.4	5.30
051	06-20-86	32	STEEL	42	71	30.0	120	0.7	403	78	55	0.6	5.20
085	06-20-86	40	STEEL	40	43	35.0	570	1.2	661	180	450	0.6	5.60
138	06-19-86	170	PLASTIC	31	280	500.0	1,500	3.3	544	1,300	3,200	0.3	0.23
139	06-18-86	154	PLASTIC	29	600	590.0	3,500	3.9	315	2,100	6,400	0.4	1.50
140	06-19-86	2	PLASTIC	24	560	280.0	870	23.0	963	2,100	960	0.3	0.10
141	07-18-86	3	PLASTIC	35	330	100.0	260	6.5	1,095	490	210	0.3	0.10
147	06-19-86	15	PLASTIC	9	500	419.0	1,099	2.2	633	3,300	2,400	0.6	0.15
148	06-19-86	35	PLASTIC	17	270	370.0	1,600	3.3	506	430	850	0.8	0.10
149	06-19-86	65	PLASTIC	22	100	120.0	310	6.7	204	900	230	0.3	0.10
151	06-19-86	25	PLASTIC	16	480	490.0	4,200	3.5	282	4,600	5,000	0.4	0.10
153	06-19-86	50	PLASTIC	29	62	100.0	1,400	1.6	585	960	1,800	0.5	0.10
155	06-19-86	203	PLASTIC	16	780	680.0	1,900	5.7	263	1,100	5,800	0.2	0.10
156	06-18-86	166	PLASTIC	28	140	67.0	830	3.6	431	500	1,100	0.5	0.10
159	06-18-86	47	PLASTIC	28	38	23.0	690	0.9	682	130	610	1.1	0.10
160	06-18-86	37	PLASTIC	24	190	120.0	1,700	3.1	643	640	2,700	0.5	0.10
161	03-10-87	17	OPEN HOLE	30	51	30.0	259	1.0	517	219	70	0.5	0.39
161	03-10-87	60	OPEN HOLE	33	65	39.0	670	0.6	559	400	610	0.5	1.70
161	03-10-87	184	OPEN HOLE	29	130	100.0	610	2.2	475	460	900	0.6	0.42
161	03-10-87	236	OPEN HOLE	28	200	179.0	1,099	4.3	395	680	2,000	0.5	0.19
161	03-10-87	346	OPEN HOLE	72	330	230.0	1,100	6.6	353	860	2,400	0.6	0.11
162	03-31-87	68	OPEN HOLE	19	66	39.0	340	3.8	250	85	550	0.3	0.40
162	04-01-87	476	OPEN HOLE	10	73	53.0	510	12.0	203	80	929	0.5	0.42

Table 4.--*Chemical analyses of ground water in Lajas Valley*--Continued

[units - mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celcius; µg/L, micrograms per liter; NA, data not available]

Well number (appen-dix)	Depth of well sampled (feet)	Dis-solved solids (mg/L)	Hard-ness (mg/L as CaCO3)	Hard-ness noncar-bonate (mg/L CaCO3)	Spe cific con-duct-ance (µS/cm)	pH (units)	Temp-ature (deg C)	Iron dis-solved (µg/L as Fe)	Man-ganese dis-solved (µg/L as Mn)	Barium dis-solved (µg/L as Ba)	Alu-minum dis-solved (µg/L as Al)
012	2	200	64	13	379	6.3	27.0	19	13	NA	NA
034	80	1,700	703	264	3,130	7.7	26.5	20	10	NA	NA
036	111	570	416	84	955	7.2	25.5	3	3	NA	NA
051	32	640	301	0	1,030	7.3	26.5	48	1	NA	NA
085	40	1,700	251	0	2,840	7.7	28.0	10	30	NA	NA
138	170	7,100	2,782	2,229	10,600	7.3	26.0	50	60	NA	NA
139	154	13,230	3,926	3,606	19,300	7.0	28.0	140	60	NA	NA
140	2	5,400	2,551	1,602	6,500	6.9	26.5	2,600	12,000	NA	NA
141	3	1,470	1,236	270	3,200	6.8	26.5	24,000	11,000	NA	NA
147	15	8,100	2,974	2,456	7,470	7.0	25.5	230	4,600	NA	NA
148	35	3,000	2,197	1,686	9,200	7.0	25.5	810	2,600	NA	NA
149	65	1,800	744	544	2,550	6.4	25.5	1,200	2,800	NA	NA
151	25	15,000	3,215	2,948	19,200	7.5	27.0	220	940	NA	NA
153	50	4,700	566	0	7,320	7.5	27.0	70	310	NA	NA
155	203	10,000	4,747	4,491	15,400	7.3	26.0	320	5,400	NA	NA
156	166	2,900	625	189	4,860	7.1	29.5	260	840	NA	NA
159	47	1,900	190	0	3,240	7.4	29.0	30	10	NA	NA
160	37	5,800	968	315	9,210	7.1	26.5	310	2,400	NA	NA
161	17	970	250	0	1,450	8.2	28.0	4	43	20	10
161	60	2,200	320	0	3,410	8.0	27.0	20	10	100	10
161	184	2,500	740	260	3,980	8.1	26.0	10	30	100	10
161	236	4,399	1,200	850	6,930	7.9	25.5	80	230	100	30
161	346	5,200	1,800	1,400	7,820	7.8	25.5	30	80	100	10
162	68	1,300	330	76	2,410	8.9	32.0	60	30	100	80
162	476	1,799	410	200	3,570	7.3	28.0	30	1,299	400	10

Table 5.--*Concentrations of iron, manganese, dissolved solids, and chloride exceeding U.S. Environmental Protection Agency drinking water standards, in ground water from wells in Lajas Valley*

[units - µg/L, micrograms per liter; mg/L, milligrams per liter; < indicates concentration was less than recommended limit; U.S. Environmental Protection Agency drinking water standards for iron, manganese, dissolved solids, and chloride are 300 µg/L, 50 µg/L, 500 mg/L, and 250 mg/L, respectively; source: U.S. Environmental Protection Agency, 1973, 1989]

Well number (appendix)	Iron (µg/L)	Manganese (µg/L)	Dissolved solids (mg/L)	Chloride (mg/L)
034	<	<	1,700	640
036	<	<	570	<
051	<	<	640	<
085	<	<	1,700	450
138	<	60	7,100	3,200
139	<	60	13,230	6,400
140	2,600	12,000	5,400	960
141	24,000	11,000	1,470	<
148	810	260	12,000	850
147	<	4,600	8,100	2,400
149	1,200	2,800	1,800	<
151	<	940	15,000	5,000
153	<	310	4,700	1,800
155	320	5,400	10,000	5,800
156	<	840	2,900	1,100
159	<	<	1,900	610
160	310	2,400	5,800	2,700
[1]161/17	<	<	970	<
161/60	<	<	2,200	610
161/184	<	<	2,500	900
161/236	<	230	4,399	2,000
161/346	<	80	5,200	240
162/68	<	<	1,300	550
162/476	<	1,299	1,799	929

[1]Number after slash indicates depth at which sample was collected.

of 500 and 250 mg/L (milligrams per liter), respectively (table 5) (U.S. Environmental Protection Agency, 1973). Samples from 13 of the wells had concentrations of dissolved iron or manganese that exceeded the recommended EPA drinking water standards of 300 and 50 μg/L (micrograms per liter), respectively (U.S. Environmental Protection Agency, 1986).

Elevated iron and manganese concentrations found in the ground water in the study area might be the result of the dissolution of iron and manganese concentrated in the sediments by organic activity during deposition of the sediments (McGuinness, 1948). The elevated iron and manganese concentrations might also be the result of weathering of magnetite, hematite, and manganese-bearing minerals found in the bedrock ridges surrounding the Lajas Valley.

The high concentration of dissolved solids found in most of the samples were due primarily to high concentrations of sodium and chloride ions. Elevated chloride concentrations in ground water have been reported in the Lajas Valley (Bonnet and Brenes, 1958; Lugo-López, and others, 1959; Vázquez and Vélez, 1967). However, Anderson (1977) reported a decrease in chloride concentrations with an increase in well depth, which has led to speculation that the alluvial deposits may be underlain by deposits containing less mineralized water. To assess the relation between chloride concentration and depth, water samples were collected from wells in the three well batteries and at selected intervals in wells 161 and 162. Analysis of samples collected from wells 161 and 162 indicated an increase in chloride concentration with depth (fig. 13). At well batteries B and C there was a decrease in chloride concentration with depth, to a depth of about 50 feet, but concentrations increased with depth below 50 feet (fig. 14). The higher chloride concentrations at shallow depths at well batteries B and C could reflect the concentrating effect of evapotranspiration. At greater depths, the increase in chloride concentration is probably attributable to connate water that has not been flushed out of the aquifer. The presence of connate water would also be the most likely explanation for the increase in chloride concentration in wells 161 and 162.

The change in chloride concentration with depth at well battery A varies anomalously (figs. 10 and 14). The chloride concentration near land surface (well 140) was higher than that of the next deepest well (well 141). The chloride concentration then began to increase with depth (wells 142, 143, and 147) to a depth of 15 feet. This anomaly is difficult to explain. Perhaps the high chloride concentration in well 140 was due to a high mineral content in the near surface soil zone due to evapotranspiration. The lower chloride concentration in well 141 and the higher chloride concentration in wells 142, 143, and 147, could be due to the nonhomogeneity of the alluvial deposits (fig. 10). Chloride concentrations decreased with depth in the wells deeper than 15 feet (wells 148, 149 and 150). This decrease may be due to the greater occurrence of coarse sand lenses at these depths (15 to about 80 feet) and the increased potential for flushing of the sand lenses by recharge through

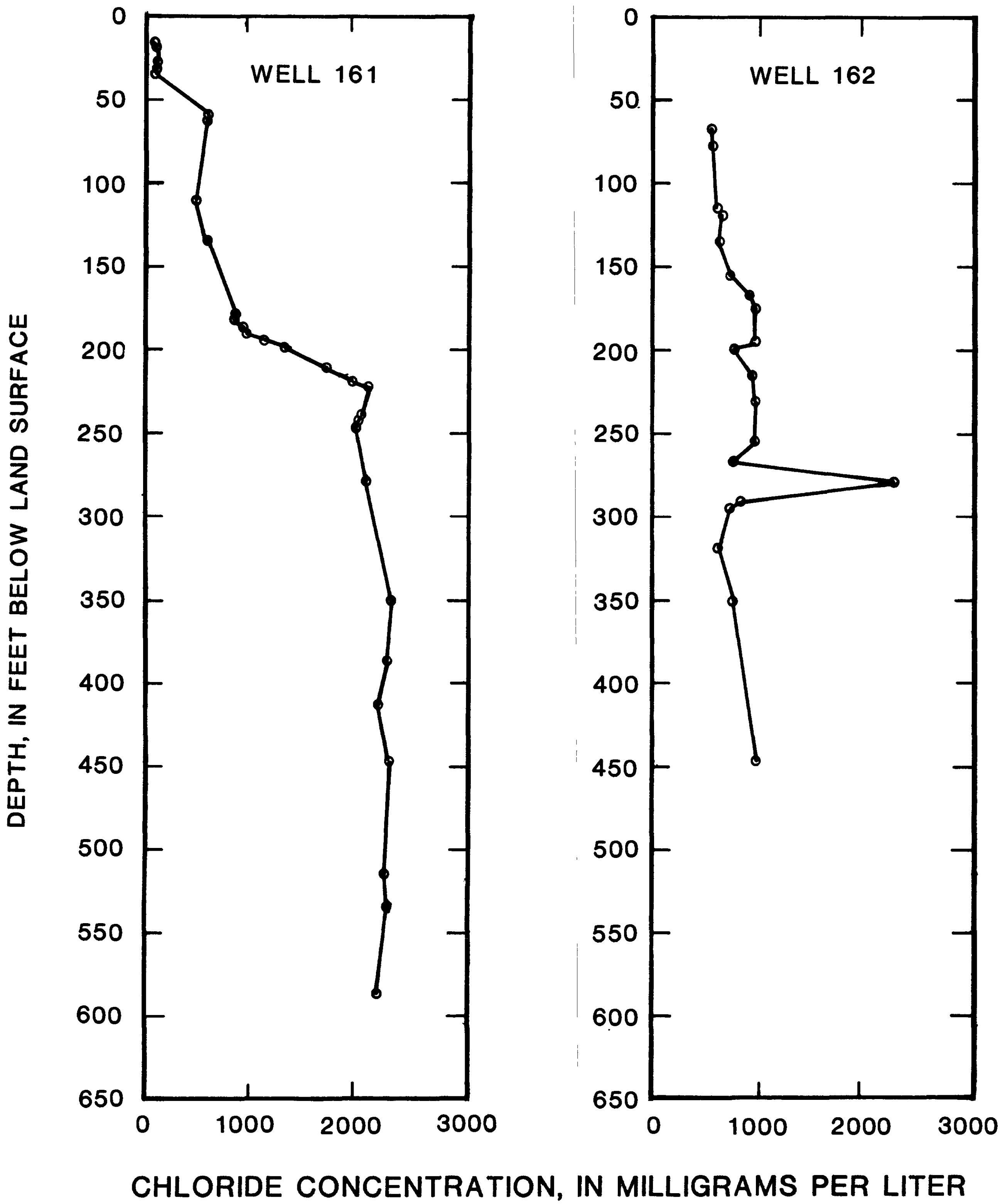


Figure 13.--Chloride concentration with depth for wells 161 and 162, March 1987.

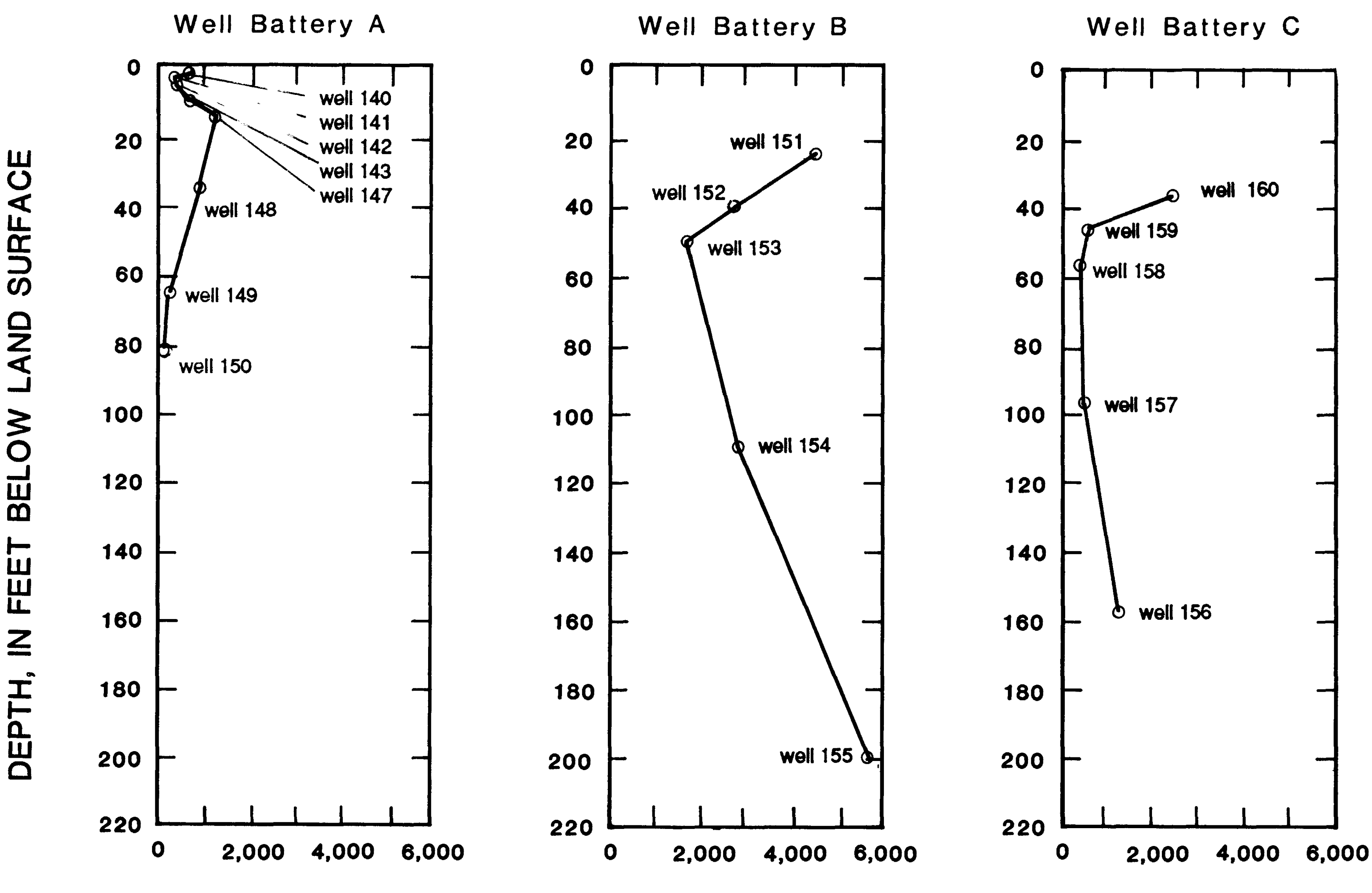


Figure 14.--Mean annual chloride concentration with depth at well batteries A, B and C, Lajas Valley, 1986

Table 6.--*Specific conductance and chloride concentrations in ground water at selected wells in Lajas Valley, March 1986*

[units - µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; ---, indicates data not available; * indicates sample exceeds 1973 U.S. Environmental Protection Agency drinking water standard of 250 milligrams per liter for chloride; Source: U.S. Environmental Protection Agency, 1973]

Well number (appendix)	Specific conductance (µS/cm)	Chloride concentration (mg/L)
01	115	30
02	690	180
03	6,000	* 1,800
04	490	120
05	229	40
07	12,100	* 3,740
09	700	120
12	370	50
14	2,220	* 260
15	1,650	110
16	2,350	* 350
19	1,100	130
20	520	40
22	3,490	* 670
29	1,970	* 250
34	3,200	* 640
36	1,160	70
37	800	50
39	2,150	240
42	810	30
43	830	50
45	800	50
46	2,100	* 310
47	2,350	* 440
48	2,330	* 425
51	1,180	50
53	920	20
54	940	30
55	1,120	---
56	2,030	180

Table 6.--*Specific conductance and chloride concentrations in ground water at selected wells in Lajas Valley, March 1986--Continued*

[units - µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; ---, indicates data not available; * indicates sample exceeds 1973 U.S. Environmental Protection Agency drinking water standard of 250 milligrams per liter for chloride; Source: U.S. Environmental Protection Agency, 1973]

Well number (appendix)	Specific conductance (µS/cm)	Chloride concentration (mg/L)
58	1,020	80
60	5,300	* 1,460
62	1,020	50
63	1,820	220
64	2,280	* 340
65	2,050	* 355
66	1,480	160
68	2,600	---
69	2,710	* 480
70	1,790	240
72	1,150	100
73	800	45
75	82	45
76	1,380	140
78	1,230	75
84	1,550	175
85	2,920	* 445
86	421	60
87	850	60
88	1,120	60
90	1,430	175
94	2,580	240
96	5,200	* 1,600
97	1,290	100
99	750	---
103	1,200	90
109	820	130
110	439	50
111	1,500	* 325
117	1,010	55

Table 6.--*Specific conductance and chloride concentrations in ground water at selected wells in Lajas Valley, March 1986--Continued*

[units - µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; ---, indicates data not available; * indicates sample exceeds 1973 U.S. Environmental Protection Agency drinking water standard of 250 milligrams per liter for chloride; Source: U.S. Environmental Protection Agency, 1973]

Well number (appendix)	Specific conductance (µS/cm)	Chloride concentration (mg/L)
119	1,230	60
120	1,600	220
122	1,120	100
124	1,350	100
125	1,360	100
126	1,010	80
127	1,230	100
132	200	15
133	2,500	190
134	2,550	* 410
138	9,200	* 2,980
139	17,100	* 6,760
149	2,646	* 260
155	16,200	* 5,700
156	4,750	* 1,280

the alluvial fan deposits. If deeper test wells were drilled at well battery A, elevated chloride concentrations, such as those measured at well batteries B and C, might be encountered.

During March 1986, water samples were collected from all available wells located in the Lajas Valley in order to map chloride concentrations (table 6). The wide variation in chloride concentration with depth, in combination with the number of wells that have different screen intervals with respect to land surface datum, necessitated the construction of three separate chloride concentration maps. Wells used to prepare these maps were divided into the following categories according to depth; 39 feet or less, 40 to 79 feet, and greater than 79 feet (fig. 15, 16 , and 17). This permitted a more accurate method of describing chloride concentrations in the valley.

Chloride concentrations generally were less than 200 mg/L in wells along the northern edge and locally along the southern edge of the alluvial valley (fig. 15, 16, and 17). The relatively low chloride concentrations in these areas can be attributed to ground-water recharge from the more permeable alluvial fans. Wells in the center of the valley were found to have chloride concentrations as high as 6,700 mg/L. The highest chloride concentrations were generally in water from wells deeper than 79 feet. Wells drilled to depths of 40 to 79 feet generally had the lowest chloride concentrations. This pattern is similar to the patterns observed at well batteries B and C and is attributed to the effect of evapotranspiration at shallow depths and connate water at greater depths.

SUMMARY

The principal aquifer in the Lajas Valley is a confined aquifer consisting of alluvial deposits of Quaternary age. The altitude of the potentiometric surface of the Lajas Valley alluvial aquifer ranges from more than 50 feet above mean sea level along the northern and southern boundaries of the valley to about 12 feet above mean sea level in the central part of the valley. Values of aquifer transmissivity range from 670 to 8,020 square feet per day; and the storage coefficient of the aquifer is approximately 0.00093.

Water-quality analyses of ground water in the alluvial aquifer indicated that, at several sites, the drinking water standards for iron, manganese, chloride, and total dissolved solids established by the U.S. Environmental Protection Agency were exceeded. Elevated chloride concentrations in excess of 5,000 mg/L were measured in water samples from several wells.

Consolidated clastic and carbonate strata of Cretaceous and Tertiary age underlie the alluvial aquifer. Chloride concentrations in ground water in wells screened in this rock ranged from 100 to 2,100 mg/L.

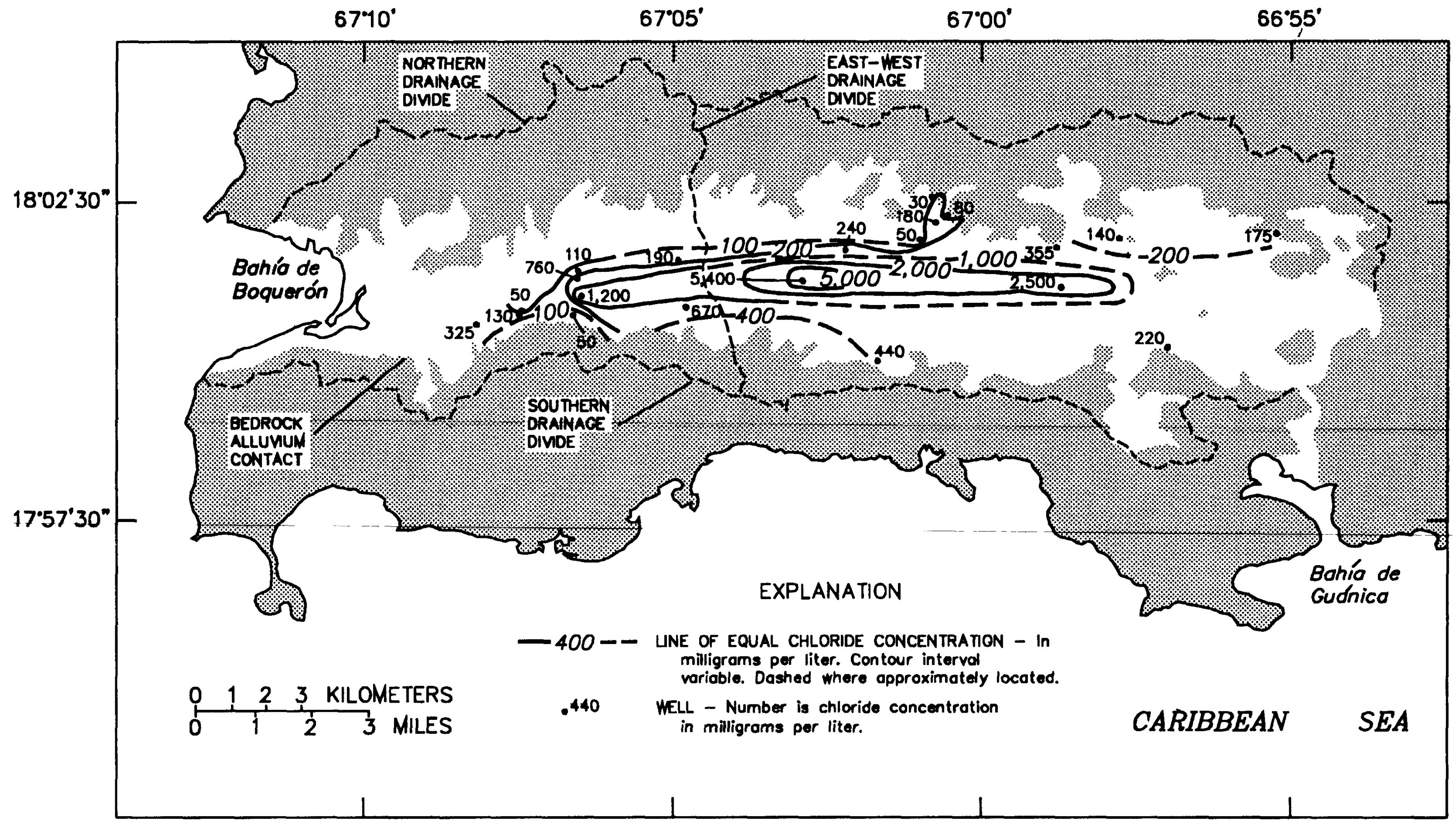


Figure 15.–Chloride concentrations in water from wells screened at depths of 39 feet or less, in the Lajas Valley, March 1986.

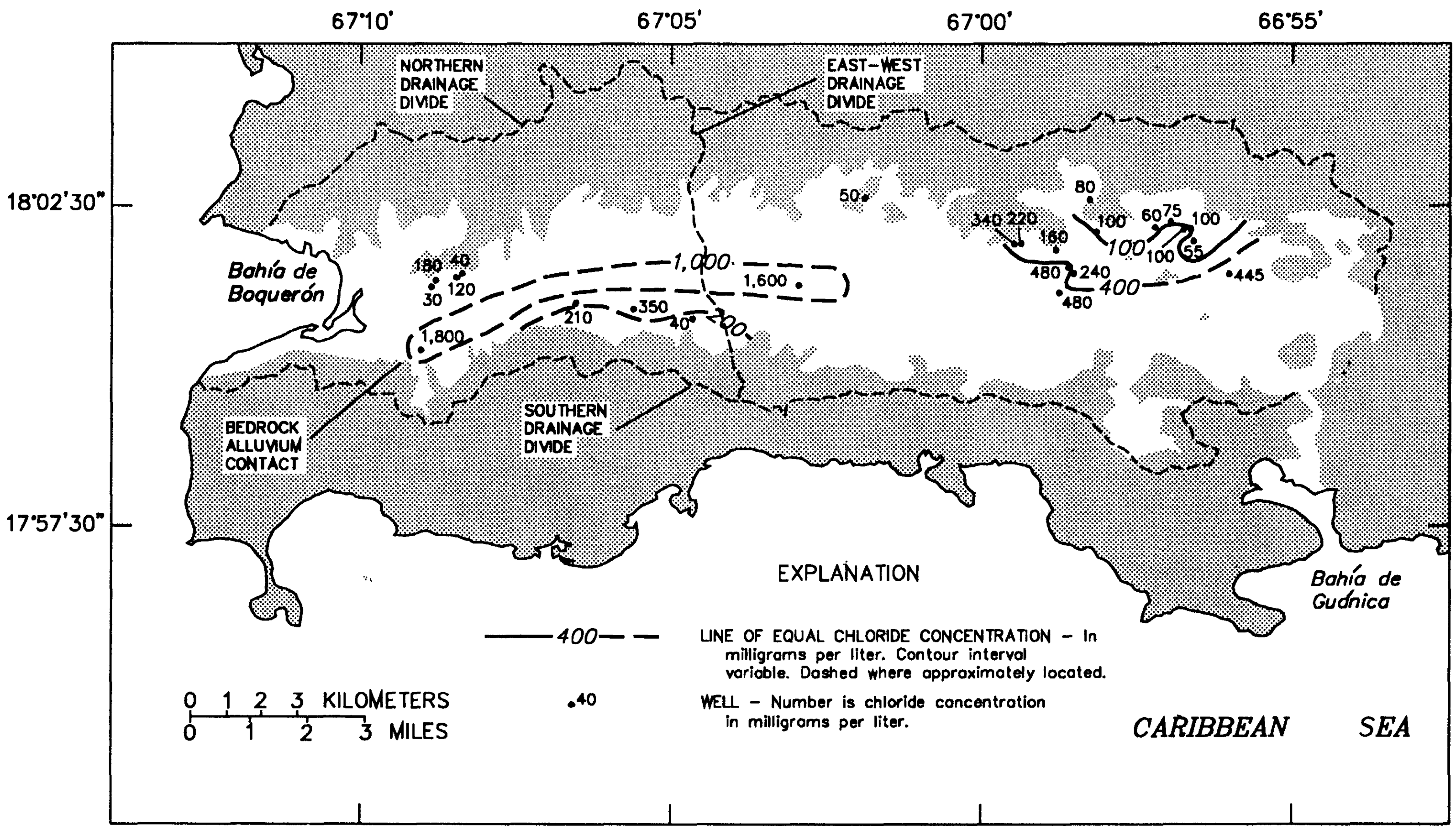


Figure 16.--Chloride concentrations in water from wells screened at depths of 40 to 79 feet, in the Lajas Valley, March 1986.

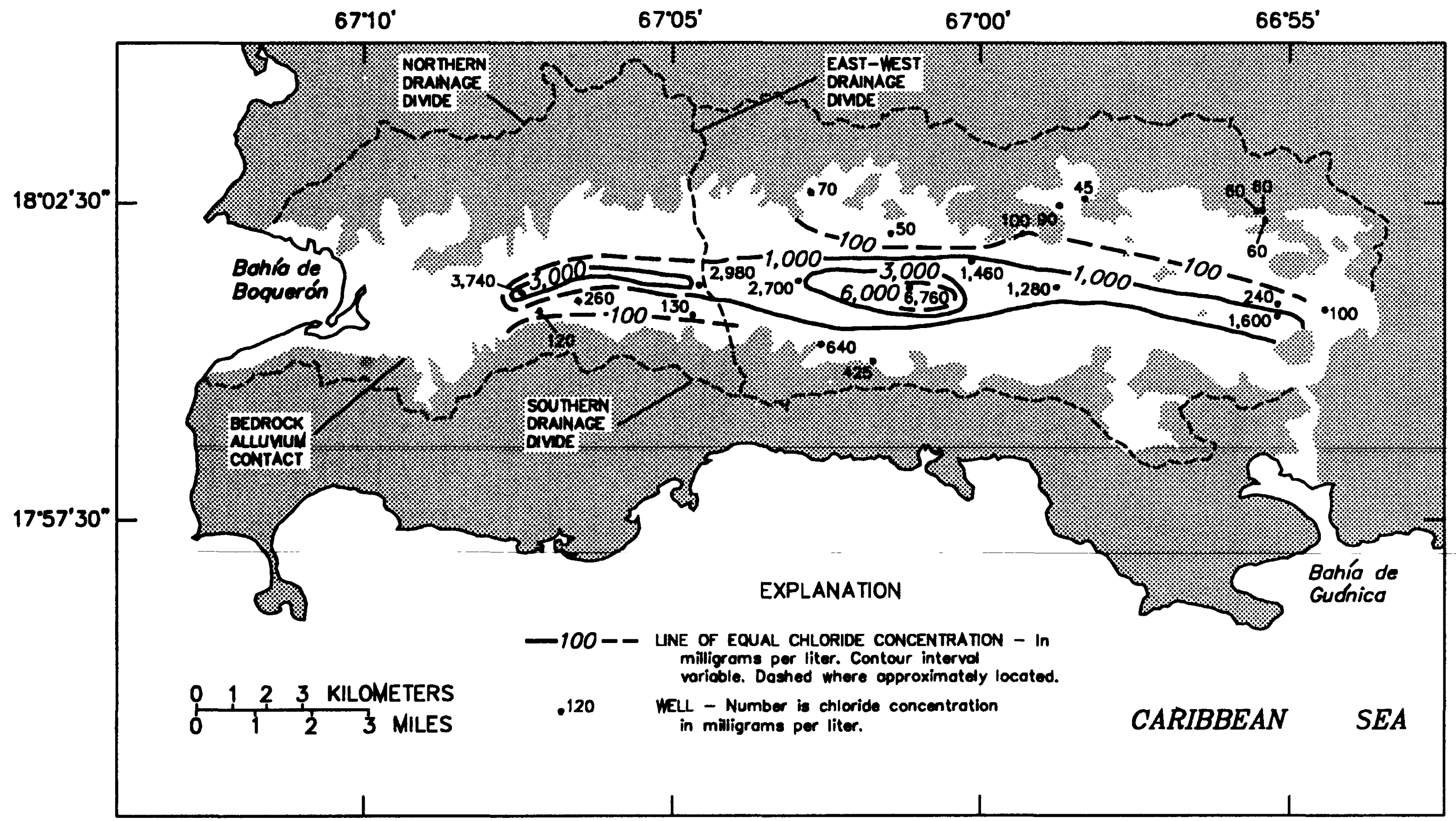


Figure 17.--Chloride concentrations in water from wells screened at depths greater than 79 feet, in the Lajas Valley, March 1986.

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Appendix--*Description of wells in the Lajas Valley*

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
01	Llanos Costa Aba. dairy well 3	NU	180114067084900 (1-67.8-3-72)	1957	80	74	----	----	----	----
02	Llanos Costa aba. dairy well 4	NU	180114067084800 (1-67.8-4-72)	1960	73	36	----	----	----	----
03	C. Pabón windmill well at road 301	A	180015067090400 (0-67.9-1-80)	1957	95	45	screen 45-90	----	----	----
04	Llanos Costa hand pump well	A	180121067082600	----	----	42	----	----	----	----
05	Llanos Costa new windmill	A	180125067082400	----	----	51	----	----	----	----
06	Rodolfo Morales well	NU	180158067072100	----	----	200	----	----	----	----
07	Llanos Costa south well 4	NU	180101067072400 (1-67.7-4-97)	----	----	----	----	----	----	----
09	Zanoget well	D	180042067070600	----	----	106	----	----	----	----
10	Laguna Cartagena old windmill	NU	180054067065400	----	----	----	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
12	Laguna Cartagena house well	NU	180047067063900	----	----	2	----	----	----	----
14	Laguna Cartagena aba. well	NU	180119067063500 (1-67.6-3-64)	----	----	38	----	----	----	----
15	Hacienda Desengaño well	NU	180122067063500 (1-67.6-4-65)	----	20	20	----	----	----	----
16	Laguna Cartagena Maguayo well (windmill)	A	180046067053700	----	----	----	----	----	----	----
18	Maguayo aba. well 6 (DRY WELL)	NU	180038067044900 (0-67.4-6-32)	----	----	32	----	----	----	----
19	Maguayo aba. well 2	NU	180041067043901 (0-67.4-2-34)	----	----	102	----	----	----	----
20	Maguayo aba. well 3	NU	180041067043902 (0-67.4-3-34)	----	----	----	----	----	----	----
22	Maguayo aba. well 7	NU	180050067045100 (0-67.4-7-12)	----	----	17	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
23	Hacienda Resolución aba. well 2	NU	180134067052500 (1-67.5-2-46)	----	----	----	----	----	----	----
24	Hacienda Resolución aba. well 1	NU	180134067050900 (1-67.5-1-49)	----	----	----	----	----	----	----
25	Hacienda Resolución aba. well 6	NU	180134067045900 (1-67.4-6-41)	----	----	----	----	----	----	----
26	Hacienda Resolución aba. well 5	NU	180135067044800 (1-67.4-2-43)	----	200	----	----	4 soil 62 clay 134 limestone	----	----
27	Experimental station aba. well 2 (DRY WELL)	NU	180143067041700	----	----	----	----	----	----	----
29	Olivares well	NU	175909067041001 (59-67.4-2-19)	----	----	77	----	----	----	----
30	Experimental agriculture station fish pond well	NU	180227067035700 (2-67.3-2-51)	1951	97	73	casing perforated 0 - 73	----	258	6
31	San Rafael farm well	NU	180223067035000 (0-67.3-1-62)	----	140	52	----	----	500	20

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
32	Road 305 old windmill	NU	180032067033500 (0-67.3-4-45)	----	----	35	----	----	----	----
34	López Díaz dairy well (windmill)	A	180015067023500 (0-67.2-1-75)	----	----	80	----	----	----	----
36	Carlos Pagán well	A	180235067024400 (2-67.2-5-43)	1950	111	100	----	----	500	25
37	Yuyín well	NU	180227067020400	----	----	9	----	----	----	----
39	Leonsillo windmill well	D	180141067021700	----	----	26	----	----	----	----
42	Quebrada well 8 (hand pump)	A	180227067015800 (2-67.1-8-51)	----	----	31	----	----	----	----
43	Germán airplane engine well	NU	180232067014800	----	----	57	----	----	----	----
45	Buenos Aires well	NU	180155067012500 (1-67.1-4-6)	1950	86	76	----	----	317	8
46	La Costa well 1 (hand pump)	A	175959067014701	----	----	100	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
47	La Costa aba. well 2	NU	175959067014702	----	----	25	----	----	----	----
48	La Costa aba. well 3	NU	175959067014703	----	----	100	----	----	----	----
49	Brick well	NU	180010067010100	----	----	10	----	----	----	----
51	J. Lugo's windmill well	NU	180153067010500 (1-67.1-6-30)	1961	32	32	----	----	----	----
52	J. Lugo's aba. well 2	NU	180226067005900 (2-67.0-2-51)	----	----	----	----	----	----	----
53	J. Lugo's aba. well 1	NU	180229067005500 (2-67.0-1-51)	----	----	80	----	----	80-100	5
54	Felius domestic well	NU	180229067005100	----	32	14	----	----	5	----
55	Guillermo Rodríguez hand pump well	D	180214067005100	----	----	32	----	----	10	----
56	Juan Hernández hand pump well	D	180206067004900	----	----	20	----	----	6	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
57	Pedro Toro	NU	180206067003900	----	----	18	----	----	6	----
58	Pedro López jet pump	D	180212067003600	----	----	19	----	----	9	----
59	Moisés Cruz hand pump well	NU	180221067003800	----	----	27	----	----	8	----
60	Valley well	NU	180117067001300	----	----	187	----	----	----	----
62	Ismael Almodóvar windmill well	A	180239066595400	----	----	----	----	----	----	----
63	La Plata windmill well 1	A	180149066592400	----	----	55	----	----	----	----
64	La Plata windmill well 2	A	180147066593000	----	----	55	----	----	----	----
65	Emilio Alvarez school well 1	NU	180145066585200	----	----	2	----	----	----	----
66	Emilio Alvarez school well 2	NU	180145066585000	----	----	52	----	----	----	----
68	Gelabert new windmill well	A	180137066583700	----	----	----	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
69	Bovy well	NU	180129066583800	----	----	----	----	----	----	----
70	Shack well	A	180125066583200	----	----	68	----	----	----	----
71	Zayas well	NU	180147066581000 (1-66.58-2-29)	----	140	100	----	----	300	5
72	Samuel Mercado hand pump well	A	180201066581100	----	----	40	----	----	7	----
73	Sabana Grande prawn farm well 1	A	180231066582000 (2-66.58-1-47)	----	162	77	casing preforated 77-162	----	674	73
75	(AAA) Prasa well, near shrimp farm	M	180233066580800 (2-66.58-2-49)	----	----	103	screened 103 - 150	----	450	----
76	Federico Santana well 1	NU	180153066575300 (1-66.57-1-12)	----	----	21	----	----	----	----
78	Majina well 1 (windmill)	A	180208066570000 (2-66.57-1-90)	1948	60	30	screened 30 - 40	0-20 clay 20-60 tosca	----	----
81	Majina 2 (windmill)	A	180147066565000 (1-66.56-1-22)	----	----	60	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
82	Favale 2	NU	180107066570800 (1-66.57-2-89)	----	125	20	----	0-7 soil 7-97 clay 97-111 gravel 111-125 sand	200	----
84	Arenas 8 well (windmill)	A	180105066560700	----	----	----	----	----	----	----
85	Arenas 7 well (windmill)	A	180122066560300	----	40	----	----	----	----	----
86	Susúa west well 1	NU	180218066553000 (2-66.55-1-75)	----	103	----	----	----	----	----
87	Susúa west well 2	D	180218066552400 (2-66.55-2-66)	----	105	92	----	----	----	----
88	Susúa well 3	D	180207066552300	----	358	----	----	----	----	----
90	Susúa well 5	NU	180154066551701 (1-66.55-2-8)	----	16	----	----	----	----	----
91	Susúa well 6	NU	180041066564000	----	----	----	----	----	----	----
93	Arenas 4 well	NU	180119066552800 (1-66.55-4-66)	1950	73	68	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
94	Fraternidad well 1	NU	180053066551300 (0-66.55-1-9)	----	100	90	----	----	----	----
95	Fraternidad new well	NU	180053066550700	----	----	----	----	----	----	----
96	Fraternidad well 2	NU	180033066551100 (0-66.55-2-49)	----	140	98	----	----	----	----
97	Fraternidad well at Fraternidad	NU	180041066542600	----	----	----	----	----	----	----
98	Fraternidad north well	NU	180048066543000	----	----	----	----	----	----	----
99	Arenas Prasa well	M	180140066542400	----	----	153	----	----	----	----
101	Susúa well 2	M	180157066543500 (1-66.54-2)	1949	185	----	----	----	96	7
102	Sabana Grande prawn farm aba. well 2 (DRY WELL)	NU	180225066583200 (2-66.58-3-55)	----	----	----	----	----	65	2

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
103	Sabana Grande prawn farm aba. well 3	NU	180222066584400 (2-66.58-4-53)	----	92	17	----	----	150	3
104	Sabana Grande prawn farm dug well	NU	180216066583200	----	----	----	----	----	----	----
105	Pozo Vivoni; USGS obs. well	NU	180132067032500 (1-67.3-3-46)	----	200	200	----	----	100	3
106	Edwin Luciano well	NU	180218067083200	----	----	30	----	----	----	----
107	Israel Toro well	NU	180041067073800	----	----	----	----	----	----	----
108	Santos Acosta	NU	180043067073800	----	----	----	----	----	----	----
109	José López	D	180044067073100	----	----	36	----	----	----	----
110	Miguel Santiago	D	180045067072900	----	----	36	----	----	----	----
111	Senón Hernández well	NU	180035067081300 (0-67.8-1-48)	----	----	31	----	----	----	----
113	Yuyín Brothers well	NU	180220067014900 (2-67.1-5-73)	----	----	119	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
114	R. Ramírez windmill well	A	180012067034200 (0-67.3-5-83)	----	----	----	----	----	----	----
115	Pozo de la Roseta (DRY WELL)	NU	180026067050100 (0-67.5-1-60)	----	----	----	----	----	----	----
116	Antongiorgi aba. well 2 (DRY WELL)	NU	180208066564500	----	----	----	----	----	----	----
117	Majina well 3 (windmill)	A	180152066563800 (1-66.56-2-14)	----	----	40	----	----	----	----
118	Fraternidad old hand pump well	NU	180050066550400	----	----	----	----	----	----	----
119	Antongiorgi well 4 (windmill)	A	180205066571500	----	----	66	----	----	----	----
120	Eddy well	NU	180010066570500	----	----	11	----	----	----	----
121	José Medina pump well	NU	180226067040200	----	----	31	----	----	----	----
122	Antongiorgi dug well 3	NU	180202066564100	----	----	42	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
123	Antongiorgi aba. hand pump well 1	NU	180230066563600	----	----	60	----	----	----	----
124	Vidro hand pump well	D	180225066582900	----	----	35	----	----	----	----
125	Rosa Silva well	A	180201066592200	----	----	110	----	----	----	----
126	Polito hand pump well	D	180225066582900	----	----	60	----	----	----	----
127	Antongiorgi aba. well 5	NU	180202066564800 (2-66.56-3-92)	----	----	41	----	----	----	----
128	Finca Juanita well 1 (DRY WELL)	NU	180016067031200 (0-67.3-1-79)	----	----	----	----	----	----	----
129	Finca Juanita well 2 (DRY WELL)	NU	180020067030600 (0-67.3-2-69)	----	----	----	----	----	----	----
131	Olivares well 2	NU	175950067041901	----	----	40	----	----	----	----
132	Olivares well 3	NU	175950067041902	----	----	18	----	----	----	----
133	Hacienda Resolución new well	NU	180132067045700	----	----	8	----	----	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
134	Radamés Ramírez (windmill)	A	175940067034000	----	----	118	----	----	----	----
135	Marcelo Ramos	NU	180207066580600	----	----	----	----	----	----	----
136	M.O. Valeriote well A	NU	175948067033100	----	----	----	----	----	----	----
137	M.O. Valeriote well B	NU	175939067032000	----	----	----	----	----	----	----
138	Lajas Experimental Station Test Well	NU	180103067042500	1986	212	90	screened 90-170	0-2 top soil 2-212 alluvial deposits	----	----
139	José B. Ramírez Test Well	NU	180100067010600	1986	172	74	screened 74-154	0-2 top soil 2-172 alluvial deposits	----	----
140	Laguna Cartagena Test Well 1	NU	180055067063301	1984	2	1	screened 1-2	0-2 top soil	----	----
141	Laguna Cartagena Test Well 2	NU	180055067063302	1984	3	2	screened 2-3	0-3 top soil	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
142	Laguna Cartagena Test Well 3	NU	180055067063303	1984	5	4	screened 4-5	0-5 top soil	----	----
143	Laguna Cartagena Test Well 4	NU	180055067063304	1984	10	8	screened 8-10	0-5 top soil 5-10 alluvial deposits	----	----
144	Laguna Cartagena Test Well 5	NU	180055067063305	1984	20	18	screened 18-20	0-5 top soil 5-20 alluvial deposits	----	----
145	Laguna Cartagena Test Well 6	NU	180055067063306	1984	50	48	screened 48-50	0-5 top soil 5-50 alluvial deposits	----	----
146	Laguna Cartagena Test Well 7	NU	180055067063307	1984	83	78	screened 78-83	0-5 top soil 5-83 alluvial deposits	----	----
147	Laguna Cartagena Test Well 8	NU	180055067063308	1984	15	13	screened 13-15	0-5 top soil 5-15 alluvial deposits	----	----
148	Laguna Cartagena Test Well 9	NU	180055067063309	1984	35	33	screened 33-35	0-5 top soil 5-35 alluvial deposits	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
149	Laguna Cartagena	NU	180055067063310	1984	65	63	sreened 63-65	0-5 top soil 5-65 alluvial deposits	----	----
150	Laguna Cartagena Test Well 11	NU	180055067063311	1984	82	80	screened 80-82	0-5 top soil 5-82 alluvial deposits	----	----
151	J. González Test Well 0	NU	180111067025200	1984	25	24	screened 24-25	0-5 top soil 5-25 alluvial deposits	----	----
152	J. González Test Well 1	NU	180111067025201	1984	40	39	screened 39-40	0-5 top soil 5-40 alluvial deposits	----	----
153	J. González Test Well 2	NU	180111067025202	1986	50	47	screened 47-50	0-5 top soil 5-50 alluvial deposits	----	----
154	J. González Test Well 3	NU	180111067025203	1986	110	107	screened 107-110	0-5 top soil 5-110 alluvial deposits	----	----
155	J. González Test Well 4	NU	180111067025204	1986	247	200	screened 200-203	0-5 top soil 5-247 alluvial deposits	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
156	R. Salcedo Test Well 1	NU	180103066583501	1986	247	158	screened 158-166	0-2 top soil 2-247 alluvial deposits	----	----
157	R. Salcedo Test Well 2	NU	180103066583502	1986	101	97	screened 97-101	0-2 top soil 2-101 alluvial deposits	----	----
158	R. Salcedo Test Well 3	NU	180103066583503	1986	59	57	screened 57-59	0-2 top soil 2-59 alluvial deposits	----	----
159	R. Salcedo Test Well 4	NU	180103066583504	1986	47	45	screened 45-47	0-2 top soil 2-47 alluvial deposits	----	----
160	R. Salcedo Test Well 5	NU	180103066583505	1986	37	36	screened 36-37	0-2 top soil 2-37 alluvial deposits	----	----

Appendix--*Description of wells in the Lajas Valley*--Continued

[units - ft, feet; gal/min, gallons per minute; (gal/min)/ft, gallons per minute per foot of drawdown; ----, indicates data not available; A, agriculture and stock well; D, domestic well; M, municipal well; NU, well not in use]

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
161	South Coast Test Well 1 (SC-1)	NU	180133067035000	1987	640	test hole back filled	0 - 60	claystone	7 - 30	----
							60 - 68	sandstone	30	----
							68 - 112	claystone		
							112 - 120	gravel and pebbles		
							120 - 132	claystone		
							132 - 140	sandstone		
							140 - 180	claystone		
							180 - 204	fossiliferous limestone	90 - 200	
							204 - 220	limestone	225	
							220 - 300	calcarnite	175 - 225	
							300 - 356	sandstone	160	
							356 - 384	claystone		
							384 - 416	limestone	180	
							416 - 544	claystone	120	
							544 - 636	igneous rock		

Appendix--*Description of wells in the Lajas Valley*--Continued

Well number	Well name	Well type	[1]Site identification number	Date drilled	Original depth of well (ft)	Depth of casing (ft)	Type of screen and screen interval (ft)	Lithologic description and thickness (ft)	[2]Yield (gal/min)	Specific capacity [(gal/min)/ft]
162	South Coast Test Well 6 (SC-6)	NU	180125067080500	3/31/87	860	test hole back filled	0 - 18	quartz sand deposits		
							18 - 36	clayey sandstone		
							36 - 114	claystone	50 - 60	----
							114 - 132	limestone	35	----
							132 - 156	claystone	80	----
							156 - 174	argillaceous limestone		
							174 - 228	siltstone		
							228 - 240	gravel and pebbles		
							240 - 294	siltstone		
							294 - 330	limestone	100	----
							330 - 354	claystone		
							354 - 372	limestone		
							372 - 450	claystone		
							450 - 486	gravel and pebbles	50	----
							486 - 522	claystone		
							522 - 540	limestone		
							540 - 726	claystone		
							726 - 846	pebbles and cobbles		
							846 - 858	igneous rock		

1 Site identification numbers in parenthesis are historical file numbers.
2 Yield of wells are values given when well was originally drilled, and does not necessarily indicate current well pumpage.