UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Ground Water Branch

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GEOLOGIC FEATURES AND WATER RESOURCES OF CAMPO, MESA GRANDE, LA JOLLA, AND PAUMA INDIAN RESERVATIONS, SAN DIEGO COUNTY, CALIFORNIA

By

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Prepared at the request
of the
Bureau of Indian Affairs, Department of the Interior

Sacramento, California
October 1953

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GENERAL FEATURES OF THE INVESTIGATION

Introduction

Purpose and Scope of the Investigation

At the request of the U. S. Bureau of Indian Affairs, the Ground Water Branch of the U. S. Geological Survey made an investigation of the geologic features and water resources of Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations in San Diego County, California.

As outlined briefly in a letter dated September 4, 1952, from Henry Harris, Jr., Acting Area Director of the Bureau of Indian Affairs, to Joseph F. Poland, District Geologist for the Ground Water Branch in California, the purpose of the investigation was to describe the geologic and hydrologic features of the specified reservations, to determine the availability of additional water for domestic and irrigation purposes, and to furnish suggestions pertaining to the feasibility of future investments for water development.

In March 1952 a brief reconnaissance of the reservations was made by G. F. Worts, Jr., and F. S. Riley, geologists from the Long Beach area office of the Ground Water Branch, in the company of Le Grand B. Ward and John S. Ryder of the Bureau of Indian Affairs.

Field work for the present investigation was done by the writer in October and November 1952 for Campo, Mesa Grande, and La Jolla Reservations and in June 1953 for Pauma Reservation. The field work consisted of a geologic reconnaissance to determine the rock types and geologic structure, and a hydrologic reconnaissance consisting of an incomplete inventory of the water wells, springs, and flowing streams on or near each of the four reservations.

The report was prepared by the writer under the immediate supervision of G. F. Worts, Jr., and J. F. Poland, and under the general supervision of A. N. Sayre, Chief of the Ground Water Branch. Chemical analyses of water samples were made by the district laboratory of the Quality of Water Branch of the Geological Survey in Sacramento.

Topographic and Geologic Setting of the Reservations

Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations are in San Diego County, near the southwestern corner of California (fig. 1). Topographically and geologically the reservations are in the Peninsular Ranges province which covers a large part of the southwestern corner of California and extends into Lower California (Jenkins, 1943, p. 87).

Crystalline rocks compose most of the interior part of the Peninsular Ranges province. Granitic rocks are by far the most extensive, although scattered bodies of metamorphic rocks occur within the granitic rocks. The granitic rocks actually are a complex of many distinct intrusive rock bodies or plutons ranging in composition from granite to gabbro. Collectively, this complex is called the "peninsular batholith of

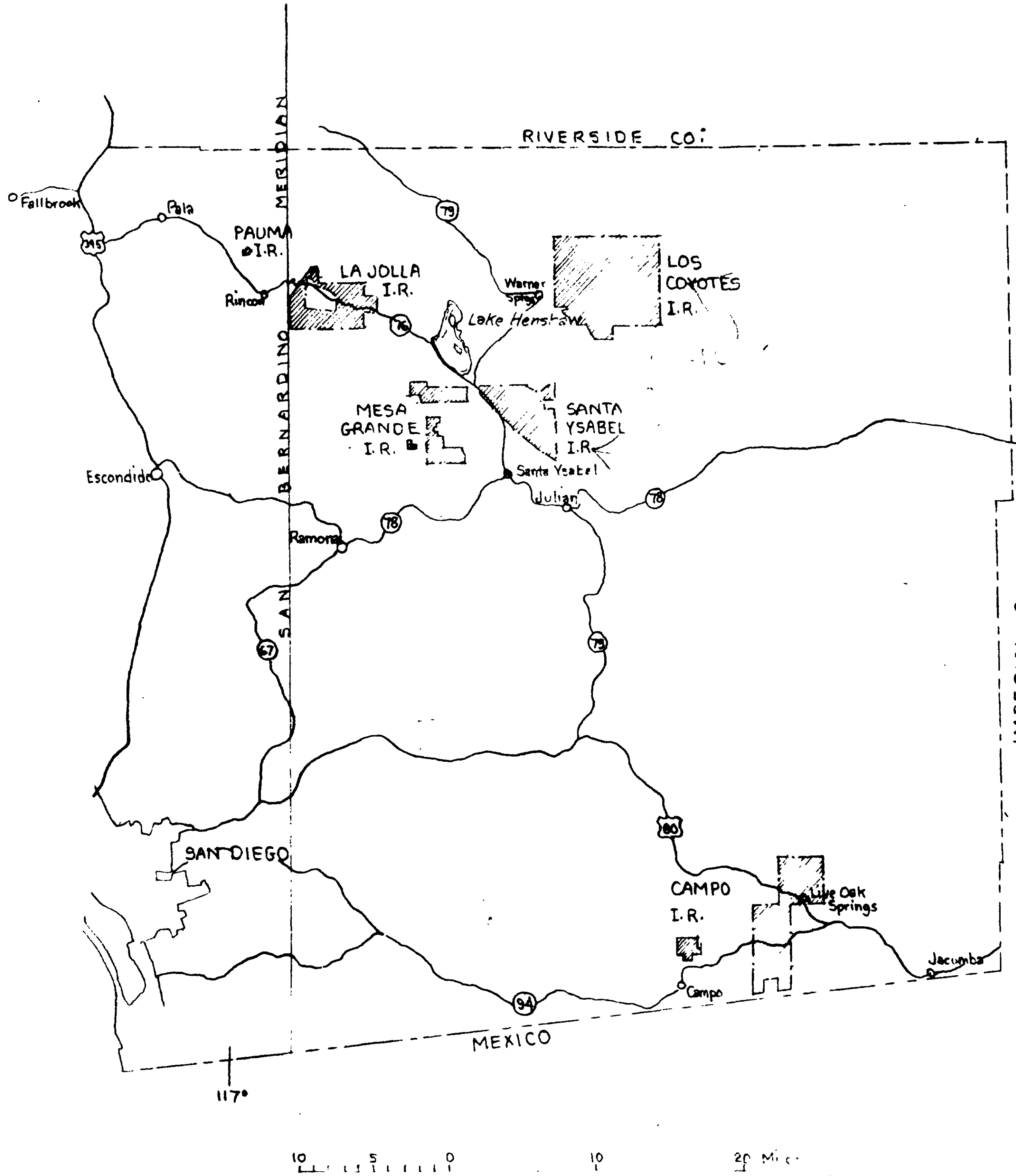

FIGURE 1. MAP OF A PART OF SAN DIEGO COUNTY, CALIFORNIA SHOWING LOCATION OF ~~SIX~~ FOUR INDIAN RESERVATIONS INVESTIGATED.

California" or "batholith of southern California." The geologic age of the batholithic rocks is believed to be Cretaceous, although some of the earliest intrusions may have been in the Late Jurassic. The metamorphic rocks probably are of Triassic age but may be all, or in part, Paleozoic.

The rocks exposed on Campo, Mesa Grande, and La Jolla Reservations are predominantly the intrusive rocks of the peninsular batholith containing roof pendants and partially assimilated masses of metamorphic rocks. Pauma Reservation is underlain by alluvial deposits perhaps as much as 400 feet thick overlying the intrusive and metamorphic rocks. Except on Pauma Reservation, alluvial deposits, which supply most of the ground water pumped for agricultural use in California are very thin and are not extensive on the reservations.

The reservations are in mountainous terrane where altitudes range from less than 1,000 to more than 5,000 feet above sea level. The mountain slopes are steep and rugged on parts of La Jolla and Mesa Grande Reservations and adjacent to Pauma Reservation; Campo Reservation is in more gently rolling country.

The reservations are all within drainage basins that supply the cities and agricultural lands of the coastal belt of San Diego County with irrigation, industrial, and domestic water. Most of Campo Reservation is drained by Campo Creek, a tributary of the Tia Juana River (fig. 1). Drainage of most of Mesa Grande Reservation is into Santa Ysabel Creek, which becomes the San Dieguito River south of Escondido (fig. 1). La Jolla and Pauma Reservations drain into the San Luis Rey River (fig. 1).

Climate

Precipitation data from four U. S. Weather Bureau stations on or near the four reservations studied are summarized in table 1. The Amago station, no longer in operation, was at La Jolla Amago, in the center of La Jolla Reservation, at an altitude of 2,715 feet (pl. 3). Mesa Grande station, also defunct, was at the town of Mesa Grande, adjacent to Number 1 Unit of the Mesa Grande Indian Reservation (pl. 2). The Campo station has been moved from time to time and is now at Warrens (Cameron Corners), about 2 miles northeast of the town of Campo on State Highway 94 (pl. 1). Nellie, now Palomar Mountain Post Office, is on the crest of the Agua Tibia Mountains at an altitude of 5,500 feet (pl. 5).

The data are believed to be fairly representative of the average precipitation on the reservations, although the topography and altitude have considerable effect on the amount of precipitation. Mountainous areas such as La Jolla and Mesa Grande Reservations and the drainage basin of Pauma Creek above Pauma Reservation, where the total relief is 3,000 to 4,000 feet, have a sizable range in the amount of precipitation from place to place -- the amount generally increasing with altitude. For example: Nellie, at an altitude of 5,500 feet, had an average precipitation of 48.89 inches for the period 1912-22; Amago, only 3 miles by air line to the south, but at an altitude of 2,715 feet, had an average precipitation of only 30.16 inches for the same period.

Table 1 clearly shows that yearly precipitation totals at the four stations vary exceedingly from year to year. The average yearly precipitation at Campo for the 63 years of record is 18.64 inches, but

Table 1.--Yearly precipitation, in inches (July 1 to June 30) at Campo, Mesa Grande, Amago, and Nellie, Calif.

Season	Campo	Mesa Grande	Amago	Nellie
1877-78	20.03			
1878-79	10.59			
1879-80	17.94			
1880-81	15.87			
1881-82	12.66			
1889-90	29.90			
1890-91	26.67			
1891-92	32.51			
1892-93	17.67			
1893-94	25.31			
1899-00	10.11			
1900-01	17.46			
1901-02	17.44			42.45
1902-03	20.00			
1903-04	8.79			
1904-05	31.61			54.01
1905-06	27.07			77.40
1906-07	25.42			49.96
1907-08	15.57			
1908-09	22.87	34.35		
1909-10	17.42	29.55		44.21
1910-11	20.39	27.75		44.96
1911-12	19.07	27.60		39.06
1912-13	12.83	25.64	21.71	39.59
1913-14	20.02	31.77	33.52	52.95
1914-15	23.23	44.46	42.32	67.19
1915-16	30.79	48.27	30.96	65.12
1916-17	16.52	27.08	31.81	44.57
1917-18	13.66	19.47	24.08	30.85
1918-19	16.56	21.05	20.94	28.83
1919-20	22.98	33.20	31.56	50.70
1920-21	10.17	24.76	21.75	32.04
1921-22	33.41	45.57	43.53	73.20
1922-23	21.36		22.18	33.93
1923-24	15.62		22.55	
1924-25	12.51		25.67	
1925-26	19.31		37.88	
1926-27	30.42		36.32	
1927-28	12.35		18.62	
1928-29	16.45		20.32	

Campo 1877-78 to 1951-52 average: 18.64
Mesa Grande 1908-09 to 1921-22 average: 31.46
Amago 1912-13 to 1943-44 average: 27.16
Nellie 1901-02 to 1922-23 average: 48.39

Table 1.--Yearly precipitation, in inches (July 1 to June 30) at Campo, Mesa Grande, Amago, and Nellie, Calif.--Cont.

Season	Campo	Mesa Grande	Amago	Nellie
1929-30	22.75		27.89	
1930-31	17.36		17.46	
1931-32	26.20		32.61	
1932-33	18.17		24.32	
1933-34	6.49		12.78	
1934-35	22.30		24.49	
1935-36	13.58		23.35	
1936-37	25.24			
1937-38	16.58		29.36	
1938-39	14.81			
1939-40	17.43			
1940-41	25.58			
1941-42	15.91		25.91	
1942-43	15.25		29.91	
1943-44	18.72		26.58	
1944-45	14.76			
1945-46	12.85			
1946-47	9.29			
1947-48	9.22			
1948-49	12.36			
1949-50	10.38			
1950-51	11.42			
1951-52	26.91			

only 6.49 inches of rain fell in 1933-34, and the total was 33.41 inches in 1921-22.

The drought during the middle and late 1940's, which is largely responsible for the present water shortage in San Diego County, is clearly indicated by the subnormal rainfall recorded at Campo from 1944-45 to 1950-51, inclusive.

Part of the winter precipitation on the higher parts of Mesa Grande and La Jolla Reservations and in the upper drainage basin of Pauma Creek occurs as snow. Julian, which is about 10 miles southeast of Mesa Grande, at an altitude of 4,200 feet, had an average seasonal snowfall of 34.1 inches for the period 1908-09 to 1929-30, and probably the parts of Mesa Grande and La Jolla Reservations and the upper drainage basin of Pauma Creek at similar altitudes receive a like amount.

The monthly precipitation record for Mesa Grande and Amago stations (table 2) shows that the bulk of the precipitation occurs in the cool part of the year. Almost seven-eighths of the average annual precipitation at these stations occurs in the half-year period from November to April, inclusive. Rainfall during the summer is extremely scanty and results almost entirely from occasional late-afternoon thunderstorms in the mountains. Large amounts of rain may fall in brief periods during these storms, the most striking example being an astonishing 11.50 inches in 1 hour and 20 minutes at Campo on August 12, 1891. In contrast, many years are without any significant amount of summer precipitation.

Table 2.--Average monthly precipitation (inches) at Mesa Grande and Amago, Calif.

Month	Mesa Grande 1909-22 average	Amago 1912-43 average
January	5.70	4.48
February	5.26	5.64
March	2.44	4.58
April	1.57	2.97
May	0.14	1.30
June	0.13	0.23
July	0.24	0.16
August	0.35	0.32
September	1.60	0.42
October	1.85	1.61
November	4.11	1.54
December	7.84	4.74
Average yearly total	31.23 inches	27.99 inches

Table 3.--Average temperatures (°F) at Amago, Calif. Length of record: 17 years

Month	Average daily temperature	Average daily maximum temperature	Average daily minimum temperature
January	45.0	50.2	39.8
February	47.3	53.2	41.3
March	48.2	54.6	41.9
April	50.2	57.0	43.4
May	54.1	61.2	47.0
June	62.0	69.7	54.4
July	68.9	77.0	60.6
August	69.8	77.3	62.4
September	65.3	72.8	57.9
October	58.6	65.3	51.9
November	53.0	58.8	47.2
December	46.8	51.9	41.7
Annual	55.8	62.4	49.1

Unfortunately, less quantitative information is available on temperature than on precipitation for the four reservations. A temperature record was kept at Amago, but no data are available for the Mesa Grande and Campo stations. Records from several weather stations in San Diego County suggest that temperature varies less with topography and altitude than does precipitation. Therefore, it is believed that the record for Amago (table 3) probably indicates the order of magnitude of the average temperatures prevailing over the four reservations. Perhaps because of its unusual topographic position on a high bench, Amago has a smaller diurnal range in temperature than most stations at similar altitudes in San Diego County, and probably most places on the reservations have somewhat higher average maximum and lower average minimum temperatures than Amago.

Well-Numbering System

The well-numbering system used by the Geological Survey in California shows the location of wells and springs according to the rectangular system for the subdivision of public land. For example, in the number 11/2E-28Q2, which was assigned to a spring on the Mesa Grande Reservation, the part of the number preceding the bar indicates the township (T. 11 S.); the part between the bar and the hyphen shows the range (R. 2 E.); the digits between the hyphen and the letter indicate the section (sec. 28), and the letter indicates the 40-acre subdivision of the section as shown in the accompanying diagram.

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

Within each 40-acre tract the wells and springs are numbered serially, as indicated by the final digit of the number. Thus, spring 11/2E-28Q2 is the second spring or well to be listed in the SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 28, T. 11 S., R. 2 E. As all six Indian reservations are south of the San Bernardino base line, the abbreviation of the township is sufficient.

Locations of objects other than wells or springs may be conveniently described by a number similar to a well number, but without the final digit. For example, a rock outcrop in the NE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 3, T. 18 S., R. 6 E. on Campo Reservation may be described as being in 18/6E-3C.

Acknowledgments

Special thanks are due Jack Ryder of San Bernardino and LeGrand B. Ward of Riverside, both of the Bureau of Indian Affairs, who took the writer on a two-day reconnaissance of Campo, Mesa Grande, and La Jolla Reservations and pointed out many of the problems of each reservation. Mr. Ryder furnished the well logs, well-construction and test-pumping data, and other useful information on water development.

The cooperation of the spokesmen of the tribal councils of the four reservations is appreciated; especially Delmer Nejo, spokesman for Mesa Grande Reservation, who furnished useful information on the present water supply of that reservation.

George Mendenhall, owner of the Mendenhall Ranch on Cuca Grant near La Jolla Reservation, Vaughn Maynard and Monta J. Moore of Pauma Valley, and F. O. Olmsted of Fallbrook supplied the writer valuable data on well construction and yields.

Water-Bearing Characteristics of the Crystalline Rocks

Rock Types

Before discussing the geologic occurrence of ground water on the four reservations studied, the general water-bearing characteristics of the crystalline rocks in San Diego County will be described briefly. Crystalline rocks, mostly medium- to coarse-grained granitic to gabbroic rocks, and associated metamorphic rocks, underlie most of Campo, Mesa Grande, and La Jolla Reservations; alluvial sediments are of minor extent and thickness except on Pauma Reservation.

Many published reports have described and named the various types of crystalline rock in San Diego County; of these, two describe briefly ground-water occurrence: Ellis and Lee (1919); and Merriam (1951). Ellis and Lee discuss the general occurrence of ground water in the highland areas of San Diego County and the paper by Merriam includes a good summary of the relative chances of obtaining good wells in the various types of crystalline bedrock. LeGrand and Mundorff (1952) discuss the general water-bearing characteristics of crystalline rocks.

Ellis and Lee (1919, p. 189) divide the water-bearing crystalline rocks into three principal classes:

1. Crystalline rocks (fresh or slightly weathered rocks containing open fractures);
2. Talus at the bottom of the mountain slopes;
3. Residuum (weathered rock popularly called "decomposed granite").

Each of these classes is discussed briefly below.

Fresh or Slightly Weathered Crystalline Rocks

Unlike clastic sediments, in which nearly all the water is contained in the interstices or void spaces between the rock or mineral fragments, most, if not all, the water in fresh crystalline rocks is open joints and other fractures. Even in extremely fractured or closely jointed crystalline rock, the total porosity is much less than in uncemented sediments. Unless the joints and other fractures extend to considerable depth below the water table and are interconnected over a large area, the total amount of water available to a well in fresh crystalline rock will be much less than that available to a well in alluvial sediments. If the fractures are not open or are far apart, yields of water from fresh crystalline rocks will be negligible.

Merriam (1951), in his discussion of the characteristics of specific bedrock types, divides the crystalline bedrock in San Diego County into four main types, on the basis of general water-bearing characteristics: (1) Metamorphic rocks; (2) gabbro; (3) tonalite; (4) granodiorite. All these groups are invaded in many places by dikes of pegmatite, aplite, alaskite, and graphic granite, and by a few quartz veins.

Talus at the Bottom of the Mountain Slopes

Talus includes angular blocks of bedrock which have been broken from the parent rock by mechanical weathering and have fallen down steep mountain sides, and landslide breccia along steep mountain escarpments such as the Agua Tibia Mountains escarpment on La Jolla Reservation.

Owing to its steep topographic setting, talus is not ordinarily a ground-water reservoir. However, the large, loose, angular rock fragments provide an excellent intake area for water which moves rapidly into valleys and canyons at lower elevations (Ellis and Lee, 1919, p. 191). Springs emerge in many places at the base of talus or slide-breccia masses; springs 10/1E-25M1 and 26R1 on La Jolla Reservation are two examples.

Residuum

Residuum, the most important source of ground water in the upland regions, is formed by weathering, in place, of fresh crystalline rock.

Several factors that control the occurrence of this weathered rock are: texture and mineral composition of the original fresh rock, topographic position, climate, vegetation, and degree of jointing, other fracturing, and shearing that the parent rock has undergone.

From the standpoint of water-bearing character, residuum may be divided into two principal categories: (1) Disintegrated rock (technically called "gruss"); (2) decomposed rock.

Before discussing these two categories, it might be well to review briefly one of the present theories that explains how residuum is formed. According to this theory, which is now widely held (Larsen, 1948, p. 113-117), the weathering that produces the residuum is brought about by chemical changes that are induced by aqueous solutions percolating down through joints and other fractures in the rock. In the first stages of weathering the mineral grains or groups of grains are merely broken apart -- with minor chemical alteration of the minerals themselves. Farther along in the process, the chemical alteration of many of the minerals has gone so far that clay minerals are formed. Alteration of the original minerals to clay is accompanied by swelling and hydration, so that the small cracks formed in the first stages of the process are closed. The end product of this weathering process consists of the chemically resistant mineral grains, such as quartz, enclosed in a matrix of clay.

The disintegrated rock or gruss is the material produced in the first stages of weathering; the decomposed rock is the end product. There are all gradations between these two categories, and there are also gradations between the very fresh parent rock and the gruss. In general, however, little water can be obtained from decomposed rock because of its high clay content, whereas numerous small cracks in the gruss may yield small to moderate supplies of water to wells.

The gruss grades sharply into fresh rock at many places, particularly in areas where the joints are several feet apart. In the jointed areas, fairly fresh boulders, called "boulders of disintegration" or "residual boulders", are enclosed in the gruss. Where the surrounding gruss has been eroded away, these rounded boulders are as much as 20 or 30 feet across in some of the granodiorite exposures, but most boulders are much smaller.

The thickness and character of the residuum locally are extremely variable, and where boulders of disintegration occur a drill hole may penetrate alternating zones of gruss or decomposed rock and fresh rock to a depth of more than 100 feet.

As mentioned earlier, the occurrence and character of the residuum depend on several factors, one of which is the texture and mineral composition of the parent rock. In general, the tonalites and quartz diorites have the thickest and most extensive masses of residuum; depths of weathering of more than 100 feet are common in these rocks. Gabbro residuum is variable, but a reddish clay containing fairly fresh small chunks of the parent rock is most common. Merriam (1951, p. 124) reports that wells more than 200 feet deep have been drilled in gabbro residuum, but it is unlikely that any of the gabbro on Mesa Grande Reservation is weathered to that depth. Granodiorite residuum is apt to be extremely irregular in extent and thickness, and, because most granodiorite exposures consist of rugged hill masses with large boulders of disintegration, this rock type generally is not favorable for ground-water development. The residuum developed on the metamorphic rocks (gneiss, schist, and quartzite) is generally less clayey than the decomposed gabbro, tonalite, or granodiorite, but in most places it is not very thick. Most of the water contained in the metamorphic rocks is in the closely spaced joints and other fractures parallel to the foliation (layering of the minerals) of the fairly fresh rock.

Climate, which in San Diego County, is largely a function of altitude has some effect on the character of the residuum. In the humid higher mountain areas the weathering is usually deep, and even the boulders of disintegration are rather rotten. This is of considerable importance, because precipitation that would ordinarily run off quickly on steep slopes such as the Agua Tibia Mountains escarpment on La Jolla Reservation is able to penetrate into and be stored in the weathered rock and thus maintain a more stable stream flow through the dry season.

Topographically, flat or gently rolling areas have a thicker weathered zone than the steep hillsides, other factors being equal. In most places, however, the topography is more or less directly a function of the other factors, particularly rock type and structure.

Well Production from the Crystalline Rocks

The crystalline bedrock in western San Diego County is not nearly as permeable as most unconsolidated alluvium in the intermontane basins and valleys of California. Table 4 compares well yields for 6 wells in bedrock with average yield for a group of 10 closely spaced wells in alluvium in western San Diego County. In order to minimize differences in well yields caused by factors other than the water-bearing characteristics of the rocks or sediments, the quantities compared are the "yield factors" of the wells. Yield factor, first defined and used by Poland others (1945, p. 57), is defined as the specific capacity of the well (yield in gallons per minute (gpm) per foot of drawdown) multiplied by 100 and divided by the thickness, in feet, of the aquifers (water-bearing materials) tapped by the well. The yield factor varies approximately with the permeability of the materials tapped by a well, and thus affords a means for comparing different water-bearing rocks and sediments.

The first five wells in the table derive all or most of their water from quartz diorite residuum. The Mendenhall well (10/1E-20R1) probably gets some water from alluvial material, but most of the yield is from fresh to moderately weathered fractured granodiorite and schist. The ten wells (L82) in the upper San Diego River valley probably derive their water from sandy alluvium.

In computing footage of water-bearing material, laterals (1- to 2-inch-diameter open holes drilled radially from the well in a nearly horizontal plane) and tunnels were treated the same as footage of vertical hole opposite water-bearing material. However, for a rigorous mathematical comparison, the small-diameter laterals should not be assumed to produce as much water per linear foot as tunnels or large-diameter vertical holes because of larger head losses due to interference between laterals and to turbulent flow. Hence, the yield factors computed for wells 9/3W-21F1 and 10/1E-20R1 are somewhat too low. On the other hand, the yield factor computed for well L98 is too high for strict comparison with the other wells because of the relatively large diameter of the hole opposite the water-bearing material.

The yield factors for the bedrock wells average about 2, a much lower order of magnitude than the yield factor of about 40 for the group of wells (L82) in the alluvium of the upper San Diego River valley. Wells tapping loose, coarse alluvial deposits in the large valleys of California commonly have yield factors of 100 to 200 -- 50 to 100 times the average for the bedrock wells in table 4.

Obviously, wells in the crystalline bedrock cannot be expected to produce as much water as wells of similar construction in the alluvial valleys, and wells of elaborate construction are required to obtain irrigation supplies from bedrock.

The productivity of the crystalline bedrock depends in part on the particular rock type, and a few generalizations on each type are given below. For purposes of reconnaissance mapping, four main bedrock units were delineated in this investigation: (1) schist; (2) mixed rock (schist and quartz diorite complex); (3) gabbro; (4) granodioritic rocks (including tonalite and quartz diorite).

The water-bearing properties of the schist and the mixed rock were discussed by Merriam (1951, p. 124) under the heading of metamorphic rocks. Merriam concluded that

> ---yield of water is most erratic in the metamorphics, and the success of a well depends largely upon local conditions and upon the characteristics of the particular phase of metamorphic rock rather than upon any general property of the group.

In general, the schist and mixed rock are the most fractured and closely jointed of the bedrock types, and are probably the best aquifers of the unweathered rocks.

Gabbro is perhaps the most favorable of the plutonic rocks, but is less uniform than the tonalites and quartz diorites (Merriam, 1951, p. 126). Most of the gabbro on Mesa Grande Reservation forms high mountain masses with few favorable well sites, however.

Merriam (1951, p. 125) divides the granodioritic rocks into two groups: tonalite and granodiorite. The tonalite tends to weather into extensive masses of residuum, and it is a uniformly good source for moderate supplies of water. The granodiorite is generally the least favorable rock owing to its tendency to form steep hilly terrane with large boulders of disintegration resulting from widely-spaced joints. On Campo Reservation boulder outcrop areas of the quartz diorite are similar to the granodiorite, but the quartz diorite residuum on Campo has water-bearing properties similar to the tonalites.

Source of Water in the Crystalline Rocks

In determining the feasibility of a proposed well the assurance of a continuing water supply is as important as an adequate pumping rate. This means that not only should the water-bearing formation be fairly permeable, but that, over a period of years, the average annual rate of replenishment to the ground-water body should at least equal the average annual withdrawal rate. In order to estimate the replenishment rate, the source of the ground water must be ascertained.

As stated by Ellis and Lee (1919), water in the crystalline rocks is derived from three sources:

(1) Absorption directly from precipitation (deep penetration);

(2) absorption from streams (influent seepage along stream channels);

(3) seepage from irrigated areas where water has been brought in from outside areas.

The most favorable conditions for a high rate of replenishment in bedrock are: (a) Large amount of precipitation; (b) thick, permeable mantle or residuum; (c) small amount of water-consuming vegetation on the watershed; (d) a large drainage area; (e) gentle topography.

CAMPO RESERVATION

General Features

Location and Extent of the Reservation

Campo Indian Reservation covers an area of 15,010 acres just north of the United States-Mexico border and 40 to 50 miles east of the business district of San Diego. The reservation is in two parts: Old Campo Unit, which is about 2 miles north of the town of Campo; and a much larger unit about 5 miles to the east, which will be referred to in this report as the Campo Agency Unit. The reservation can be reached from San Diego either by State Highway 94 or by U. S. Highway 80. Live Oak Springs resort is just south of the Campo Reservation boundary on U. S. Highway 80, but the springs that supply the resort are within the reservation.

The Water Problem

Briefly the problem on Campo Reservation is one of developing sources of water to supplement the present supply, which is mostly from stream diversions and from springs, many of which are dry in the late summer and autumn in years of subnormal precipitation. The alluvial flats along Campo Creek and its tributaries could support a small-scale agricultural development if a more reliable and stable supply of water were obtainable. Surface water now used in the vicinity of the old Agency Headquarters probably does not meet U. S. Public Health Service standards for drinking water, although the supply is probably adequate for minimum domestic requirements even in the late summer and early autumn. Along the smaller tributaries of Campo Creek, many of the original residents have moved away because of late-season failure of supply, however. According to the Bureau of Indian Affairs, in March 1952 the population of the reservation was 90. Many of the dwellings are now vacant, and the permanent population in October 1952 was believed to be considerably less than 90.

Geology

Rock Units

Quartz diorite.- The crystalline bedrock exposed on Campo Reservation is almost entirely a light-gray medium to coarse-grained quartz diorite containing, in decreasing order of abundance, plagioclase, quartz, biotite, hornblende, and a small scattering of sphene and magnetite. Euhedral to subhedral black biotite and hornblende crystals are uniformly distributed, rarely have a preferred orientation, and compose 10 percent or less of the total volume. The quartz forms glassy fillings between the other minerals; the plagioclase crystals are white and make up about two-thirds of the rock. The name applied to this rock by W. J. Miller (1935, p. 129), who mapped the geology of a narrow strip along both sides of U. S. Highway 80, is "La Posta quartz diorite." All the bedrock on Campo Reservation is believed to be correlative with the La Posta quartz diorite, except possibly a dark-gray rock exposed along the western margin of Old Campo Unit. This rock contains more biotite and hornblende than the typical

La Posta quartz diorite, and may be correlative with Miller's Alpine quartz diorite or with the Bonsall tonalite described and mapped by Everhart (1951) in the Cuyamaca quadrangle about 10 miles to the northwest.

The quartz diorite is locally intruded by small dikes of fine to coarse-grained granitic pegmatite, aplite, and related dike rocks in which quartz and potash feldspar are the predominant minerals. The dikes are not abundant, except in a few places such as in the northeastern part of Campo Agency Unit, and dikes thicker than 3 feet are exceedingly rare.

Quartz diorite residuum.- Although boulder outcrops of moderately fresh quartz diorite are numerous in parts of the reservation, residuum is perhaps more extensive. The residuum consists primarily of disintegrated quartz diorite or gruss; decomposed rock is rather uncommon except within 3 to 5 feet of the land surface where a gray-brown sandy clay loam soil has formed in many areas. The gruss is by far the most extensive and important water-bearing unit on the reservation, although the alluvium is perhaps more permeable.

Alluvium.- Alluvium, probably of Recent age, is not thick or extensive on the reservation. The alluvium is made up of quartz diorite detritus containing small chunks of pegmatite and aplite. Very coarse sand and fine gravel, containing fragments averaging between 2 and 8 mm in a silty matrix, is most common. The fragments consist either of individual mineral grains or of small rock fragments derived from the loose, disintegrated residuum, or gruss. The alluvium is generally more porous than the gruss, but probably is not much more permeable, because of the greater proportion of silt and clay particles distributed rather uniformly through most of the alluvium.

The alluvium is described as "sandy soil" in the logs (table 9) of three wells drilled on the reservation for the Bureau of Indian Affairs. Well 18/5E-3D1 was reported to penetrate 46 feet of "sandy soil" overlying "soft granite" at Old Campo Unit. The alluvium is evidently about 28 feet thick at the Campo Agency well (17/6E-34N1) along Campo Creek, and possibly 30 feet of alluvium was penetrated in the John Williams well (17/6E-32H1), although the "sandy" interval reported between 18 and 30 feet depth may be loose residuum.

The alluvial fill appears to be at least 20 to 30 feet thick in places along Campo Creek, but the base is very irregular, and bedrock may be exposed a short distance away from a fairly thick section of channel fill. The alluvium along Campo Creek and its tributaries is discontinuous (pl. 1), the creek channel being cut into bedrock along some reaches. Diebald Canyon, Castle Rock Dam, and the ravine under the railroad trestle are examples of areas where alluvium is absent. This feature will be discussed further under the heading of topography.

Geologic Structure

Joints.- The dominant structural feature on Campo Reservation is the joint system in the quartz diorite. This system consists of three sets of mutually perpendicular joint planes, one approximately horizontal, the other two vertical or nearly so. The strike of the vertical joints averages about N. 10° W. and N. 80° E. Joints striking in other directions are developed locally on a small scale but do not show a consistent pattern and are unimportant regionally.

A few masses of unjointed rock are scattered over the area. These massive bodies of quartz diorite form exfoliated domes, similar to those in Yosemite National Park, or, in some places, broad, flat outcrops as much as 100 yards across. One particularly impressive domelike hill rises about 400 feet above the surrounding surface a mile east of the Old Campo Unit.

Spacing of most of the joints ranges from 5 to 20 feet, although the set striking N. 10° W. is more closely spaced in places, possibly where shearing has occurred. Weathering appears to be controlled largely by the joints, and rounded residual boulders are particularly prominent in areas where the spacing is regular and the three sets are equally well developed. Most of the boulders of disintegration of the medium-grained quartz diorite are seemingly hard on the surface, but they are rotten inside and disintegrate readily when struck with a hammer.

Faults.- Faulting is of minor importance on Campo Reservation. The only noted evidence of faults was alinement of vegetation and damp areas along some N. 10° W. trends in the northeastern part of the reservation, and some very closely jointed zones associated with possibly sheared gneissic quartz diorite, also having a N. 10° W. trend. This evidence may indicate some horizontal displacement along certain of the N. 10° W. joints. Some of the springs in the area may be related to these sheared zones.

Topography

Old upland surface.- Topographically the upland region around the Campo Reservation may be described as an old gently sloping erosional surface cut by small, steep-sided canyons which form a rectangular pattern. The principal canyons have a N. 10° W. trend, but the trunk stream, Campo Creek, and some other, smaller streams are generally perpendicular to this trend. The obvious inference is that the dissection of the old upland surface has been controlled by the master joint pattern.

The time of formation of the old upland surface is not known, and this determination would require a regional study. The surface is being slowly destroyed by the present streams which in places have cut their canyons to a depth of more than 500 feet below the old surface.

The upland surface is best preserved in the southern part of the reservation, which is a plateau ranging in altitude from 3,500 to 3,700 feet. The rock underlying this surface is deeply weathered; it is primarily a coarse-grained quartz diorite gruss here and there cut by dikes of more resistant pegmatite and aplite.

Farther north, remnants of the surface consist of some of the ridge tops and hill summits, although the surface is fairly extensive in the broad, flat area in secs. 2 and 3, T. 17 S., R. 6 E. where the altitude is about 4,500 to 4,600 feet. The upland slopes gently southwestward from about 4,500 feet in the northeastern part of the reservation to 3,000 feet in the vicinity of the "Old Campo" part of the reservation.

Present drainage system; small alluvial valleys.- The present drainage has a roughly rectangular pattern which is controlled by the joint system in the quartz diorite. Campo Creek and the larger N. 10° W. - S. 10° E. tributaries are cut about 500 feet below the old upland surface, and their canyons and small valleys are floored by narrow, discontinuous alluvial flats. These streams show marked irregularities in longitudinal profile, the stream slope being alternately gentle in the reaches across the small alluvial flats and steep where the stream is cutting westward through bedrock. The bedrock reaches are always where the streams cross N. 10° W. ridges of relatively fresh rocks; the alluvial flats seem to be alined with the less resistant zones of bedrock.

Some of the present stream channels are incised as much as 20 feet below the surfaces of the alluvial flats. (This condition was observed in other areas throughout San Diego County, also). According to the older Indians who were queried on this matter, much of this cutting took place in a single season of destructive floods in 1916. Before 1916, the streams were incised only slightly and presumably were depositing alluvium over the surface of the flats.

Occurrence of Ground Water

General Features

The ground-water body on Campo Reservation is contained primarily in the quartz diorite residuum and in open joints in the fresher rock; a smaller volume is present in the small bodies of Quaternary alluvium. At the springs and seeps the water table is at the land surface, but elsewhere the top of the water body is below the ground. In general, the shape of the water table conforms to the topography but is more subdued, the depth to water under the hilltops being greater than the depth under the valleys and ravines. The lower limit of the water body is vague and depends on the depth to which open joints and other fractures extend in the fresh bedrock. Locally, zones of unjointed rock interrupt the ground-water body and may force water to the surface in springs where the ledges are downslope from masses of residuum or jointed rock that contain ground water.

The ground-water body on the Campo Agency Unit of the Campo Reservation is subdivided into a number of "basins" or areas delineated by ground-water divides (fig. 2). The divides are assumed to approximate the positions of the land-surface drainage divides, and the direction of movement of ground water in each basin probably approximates the direction of land-surface slopes.

Base flow in Campo Creek is supplied by ground water, and where the creek channel is in fresh bedrock, as at Castle Rock Dam, the flow represents the discharge from the basin above, except for water that moves through joints past the natural dam formed by the rock without appearing as surface flow. If the amount of water moving out of the basin underground through joints in the rock is assumed to be negligible, the stream flow can be considered to represent the net ground-water discharge from the lower end of the basin.

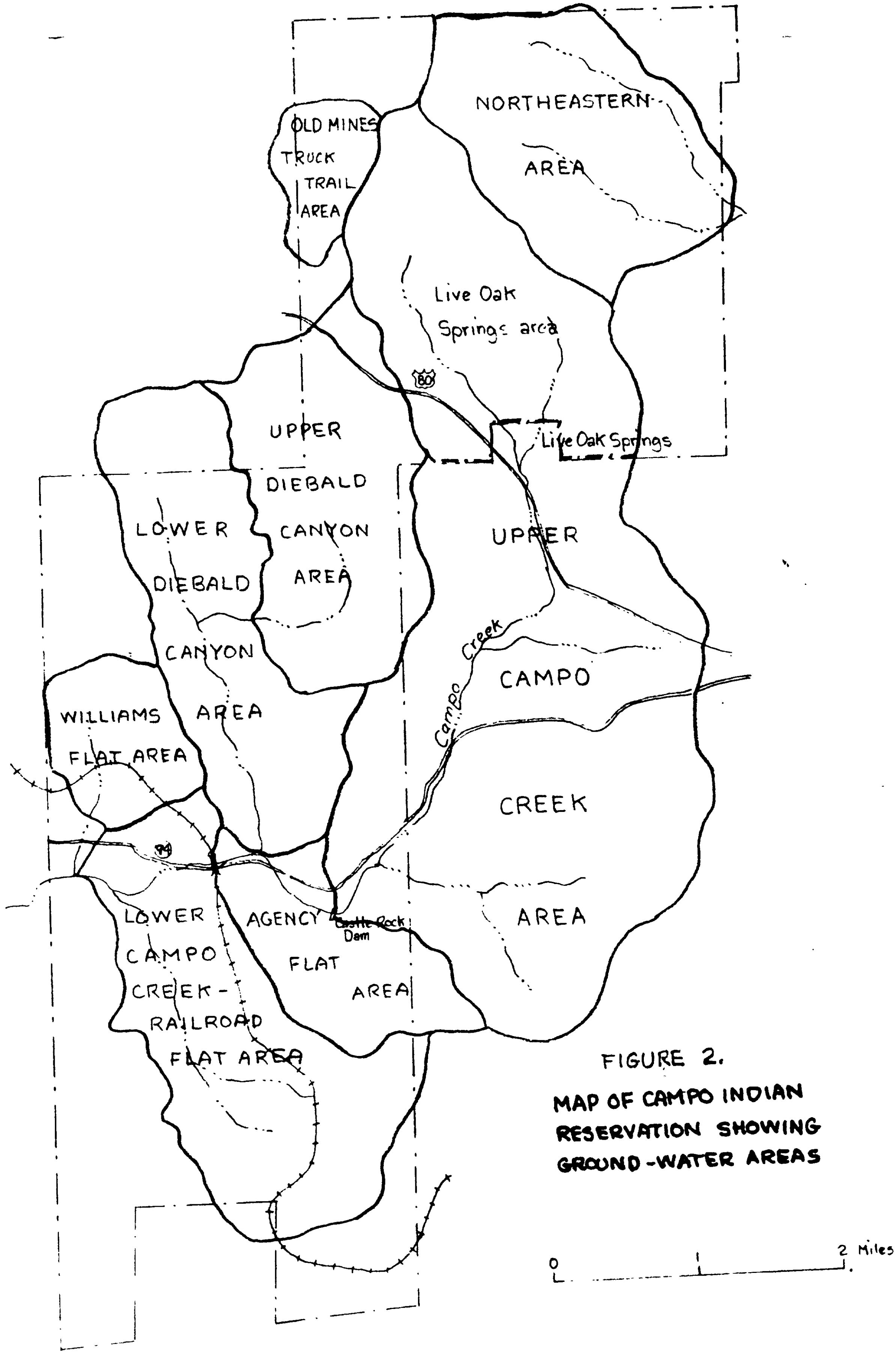

FIGURE 2.

MAP OF CAMPO INDIAN RESERVATION SHOWING GROUND-WATER AREAS

For convenience the occurrence of ground water on the reservation is discussed by areas as shown on fig. 2; a discussion of the Old Campo Unit also is included. In general, the amount of water available for perennial supply is approximately a function of the size of the drainage area above the site of development -- a large area can be more extensively developed than a small one.

Northeastern Area

The northeastern area is in the northeastern corner of the reservation, east of the Tecate divide between Campo and Tule Creeks. Except for a small area at the southern end of the reservation this is the only part of the reservation that is not within the drainage basin of Campo Creek. The drainage of this area, about 1,770 acres, is eastward into Tule Creek (pl. 1). The land surface slopes eastward from a maximum altitude of 4,600 feet on the old upland surface to less than 3,800 feet where the two major tributaries of Tule Creek join just east of the eastern reservation boundary. The ground-water gradient presumably is eastward also but has a slightly gentler slope.

Outcrops of fairly fresh quartz diorite are discontinuous, and most of the area is floored by coarse sandy residuum, a minor amount of local slope wash, and loose sandy alluvium along the lower reaches of the two major creeks. Judging by the number of springs and seeps, and the shallow depth to water in well 17/6E-1L1 ($2\frac{1}{2}$ feet, Oct. 29, 1952), the water table is close to the land surface, even in late summer and fall. North to N. 20° W. alinement of seeps and rows of trees suggests that water comes to the surface along some of the N. 10° W. joints, possibly at ledges of fresh rock downslope from masses of residuum or more highly fractured quartz diorite. The extensive area of loose sandy residuum favors a high rate of infiltration to the water table, and it is not surprising that the water table is high. Small (less than 4 feet thick) aplite and pegmatite dikes extend several hundred yards along the N. 80° E. joints in places and are no doubt effective barriers to ground-water movement in the few localities where they are perpendicular to the slope of the water table. Spring 17/6E-1D1 is formed by the damming action of such a series of small dikes cutting the residuum.

Upper Campo Creek Area

The upper Campo Creek area includes all of Campo Creek drainage above Castle Rock Dam in sec. 3, T. 18 S., R. 6 E., including the Live Oak Springs subarea, and the area south of Live Oak Springs which is not on the reservation. The total drainage area above the dam is 6,860 acres. The dam is in fresh jointed quartz diorite, and the stream flow at this site probably represents most of the discharge from the basin above. The flow on the morning of October 30, 1952 was estimated at one-half cubic foot per second (cfs), or something like 200 to 250 gpm, and it probably was very nearly the minimum flow for the year.

Live Oak Springs Subarea

The Live Oak Springs subarea includes the headwaters of Campo Creek and is defined as that part of the upper Campo Creek area north of the reservation boundary near Live Oak Springs resort. Quartz diorite outcrops are mostly restricted to the slopes adjacent to the alluvial flat along upper Campo Creek; most of the higher lands are underlain by residuum. The water table appears to slope generally south, although springs 17/6E-13M1 and 13N1 east of the resort may be controlled by north-south ledges of hard rock across a locally west-sloping ground-water body. Springs 17/6E-13M1 and 14J1, which furnish water for the resort, are reported to be perennial, and the minimum flow of 14J1 is said to be 6 gpm. Spring 17/6E-11D1, known as "Bubbling Spring," also is perennial, and together with several more springs farther south it furnishes the flow in upper Campo Creek above Live Oak Springs resort. The stream quickly sinks underground in the sizable body of coarse sandy alluvium along the creek, but it reappears in the bedrock-floored canyon south of the resort.

The total drainage area of the Live Oak Springs subarea is 1,890 acres, of which about two-thirds drains into the main branch of Campo Creek. As in the northeastern area, conditions are favorable for ground-water recharge.

Old Mines Truck Trail Area

The Old Mines truck trail area, near the northwest corner of the reservation, about 2 miles northwest of Live Oak Springs, is the drainage area adjacent to the small flat along the stream in sec. 10, T. 17 S., R. 6 E. No stream flow was observed in October 1952, but the water table is near the land surface along the alluvial flat, as indicated by the damp stream bed and a depth to water of less than 2½ feet in shallow dug well 17/6E-10F1.

The drainage area above the point where the small creek crosses the west boundary of the reservation (pl. 1) is 380 acres. Most of this area is underlain by residuum, although fresh jointed and massive quartz diorite crops out locally and may be close to the land surface at many other places. No perennial springs are known to be within the area.

Upper Diebald Canyon Area

As defined here, the upper Diebald Canyon area consists of the drainage basin above the bedrock-floored Diebald Canyon along the northeast edge of sec. 28, T. 17 S., R. 6 E. Unlike the areas previously discussed, a large part of this basin has boulder outcrops of quartz diorite, although residuum is extensive along the northern and eastern margins of the area. Alluvium extends along the stream from the broad flat in the southern part of sec. 15, T. 17 S., R. 6 E., to Diebald Canyon, but it is nowhere more than 25 feet thick, and the stream bed is trenched as much as 20 feet in places. Surface flow is small or absent along the reaches where the alluvium is most extensive, but the flow in the bedrock channel of Diebald Canyon at the lower end of the basin was estimated to be 10 gpm on October 28, 1952. The "bedrock" channel is actually cut in residuum where the flow was estimated, however, and the flow does not represent the total ground-water discharge from the basin. The total drainage area above Diebald Canyon is 1,750 acres.

Several springs and small seeps were found; not all these are shown on the map (pl. 1). One line of seeps and trees is parallel to and about one-third mile east of the upper reach of the stream. This line of "rising water" is evidently along the east edge of the quartz diorite outcrops and at the west edge of the body of residuum. As it moves westward downslope the water in the residuum is brought to land surface by the hard rock. Joints in the fresh quartz diorite are rather widely spaced (10 feet or more) over most of the area, and only a small amount of ground water moves through these fissures.

No apparent structural control was seen for spring 17/6E-27B1, which is in an area of thick residuum. This spring is now (October 1952) used only for stock and is reported to be perennial.

Lower Diebald Canyon Area

The Lower Diebald Canyon area, some 1,360 acres, comprises the drainage basin above the junction of "Diebald Creek" and Campo Creek and below Diebald Canyon. The alluvial flat along Diebald Creek is underlain by as much as 30 and possibly 50 feet of alluvium, and is the most extensive and perhaps thickest body of alluvium on the reservation. The depth to water in well 17/6E-28J1 was about 28 feet on October 28, 1952, although there was no local pumping draft from this area in the preceding season. No trace could be found of the spring reported to be a short distance east of the small rock reservoir in the NE$\frac{1}{4}$ sec. 34, T. 17 S., R. 6 E. The reservoir was only partly full when visited on October 28, 1952, and no inflow was evident.

Agency Flat Area

The site of the former Campo agency headquarters is on the alluvial flat along Campo Creek between the bedrock channel at Castle Rock Dam and the bedrock channel a mile downstream under the railroad trestle. The drainage area tributary to the flat below Castle Rock Dam is about 910 acres, mostly to the south. The alluvium underlying the flat is predominantly a gray-brown silty quartz dioritic sand and is variable in thickness. The log of well 17/6E-34N1 at the site of the former agency headquarters reports 28 feet of "sandy soil" (alluvium) overlying "decomposed granite." (See table 9.) Hard rock was encountered near the bottom of the well, which is 54 feet deep. At the lower end of the flat, just east of the railroad trestle, the alluvium is trenched to a depth of about 15 feet by Campo Creek. A bedrock hill immediately southeast is completely surrounded by alluvium. As mentioned in an earlier section, much of the trenching, which is always deepest at the lower ends of the alluvial flats, occurred in 1916. This trenching reduces the thickness of alluvium through which the ground water can move, and a steeper ground-water gradient than existed prior to the trenching is thus maintained across the flat.

An indication of the productivity of the alluvium may be obtained from the development test of well 17/6E-34N1. On this test, in April 1939, the well produced 60 gpm with a drawdown of 39 feet. The depth to the static water level at the start of the test was 5 feet, so nearly half the saturated thickness contributing water was alluvium, the remainder being "decomposed granite." (See table 9.) The yield factor, 4.2, is about the same as the yield factors of wells 17/6E-32H1 and 18/5E-3D1 which obtain their water entirely from residuum.

Spring 17/6E-33R1, at the western edge of the Agency Flat, has a reported perennial flow adequate for domestic and garden needs for one family. When the spring was visited on October 24, 1952, the flow was 2½ gpm, which was probably about the low flow for the year. The source of the water is not the alluvium to the east but is evidently open joints in fairly fresh quartz diorite to the south and west. A sizable drainage area is required to sustain a flow of this magnitude so late in the dry season, and the joint system supplying the spring must be extensive.

Lower Campo Creek - Railroad Flat Area

The lower Campo Creek - Railroad Flat area is the drainage basin adjacent to the alluvium along the flat north of Railroad Spring (18/6E-9R1) here designated as "Railroad Flat" and the area adjacent to the alluvium along Campo Creek below the railroad trestle (pl. 1). The "headwaters" of the Railroad Flat drainage are in the deeply disintegrated residuum of the old upland surface described earlier in the discussion of topography of the reservation. This favorable ground-water intake area, and the fairly extensive area of the basin, 2,200 acres, are factors which contribute to provide ample water supply for domestic and small-scale agricultural use at the lower end of Railroad Flat and along Campo Creek. Unfortunately, like the Agency Flat area, this lower flat area has been trenched to a depth of about 15 feet, and the conditions for ground-water storage in the latest part of the dry season are not nearly so favorable as they were before the trenching occurred. Well 17/6E-33N1, a dug pit 6 feet in diameter and 15 feet deep, was dry when visited in late October 1952. The bottom of the pit is the same altitude as the stream bed directly south, which also was dry, but the water table probably was not far below the stream bed, because a pool of water was standing in the stream bed a few hundred feet east.

Williams Flat Area

The small area surrounding the site of John Williams' dwelling, which burned down in 1947, is here designated "Williams Flat." The area is underlain mainly by thick, rather loose, sandy residuum. The log of well 17/6E-32H1 reports 18 feet of "sandy soil" (probably alluvium), overlying 12 feet of sand (possibly residuum), which in turn rests on 30 feet of "soft granite." During the development test in April 1939 this well produced 36 gpm with a drawdown of 35 feet for a yield factor of 3.4. The depth to water on October 30, 1952, was about 20 feet. The drainage area above the lower end of the flat is 610 acres, and the gentle topography, together with the thick mantle of loose, permeable residuum, should provide good conditions for recharge to the ground-water body.

Old Campo Unit

Alluvium is rather extensively developed in the Old Campo Unit. The log of well 18/5E-3D1 reports 46 feet of "sandy soil" overlying "soft granite." Presumably this material is alluvium, although some of it might be loose residuum. At the time of the development test in April 1939 the well produced 58 gpm with a 30-foot drawdown. The static water level at the start of the test was 46 feet, so the alluvium or loose residuum was dry, and all the water was produced from the "soft granite" (residuum). The depth of the well is 104 feet, the last 2 feet being in fresh rock. The yield factor for the test is 4.2, the same as the yield factor of well 17/6E-34N1 at the Campo Agency site. The abandonment of two test holes farther north, up the alluvial flat, when fresh bedrock was encountered at 28 and 38 feet, indicates the importance of locating a well in an area of thick residuum. Jointing is not as regular or persistent in the fresh rock exposed in the Old Campo Unit as it is in the quartz diorite on the main part of the reservation to the east. For this reason, Old Campo Unit has only a small amount of recoverable ground water. The alluvium, though perhaps thicker than anywhere on the eastern part of the reservation, seems to be entirely above the late-dry-season zone of saturation, except in the small meadow at the northeast corner of the unit.

Quality of Water

Data from partial chemical analyses of water samples from four localities on Campo Reservation are summarized in table 5. In general, all four waters are of fairly good quality and could be used for domestic and irrigation purposes without harmful effect. The waters are of the same general type, nitrate being the only constituent varying markedly in the samples. The total concentration of dissolved solids was not determined, but the specific conductance affords a rough indication of the relative amounts of dissolved solids in waters; in many waters the dissolved-solids content, in parts per million, is approximately equal to the specific conductance times 0.7.

The difference in specific conductance and concentration of the various ions can be attributed, in part at least, to the position of the locality within its surface drainage area. The water having the lowest concentration is that from spring 17/6E-13M1 at Live Oak Springs near the upper end of the Campo Creek drainage basin; the highest concentrations are in the Campo Creek water at Castle Rock Dam, several miles downstream from Live Oak Springs. The bulk of the water at Castle Rock Dam has probably moved farther from its source than any of the other three waters, and it has also moved through more alluvial material where it presumably can dissolve more mineral matter than in the bedrock.

Table 5.--Chemical-quality of waters on Campo Indian Reservation

[Analyses by U. S. Geological Survey; expressed in parts per million]

Sample number	5688	5689	5690	5691
Date of collection (1952)	10-24	10-24	10-29	10-30
Temperature (°F)	65+	-	60+	-
Calcium (Ca)	48	37	29	61
Magnesium (Mg)	10	8.4	5.3	12
Sodium (Na)	54	46	40	71
Potassium (K)	2.2	2.2	1.2	1.9
Bicarbonate (HCO_3)	232	176	138	274
Carbonate (CO_3)	0	0	0	8
Chloride (Cl)	49	54	34	66
Nitrate (NO_3)	4.3	0.6	10	0.5
Boron (B)	.10	.09	.14	.11
Hardness as $CaCO_3$:				
Total	161	127	94	202
Noncarbonate	0	0	0	0
Specific conductance (Micromhos at 25° C)	550	466	364	675
Percent sodium	42	44	48	43
pH	8.0	8.2	8.1	8.4

Sample number	Source
5688	Spring 17/6E-33R1, from iron pipe at spring.
5689	Stream at 17/6E-22F, upper Diebald Canyon area.
5690	Spring 17/6E-13M1, overflow from concrete reservoir.
5691	Campo Creek at 18/6E-3C, 50 yards above Castle Rock Dam.

Present Water Development

With the exception of well 18/5E-3D1 on Old Campo Unit, the present sources of water supply on Campo Reservation are springs, shallow dug pits, and surface diversions.

Well 18/5E-3D1 was drilled in February 1939, after abandonment of two test holes a short distance north which encountered hard "granite" at 28 and 38 feet, respectively. A windmill was installed in June 1939, and three-fourths mile of distribution pipe and a reservoir were constructed to supply three families. The windmill was replaced with gasoline-engine-driven pump in 1952. The pipeline is reported to be continually corroding, but the cause of this corrosion is not known.

Two other wells were drilled by the Bureau of Indian Affairs on the Campo Agency Unit in March and April 1939, and one additional well was drilled by the owner in 1949. None of these three wells is in use at present (October 1952), however.

There are two surface diversions on the Campo Agency Unit, one at Castle Rock Dam just above Agency Flat, the other in Diebald Canyon. Most of the low flow of Campo Creek is diverted at Castle Rock Dam into a pipe distribution system which supplies domestic water for two or three families at Agency Flat. Because of inadequate sanitation facilities, this water is not used for drinking, however; bottled water is used for this purpose. The Diebald Canyon diversion takes water from "Diebald Creek" into a distribution system which supplies water used mainly for domestic purposes to three families living on the flat below.

The rest of the Indian families on the large Campo unit have located their dwellings near springs or have dug shallow wells in nearby stream beds. Most of these springs are reported to be perennial, although the flow in the latter part of the dry season may be barely sufficient for minimum domestic requirements. Several dwellings that were situated near seasonal springs have been abandoned for lack of water during the long period of subnormal rainfall from 1944-45 to 1950-51 (table 1).

In general, the present water supply is inadequate for irrigation, although four of the wells (17/6E-28J1, 32H1, 34N1, and 18/5E-3D1) are probably capable of supplying water to irrigate several acres, if used properly. The Campo Creek water diverted at Castle Rock Dam could also be used to irrigate several acres.

Possibilities for Additional Water Supply

General Considerations

Additional water for irrigation and domestic use on Campo Reservation would have to be developed primarily from wells, although the existing surface-water supply could be used more effectively than at present. The following factors need consideration in planning future well development:

1. Whether the cost of constructing the well and installing the pump would compare favorably with the economic benefits to be derived, particularly in the case of an irrigation well. A large-diameter well with laterals would be required to assure an irrigation supply through a period of dry years, even at the most favorable

sites indicated on the reservation. This elaborate type of well is much more costly to construct than a conventional drilled well of small diameter.

2. Whether the well site would be near a present Indian settlement or where Indians might live in the future.

3. Whether the topographic and geologic factors at the well site (discussed on p. 49-50) are favorable.

Topographic and Geologic Factors in Selecting a Well Site on Campo Reservation

Before listing the areas where water might successfully be developed from wells, the topographic and geologic factors that must be considered in selecting specific locations in any of these areas will be reviewed briefly. In general, it is desirable to explore the most likely sites with nets of small-diameter test holes, particularly in places where possible construction of expensive lateral-type wells is contemplated. A test-hole net would furnish such necessary information as depth to water, thickness of alluvium, thickness and character of residuum, and degree of fracturing of the fresh bedrock; also, at some places the test holes could be bailed or pumped for information on yield.

As a rule, a site as far as possible from outcrops of fresh bedrock is least likely to encounter hard rock at prohibitively shallow depth. The buried surface of the fresh quartz diorite is probably very irregular, and finding a thick "pocket" of residuum is largely a matter of chance.

Nevertheless, the possibilities of encountering a thick body of alluvium or residuum are improved by placing the well as far as possible from outcrops of fresh rock.

The water-bearing formation, whether it is residuum or alluvium, or both, should be sufficiently thick and permeable at the well site that an adequate pumping rate can be maintained for a period of several days without pumping the well dry. A site near the downstream end of a deeply trenched alluvial flat is not generally as favorable as a site near the center or toward the upstream end of the flat. (See discussion of Agency Flat area, p. 41.)

The drainage area above the proposed well site should be adequate to assure a perennial rate of recharge to the ground-water body at least equal to the perennial rate of net withdrawal by the well.

Finally, the site should be as far as possible, preferably up-gradient, from any possible source of contamination or pollution.

Localities of Possible Water-Well Development

The general areas where water might be developed by wells are listed below. The topographic and geologic factors to be considered in the selection of a specific well site have been summarized briefly in the preceding discussion (p. 49-50), and a description of each of the areas listed below is given in the discussion of the occurrence of ground water (p. 34-44).

Although the areas cannot be listed strictly in order of their chances of successful development, the possibilities of obtaining successful wells are believed to be best in the areas near the top of the list.

	Area	Location[1]	Page reference in text
1.	Alluvium of Agency Flat area	18/6E-3, 17/6E-34	41,42
2.	Alluvial flat along Campo Creek in southern part of Live Oak Springs area	17/6E-14	38
3.	Alluvium and adjacent residuum in northeastern area	17/6E-1,12	36,37
4.	Alluvial flat in lower Diebald Canyon area	17/6E-21, 28,33	40,41
5.	Alluvium and bordering residuum in SE$\frac{1}{4}$ sec. 22 and NE$\frac{1}{4}$ sec. 27, upper Diebald Canyon area	17/6E-22,27	39,40
6.	Alluvial flat on Old Campo Unit south of well 18/5E-3D1	18/5E-3	44
7.	Alluvium and bordering thick residuum of Williams Flat	17/6E-32	43
8.	Alluvium and bordering residuum of lower Campo Creek-Railroad Flat area	17/6E-32,33 18/6E-4	42,43
9.	Small area of alluvium in Old Mines truck trail area	17/6E-10	39
10.	Thick residuum of old upland surface in southern part of lower Campo Creek-Railroad Flat area	18/6E-9,10, 15,16	42,43,33
11.	Alluvium upstream from Castle Rock Dam	17/6E-34	37

1/ Township/range - section (s)

MESA GRANDE RESERVATION

General Features

Location and Extent of Reservation

Mesa Grande Indian Reservation has an area of 5,963 acres in north-central San Diego County about 10 miles northeast of Ramona. (See fig. 1.) The reservation is in three parts: (1) a strip about 1 mile wide and 4 miles long which was formerly Santa Ysabel Indian Reservation number 1, just north of the town of Mesa Grande; (2) an L-shaped area of about 5 square miles, formerly the Santa Ysabel Indian Reservation number 2, south of Mesa Grande; (3) a small area (120 acres) which was the original Mesa Grande Reservation in Black Canyon about 3 miles south of Mesa Grande. For convenience, the first part will be referred to in this report as "Number 1 Unit", the second as "Number 2 Unit", and the small area as "Old Mesa Grande Unit".

The Water Problem

Most of the Indians live in the western part of Number 1 Unit and in the northernmost part of Number 2 Unit. According to the Bureau of Indian Affairs, the number of Indians living on the reservation in the spring of 1952 was 100; however, in November 1952 the number of permanent residents was closer to 50, according to Delmer Nejo, tribal-council spokesman.

Most of the water is used for domestic purposes and is derived from springs, some of which dry up in the latter part of the dry season. Some of the families are forced to haul water during these dry months.

Briefly, a source of water that does not fail in the late summer and early autumn is required, and developments of ground water that could sustain a small agricultural development on the small flat along Scholder Creek on the Number 1 Unit, and on the other flat area in the southeastern part of the Number 1 Unit, would be desirable.

Geology

Rock Units

General relations.- Mesa Grande Reservation is covered by a report and geologic map of the southern part of the Ramona quadrangle by Richard Merriam (1946), and some of the geology shown on the map (pl. 2) accompanying the present report and a few of the rock descriptions in the following paragraphs are taken from Merriam's paper.

In general, Mesa Grande Reservation is underlain by schistose metamorphic rocks which are probably Triassic but may be older, and by several intrusive rocks of Jurassic (?) and Cretaceous (?) age which have, in places, invaded the metamorphic rocks. Alluvium of Quaternary age is of exceedingly small extent and thickness, and weathered bedrock (residuum) is likewise thin and not extensive.

Schist.- The metamorphic rocks are predominantly mica schist, with subordinate quantities of interbedded sillimanite schist, quartzite, and amphibolite. This assemblage was named the "Julian schist" by Hudson (1922) from its typical occurrence near the town of Julian, about 12 miles southeast of Mesa Grande. The Julian schist of the type area has been described in detail by Donnelly (1934).

The mica schist consists of quartz, plagioclase, and muscovite and biotite (micas) and is mostly very fissile. The sillimanite schist is similar to the mica schist but contains prisms of sillimanite in addition to the minerals just mentioned, and it is generally coarser-grained.

The quartzite is either massive or laminated, and it grades into the mica schist. Dark-green beds of amphibolite are locally abundant but constitute only a small percentage of the metamorphic rocks.

The schist in places is cut by dikes and sills of quartz and pegmatite (coarsely crystalline quartz and potash feldspar) generally less than 2 feet thick. Much of the schist has been invaded also by quartz diorite (Stonewall quartz diorite of Merriam, 1946), but the proportion of quartz diorite is not large in the areas shown as schist on the map (pl. 2).

Mixed rock.- As delineated in this report, the mixed rock corresponds to Merriam's Stonewall quartz diorite and is probably equivalent to the mixed rock of Julian schist and Stonewall granodiorite of Everhart (1951, p. 64-65) in the Cuyamaca quadrangle, south of Mesa Grande Reservation.

Although bodies of the Julian schist and Stonewall quartz diorite as much as several hundred feet across and a mile or more in length are included in this unit as shown on the map (pl. 2), most of the mixed rock consists of schist that has been intimately injected, partially assimilated, or replaced by the quartz diorite. The resultant hybrid rock is generally gneissic, ranging from strongly banded lit-par-lit injection gneiss to moderately foliated coarse-grained quartz diorite.

Gabbro.- The gabbro on Mesa Grande Reservation has been mapped as the San Marcos gabbro by Merriam (1946), who correlated it with that in the type locality of Miller (1937), and it is believed to be correlative with Hudson's Cuyamaca basic intrusive (Hudson, 1922). Most of the rock is massive to slightly foliated, dark gray to nearly black, and medium grained (average crystal length 2 to 3 mm). Very coarse-grained rock with hornblende crystals up to 20 mm long occurs locally, and the southwestern margin of the mass on Number 1 Unit, adjacent to the mixed rock of Julian schist and Stonewall quartz diorite, consists of a fine- to medium-grained slightly gnessic gabbro containing phenocrysts of white plagioclase about 5 mm long. The minerals include plagioclase, hornblende, biotite, quartz, and a few other minerals difficult to identify megascopically. In some of the rock, such as that north of Scholder Creek, biotite and quartz are absent.

Granodioritic rocks.- This rock on Mesa Grande Reservation is composed entirely of the Bonsall tonalite, as mapped by Merriam (1946). The Bonsall tonalite is not easily distinguished from some of the adjacent Stonewall quartz diorite of the mixed-rock unit, and the boundaries shown on the map (pl. 2) are interpreted from Merriam's small-scale geologic map of the area. The southwestern border of the mixed rock (northeast edge of the Bonsall tonalite) may be about 2,000 feet northeast of the boundary shown on the map.

The Bonsall tonalite exposed in the western part of Number 2 Unit is a moderately gneissic to massive coarse-grained medium-gray quartz diorite or tonalite containing plagioclase, quartz, biotite, hornblende, and minor amounts of accessory minerals. Locally, a light-gray fine-grained rock, slightly to moderately foliated and containing biotite shreds, granulated quartz, and some feldspar, is abundant. Elongate bodies of partially assimilated Julian schist sparsely scattered through the tonalite are generally not more than 5 feet thick. The tonalite is cut by small dikes of pegmatite which are most numerous on the Old Mesa Grande Unit.

Alluvium.- Alluvium, of Recent age, is of minor extent and thickness on the reservation. The only alluvium sufficiently thick or extensive to be considered a possible source of ground water is beneath the flat along Scholder Creek in the northeast part of sec. 28, T. 11 S., R. 2 E. The material underlying the flat appears to be predominantly gray-brown sandy silt containing a few angular fragments of gabbro and other bedrock types. The thickness of the deposit is probably less than 40 feet. The area of the flat is about 60 acres, and the total ground-water storage capacity of the alluvium is very small -- perhaps less than 200 acre-feet.

Geologic Structure

No large-scale faults are evident on the reservation. The dominant structural feature is the foliation and jointing of the various crystalline rocks.

The gabbro body crossing the middle part of the Number 1 Unit consists mostly of massive rock having no pronounced foliation or lineation except in a narrow zone along the southwestern boundary. Joints and other fractures are prominent in fresh outcrops but have no apparent areal pattern.

The details of the structure in the mixed rock on both sides of the gabbro body differ from place to place, depending on the dominant type of rock, but in general the foliation and joints have a northwest regional trend. The thinly laminated schistose zones have closely spaced (one-half to 3 inches) fractures parallel to the laminae, and irregularly spaced joints in other directions. In the more coarsely crystalline zones of moderately gneissic quartz diorite, the joints are farther apart than in the schist, and a more regular rectangular pattern is evident.

The northwest trend of joints and foliation continues into the mixed rock in the north half of sec. 3, T. 12 S., R. 2 E., on Number 2 Unit, but in the area to the south the trend changes to northeast.

In the southeastern corner of Number 2 Unit, the moderately gneissic quartz diorite containing a few schist remnants has a northwest foliation and jointing, and subordinate northeast jointing. The joints are generally several feet or tens of feet apart.

Except for locally prominent horizontal joints or sheeting in the more massive phase of quartz diorite, the dip of all the joint planes in the area is very nearly vertical.

Topography

Mesa Grande Reservation is in mountainous terrane where the total relief is about 2,500 feet in a few miles. The mountains on Number 1 Unit north and east of Mesa Grande have an altitude of nearly 4,500 feet, about 1,500 feet above their western base, and the bottoms of Black Canyon and the canyon of Bloomdale Creek have an altitude of about 2,000 feet in the southern parts of the reservation. Except for the 60-acre flat along Scholder Creek in the northern part of the area, none of the reservation is flat enough for farming, although a small area in the SW$\frac{1}{4}$ sec. 25, T. 11 S., R. 2 E. and parts of sec. 13, T. 12 S., R. 2 E. could be used for growing crops on a small scale.

Occurrence of Ground Water and Present Water Development

General Features

The alluvium on Mesa Grande Reservation is very thin and covers only a small area; hence, most of the ground water occurs in the crystalline rocks. Unlike Campo Reservation, where some of the topography in the bedrock exposures is fairly gentle, and thick masses of disintegrated rock provide possible ground-water reservoirs, the Mesa Grande area is mostly hilly or mountainous, and relatively flat areas underlain by residuum are small and scattered. Most of the water on the reservation is therefore contained in the soil and in fractures of the crystalline rocks. Springs that can be relied on for supply through the dry season are widely scattered, although groups of perennial springs occur at several localities.

In the hydrologic reconnaissance made during the present investigation, the only areas examined in any detail were near present Indian settlements or where the topography and accessibility might favor future settlement. The southern part of Number 2 Unit was not examined because of the inaccessibility and exceedingly rough terrane.

Number 1 Unit

Mesa Grande School area.- This area lies on the west and southwest flanks of the mountain mass north and east of Mesa Grande, and is underlain chiefly by Julian schist and somewhat gneissic Stonewall quartz diorite of the mixed rock unit. Several small springs and seeps that emerge near the base of the mountain slope derive their water from joints and other fractures. These springs are used locally for domestic and stock purposes by several Indian families. None of the springs was flowing more than 1 gpm when visited in November 1952.

A well (11/2E-28R1) was drilled at the Tillie La Chappa residence in 1941. This well, which is 53 feet deep, is primarily in residuum (gruss) of the Stonewall quartz diorite. Under test pump, the discharge was 4 gpm with a drawdown of 18 feet. According to Delmer Nejo, tribal spokesman, the practice followed in the summer of 1952 was to pump the well only half an hour a day, this being ample for the domestic requirements of one family. The static water level on November 5, 1952, was 26.40 feet. Two test holes a short distance southwest of the road junction in the north-central part of sec. 28, T. 11 S., R. 2 E. (11/2E-28G1, 2), were abandoned when "solid rock" (mica schist and quartzite) was encountered at a depth of 20 feet.

Flat along Scholder Creek and vicinity.- The only alluvium on Mesa Grande Reservation thick and extensive enough for a sizable ground-water development is along Scholder Creek in the northeast corner of sec. 28, T. 11 S., R. 2 E. This alluvial area, about 60 acres, has not been developed to date, although there has apparently been some irrigation using surface water from Scholder Creek. A small rock diversion dam was built across the bedrock channel at the upper end of the flat, but the creek water was not being used in November 1952. The flow past the dam on November 4, estimated to be 5 gpm, probably is very nearly the net ground-water discharge from the basin above. The creek bed is fresh gneiss in which the joints are several feet apart, and a sizable quantity of underflow through joints at this point is unlikely.

The stream flow across Scholder flat was practically zero at the time investigated. However, the creek was flowing at the lower end of the flat near the gravel road crossing, and at a point 250 yards downstream from the road, the discharge was estimated to be 6 gpm on November 4, 1952. A small amount of water, less than 2 gpm, was contributed by the small stream from the north that joins Scholder Creek near the west end of the flat. About 4 gpm is probably effluent seepage from the ground-water body in the alluvium of the flat.

Hill slopes north of Scholder Creek.- Several springs occur in the area north of Scholder Creek in the S$\frac{1}{2}$ sec. 21, T. 11 S., R. 2 E. The rock in this area is irregularly jointed gabbro, intruded by small pegmatite dikes.— A thick reddish-brown clayey soil has formed in places, particularly on the sloping bench near the center of sec. 21. At least three springs occur on this bench, one of which, 11/2E-21K1, has been piped to a nearby dwelling. Spring 11/2E-21R1 supplies water to the dwellings on the Scholder Creek flat area via a reservoir and a pipeline distribution system.

Mountains east of Mesa Grande.- Two rounded mountains east of Mesa Grande about in the center of Number 1 Unit have altitudes of about 4,300 and 4,400 feet. These mountains are underlain by gabbro, which is bordered on the north and east by mixed rock of Julian schist and Stonewall quartz diorite. A swarm of pegmatite dikes and quartz veins, and several springs, occur along the contact zone of the gabbro and the mixed rock. The springs are mostly in thick soil but may be genetically related to the pegmatite dikes, or possibly to the gabbro-mixed rock contact. The springs are not far below a saddle in the ridge and must derive their water from the rounded summits above. Springs 11/2E-27H1 and H2 are circular pits scooped out of thick soil and are now used for watering stock. Spring 11/2E-27J1 along the road is not used at present. Spring 11/2E-26E1 on a thick soil-covered flat is used for stock and on November 3, 1952 had a flow estimated to be slightly less than 1 gpm.

Quail Spring (11/2E-26A1) does not appear to be related to the gabbro-mixed rock contact, but evidently derives its flow from joints in quartz diorite gneiss of the mixed rock. The water is collected by a perforated pipe in the soil and flows into a standard 10- by 15-foot Civilian Conservation Corps stone reservoir along the road. The measured overflow from the reservoir on November 3, 1952, was one-fourth gpm.

Flats in southwest corner of sec. 25, T. 11 S., R. 2 E.- The relatively gentle terrane in the SW$\frac{1}{4}$ sec. 25 in the southeastern part of Number 1 Unit was once the site of a small Indian settlement. This area, which is drained by a south-flowing tributary of Bloomdale Creek, is underlain by a thick soil, with scattered outcrops of mixed rock of quartz diorite and schist. Several damp spots, probably wet-season springs, are scattered through the area, and spring 11/2E-25N1 was flowing a little less than 1 gpm on November 6, 1952. This spring is a seep along the creek, which has been developed with a 4- by 4-foot stone reservoir. It has been used for domestic and irrigation water on the adjacent flat but is now used primarily for watering stock.

Number 2 Unit

Upper Bloomdale Creek area.- With the exception of the southeast corner, the Number 2 Unit of Mesa Grande Reservation is within the drainage area of Bloomdale Creek. Most of the Indians live within a 40-acre tract in the NW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 3, T. 12 S., R. 2 E., where several perennial springs are adequate for domestic needs. These springs (12/2E-3B1,2,3,4, and 5) flow from closely jointed schist-quartz diorite injection gneiss in an amphitheater at the head of a small south-flowing tributary of Bloomdale Creek. Although the drainage area above them is less than 20 acres, the springs are perennial, and 12/2E-3B2, the largest, was flowing at a rate of 2$\frac{1}{2}$ gpm on November 5, 1952. The geologic control for these springs is a fairly thick soil mantle at the head of the canyon, with hard schist ledges downslope at right angles to the surface slope. Water moving downslope through the soil evidently rises to the land surface along northwest vertical joints bounding the hard, impervious schist ledges. A similar structural control seems to account for spring 12/2E-3P1, about three-fourths mile south, which had a discharge of 5 gpm on November 5.

The ravines in sec. 3 all showed evidence of a shallow water table and were flowing a small amount in some reaches. The Bonsall tonalite in the western part of this area is cut by widely spaced vertical joints in two directions, one parallel to the somewhat foliated zones in the rock, the other perpendicular. Oddly enough, some of the flowing reaches of the creek in the SW¼ sec. 3 and NW¼ sec. 10 were in thin alluvium, whereas many of the reaches floored by fresh tonalite with joints 30 feet or more apart had little or no water flowing. Evidently water moves downward through open joints to reappear as stream flow downstream.

Several springs occur in the eastern part of sec. 10. The geologic control for these springs appears to be similar to that for the springs in the northeastern part of sec. 3, the springs generally occurring where the joints in the schistose rocks are at right angles to the movement of ground water downslope. The thick soil-covered divide in the NE¼ sec. 10 acts as a ground-water intake and storage area which supplies a perennial flow to springs 12/2E-10G3 and 10H3. Spring 12/2E-10G3 was discharging about one-third gpm on November 5, the water being used at that time for livestock.

Springs 12/2E-10G1 and 10G2 were not flowing when visited, but the water standing in 10G2 was being hauled to the house nearby for domestic use. Springs 10H1, 10H2, and 10H3 were not developed or used, although they were reported to have a perennial flow.

Southeastern area.- The southeastern part of Number 2 Unit, in sec. 13, T. 12 S., R. 2 E., is underlain principally by gneissic quartz diorite, although some areas of thin alluvium are along the streams. On November 6, 1952, the main ravine which drains southward had no flow, and the water level in the windmill well owned by Charles Ponchetti (12/2E-13Q1) was about 7½ feet below the surface of the adjacent stream bed. Residuum is not thick or extensive in this area, and most of the ground water probably occurs in the widely spaced vertical joints of the quartz diorite. The water produced by well 12/2E-13Q1 is used for stock, irrigation, and domestic purposes, and there had evidently been an adequate supply for all uses in 1952.

Old Mesa Grande Unit

The Old Mesa Grande Unit is in Black Canyon at the junction of Scholder Creek and a small unnamed tributary from the east. The area, some 120 acres, is now used for grazing, and the single dwelling is unoccupied. The canyon walls are precipitous, and the narrow floor of the canyon is underlain by coarse, loose sand and gravel. The main creek was not flowing at the time visited, the water evidently moving down canyon as underflow through the gravel. No sign of any water development was seen; evidently the family that once lived here obtained domestic water from the stream.

Quality of Water

Table 6 lists the results of partial chemical analyses of water samples from six localities on Mesa Grande Reservation. The waters generally show more variation in type than those on Campo Reservation, probably owing in part to the greater variety of rock types on Mesa Grande Reservation.

In general, all the waters appear to be of good to excellent quality and can be used for domestic or irrigation purposes without harmful effects.

Table 6.--Chemical quality of waters on Mesa Grande Indian Reservation

[Analyses by U. S. Geological Survey; expressed in parts per million]

Sample number	5692	5693	5694	5695	5696	5697
Date of collection (1952)	11-3	11-4	11-5	11-5	11-6	11-6
Temperature (°F)	50±	-	60±	-	-	60±
Calcium (Ca)	11	42	25	20	27	14
Magnesium (Mg)	3.1	33	1.5	9.4	6.9	5.1
Sodium (Na)	21	16	13	22	32	17
Potassium (K)	2.8	.7	1.5	4.1	4.1	3.5
Bicarbonate (HCO_3)	61	286	83	118	134	72
Carbonate (CO_3)	0	0	0	0	0	0
Chloride (Cl)	17	17	7.8	10	28	14
Nitrate (NO_3)	.4	.6	3.2	2.4	.4	1.9
Boron (B)	.37	.06	.28	.05	.06	.46
Hardness as $CaCO_3$:						
Total	40	240	69	89	96	56
Noncarbonate	0	6	1	0	0	0
Specific conductance (Micromhos at 25° C)	175	489	188	268	342	191
Percent sodium	51	13	29	34	41	38
pH	7.1	7.8	7.9	7.5	7.7	7.0

Sample number	Source
5692	Spring 11/2E-26A1 (Quail Spring), from iron pipe at spring.
5693	Spring 11/2E-21K1, from hydrant at dwelling.
5694	Spring 12/2E-3B2, from iron pipe at spring.
5695	Spring 12/2E-10G3, from iron pipe at spring.
5696	Well 12/2E-13Q1, from storage reservoir.
5697	Spring 11/2E-25N1, from stone "well".

Possibilities for Additional Water Supply

General Considerations

Two principal methods of developing additional water on Mesa Grande Reservation are: (1) Drilling wells; (2) enlarging and improving existing perennial springs. By drilling wells, sufficient water for small-scale irrigation possibly could be developed; enlarging the existing springs would increase the amount of water available for stock and domestic use but, in most places, would not furnish enough water for irrigation.

The requirements to be considered in planning future well development summarized in the section on Campo Reservation (p. 48-49) also apply to Mesa Grande Reservation. The economic aspects are of particular importance because, as at Campo Reservation, costly lateral-type wells would be required to obtain a perennial irrigation supply even in the most favorable areas on the reservation.

Wells

As has been emphasized, Mesa Grande Reservation is in rough terrane, and few localities are favorably situated for ground-water development.

The most likely locality for well development is the flat along Scholder Creek in the NE$\frac{1}{4}$ sec. 28, T. 11 S., R. 2 E. This area, about 60 acres, is underlain by alluvium probably less than 40 feet thick. The alluvium is not very permeable, but a conventional drilled well in it would probably yield enough water for domestic use of three or four families. More water, for irrigation or other uses, might be obtained from a large-diameter lateral-type well. Such a well should be drilled or dug into the bedrock below the alluvium, and the laterals in the upper part of the bedrock drilled horizontally or with a slight inclination toward the well. The bedrock underlying the alluvium is probably mica schist and quartz diorite of the mixed rock, having the closest-spaced and most prominent joints parallel to the foliation (northwest, with a nearly vertical dip). To intersect the maximum number of joints for the distance drilled, the laterals should be drilled either northeast or southwest -- that is, perpendicular to the joint system.

The alluvium along Scholder Creek below the broad flat is not extensive, and the thickness of unconsolidated material is probably insufficient to provide water yields suitable for irrigation development to a conventional small-diameter drilled well.

Ground water could be developed by a lateral-type well in the small, gently sloping area in the vicinity of spring 11/2E-28Q2, but a conventional drilled well probably would not be successful there because of the presence of hard mica schist and quartzite at shallow depth. Similar rock was encountered at a depth of 20 feet in two unsuccessful test holes about half a mile to the north (11/2E-28G1,2).

Wells might be successfully constructed in the relatively flat area in the southwest part of sec. 25 on Number 1 Unit. Damp ground and the spring 11/2E-25N1 indicated a near-surface water table in this area in early November 1952. The bedrock, covered by a mantle of clayey soil in most places in the area, consists predominantly of moderately to strongly foliated gneiss (mixed rock). A lateral-type well probably would yield sufficient water for irrigating 2 to 5 acres, or a conventional drilled well might be sufficient for domestic use by two or three families.

Additional water could be developed feasibly by wells at only a few likely places on Number 2 Unit of the reservation. The small alluvial flat in the SW¼ sec. 3, T. 12 S., R. 2 E., might be developed by a conventional drilled well, but the possibility of encountering fresh rock at shallow depth is great, and the yield of a well in this area would probably be very small (possibly only 1 or 2 gpm).

The alluvial flat in the NW¼ sec. 13, T. 12 S., R. 2 E., has somewhat better possibilities for water than the area just mentioned. Although the alluvium probably is not thick or extensive enough to provide a perennial supply to a well, the underlying bedrock conditions appear to be fairly favorable, particularly on the north side of the flat. The rock on the north side of the flat is gabbro intruded by numerous pegmatite dikes near its margin. If the pegmatite dikes are highly fractured, as they seem to be along the road to the northwest, a lateral-type well might produce enough water for domestic use by several families.

Springs

Several of the springs visited during the present investigation seemed to be susceptible of more extensive use if improved or developed. Improvements and developments would include digging out and enlarging the spring, constructing a small stone or concrete reservoir, and piping water to the point of use.

A large proportion of the perennial springs on the reservation have been developed in some way, although some of these springs, particularly 11/2E-27N1, 28Q1, 21R1, 21K1, 26E1, and 12/2E-3B3, 10G1, 10G2, could furnish a larger and more stable supply of water if they were further improved. 11/2E-21K1 was not being used except for watering stock in November 1952, although it is reported to be perennial and had a flow apparently sufficient to supply two or three families at the time it was visited.

LA JOLLA RESERVATION

Introduction

Location and Extent of Reservation

La Jolla Indian Reservation is an area of 8,329 acres in T. 10 S., R. 1 E., San Bernardino base and meridian, about 15 miles air line northeast of Escondido. (See fig. 1.) Cuca Grant, an old Spanish or Mexican land grant, is in the west-central part and is completely surrounded by the reservation.

The reservation is on the southwestern slopes of the Agua Tibia Mountains along State Highway 76 between Rincon and Lake Henshaw. The road to Palomar Observatory crosses the reservation. La Jolla Amago, an old Indian settlement, is in the east-central part of the reservation.

The Water Problem

Most of the Indians, reported to be 112 in number in March 1952, live in the vicinity of La Jolla Amago, or on the flats to the south and east, and obtain water principally from two streams, La Jolla and Yapicha Creeks. Both creeks head in a recreational area in Cleveland National Forest on top of the Agua Tibia Mountains (Palomar Mountain) and flow the entire year, although the late dry season discharge is sometimes only a few gpm. The Bureau of Indian Affairs believes that the quality of water would not meet U. S. Public Health Service standards because of pollution, presumably from the recreational area in the headwaters of the two streams. Therefore, other sources of water are needed for domestic use, although the creek waters probably could be used for irrigation. Another objective is the development of a supplemental supply of ground water for late dry-season irrigation when the creek's water supply becomes inadequate.

Geology

Rock Units

Schist.- The schistose metamorphic rocks exposed on La Jolla Reservation are similar to those on Mesa Grande Reservation. Mica schist containing quartz, muscovite, biotite, and generally some plagioclase is perhaps the most abundant type, but a considerable quantity of quartzite is interbedded with the schist in some places, particularly in the exposures in the north-central part of sec. 28, T. 10 S., R. 1 E. Most of the quartzite is light gray and is almost as thinly laminated as the mica schist.

As mapped (pl. 3), the schist includes a small amount of granodioritic material, quartz veins, and pegmatite dikes that have injected the schist. However, where the igneous rocks become abundant, the rocks are mapped as mixed rock. The schist exposed at the western edge of the reservation was mapped as Julian Schist by Hanley (1951) who believed that the rocks were the metamorphosed equivalent of Larsen's (1948) Bedford Canyon formation.

<u>Mixed rock</u>.- This unit is generally very similar to the mixed rock on Mesa Grande Reservation. As mapped, it includes rocks ranging from mica schist and quartzite to massive, coarse-grained granodiorite and quartz diorite, but most of the types appear to be a mixture of schist and the granodioritic rocks. Possibly the most abundant phase of mixed rock is a fine- to medium-grained biotite-feldspar-quartz gneiss, in which the biotite occurs as long granulated and shredded streaks. Hornblende is locally present in small amounts, and some of the rock is stained pistachio green, apparently by small quantities of epidote and chlorite. In some localities, especially in the exposures along the highway in secs. 26 and 27, the foliation is not as distinct a feature as the lineation. A minutely crumpled and crenulated schist-quartz diorite migmatite (mixed rock) is commonly developed near the margins of the schist masses, usually near fairly sizable bodies of quartz diorite. This distinctive rock is abundant in the northeast part of sec. 29 and in the southwest part of sec. 28.

Most of the boundaries between the mixed rock and the adjacent units are gradational, as might be deduced from the nature of the mixed rock as here defined. This gradational relation is particularly marked in the interfingering area of granodioritic rock and mixed rock about a mile south-southwest of La Jolla Amago.

<u>Granodioritic rocks</u>.- As mapped on La Jolla Reservation, this geologic unit includes the Bonsall tonalite of Hurlbut (1935), the Woodson Mountain granodiorite, as described by Larsen (1948), and possible correlatives of the Stonewall quartz diorite and granodiorite as mapped by Merriam (1946) in the area south and southwest of the

reservation. Owing to their general similarity in outcrop and water-bearing characteristics, these rock units were not subdivided on plate 3.

The Woodson Mountain granodiorite underlies the steep, rugged area in the southwestern part of the reservation, where it forms large boulder outcrops and a few great exfoliated masses of virtually unjointed rock along the San Luis Rey River canyon walls. The granodiorite is typically grayish pink, massive to faintly gneissic, and coarse grained and is composed of plagioclase, quartz, orthoclase, biotite, and small amounts of accessory minerals. The rock is cut by small pegmatite and aplite dikes in places, but dikes are not generally as abundant as they are in the Bonsall tonalite.

The Bonsall tonalite is a medium- to light-gray rock that weathers to a darker color and forms less prominent outcrops than the Woodson Mountain granodiorite. The tonalite crops out along the western margin of the reservation and underlies most of the southeastern area, as well as a large proportion of the Agua Tibia Mountains escarpment. Most of the rock is medium-grained and massive to moderately foliated. It contains plagioclase, quartz, biotite, hornblende, and accessory minerals, such as sphene and magnetite.

Terrace clay.- Because of the steepness of the mountain slopes, residuum is not thick or extensive on La Jolla Reservation. The terraces along the San Luis Rey River are about the only areas where weathered bedrock susceptible of possible ground-water development occurs. These terraces, discussed later in the report, are in part underlain by a reddish-brown sandy clay which is probably weathered gneiss and tonalite, although scattered cobbles, possibly stream-transported, occur locally at the land surface. The thickness of the clay probably is exceedingly variable; fresh bedrock ledges stick up through it in many places. Only exposures of terrace clay that are relatively free of rock outcrops are shown on the map. Because of the large percentage of clay, the material is not very permeable, although the soil may be suitable for some crops.

Slide breccia.- Landslides have formed along the Agua Tibia Mountains escarpment where oversteepened slopes are developed on fractured and weathered rocks. The slide material ranges from greenish sandy clay to a breccia of huge angular and subangular blocks of crystalline bedrock. In places the deposits are crudely stratified and the larger rock fragments are rounded, indicating that streams and mud flows reworked some of the material.

The deposits are thin and discontinuous in many areas, and the slide-breccia mapped on plate 3 includes areas where the breccia is discontinuous. In general, the thickest and most extensive slide deposits are in the southeastern part of the reservation.

Fanglomerate.- A system of coalesced alluvial fans along the base of the Agua Tibia Mountains escarpment is high above the present channel of the San Luis Rey River and probably in large part represents an earlier cycle of deposition, although some of the material near land surface undoubtedly has been deposited in Recent time. The fanglomerate, alluvial detritus of the fans feathers out or buttresses against low ridges of hard bedrock at its lower margins.

The fanglomerate generally is poorly sorted and is coarsest near the apexes of the fans at the small canyon mouths and finest at the toes of the fans. Cobbles and boulders of granodiorite and related crystalline bedrock types are prominent, but poorly sorted brownish to grayish sandy silt and clay are perhaps more abundant. The material at the lower margins of the fans may be better sorted, however; the materials penetrated by the George Mendenhall well on Cuca Grant (10/1E-20R1) were principally clay and loose sand, in alternating beds from 1 to 2 feet thick. Fifty-seven feet of fanglomerate was penetrated by this well, but the usual thickness is probably less; it is doubtful that the fanglomerate in the vicinity of La Jolla Amago is anywhere more than 40 feet thick.

Alluvium.- The alluvium of Recent age on La Jolla Reservation lies along the channel of the San Luis Rey River, and consists of unconsolidated sand, gravel, and silt. The deposits are probably nowhere thicker than 25 or 30 feet, and the maximum width is less than 750 feet. Pebble and small cobble sizes are most numerous in the gravel and the fragments consist of the harder rock types of the drainage basin; Woodson Mountain granodiorite and Bonsall tonalite are most common.

Geologic Structure

Elsinore fault system.- The most important geologic feature of La Jolla Reservation is the Elsinore fault, which crosses the reservation in a northwesterly direction near the base of the Agua Tibia Mountains escarpment. The fault is not a single large fracture but is a series of subparallel faults in a zone perhaps one fourth to one-half mile wide. This great fault system is marked topographically by the alinement of mountain escarpments, stream valleys, and canyons from north of Lake Elsinore past the southwest flank of the Agua Tibia Mountains and the southwest side of Lake Henshaw into the western Colorado Desert beyond Julian.

The fault zone follows the San Luis Rey River canyon in the eastern part of the reservation, but lies near the base of the mountain escarpment farther northwest. Actual exposures of the faults are hard to find; slide breccia and surficial weathered rock obscure the relations in most places. In general, however, rocks in the fault zone are intensely shattered, and in places, a greenish clay (probably gouge) marks a zone of completely crushed rock.

Because the positions of the fault traces are difficult to ascertain, and inasmuch as the faults appear to have no particular bearing on the occurrence and movement of ground water on the reservation, little time was spent in field mapping the fault system. The approximate position of the fault zone shown on the map (pl. 3) is believed to be essentially correct, however.

Joints and other fractures in the crystalline rocks.- The most important structural feature that is related to the occurrence and movement of ground water in the area is the joint system in the foliated crystalline rocks that underlie the relatively gentle terrane southwest of the Elsinore fault. The massive granodioritic rocks in the southern and southwestern parts of the reservation are likewise prominently jointed, but the relatively wide spacing of the joints, and the rough, mountainous topography characteristic of the areas of exposures of these rocks, eliminates most of them from consideration as a source of substantial supplies of ground water.

In general, in the area southwest of the Elsinore fault, one set of joints is parallel to the foliation of the rocks. Except in a narrow zone at the west edge of the reservation where the strike of the foliated rocks is about north, the general trend of the steeply dipping foliation is northwest, roughly parallel to the fault zone but probably a little more northerly than the approximately N. 55° W. strike of the fault. The joints are most closely spaced in the thinly laminated schist where they may be inches apart; they are farthest apart in the massive phases of the granodioritic rocks where the spacing may be 20 feet or more.

Another set of prominent joints is perpendicular to the foliation, the strike being northeast and the dips being steeply northwest. These joints are generally farther apart than the joints parallel to the foliation, the distance between open joints averaging 20 feet even in the rather strongly foliated gneiss.

A joint system is prominently developed in the gneiss in the vicinity of La Jolla Amago. This joint set also strikes northeast, but the dip is southeast and averages about 45°. These joints are spaced less than 3 feet apart in some zones, and are approximately parallel to the lineation of the biotite shreds in the gneiss. This jointing and lineation resemble foliation and could be mistaken for it.

Some of the tonalite in the Elsinore fault zone is cut by closely spaced irregularly oriented fractures. These fractures average less than a foot apart, and are wavy instead of plane surfaces. They are prominent in a rather fine-grained phase of the tonalite exposed in the highway cut near spring 10/1E-26R1.

Topography

General features.- Topographically, La Jolla Reservation may be divided into six areas, from northeast to southwest: (1) The Agua Tibia Mountains escarpment; (2) the high alluvial flats; (3) the low, northwest-alined schist and gneiss ridges; (4) the low flats of the old San Luis Rey River valley; (5) San Luis Rey River gorge; and (6) the mountainous granodioritic rock terrane along the southern and southwestern margins of the reservation.

The altitude on the reservation ranges from 900 feet in the San Luis Rey River gorge near the southwestern corner of the area to over 5,000 feet at the top of the Agua Tibia Mountains escarpment at the northeast corner. The local relief of the Agua Tibia escarpment averages about half a mile in height in a horizontal distance of between 1 and $1\frac{1}{2}$ miles, and the canyon of the San Luis Rey River is as much as 2,200 feet deep in the southwestern part of the reservation.

Agua Tibia Mountains escarpment.- This great mountain front, clearly of fault origin, separates the rather gentle hilly country on top of the Agua Tibia Mountains block (including Palomar Mountain) from similar hilly terrane at the base of the escarpment. The scarp is incised by small streams, the largest of which head in the high hilly country on top of the mountain. Two of the larger streams, Yapicha Creek and La Jolla Creek (Cedar Creek) drain a sufficient area underlain by weathered and fractured rock in the high country to have a perennial flow from ground-water discharge.

High alluvial flats.- The base of the Agua Tibia escarpment is bordered by a series of coalesced alluvial fans. From the main flat area narrow tongues of alluvial material extend northeastward along the small streams to altitudes of 3,200 feet, but the main parts of the alluvial fans are at altitudes of from 2,600 to 2,900 feet. Most of the flats are underlain by at least a veneer of fanglomerate, but bedrock is exposed locally, such as at La Jolla Amago and immediately west.

Low schist and gneiss ridges.- Southwest of the alluvial flats are low northwest-alined ridges of gneissic mixed rock and schist. These bedrock ridges apparently have acted as a barrier to the southwestward extension of the alluvial fans, particularly the fans on Cuca land grant.

Low flats of the old San Luis Rey River valley.- One of the most prominent physiographic features of the area is the old valley of the San Luis Rey River. The remnants of this valley occur as small flat valleys and terraces along the river from the southeast corner of sec. 26 to the flats in the northern part of sec. 33. The bottom of the present inner gorge of the river ranges from about 150 feet below the old valley surface upstream to about 300 feet at the downstream end of the old valley. In general, the old surface is more extensive on the north side of the river, but the valley remnants are clearly preserved on the south side as well. The width of the old valley averages about half a mile; its gradient is about 125 feet per mile.

San Luis Rey River gorge.- With the exception of small flats less than 250 yards wide at the western edge of the reservation, at the junction of La Jolla Creek, and along a 1-mile reach at the eastern margin of the reservation, the San Luis Rey River flows in a narrow gorge cut in bedrock and floored by shifting gravels and sands of minor extent and thickness. The canyon walls are steep, and the river is rather inaccessible along most of its course across the reservation.

Mountainous granodioritic rock terrane.- This area, about 6 square miles in the southern and southwestern part of the reservation, is characterized by steep slopes and an abundance of almost impenetrable chaparral. The part of the area underlain by Woodson Mountain granodiorite has abundant large boulder outcrops; the remainder of the area has fewer and generally smaller outcrops of tonalite.

Occurrence of Water and Present Water Development

General Features

Except for a few springs that are sometimes used for watering stock and two or three springs used for domestic purposes, the sources of water on La Jolla Reservation are Yapicha and La Jolla Creeks. These two small streams drain a part of the Agua Tibia Mountains escarpment as well as small areas on top of the mountains. The streams are perennial, probably because their upper drainage area is underlain by a fairly thick mantle of fractured and weathered crystalline rocks which absorbs precipitation readily and releases the water gradually, long after the wet season.

The San Luis Rey River, which crosses the southern part of the reservation, has a sustained summer flow resulting from controlled releases from Lake Henshaw. This flow is diverted into the Escondido

Mutual Water Co's. canal at a dam in sec. 33, T. 10 S., R. 1 E., in the south-central part of the reservation. It is reported that the Indians of La Jolla Reservation have no surface-water rights on the San Luis Rey River.

Yapicha Creek

Yapicha Creek rises in the Birch Hill summer-home district on top of the Agua Tibia Mountains and flows down the escarpment in a steep-sided precipitous ravine. The upper part of the drainage basin, at altitudes of more than 5,000 feet, receives an average annual precipitation of more than 40 inches, some of it as winter snowfall. (See isohyetal map in Ellis and Lee, 1919.) The rock exposed in the upper drainage area is largely weathered tonalite which is probably highly absorptive, and several perennial springs near the head of the drainage basin supply water to the stream.

A small dam near the middle of sec. 22 diverts the surface flow of the creek into a concrete-pipe distribution system about 1½ miles long, having numerous laterals. This system serves the flat area in the vicinity of La Jolla Amago with domestic and irrigation water.

The basin above the diversion has an area of about 900 acres. If the average annual precipitation on the drainage basin is assumed to be 36 inches, the average annual volume of water falling on the area is 2,700 acre-feet. The average annual runoff is probably only a fraction of this, however, because of the loss of water by evaporation and transpiration.

La Jolla Creek

The drainage basin of La Jolla Creek is southeast of that of Yapicha Creek. Besides draining the southern part of the Birch Hill district, the upper La Jolla Creek drainage includes Jeff Valley, an area of relatively gentle topography on top of the Agua Tibia Mountains. The rocks exposed within the basin are similar to those in the Yapicha Creek area, and dry-season stream flow is maintained by ground-water discharge from the fractured and weathered rocks.

The creek water is diverted into a concrete-pipe distribution system about 3½ miles long. This system supplies domestic and irrigation water to several Indian families on the flats east and south of the upper flats at La Jolla Amago. The Yapicha and La Jolla systems were both built in 1913 and were reported to be in good condition in 1952, although several leaks along the Yapicha line were noted during the investigation in November.

The discharge of La Jolla Creek below the junction of the two main branches in the southern part of sec. 23 was estimated to be between one-third and one-half cfs (150-225 gpm) in the late afternoon of November 10, 1952. The drainage area above the junction of the two principal branches is approximately 2 square miles, about 50 percent greater than that of upper Yapicha Creek, and the average flow of La Jolla Creek is correspondingly greater.

Other Creeks in the Reservation

Several other small streams within the reservation drain the Agua Tibia escarpment. Most of these were dry in their lower reaches in November, although the unnamed stream in the southeastern part of sec. 25 had an estimated discharge of one-fourth to one-third cfs (100-150 gpm), and a smaller flow was noted in the stream in the western part of sec. 25 on the morning of November 11, 1952.

The small north-flowing tributaries of the San Luis Rey are shown as intermittent streams on the topographic maps (U. S. Geol. Survey Bourcher Hill and Palomar Observatory quadrangles). However, a small perennial flow is supplied to the lower reach of the unnamed stream in the western part of sec. 35 by spring 10/1E-35E1.

Perennial Springs

In the limited time of the field work, only a few of the springs on the reservation were visited.

The largest and apparently the most prolific spring visited was 10/1E-35E1. This spring, apparently a seep from soil on tonalite bedrock, had a measured discharge of 5 gpm on the afternoon of November 19. The water is collected in a 6- by 6-foot stone reservoir but is not being used at present.

Springs 10/1E-25M1 and 26R1 are near the base of the steep canyon wall on the north side of the highway along the San Luis Rey River in the eastern part of the reservation. The water in these springs appears to discharge from the base of coarse slide breccia and old stream gravel deposits, although the discharge in 25M1 may be, in part at least, from highly fractured diorite in the Elsinore fault zone.

Spring 10/1E-32B1 in the southwestern part of the reservation had a discharge of about one-fourth gpm in the late afternoon of November 18. The water flows from highly fractured and jointed mica schist, and it was evidently used years ago by a group of Indians living on a small flat about 200 feet to the southwest where there are now ruins of an adobe dwelling.

Spring 10/1E-20D1 is a seep in a small ravine in the northwestern part of the reservation. The water appears to come out of soil overlying mica schist. It is used for watering stock.

Ground Water in the Fanglomerate

Much of the water moving down the Agua Tibia escarpment in the small streams and through fractures in the bedrock moves into the fanglomerate. Thence it continues to move slowly downslope to the lower margins of the alluvial fans where some of it comes to the surface. The damp spots and seeps along the lower margins of the alluvial fans at La Jolla Amago and the springs and seeps at the lower edges of the larger alluvial fans on the Cuca Grant (not shown on pl. 3) are a result of this "rising" water.

The geologic control for this phenomenon is a feathering out or buttressing of the deposits against essentially impervious crystalline bedrock. George Mendenhall's irrigation well (10/1E-20R1), near the lower end of the large alluvial slope on Cuca Grant, is favorably situated to take advantage of the damming effect of the bedrock ridge southwest of the alluvial fans.

Ground Water in the Fractured Crystalline Rocks

Except for the springs mentioned, little is known about the occurrence of ground water in the bedrock on La Jolla Reservation. Presumably most of the water is contained in open joints and other fractures, although some water undoubtedly occurs in the soil and in the clayey residuum (terrace clay) along the flats above the San Luis Rey gorge.

A fair indication of the water-bearing character of the gneissic mixed rock in the central part of the area may be obtained from data on the George Mendenhall well 10/1E-20R1 (table 2). Five small-diameter holes (called laterals) were drilled radially in a horizontal plane from a point near the bottom of the well. The aggregate footage of these laterals is 950 feet, and the well is reported to produce 300 gpm with a drawdown of about 50 feet. Probably most of this water is produced from the bedrock, although an indeterminate amount drains down from the overlying 57 feet of fanglomerate which is shut off from direct connection with the well by concrete casing. The laterals penetrated alternating zones of hard and soft rock, and most of the water is probably yielded by the soft rock, but open joints in the hard zones may yield a sizable proportion of the total.

Quality of Water

Table 7 lists the results of partial chemical analyses of water samples from La Jolla and Yapicha Creeks, the two principal sources of water supply on La Jolla Reservation.

The two waters are of similar character and quality. The waters are of generally excellent chemical quality and chemically are entirely suitable for agricultural and domestic use.

Possibilities for Additional Water Supply

General Considerations

As stated earlier, the problem on La Jolla Reservation is one of finding additional sources of water to supplement the present supply from Yapicha and La Jolla Creeks. Possible additional sources are: Springs; the San Luis Rey River; ground water which would be developed by wells; and small streams.

Springs

Unfortunately, most of the springs on the reservation are far from places where the water might be used. A few seeps in the La Jolla Amago area could be developed for domestic supply, but there is little incentive to do this because of the more abundant supply from the Yapicha Creek distribution system.

Table 7.--Chemical quality of waters on La Jolla Indian Reservation

[Analyses by U. S. Geological Survey; expressed in parts per million]

Sample number	5698	5699
Date of collection (1952)	11-11	11-20
Temperature (°F)	-	55±
Calcium (Ca)	32	33
Magnesium (Mg)	6.7	7.9
Sodium (Na)	20	23
Potassium (K)	4.3	4.2
Bicarbonate (HCO_3)	148	135
Carbonate (CO_3)	0	0
Chloride (Cl)	11	13
Nitrate (NO_3)	.0	.0
Boron (B)	.05	.03
Hardness as $CaCO_3$:		
Total	107	115
Noncarbonate	0	4
Specific conductance (Micromhos at 25° C)	297	315
Percent sodium	28	29
pH	8.1	8.1

Sample number	Source
5698	Yapicha Creek, from pipeline at outlet of reservoir in 10/1E-22L.
5699	La Jolla Creek, in 10/1E-26D

Spring 10/1E-35E1 south of the San Luis Rey River has a late dry-season discharge sufficient for domestic use by several Indian families, but there are no people living in the vicinity at the present time (November 1952).

Springs 10/1E-32B1 and 20D1 also could be used for domestic purposes, but no Indians live near these springs at present, and the distances from these springs to present dwelling areas may be prohibitive.

San Luis Rey River

The San Luis Rey River has a late dry-season flow sustained by releases from Lake Henshaw, but the water is all diverted into the Escondido Mutual Water Co's. canal and the Indians are reported to have no rights to use of the water. Even if the river water were available, a minimum pumping lift of 150 feet would be required to furnish water to the terraces north of the river. These terraces are now supplied with La Jolla Creek water which is reported to be sufficient for irrigation, domestic, and stock use except possibly at the end of the dry season during years of subnormal runoff.

The small flat areas along the river channel are mostly unsuitable for farming or dwelling sites, so it is doubtful whether any of the river water could be used in those areas.

Ground Water that Could be Developed by Wells

To date, no wells have been drilled on La Jolla Reservation. The relative abundance of the present surface-water supply from La Jolla and Yapicha Creeks, and the probable necessity of constructing costly lateral-type wells to obtain an irrigation supply makes a study of economic benefits to be derived from wells even more imperative than on Campo and Mesa Grande Reservations. In the following brief discussion, areas where it is believed physically possible to develop ground water are enumerated, but economic feasibility is not considered as it is beyond the scope of this report.

Perhaps the most favorable locality for wells is the upper part of the high flat between Yapicha and La Jolla Creeks, in the vicinity of La Jolla Amago. The fanglomerate in this area is probably not more than 40 feet thick, but it should yield sufficient water to a conventional drilled well for domestic and small-scale irrigation uses. Larger amounts of water and a more stable supply through dry seasons might be obtained from a large-diameter well with laterals drilled in the bedrock underlying the fanglomerate. The bedrock underlying the fanglomerate along the upper margin of the flat is mostly massive to somewhat gneissic quartz diorite which is highly fractured in places, probably along faults of the Elsinore fault system. The fractured rock might yield moderate quantities of water to laterals drilled into it. Northwest-trending vertical joints are the most closely spaced and consistent of the joint systems in the gneissic rock. Laterals drilled northeast or southwest would probably intersect the maximum number of joints in the gneiss per foot of lateral. Diamond bits would be required for drilling some of the laterals because some of the quartz diorite and gneiss is fresh and hard.

The flats along the old broad valley of the San Luis Rey River north of the present stream are a possible area of ground-water development. The terrace clay beneath parts of these flats is probably not very permeable, however, and large-diameter lateral-type wells drilled into the bedrock would be required to obtain yields sufficient for irrigation. Moderately to strongly foliated gneiss (mixed rock) underlies most of the flats, and laterals should be drilled in a north-northeast or south-southwest direction to intersect the maximum number of joints, which are mostly parallel to the foliation. Joints in the massive tonalite or quartz diorite usually are more widely spaced than in the gneiss and are locally as much as 20 feet apart. In general, in the low, flat areas, the gneissic mixed rock is a more likely source of water than the granodioritic rock (quartz diorite or tonalite).

Small Streams

Besides La Jolla and Yapicha Creeks, several small perennial streams on the reservation could be developed as additional sources of water. The small southwest-flowing tributary that joins the San Luis Rey at the Escondido Mutual Water Co's. diversion dam in the NE$\frac{1}{4}$ sec. 33, T. 10 S., R. 1 E., was flowing 10 to 15 gpm on November 18, 1952. That should be ample to supply the small flat to the northeast with water for stock or small-scale irrigation use.

The several small creeks northwest of Yapicha Creek may have enough water in some of their reaches for domestic supplies, and two creeks on the reservation east of La Jolla Creek had a small flow in November 1952. Like the headwaters of Yapicha and La Jolla Creeks, however, these streams may be polluted.

PAUMA RESERVATION

General Features

Location and Extent of the Reservation

Pauma Indian Reservation includes an area of 225 acres in Pauma Valley in northwestern San Diego County, Calif. (See fig. 1.) The reservation occupies a part of the old Pauma land grant in T. 10 S., R. 1 W., San Bernardino base and meridian, and can be reached by a paved road east from State Highway 76 about 5 miles southeast of Pala.

Unlike Campo, Mesa Grande, and La Jolla Reservations, which are underlain principally by crystalline bedrock, Pauma Reservation is on an alluvial fan (pl. 5) underlain by coarse deposits derived from the Agua Tibia Mountains to the east and north. Pauma Creek drains a large part of the northern Agua Tibia Mountains and flows across the alluvial slope near the southern boundary of the reservation. It emerges from the canyon mouth about half a mile east of the reservation and empties into the San Luis Rey River, which flows northward through Pauma Valley about a mile west of the reservation.

The Water Problem

About 65 Indians were living on Pauma Reservation in the spring of 1952, and more than 70 in June 1953. Except for irrigation of 7 acres of oranges, most of the water is used for garden, household, and livestock needs. Nearly all the reservation land is potentially irrigable and is suitable for growing citrus fruits, avocados, or deciduous fruits.

The present source of water supply is Pauma Creek, from which the Indians have prior right (included in terms of a trust deed to the land) to the first 30 miner's inches of flow (about 270 gpm or 0.6 cfs). The supply is adequate except in late summer and early autumn of dry years, when the creek flow at the diversion site is substantially less than 30 inches and at times is insufficient to irrigate the 7 acres of oranges.

According to the Bureau of Indian Affairs, it is doubtful that the water would meet U. S. Public Health Service standards for drinking water because of possible pollution. An uncovered reservoir on the northeast boundary of the reservation is believed to be the principal source of pollution--this reservoir is used for swimming during warm weather. Another possible source of pollution is the Palomar Mountain State Park recreation area in the headwaters of Pauma Creek, although the chances of pollution from this area are believed to be slight.

The present water problem on Pauma Reservation is twofold: (1) To find a source of domestic water not subject to pollution, and (2) to obtain an additional late-summer supply for irrigation in years of deficient runoff in Pauma Creek.

Geology and Occurrence of Ground Water

General Features

Pauma Reservation lies on an alluvial slope at the southwestern base of the Agua Tibia Mountains and is underlain by predominantly coarse-grained ill-sorted alluvial-fan deposits of Quaternary age.

(See pl. 4.) The alluvial-fan deposits, or fanglomerate, are a complex group representing several depositional cycles, and they range from channel deposits of Recent age along Pauma Creek to weathered gravels of high terraces that were deposited during the early stages of uplift of the Agua Tibia Mountains sometime in the Pleistocene.

Alluvial-fan sediments representing at least four depositional cycles underlie the area adjacent to the reservation; for convenience these have been designated as follows (pl. 4):

(1) Channel deposits (Qrc)

(2) Younger fanglomerate (Qf_1)

(3) Intermediate fanglomerate (Qf_2)

(4) Older fanglomerate (Qf_3)

The younger, intermediate, and older fanglomerates probably are the Pala conglomerate of Ellis (1919, p. 70), which is reported to contain scattered bones of Pleistocene horses and elephants (Jahns and Wright, 1951, p. 13).

The crystalline rocks, which are exposed in the Agua Tibia Mountains and underlie the fanglomerates to the southwest, have not been subdivided here as they were in the discussion of La Jolla and Mesa Grande Reservations southeast of Pauma Reservation. It is believed that the crystalline rocks are not likely to be developed as a source of ground water at Pauma, and they are considered in this report as one unit: crystalline basement complex (bc).

In addition, a landslide made up of coarse basement-complex detritus at the mouth of the canyon of Pauma was mapped (Qsb on pl. 4).

Most of the ground-water replenishment in the vicinity of the reservation is believed to be by influent seepage from Pauma Creek and the small streams flowing down the escarpment on either side of Pauma Creek, but some is by infiltration of rain that falls on the alluvial fans.

Water levels in wells 10/1W-3M1, 9A1, and 9B2 (table 8) indicate a hydraulic gradient away from the Aqua Tibia Mountains, down the alluvial slope. Unfortunately, the data are too scanty to indicate the depths to water that might be encountered north of Pauma Creek, on the reservation. For example, the depth to water was about 30 feet on June 2, 1953, in well 10/1W-3M1 which is at the north edge of the flood channel of Pauma Creek, a quarter of a mile northeast of the reservation boundary. In well 10/1W-4M1, about 500 feet north of the northwest corner of the reservation, the depth to water was more than 100 feet on the same date. (See table 8.) It seems likely that minimum depths to water would occur along the southern boundary of the reservation, and maximum depths in the northern part of the reservation, up the alluvial slope.

Crystalline Basement Complex

The crystalline rocks are exposed in the Agua Tibia Mountains less than a mile northeast of the reservation, and these rocks underlie the fanglomerates at depths ranging from a featheredge at this outcrop to at least 350 feet on and near the reservation. The crystalline rocks were not examined in detail during the investigation, but they are believed to include the units described on La Jolla Reservation 5 miles southeast, namely: Granodioritic rocks; mixed rock (schist and granodiorite); schist (including smaller amounts of quartzite, amphibolite, and marble).

The rocks exposed near the mouth of Pauma Creek canyon are predominantly schist and mixed rock with foliation and prominent joints dipping steeply northeastward.

Granodiorite crops out in a small hill in 10/1W-9J and K about a mile south of the reservation. This rock may underlie part of the area to the north, beneath the fanglomerates, but whether it does is not significant hydrologically.

The crystalline rocks are not important as a possible future source of ground water for this reservation because of the extensive overlying deposits of fanglomerate which have much higher permeability and because of the relatively abundant supply of surface water from Pauma Creek. The deeply weathered masses of residuum in the upper drainage basin of Pauma Creek do have a favorable effect on the water supply, however, in that they provide storage capacity for precipitation and so maintain a much more stable dry-season flow in the creek than would obtain if the rocks underlying the drainage area were fresh and unweathered.

Slide Breccia

A landslide made up of basement-complex boulders in a matrix of sand, silt, and clay underlies a small part of the mountain escarpment on the north side of the mouth of Pauma Creek canyon in 10/1W-3F. Similar smaller slides occur to the northwest, along the steep mountain face, but are not shown on the geologic map (pl. 4). These slide materials, equivalent to the slide breccia described on La Jolla Reservation, are significant only as probable ground-water intake areas; their steep topographic setting precludes development as ground-water reservoirs.

Older Fanglomerate

The high, dissected terrace in the S$\frac{1}{2}$ sec. 3, T. 10 S., R. 1 W., just east of the reservation (pl. 4) is underlain by fanglomerate consisting of an ill-sorted assemblage of moderately to deeply weathered basement-complex boulders, cobbles, and pebbles in a matrix of sand, silt, and clay. The deposit is reddish brown, probably from ferric oxide resulting from decomposition of the iron-bearing minerals in the rocks.

Like the younger fanglomerates, this "older fanglomerate" was deposited on alluvial fans of steep gradient in the same way the coarse, bouldery materials are now being deposited along the present wash of Pauma Creek. It may be inferred from its relatively high topographic position and consequent deep dissection by stream erosion that this alluvial fan is older than the adjacent fans.

The maximum thickness of the older fanglomerate is not known, but it is at least 200 feet--the height of the scarp cut in it along the southeast bank of Pauma Creek in the SW$\frac{1}{4}$ sec. 3, T. 10 S., R. 1 W. The older fanglomerate is not favorably situated for ground-water development by means of wells, but it is important as an intake area for water that moves laterally into the adjacent younger sediments.

Intermediate Fanglomerate

The fanglomerate of intermediate age is exposed along the base of the mountain escarpment northwest of the reservation and also to the southeast, south of Pauma Creek, where it underlies a terrace whose surface is about 200 feet lower than the surface of the adjacent older fanglomerate. The exposed thickness of the intermediate fanglomerate is 200 feet; the total thickness may be considerably greater.

The intermediate fanglomerate is indistinguishable from the older and younger fanglomerates except by its intermediate topographic position. In places, such as along the base of the mountain front northeast of the reservation, the surface of the intermediate fanglomerate merges almost imperceptibly with the surface of the younger fanglomerate so that a definite boundary between the two cannot be established.

Younger Fanglomerate

The younger fanglomerate consists of ill-sorted and obscurely bedded deposits ranging in grain size from silt and clay to boulders several feet in diameter. Excellent exposures of these sediments can be seen in cuts along the Pala-Rincon Road (State Highway 76) a few miles northwest of Pauma Reservation and along the high escarpment cut by the San Luis Rey River in this vicinity. Crude stratification is characteristic of these exposures; beds of coarse boulders alternate with beds of sand and silty sand and clay.

Although many of the boulders are but slightly weathered, most are badly disintegrated and crumble readily when struck with a hammer or drilled through in a well. The weathering of these boulders--mostly granodiorite and tonalite--must have occurred in place after deposition; the rocks are completely incapable of stream transport in their present friable condition.

The high proportion of clay and silt in even the coarsest boulder beds is likewise indicative of weathering in place after deposition, as is the abundance of ferric oxide which imparts a characteristic reddish-brown hue to the beds. By contrast, clay is much less abundant, and grayish rather than reddish colors are more characteristic in the channel deposits of Recent age along Pauma Creek, where the time since deposition has been insufficient for such extensive weathering.

The log of well 10/1W-9B2, about a quarter of a mile south of the reservation and 344 feet deep, affords a useful picture of the character of the younger fanglomerate (and probably also the intermediate fanglomerate) in the area. (See table 9, p. 119) The poor size sorting of most of the materials is apparent from the log; probably even the beds reported as sand and gravel or gravel are not well sorted. The well pumps 200 gpm at a drawdown of 70 feet for a yield factor (yield in gpm per foot of drawdown multiplied by 100 and divided by thickness, in feet, of aquifers) of only 1.0 for the entire saturated thickness, or a factor of 13 for the 3 feet of sand and gravel and 19 feet of gravel, if the entire production is from these two beds.

The thickness of the younger fanglomerate is unknown. The basement complex probably was penetrated in well 10/1W-9A1, 405 feet deep, but the bottom of well 10/1W-9B2, a quarter of a mile to the west, was reported to be in alluvial material 344 feet below the land surface. Some of this material may be intermediate fanglomerate underlying the younger fanglomerate. (See log in table 9.) The basement complex is exposed in a low hill about half a mile south of well 10/1W-9B2, which suggests that the bedrock surface has considerable local relief. Thus, it is difficult to predict the thickness of fanglomerate that might be penetrated by a well drilled anywhere on the Pauma Reservation.

Channel Deposits

Deposits of sand, gravel, boulders, and silt, representing the most recent cycle of deposition in the area, lie along the present channel of Pauma Creek from the mouth of the canyon to the junction of the creek with the San Luis Rey River about 2½ miles to the southwest. These coarse materials are deposited during floods along a wash which ranges in width from less than 100 yards near the canyon mouth to about half a mile at the highway. The south boundary of the reservation lies approximately along the north edge of this wash, although a few acres in the southwest corner of the reservation are in the wash.

Although the channel deposits appear to be less consolidated and to contain less clay than the fanglomerates, they are of little importance as a source of ground water, except in their function as a ground-water intake area. The thickness is probably not more than a few tens of feet, and most of the deposits are above the zone of saturation during a large part of the year.

Well 10/1W-3M1, about half a mile west of the canyon mouth, is reported by the owner (Monta J. Moore) to reach granite bedrock somewhere below the 53-foot depth. The chief aquifer in this well, which has a total depth of 189 feet, is a sand-and-gravel stratum at 53 feet. Water entered the well and rose to within 31 feet of land surface at the time this aquifer was penetrated during drilling, which indicates that the overlying material is of sufficiently low permeability to act as a confining layer. The rate at which this well can be pumped continuously is reported to be only 10 gpm; the pump setting is 150 feet, hence the drawdown at this pumping rate is approximately 120 feet.

On May 5, 1952, G. F. Worts, Jr., of the Geological Survey estimated the flow of Pauma Creek at the highway to be between 2 and 3 cfs (cubic feet per second), and about 4 cfs at the ford, three-fourths of a mile upstream, which would indicate that the channel in this reach is moderately absorptive. The apparent confinement due to fine-grained material between a depth of 53 feet and land surface may be only local at well 10/1W-3M1; coarse-grained deposits probably predominate beneath much of the wash between the canyon mouth and the highway.

Surface-Water Features

General Description of Pauma Creek

The principal source of water and the only stream of any consequence near Pauma Reservation is Pauma Creek, which drains a large area in the Agua Tibia Mountains, including a part of the astronomical observatory at Palomar Mountain. (See pl. 5.)

The Pauma Reservation Indians have rights to the first 30 miner's inches of flow (about 270 gpm or 0.6 cfs) in Pauma Creek, but the flow drops to less than this amount in late summer of dry years. Their original diversion site was about a quarter of a mile downstream from the Pauma Water Co. diversion (pl. 4), but their right is prior to that of the water company.

The drainage area of Pauma Creek above the diversion site of the Pauma Water Co. near the mouth of the canyon is about 6,900 acres (10.8 sq. mi.). (See pl. 5.) Altitudes within the drainage basin range from 1,360 feet at the lower end to nearly 5,700 feet along the divide west of Palomar Observatory. About 5,400 acres, or 78 percent of the drainage area, is above 4,000 feet. About 3,100 acres, or 45 percent of the drainage area, is above the old gaging station at the lower end of Doane Valley and may be considered the upper headwater area or upper basin as shown on plate 5. Much of the high land in the upper headwater area receives some of the precipitation as snow each winter. The crystalline rocks, which underlie all the drainage area, are at most places deeply weathered or highly fractured so that a part of the precipitation is stored for later release as ground-water discharge from springs and seeps. A small but rather stable late dry-season flow in the creek is thus maintained. (See tables 9, 10, and 11.)

A recreational area of summer homes and camp sites, including a part of Palomar Mountain State Park, occupies some of the upper part of the drainage basin, which is characterized by coniferous and hardwood forest, meadows, and chaparral. The lower part of the basin is on the steep slopes of the Agua Tibia escarpment across which Pauma Creek flows in a narrow canyon 1,000 to 1,500 feet deep.

Runoff

Two continuous gaging stations were operated on Pauma Creek by the San Diego Consolidated Gas and Electric Co. during the water year 1920-21. Except for sporadic miscellaneous measurements made between 1912 and 1923, these are the only data available on the flow of this stream. (See tables 11, 12, and 13.)

Table 11.--Monthly discharge of Pauma Creek near Nellie, Calif., for the year ending Sept. 30, 1921

(From U. S. Geol. Survey Water-Supply Paper 531.)

Month	Discharge in second-feet			Runoff in acre-feet
	Daily maximum	Daily minimum	Mean	
October	5.0	0.3	0.50	30.7
November	.6	.4	.44	26.2
December	1.6	.4	.60	36.9
January	8.1	.5	1.44	88.5
February	3.3	1.0	1.56	86.6
March	33	1.2	4.54	279
April	2.8	1.1	1.67	99.4
May	17	1.1	3.97	244
June	2.9	.7	1.46	86.9
July	.8	.3	.50	30.7
August	.5	.2	.32	19.7
September	1.0	.2	.28	16.7
The year	33	0.2	1.44	1,045

Table 12.--Monthly discharge of Pauma Creek at Pauma Indian Reservation for the year ending Sept. 30, 1921

(From U. S. Geol. Survey Water-Supply Paper 531.)

Month	Discharge in second-feet			Runoff in acre-feet
	Daily maximum	Daily minimum	Mean	
December 15-31	. . .	. . .	2.32	78.2
January	12	1.9	3.54	218
February	6	2.6	3.81	212
March	44	3.0	7.88	485
April	5.5	2.6	3.66	218
May	25	2.6	7.28	448
June	6	1.9	3.35	199
July	2.0	1.1	1.42	87.3
August	1.3	.8	.97	59.6
September	1.1	.9	.93	55.3
The year	. . .	. . .	. . .	2,060

Fortunately, precipitation records covering a somewhat longer time are available for two nearby stations: Amago, on La Jolla Reservation, and Nellie (now Palomar Mountain Post Office), on top of Palomar Mountain (table 1). The records for Nellie are believed to be representative of the maximum precipitation in the upper part of the drainage basin; the precipitation at Amago is probably somewhat greater than that at the canyon mouth at the lower end of the basin. (See Ellis and Lee, 1919, pl. XV.)

If runoff were directly related to precipitation, the relationship indicated for the single year of streamflow records, 1920-21, might be used to estimate the order of magnitude, at least, of the runoff for other years in which precipitation records are available. Actually, however, runoff and precipitation are related only through a complex system of variable factors, and the assumption stated above would be considerably in error for some years. For example, in dry years a great proportion of the total precipitation is lost as evaporation and transpiration; in wet years the proportion lost is far less.

The precipitation at Amago and Nellie for the water year (Oct. 1 to Sept. 30) 1920-21 was 23.33 inches and 37.72 inches, respectively--about 80 percent of normal (average for period of record) for the two stations. The precipitation in the preceding year, 1919-20, was about 110 percent of normal for both stations. Thus, the 1920-21 runoff of approximately 2,250 acre-feet for Pauma Creek at the canyon mouth half a mile east of the reservation was probably slightly below normal. (Table 12 is incomplete, covering only the period December 15, 1920, to September 30, 1921. The runoff at the canyon mouth for the entire water year, based on a comparison with the record at Nellie, would be approximately 2,250 acre-feet.)

The minimum yearly precipitation at Amago during the period of record, 1912-13 to 1943-44, was slightly less than half the average. On a direct comparison the minimum yearly runoff would be slightly less than half the average, or on the order of 1,000 acre-feet. However, because a greater proportion of the total precipitation is lost as evaporation and transpiration in dry years than in wet years, the minimum runoff of Pauma Creek at the canyon mouth must be substantially less than 1,000 acre-feet per year. Nevertheless, there should be sufficient water in the winter and spring of even the driest years to permit storing several tens of acre-feet, if facilities were available.

Table 13 contains additional data available on the flow of Pauma Creek at various sites selected for miscellaneous measurements.

Table 13.--Miscellaneous discharge measurements of Pauma Creek

(Data from U. S. Geol. Survey Water-Supply Papers 447 and 571.)

Date	Locality	Discharge (cfs)
Feb. 12, 1912	One-half mile above Pauma Indian Reservation reservoir (10/1W-3F)	1.4
Apr. 20, 1912	County highway bridge near Pala (10/1W-9E)	22
May 2, 1912	do	6.6
May 22, 1912	do	4.1
June 15, 1912	do	0
July 11, 1912	1,500 feet above intake for Pauma Indian Reservation canal (10/1W-3G)	1.9
do	County highway bridge near Pala (10/1W-9E)	0
Jan. 19, 1913	Near county highway ford on road from Pala to Pauma Indian Reservation	.4
Apr. 18, 1913	do	8.5
May 19, 1913	do	0
Jan. 24, 1914	Near Pala (10/1W-9E)	2.2
Apr. 25, 1914	do	10
May 14, 1914	do	3.6
May 28, 1914	do	1.2
July 20, 1916	Just below intake of ditch (10/1W-3F)	4.0
Aug. 1, 1916	do	4.6
Aug. 15, 1916	do	2.6
Sept. 14, 1916	do	2.1
Nov. 23, 1916	do	3.5

Table 13.--Miscellaneous discharge measurements of Pauma Creek--Cont.

Date	Locality	Discharge (cfs)
Jan. 13, 1916	Pala-Rincon road crossing (10/1W-9E)	4.9
Jan. 15, 1916	do	22
July 20, 1916	do	1.3
Oct. 11, 1916	do	3.2
Sept. 29, 1923	San Diego Cons. Gas & Elec. Co.'s gaging sta. near Nellie (9/1E-31J)	.2
Sept. 30, 1923	do	1.1

Present Water Supply

The present source of water on Pauma Reservation is Pauma Creek; there are no wells or springs on the reservation. From before the turn of the century until 1920, the 30 miner's inches of flow was diverted at a small concrete dam in 10/1W-3F, but the water is now diverted at the dam of the Pauma Valley Water Co., about a quarter of a mile upstream in 10/1W-3G. (See pl. 4.)

Subsequent to an agreement with the water company, a steel pipeline was constructed from a division box on the company's 16-inch concrete line to a weir box below the old diversion dam. In this way the 30-inch flow is provided for the reservation; the excess water up to about 1,500 gpm (170 inches) goes into the Pauma Valley Water Co.'s distribution system. According to the agreement, when the creek flow drops to 30 inches or less, all the water is diverted into the reservation pipeline.

A 10-inch concrete pipe extends about half a mile west from the weir box below the old diversion dam to a small open reservoir on the northeast boundary of the reservation. Water for irrigation is taken from this reservoir through another pipeline and ditch, but some water for domestic use is taken out of the concrete line above the reservoir through 1,860 feet of 2-inch steel line, so as to avoid pollution at the reservoir. This 2-inch line is said to be inadequate when more than one family at a time is using water.

The concrete-lined reservoir is 106 feet long, 56 feet wide, and 8 feet deep. The estimated capacity is about 350,000 gallons, or slightly more than 1 acre-foot.

Water Requirements

Present water requirements on Pauma Reservation are mainly for domestic use and irrigating 7 acres of oranges. The supply probably is adequate for domestic needs, except possibly in late summer of extremely dry years, when Pauma Creek becomes almost dry. The present 2-inch pipeline for domestic use is too small for adequate distribution, however, and a small reservoir is needed for storage to meet peak daily demands. The present storage reservoir, downstream from the turnout to the 2-inch pipeline, is subject to pollution and also is used for storing irrigation water. It might be possible to cover it, in which case it could be used also for storing domestic water, although a schedule would have to be worked out for irrigation.

According to a compilation of data by A. A. Young (1945, p. 26), mature citrus trees in the Vista and Fallbrook districts of northwestern San Diego County require about 18 acre-inches of irrigation water per acre in an average year. Beckett and others (1930) concluded that mature citrus groves near Fallbrook and Escondido require 18 acre-inches of water per acre during the summer season (April 1 to October 15). Adams and Huberty (1933, p. 99) indicate that 15 to 20 percent of the total annual irrigation, or about 2.7 to 3.6 acre-inches per acre, is required in each of the four hottest months of June through September.

The total irrigation requirements probably are somewhat higher in Pauma Valley, which is farther inland and has warmer summers than Fallbrook or Escondido. For the 7 acres of oranges now irrigated the seasonal irrigation requirement might be 10 to 15 acre-feet and a monthly demand of as much as 2 to 3 acre-feet during the hottest months of extremely dry years. During 3 summer months of a very dry year the amount necessary to irrigate the 7 acres of oranges might be 6 to 9 acre-feet. Domestic needs probably would increase this amount by 1 to 2 acre-feet. Thus, the total needs for 3 hot months under present culture would range from 7 to 11 acre-feet.

The present reservoir, the capacity of which is about 1 acre-foot, is wholly inadequate for seasonal storage for irrigation uses. Under the present culture, the need is for either a larger reservoir or a well or wells that could be pumped when flow in the creek drops below late-summer irrigation requirements.

Possibilities for Additional Water Supply

Additional water for Pauma Reservation could be obtained in either of two ways: (1) by building a reservoir large enough to store winter and spring runoff from Pauma Creek for use in late summer when the creek is nearly dry; or (2) by drilling a well or wells.

The relative cost of the two methods would be the deciding factor. A cost analysis of reservoir construction and of a well-drilling program is beyond the scope of this report, but the physical factors can be indicated.

Additional Storage of Pauma Creek Water

The present reservoir of about 1-acre-foot capacity is too small for storing enough water to irrigate 7 acres of oranges in late summer of exceptionally dry years, when Pauma Creek is nearly dry at the diversion site. On the other hand, the reservoir capacity is larger than necessary for storage of domestic water alone, but the water is subject to pollution by swimmers at the present time.

Unfortunately, data are lacking on the duration of periods of essentially zero flow in Pauma Creek at the diversion site in the dry years of the last decade. However, an assumption of 3 summer months of zero flow in Pauma Creek is made, which probably is conservative; a further assumption is here made that the flow during the remaining 9 months would be adequate for irrigation and domestic requirements on the reservation.

The following assumptions, then, are made as a basis for computing the reservoir capacity that would be needed on the reservation:

1. Ten acres of citrus to be irrigated (roughly half again as much as at present);

2. Three months of zero flow in Pauma Creek at the diversion;

3. One-third acre-foot of water per acre per month required during the 3 months.

On this basis, neglecting evaporation loss, a reservoir capacity of 10 acre-feet would be required. If the reservoir were uncovered, 1 acre in area, and 10 feet deep, the total evaporation loss for the 3 hottest months might be 2 to 2½ acre-feet. (See data in Ellis and Lee, 1919, p. 99-104.) Allowing for a margin of safety, a 15-acre-foot reservoir capacity would assure a supply of 10 acre-feet. For a shallower reservoir of correspondingly greater surface area, the evaporation loss would of course be greater.

A 15-acre-foot reservoir having impervious walls such as concrete, asphalt, or clay would be costly to construct, and the economic benefits to be derived would need to compare favorably with the cost of construction.

The present reservoir of 1-acre-foot capacity could be used for storing water for domestic use but it would have to be covered. A pipeline larger than the present 2-inch steel line that bypasses the reservoir would also be needed.

Wells

Additional water for irrigation or domestic use could be developed by means of a well or wells. No wells or test borings have been made on the reservation, but the yields of several nearby wells (table 8) range from 10 to more than 200 gpm.

The wells near the reservation are all conventional drilled wells of about 1-foot diameter and are finished with perforated stovepipe casing. The bottom part of the hole is left uncased in some of the wells, although this practice is not considered safe because of the possibility of caving, particularly when the well is pumped hard. The wells near the reservation range in depth from 100 to more than 400 feet and reportedly penetrate only fanglomerate, possibly excepting wells 10/1W-3M1 and 9A1 which may bottom in the basement complex.

The wells having the highest yield--about 200 gpm--are those farthest out on the alluvial fans, away from the Agua Tibia Mountains. Probably the best location for a well on the reservation, so far as yield alone is concerned, is in the southwestern corner, north of the wash of Pauma Creek. Of course, the greatest overland pumping lift and longest pipeline to the point of use would be required here. A site near the orange grove, where most of the water would be used, perhaps would be nearly as favorable, and the need for a long pipeline would, of course, be cbviated.

List of abbreviations used in tables 8 and 10

Type of well

D - Drilled

Type of pump

J - Jet
L - Lift
T - Turbine

Use

D - Domestic
Irr - Irrigation
S - Stock
Un - Unused

Other data

L - Log
Cp - Partial chemical analysis

CCC - Civilian Conservation Corps

Table 9.--Drillers' logs of wells on Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations, Calif.

17/6E-32H1. John Williams. On Campo Indian Reservation, about 4 miles southwest of Live Oak Springs, 0.33 mile northwesterly along unpaved access road from junction with State Highway 94, on small flat 100 feet east of wash, 75 feet north of large live oak, between two rows of cedars. Open casing, top about 1 foot above land surface, diameter 8 inches, perforated 18-48 feet, gravel-packed.

Material	Thickness (feet)	Depth (feet)
Sandy soil	18	18
Sandy	12	30
Soft granite	20	50
Hard granite	10	60

17/6E-34N1. Campo Agency. On Campo Indian Reservation, about 3½ miles south-southwest of Live Oak Springs, 800 feet southerly along unpaved access road from junction with State Highway 94, on alluvial flat 100 feet east of road, 30 feet south of fence, on 8- by 10-foot concrete slab. Open casing, diameter 8 inches, perforated 10-52 feet, gravel-packed.

Sandy soil and fill	28	28
Decomposed granite	23	51
Hard granite	3	54

Table 9.--Drillers' logs of wells on Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations, Calif.--Cont.

18/5E-3D1. Old Campo 1-2. On Old Campo Unit, about 0.85 mile northerly along unpaved access road from intersection with State Highway 94 just east of Warrens, 180 feet west of road, 300 feet southwest of Indian dwelling, on 10- by 10-foot concrete slab under steel windmill tower. Casing diameter 8 inches, perforated 46-100 feet, gravel-packed.

Material	Thickness (feet)	Depth (feet)
Sandy soil	46	46
Soft granite	56	102
Hard granite	2	104

11/2E-28R1. Tillie La Chappa. On Mesa Grande Indian Reservation, about one-fourth mile northwest along paved road from Mesa Grande store, 50 feet northwest of junction of paved road and unpaved private drive, in metal pump house. Casing diameter 8 inches, perforated 15-33 feet, gravel-packed.

Top soil	3	3
Loose sand, gravel, and clay	12	15
Coarse gravel	11	26
Fine sand	7	33
Decomposed granite	20	53

Table 9.--Drillers' logs of wells on Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations, Calif.--Cont.

10/1E-20R1. George Mendenhall. On Cuca grant about one-half mile south of Palomar Junction, 0.3 mile southwesterly along dirt access road from junction with State Highway 76, near southwest corner of irrigated pasture, on small low ridge, electric pump motor on small concrete slab. Concrete casing, inside diameter 4 feet, length 57 feet.

Material	Thickness (feet)	Depth (feet)
Top soil, some clay; round rocks at surface	16	16
Alternating fluid sand and clay; 1-2 ft.beds	40	56
Black mud and loose rock	1	57
Decomposed granite, hard at bottom	16	73

10/1W-9B2. Vaughn Maynard. About one-fourth mile south of Pauma Indian Reservation on north side of Jaybird Creek, 40 feet northeast of unpaved access road, 14 feet northwest of well 10/1W-9B1. Electric pump motor on a 3- by 3-foot concrete base. Casing diameter 12 inches, perforated 40 to 226 feet, uncased below 226 feet.

Soil and boulders	78	78
Sandy clay	36	114
Sand and gravel	3	117
Conglomerate consisting of clay, decomposed granite, and boulders	68	185
Gravel	19	204
Sandy yellow clay	91	295
Red clay	2	297
Yellow clay	7	304
Conglomerate consisting of clay, decomposed granite, and boulders	40	344

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.

USGS No.	Altitude of water surface (feet)	Date (1952)	Estimated discharge (gpm)	Temperature (°F)	Geologic Occurrence	Remarks
			Campo Indian Reservation			
17/6E-11D1 (Bubbling Spring)	4,400	Oct. 29	-	-	Seep from joints in quartz diorite.	Small pond on side of hill; water piped to dwelling. Perennial.
12F1	3,950	Oct. 29	(a)	-	Pool in fractured quartz diorite.	Small rock dam built to enlarge pool. Reported to be very steady perennial flow.
13M1	3,910	Oct. 29	2+	60+	Seep from quartz diorite residuum.	Covered concrete reservoir. Water is piped to resort. Cp.
13N1	3,880	Oct. 29	negligible	-	Hard ledge of quartz diorite across stream bed.	Not used Oct. 29, 1952. Shown on U. S. Army Campo quadrangle. No improvements

a Estimated to flow less than 1 gpm.

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.--Cont.

			Campo Indian Reservation--Continued			
17/6E-14J1	3,880	Oct. 29	b6	-	Seep from residuum and jointed quartz diorite.	Covered concrete reservoir. Water is piped to resort.
15P1	3,850	Oct. 27	none	-	Seep in stream bed.	3-foot diam. pit dug in stream bed. Water about 2 feet down.
27B1	3,650	Oct. 27	(a)	--	Seep from thick residuum.	Water piped to 10 x 15 foot CCC stone reservoir.
33R1	3,280	Oct. 24	2½	65±	Pool in jointed fresh quartz diorite.	Water piped 430 feet to dwelling. Cp.
18/6E-9R1 (Railroad Spring)	3,440	Oct. 24	(a)	-	Seep from quartz diorite residuum.	Water piped to 10 x 15 foot CCC stone reservoir.
			Mesa Grande Indian Reservation			
11/2E-21K1	3,620	Nov. 4	(a)	-	Seep from gabbro residuum.	5-foot stone reservoir. Water piped to dwelling. Cp.
21K2	3,620	Nov. 4	(a)	-	Seep from gabbro residuum.	No improvements.

a Estimated to flow less than 1 gpm.
b Reported minimum discharge.

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.--Cont.

Mesa Grande Indian Reservation--Continued

11/2E-21K3	3,590	Nov. 4	(a)	-	Seep from gabbro residuum.	No improvements.
21R1	3,420	Nov. 4	Dry	-	Seep in ravine.	8 x 15 ft. covered stone reservoir. Water piped to dwellings below.
25N1	3,770	Nov. 6	(a)	60±	Seep in ravine.	4 x 4 ft. stone reservoir. 1-in. pipe to small watering trough downstream.
26A1 (Quail Spring)	3,710	Nov. 3	$\frac{1}{4}$	50±	Closely spaced joints in quartz diorite gneiss.	Water piped to 10 x 15 foot CCC stone reservoir.
26E1	3,920	Nov. 3	(a)	-	Seep from residuum. Abundant pegmatite in area.	Piped downstream to small concrete reservoir.
27H1	3,920	Nov. 3	negligible	-	Seep from thick soil mantle.	Small circular earth reservoir.
27H2	3,920	Nov. 3	negligible	-	Seep from thick soil mantle.	Small circular earth reservoir.
27J1	3,975	Nov. 3	negligible	-	Seep from soil; 2 pits in slope above road.	No improvements.

a Estimated to flow less than 1 gpm.

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.--Cont.

Mesa Grande Indian Reservation--Continued

11/2E-27N1	3,300	Nov. 6	(a)	-	Dug pit in soil with boulders.	Spring dug out by CCC. Water piped to dwelling.
28Q1	3,230	Nov. 3	none	-	Seep from jointed quartz diorite gneiss on hillside.	5-foot rock well.
28Q2	3,180	Nov. 7	1	-	Seep from jointed schist and gneiss along small gully.	3-foot concrete well, piped to 3-foot concrete standpipe.
12/2E- 3B1	3,320	Nov. 5	-	-	Seep from weathered schist and gneiss in small ravine.	5-foot stone well. Water piped to dwelling below.
3B2	3,250	Nov. 5	$2\frac{1}{2}$	60±	Seep from jointed schist on hill slope.	9 x 18-foot stone reservoir. Cp.
3B3	3,625	Nov. 5	(a)	-	Seep from fractured schist on east slope of hill.	4-foot square stone well.
3B4	3,260	Nov. 6	$1\frac{1}{2}$	-	Seep from schist and gneiss along ravine.	Small rock dam across ravine.

a Estimated to flow less than 1 gpm.

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.--Cont.

Mesa Grande Indian Reservation--Continued

12/2E- 3B5	3,240	Nov. 6	1	-	Seep from schist and gneiss along ravine.	Small rock dam across ravine; water pumped uphill to tank storage.
3P1	2,860	Nov. 5	5	-	Small pool along stream bed in jointed schist.	Small rock reservoir built a few feet downslope.
10G1	2,960	Nov. 5	none	-	Seep from schist along ravine.	Small rock reservoir; water piped to house. Dry in late summer.
10G2	2,935	Nov. 5	none	-	Seep from schist along ravine.	Small rock well. Reported to have no flow in late summer and fall.
10G3	2,900	Nov. 5	1/3	60±	Hard ledge of schist brings water to surface along ravine.	Small rock reservoir. Reported to be perennial flow. Cp.
10H1	2,930	Nov. 5	1	-	Seep from jointed schist and gneiss along ravine.	No improvements.
10H2	2,870	Nov. 5	(a)	-	Seep from soil along ravine. Schist bedrock.	No improvements. Near junction of several ravines.

a Estimated to flow less than 1 gpm.

Table 10.--Description of springs on Campo, Mesa Grande, and La Jolla Indian Reservations, Calif.--Cont.

			Mesa Grande Indian Reservation--Continued			
12/2E-10H3	2,940	Nov. 5	1	-	Seep from deep soil near saddle. Schist bedrock.	No Improvements.
			La Jolla Indian Reservation			
10/1E-20D1	2,540	Nov. 18	none	-	Seep from soil along broad ravine. Schist bedrock.	4-foot circular stone well.
25M1	2,300	Nov. 10	1	-	Seep from fractured quartz diorite near base of steep mountain slope.	No improvements. Along roadside.
26R1	2,300	Nov. 10	(a)	-	Seep from slide breccia near base of steep mountain slope.	No improvements. Along roadside.
27L1	2,400	Nov. 18	1	-	Seep from jointed gneiss near base of steep ravine.	Used for stock.
32B1	2,620	Nov. 18	1/4	-	Small pool in jointed schist along ravine.	Water piped 15 feet to 2 x 10 ft. stone watering trough.
35E1	2,390	Nov. 19	5	60±	Seep from jointed quartz diorite.	6 x 6 ft. stone reservoir. Flow reported to be perennial.

a Estimated to flow less than 1 gpm.

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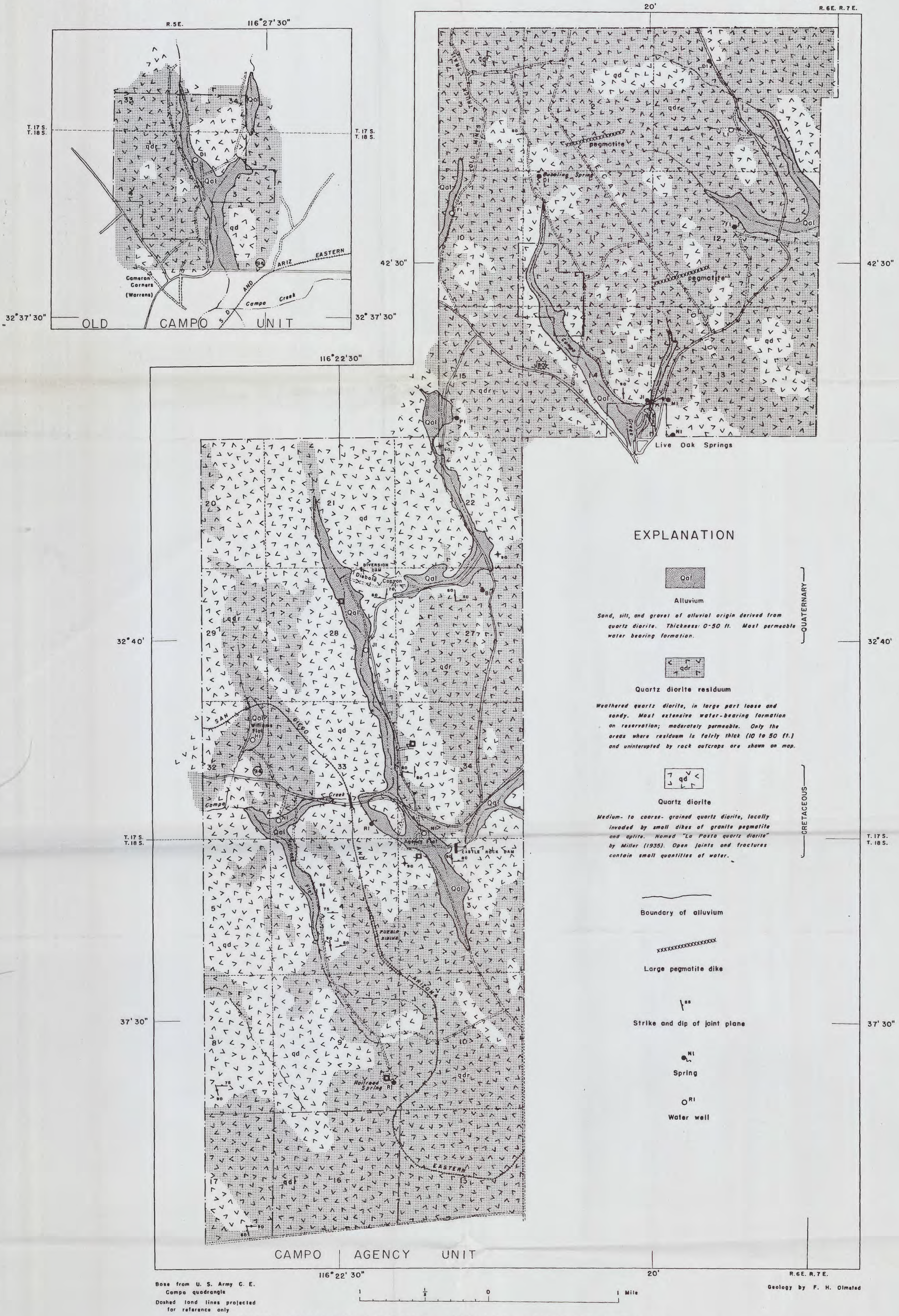
U. S. GEOLOGICAL SURVEY

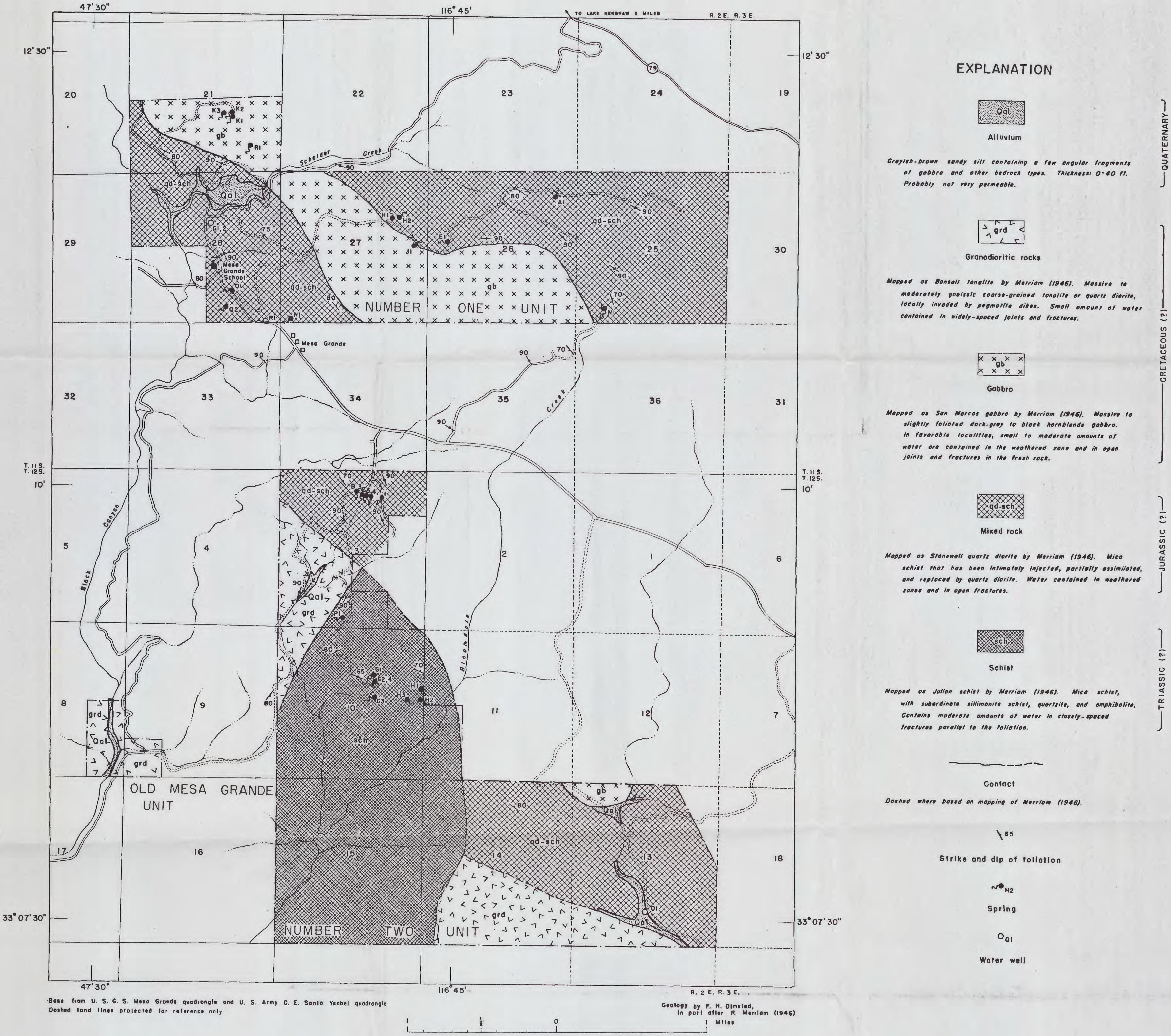
PLATE I



GEOLOGIC MAP OF CAMPO INDIAN RESERVATION, SAN DIEGO COUNTY, CALIFORNIA

U. S. GEOLOGICAL SURVEY

PLATE 2

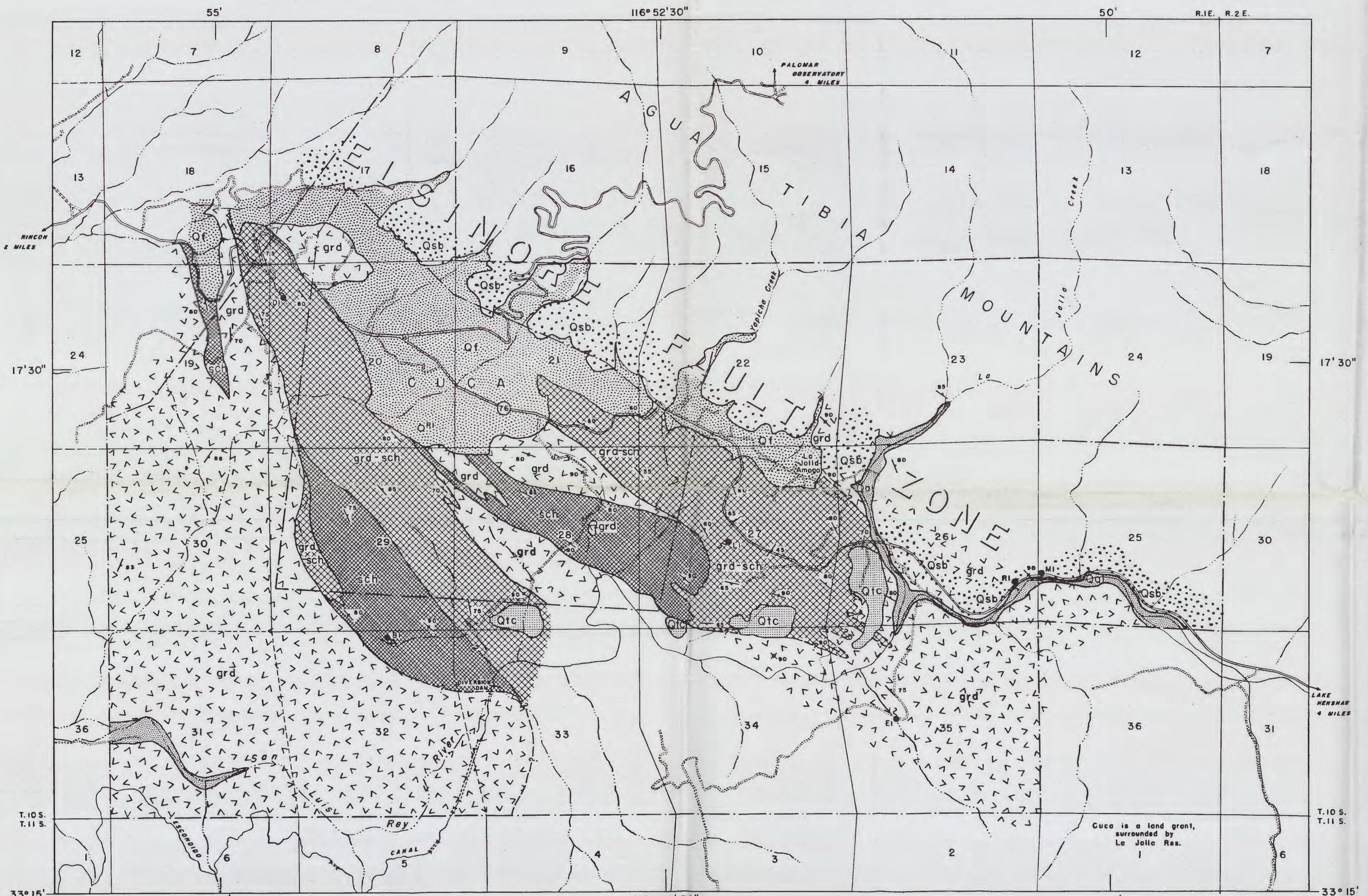


GEOLOGIC MAP OF MESA GRANDE INDIAN RESERVATION, SAN DIEGO COUNTY, CALIFORNIA

53-201

U. S. GEOLOGICAL SURVEY

PLATE 3



Base from U. S. G. S. Boucher Hill and Palomar Observatory quadrangles

Dashed land lines projected for reference only

Geology by F. H. Olmsted, in part after J. B. Hanley (1951)

1 ½ 0 1 Mile

EXPLANATION

Qal

Alluvium

Unconsolided sand, gravel, and silt along channel of San Luis River and La Jolla Creek. Thickness: 0-50 ft. (?). Highly permeable, but of small extent and subject to flooding.

Qf

Fanglomerate

Poorly-sorted alluvial-fan detritus ranging from silt and clay to large cobbles and boulders. Thickness: 0-60 ft. (?). Sand and gravel lenses moderately permeable.

Qsb

Slide breccia

Coarse landslide detritus at base of Agua Tibia Mountains escarpment. Map symbol includes areas where breccia is discontinuous. May be locally important as a ground-water intake area.

Qtc

Terrace clay

Reddish-brown sandy clay of predominantly residual origin. Not highly permeable, but topography favorable for water well development.

QUATERNARY

grd

Granodioritic rocks

Includes probable correlatives of Woodson Mountain granodiorite, Bonsall tonalite, and Stonewall quartz diorite. Contains small quantities of water in weathered zone and in joints and fractures.

CRETACEOUS(?)

grd-sch

Mixed rock

Mica schist and quartzite that have been intimately injected and partially assimilated and replaced by granodioritic rocks. Small to moderate quantities of water contained locally in weathered and closely-jointed zones.

sch

Schist

Mica schist, with subordinate quartzite, and a minor amount of granodioritic rock, pegmatite, and vein quartz. Probably equivalent to Julian schist and Bedford Canyon formation. Water contained in closely-spaced fractures parallel to foliation.

TRIASSIC(?)——JURASSIC(?)

Contact

Dashed where approximately located or gradational.

70 Strike and dip of foliation

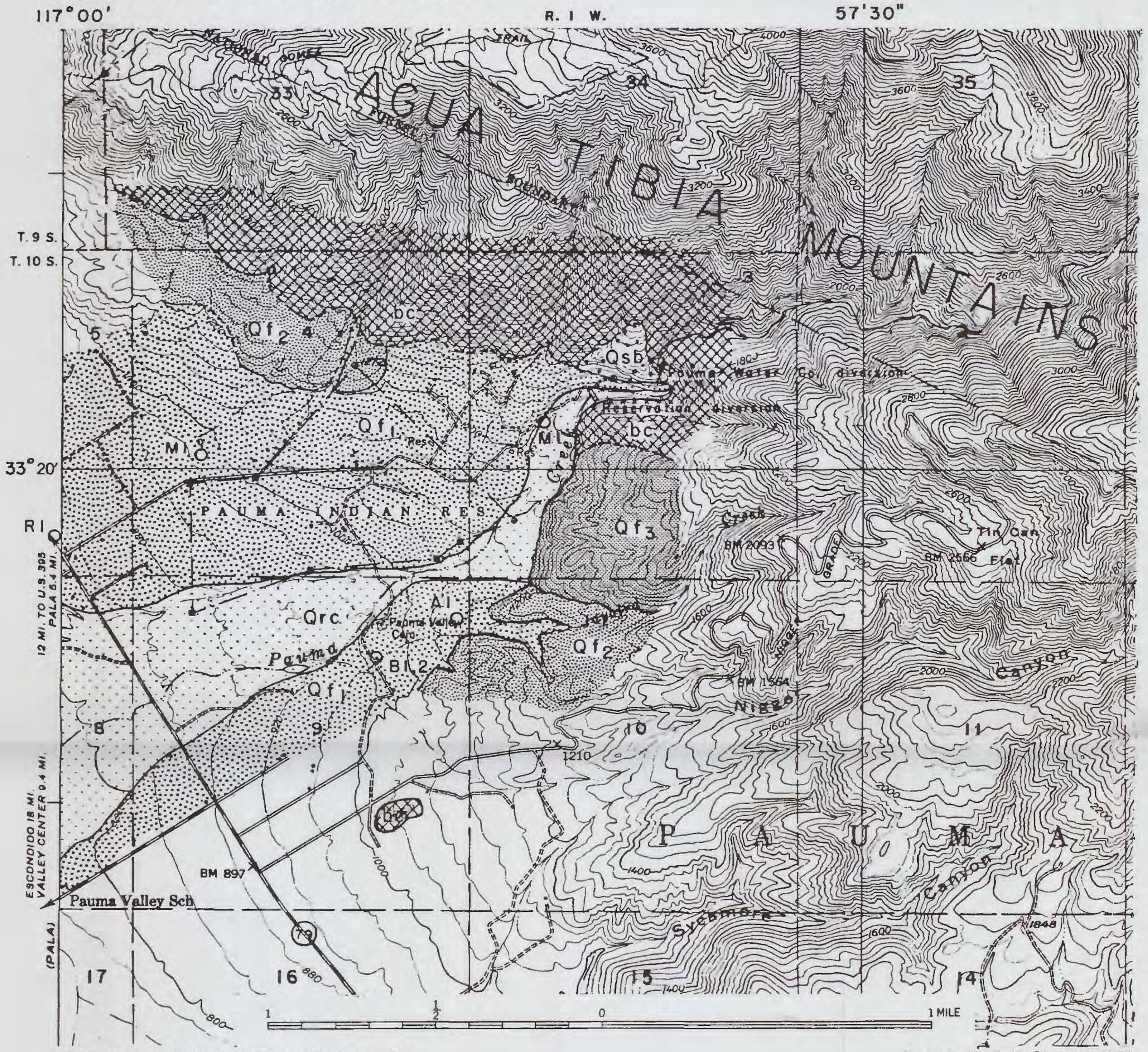
F1 Spring

45 Strike and dip of joint plane

R1 Water well

GEOLOGIC MAP OF LA JOLLA INDIAN RESERVATION, SAN DIEGO COUNTY, CALIFORNIA

53-201



Base from U. S. G. S. Boucher Hill quadrangle

Geology by F. H. Olmsted 1953

GEOLOGIC MAP OF PAUMA INDIAN RESERVATION AND VICINITY, SAN DIEGO COUNTY, CALIFORNIA

EXPLANATION

QUATERNARY

Qrc

Channel deposits

Unconsolidated sand, gravel, boulders, and silt along flood channel of Pauma Creek. Moderately permeable, but largely above saturated zone. Thickness: 0-50+ ft.

Qf_1

Younger fanglomerate

Unconsolidated to somewhat indurated, ill-sorted alluvial-fan detritus ranging from silt and clay to large cobbles and boulders. Sand and gravel lenses moderately permeable.

Qf_2

Intermediate fanglomerate

Similar in lithology to younger fanglomerate. No wells in vicinity of reservation start in this material. Forms terraces topographically below older fanglomerate and above younger fanglomerate.

Qf_3

Older fanglomerate

Similar in lithology to intermediate and younger fanglomerates. Not tapped by wells near reservation. Forms topographically highest terrace in area.

Qsb

Slide breccia

Coarse landslide detritus at base of Agua Tibia Mountains escarpment. Hydrologically unimportant except as a ground-water intake area.

CRETACEOUS AND OLDER

bc

Crystalline basement complex

Schist, mixed rock, granodioritic rocks. Small amounts of water contained in weathered and fractured zones, but not likely to be developed as a source of ground water in the reservation area.

Contact

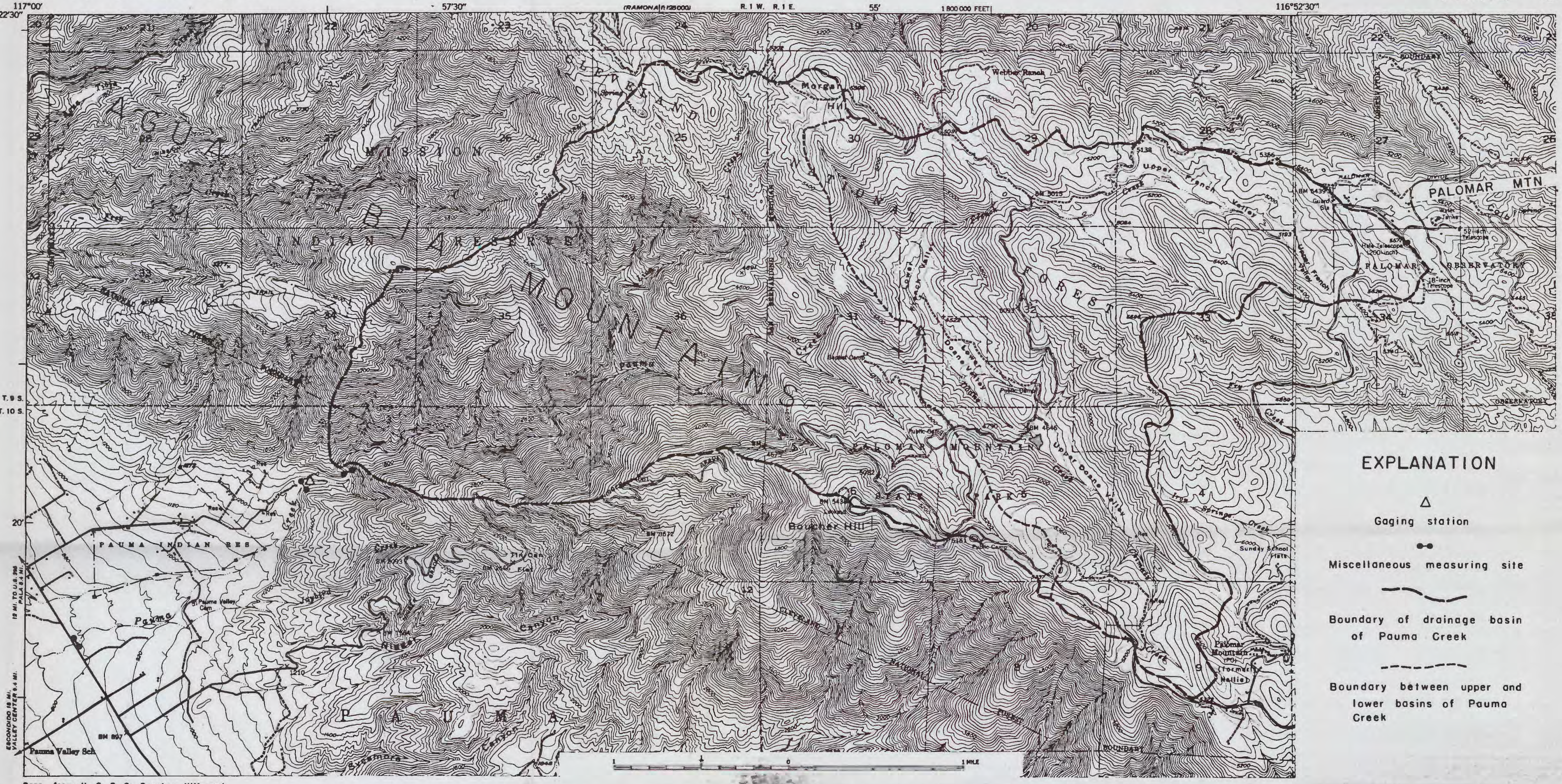
Dashed where approximately located

o M1

Water well

Contour interval 40 feet

Dashed land lines projected for reference only



Base from U. S. G. S. Boucher Hill and Palomar Observatory quadrangles

MAP SHOWING DRAINAGE AREA OF PAUMA CREEK

Table 4.--Yields of 6 representative wells in crystalline bedrock and average yield of 10 wells in valley alluvium in western San Diego County

Well	Dimensions of well				Pump-test data						Remarks
			Laterals								
	Depth (feet)	Diameter (inches)	Total length (feet)	Diameter (inches)	Discharge (gpm)	Depth to water at start of test (feet)	Drawdown at end of test (feet)	Length of test (hours)	Water-bearing material tapped by well (feet)	YIELD FACTOR[a]	
11/2E-28R1 (LaChappa well at Mesa Grande I. R.)	53	8	(None)	. . .	4	15	18	Unknown	18	1.2	In quartz diorite residuum. Drilled well; 18 feet of perforations.
17/6E-32H1 (John Williams well at Campo I. R.)	60	8	(None)	. . .	36	15	35	12	30	3.4	Mostly in quartz diorite residuum. Drilled well; 30 feet of perforations.
9/3W-21F1 (F. O. Olmsted well, 3 miles east of Fallbrook.) d/	78	60	300	1¼	55	58	18	14	[b]320	1.0	In Bonsall tonalite residuum. Dug well with laterals.
K13 (W.S.P. 446) (Well in Poway Valley.) d/	66	120	210	48-120	250±	17	36	11	[b]260	2.7 [c]2.4	36 feet of alluvium, 30 feet of residuum. Dug well with two horizontal tunnels at bottom, 90 and 120 feet long.
L98 (W.S.P. 446) (Well 2 miles east of El Cajon.) d/	68.5	72	(None)	. . .	79	11	24.7	3½	57.5	5.5 [c]3.8	In residuum. Dug well, no laterals.
10/1E-20R1 (Mendenhall well near La Jolla I. R.)	73	48	950	1¼	300	Unknown	50	Unknown	[b]966	.6	57 feet of alluvium, 16 feet of bedrock. Dug well with laterals drilled through alternating hard and soft "granite". Concrete casing opposite alluvium.
L82 (W.S.P. 446) (Average of 10 wells in upper San Diego River valley.) d/	60	12	(None)	. . .	248 (average)	8	12	0.8	50	41	In valley fill (alluvium). Ten drilled wells interconnected to same pump. Total discharge of 10 wells was 2,475 gallons per minute.

a YIELD FACTOR = $\frac{\text{yield in gpm per foot of drawdown x 100}}{\text{thickness in feet of water-bearing material tapped by well}}$

b Includes footage of laterals or tunnels.

c Adjusted for volume pumped from storage in well.

d For location see fig. 1.

Table 8.--Description of wells and test holes on Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations Calif.

USGS No.	Owner or name of well	Year completed	Altitude of land-surface datum (feet)	Depth (feet)	Type of well, and casing diameter (inches)	Water level: Date measured	Water level: Feet below land-surface datum	Type of pump	Use	Discharge (gpm) Drawdown (feet)	Other data	Remarks
						Campo Indian Reservation						
17/6E-1L1	Tom Osway	-	3,900	-	Dug, 24	Oct. 29, 1952	2.5	None	D	-	-	Shallow dug well in creek bed.
10F1	-	-	4,210	7.4	Dug, 24	Oct. 29, 1952	2.39	None	D	-	-	Shallow dug well in creek bed.
28J1	W. C. Coleman	1949	3,350	55	Dug,D,36	Oct. 28, 1952	28.36	J	Un	-	-	Dug 25 ft. drilled remainder. Hard rock reported at bottom.
32H1	John Williams	1939	3,195	60.0	D, 8	Apr. 15, 1939 Oct. 23, 1952 Oct. 30, 1952	a15 20.65 20.34	None	Un	36/35	L	Obtains most of water from residuum
33N1	Joe Pablo	-	3,115	15.0	Dug, 72	Oct. 23, 1952	Dry	None	Un	-	-	Dug well in sandy alluvium. Bottom of hole same altitude as stream bed to the south.
34N1	Campo Agency	1939	3,280	54	D, 8	Apr. 8, 1939 Oct. 24, 1952	a 5 15.77	L	Un	60/39	L	Obtains most of water from "decomposed granite". Gasoline engine removed in 1941.
18/5E-3D1	Old Campo 1-2	1939	2,735	104	D, 8	Apr. 8, 1939 Feb. 28, 1952 Oct. 23, 1952	a46 a62 54.31	L	D,Irr	58/30	L	Obtains most of water from "soft granite" 46 to 102 feet. Two test holes farther north were abandoned when "hard granite" was found at 28 and 38 feet.
						Mesa Grande Indian Reservation						
11/2E-28G1,2	Test holes no's. 1 and 2	1941	3,240	20	D, 8	-	-	-	-	-	-	Abandoned when solid rock was encountered at 20 feet.

a Measured by Bureau of Indian Affairs.

Table 8.--Description of wells and test holes on Campo, Mesa Grande, La Jolla, and Pauma Indian Reservations, Calif.--Cont.

USGS No.	Owner or name of well	Year completed	Altitude of land-surface datum (feet)	Depth (feet)	Type of well, and casing diameter (inches)	Water level		Type of pump	Use	Discharge (gpm) / Drawdown (feet)	Other data	Remarks
						Date measured	Feet below land-surface datum					
	Mesa Grande Indian Reservation--Cont.											
11/2E-28R1	Tillie La Chappa	1941	3,280	53	D, 8	Dec. 8, 1943	[a]15	L	D	4/18	L	Obtains water from quartz diorite residuum.
12/2E-10G4	Juvencio Valle	-	2,935	70	D, 24	Nov. 5, 1952	Flowing	None	D,S	-	-	10 feet north of spring 10G2.
13Q1	Charles Ponchetti	1935	2,870	-	Dug, 36	Nov. 6, 1952	[b]17.62	L	D,S,Irr	-	Cp	Windmill well.
	Cuca Grant near La Jolla Indian Reservation											
10/1E-20R1	George Mendenhall	1950	2,555	73	[c]Dug, 48	Nov. 18, 1952	32.60	T	Irr	300/50	L	950 ft. of laterals in bedrock. 57 ft. of fanglomerate cemented off.
	Near Fallbrook											
[d]9/3W-21F1	F. O. Olmsted	1947	798	78	[c]Dug, 60	-	-	T	Irr,D	55/18	-	300 feet of laterals.
	Wells near Pauma Indian Reservation											
10/1W- 3M1	Monta J. Moore	-	1,190	189	D, 12	June 2, 1953	29.75	L	D	10/120	-	-
4M1	Pauma Valley Water Co.	-	975	400+	D, 12	-	>100	None	Un	-	-	Reported to sand up when pumped.
5R1	Kenneth Cawthorne	1949	825	200-	D, 12	1949	[e]108	T	Irr	200+	-	-
9A1	Vaughn Maynard	1949	1,070	405	D, 12	June 2, 1953	93.5	None	Un	25/70	-	-
9B1	Vaughn Maynard	-	970	100	D	1947	[f]70	J	D	40	-	Dirty gravel at 96 ft. is main aquifer.
9B2	Vaughn Maynard	1947	970	344	D, 12	Winter 1952-3	[f]43	T	Irr	200/70	L	14 ft. NW of 9B1.

a Measured by Bureau of Indian Affairs.
b Land-surface datum is 10 ft. above adjacent stream bed.
c Dug well with laterals.
d Location shown on fig. 1.
e Reported at time of drilling.
f Reported.