GEOHYDROLOGY OF THE ANZA-TERWILLIGER AREA

RIVERSIDE COUNTY CALIFORNIA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-10

PREPARED IN COOPERATION WITH THE
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16. Abstracts The Anza-Terwilliger area consists of about 96 square miles (249 square kilometres) in the upper parts of the Santa Margarita River and Coyote Creek drainage basins in Riverside County, Calif., about 90 miles (145 kilometres) southeast of Los Angeles. This report deals with geology, steady state and transient state of ground water, net depletion of ground water, surface-water flow, precipitation, chemistry of water, land and water use, and gravity data for the Anza-Terwilliger area. The data indicate that the rate of ground-water depletion has accelerated since 1950. Pumping depressions adjacent to the Cahuilla Indian Reservation have increased the hydraulic gradient and are causing water beneath the reservation to flow toward these depressions. Total depletion of ground water since 1950 is about 14,000 acre-feet (17.3 cubic hectometres). Chemical analyses indicate that the ground water in local areas contains concentrations of nitrate above that recommended by the Environmental Protection Agency for human consumption.

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March 1976

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometres)
ft (feet)	3.048×10^{-1}	m (metres)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic metres per second)
gal/d (gallons per day)	3.785×10^{-3}	m^3/d (cubic metres per day)
gal/min (gallons per minute)	6.309×10^{-1}	l/s (litres per second)
in (inches)	2.540×10	mm (millimetres)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)
mi^2 (square miles)	2.590×10^2	ha (hectares)

GEOHYDROLOGY OF THE ANZA-TERWILLIGER AREA

RIVERSIDE COUNTY, CALIFORNIA

By W. R. Moyle, Jr.

ABSTRACT

The Anza-Terwilliger area consists of about 96 square miles (249 square kilometres) in the upper parts of the Santa Margarita River and Coyote Creek drainage basins in Riverside County, Calif., about 90 miles (145 kilometres) southeast of Los Angeles.

The purpose of the study was to evaluate the effects of ground-water pumpage and to determine the changes in ground-water quality in Anza and Terwilliger Valleys resulting from the extraction of ground water.

The data indicate that the rate of ground-water depletion has accelerated since 1950. Pumping depressions adjacent to the Cahuilla Indian Reservation have increased the hydraulic gradient and are causing ground water beneath the reservation to flow toward these depressions. Total depletion of ground water since 1950 is estimated to be 14,000 acre-feet (17.3 cubic hectometres).

Chemical analyses indicate that the ground water from five wells contains concentrations of nitrate which exceed the limit recommended by the Environmental Protection Agency for human consumption (44 milligrams per litre). The highest value for nitrate analyzed in the study area was 128 milligrams per litre.

INTRODUCTION

The Anza-Terwilliger area (fig. 1) consists of about 96 mi^2 (249 km^2) in the upper parts of the Santa Margarita River and Coyote Creek basins in Riverside County, about 90 mi (145 km) southeast of Los Angeles. Anza, Burnt, Cahuilla, Durasna, and Durasno Valleys are tributary to Cahuilla Creek which drains into the Santa Margarita River, which in turn drains westward to the Pacific Ocean. Terwilliger Valley is tributary to Coyote Creek, which drains southeastward to the Salton Sea.

In this report the area within the Cahuilla Creek drainage is referred to as the Anza area, and the area within the Coyote Creek drainage is referred to as the Terwilliger area.

There are no perennial streams in the Anza-Terwilliger area. All water is derived from local precipitation that recharges the aquifers. Most water used in the area is pumped from ground water.

Within the study area the land-surface altitude ranges from 3,360 ft (1,024 m) near the surface-water outlet for the Anza area to 6,811 ft (2,076 m) at the lookout station on the top of Thomas Mountain in the northernmost part of the study area (fig. 1).

Purpose and Scope

The purpose of this investigation made in cooperation with the U.S. Bureau of Indian Affairs was to evaluate the effects of ground-water pumpage and to determine changes, if any, in water quality with time in the Anza-Terwilliger area. The Cahuilla Band of Mission Indians is concerned about the possibility of ground-water depletion beneath the Cahuilla Indian Reservation (fig. 1) that may have been caused by pumping water from wells adjacent to the reservation. The Cahuilla Band is also concerned about the possible chemical deterioration of any water which may return to the ground-water system.

The scope of the study was to collect, interpret, and evaluate the hydrologic, geologic, and geophysical data from the Anza-Terwilliger area. This included water quality, water in storage, water and land use, precipitation, ground-water depletion, and gravity data.

Most field data collection and related activities were accomplished during the period July-October 1973. Additional measurements were made in 1974 and 1975.

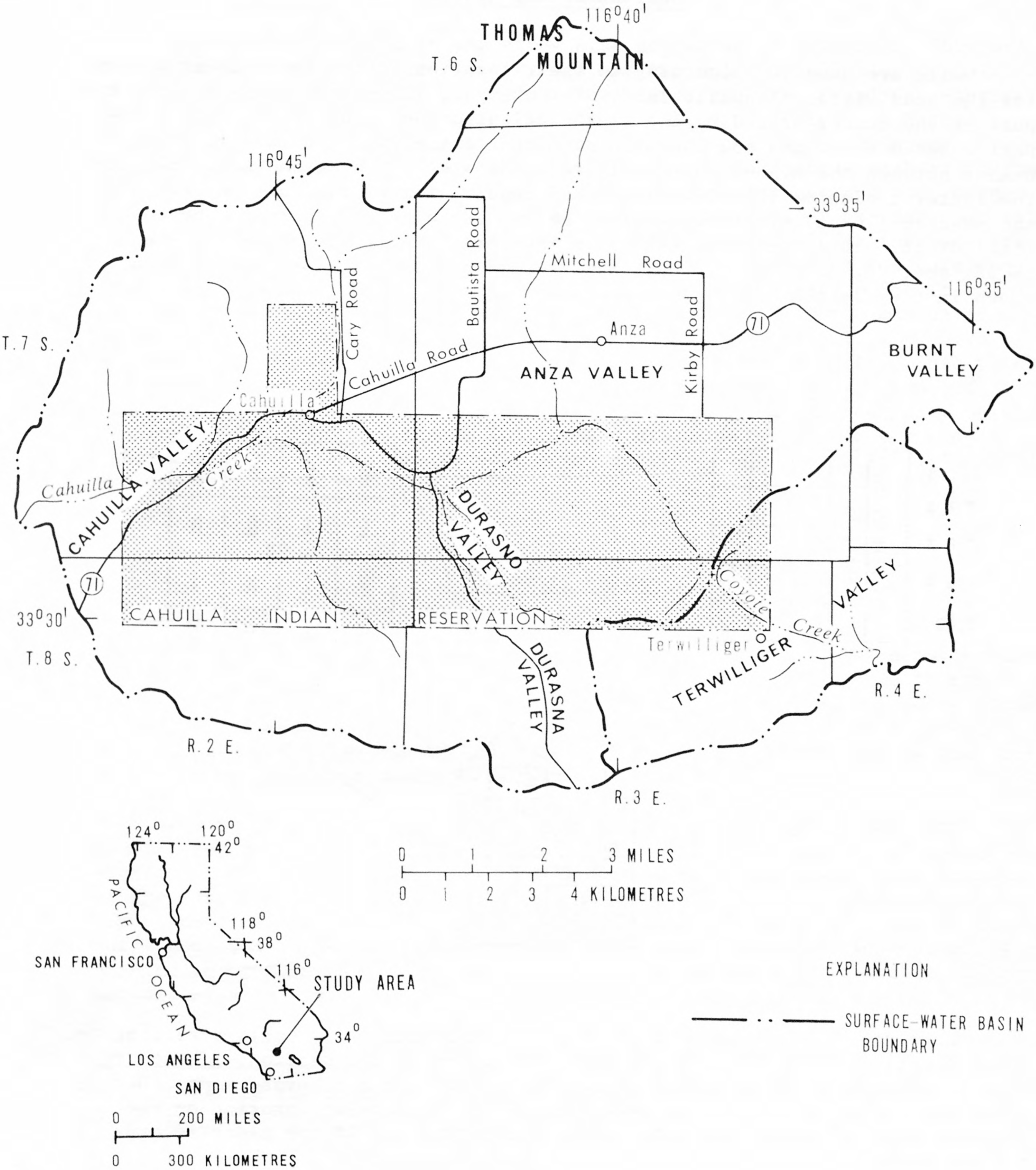
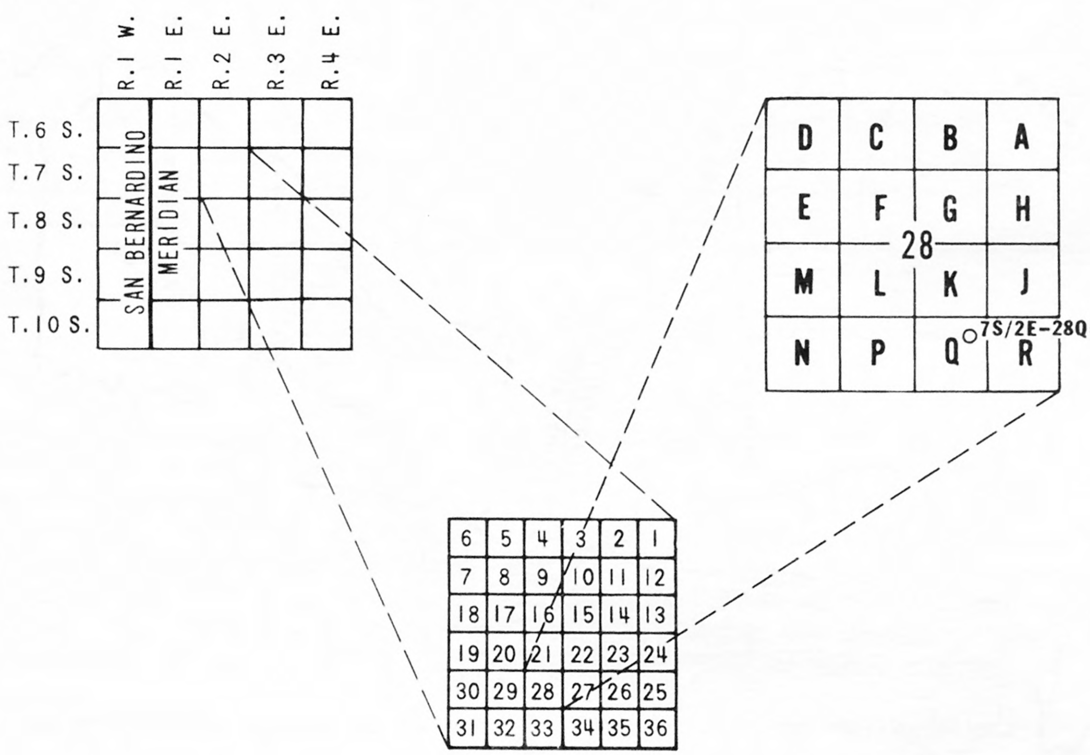


FIGURE 1.--Index map.

Well-Numbering System

Wells are numbered according to their location in the rectangular system for the subdivision of public land. For example, in the number 7S/2E-28Q1 the part of the number preceding the slash indicates the township (T. 7 S.), the part between the slash and the hyphen indicates the range (R. 2 E.), the number between the hyphen and the letter indicates the section (sec. 28), and the letter indicates the 40-acre (16-ha) subdivision of the section. Within the 40-acre (16-ha) tract wells are numbered serially, as indicated by the final digit. Thus, well 7S/2E-28Q1 is the first well to be listed in the SW¼SE¼ sec. 28, T. 7 S., R. 2 E., San Bernardino base line and meridian as shown in the diagram below:



There are a few exceptions to this system of numbering wells according to their location in the 40-acre (16-ha) subdivision of the section. These are wells that were assigned numbers based on earlier, less accurate maps. During this investigation these wells were plotted at the correct location on the map, but the old number was retained to facilitate use of the older records for the well.

GEOLOGY

Three geologic units in the study area are shown in figure 2. They are the basement complex of pre-Tertiary age and two units of alluvial deposits of Quaternary age. The basement complex consists of granite, tonalite, diorite, granite gneiss, diorite gneiss, hornblend schist, mica schist, with some xenolith inclusions, and pegmatite dikes. It yields small to moderate quantities of water from joints and fractures or where deeply weathered. The two alluvial units are the older alluvium of Pleistocene age and the younger alluvium of Holocene age. The older alluvium is composed of boulders, gravel, sand, silt, and clay that are moderately indurated and includes the Bautista Beds of Frick (1921) as described by Fraser (1931). Well logs indicate the older alluvium generally ranges in thickness from a few feet to 550 ft (168 m); however, gravity data indicate that the older alluvium may be as much as 800 ft (244 m) thick along the San Jacinto fault in sec. 11, T. 7 S., R. 3 E. Most of the highest yielding production wells are drilled into thick sequences of saturated older alluvium. The younger alluvium is composed of unconsolidated boulders, gravel, sand, silt, and clay and is generally only a few feet thick. In most places the younger alluvium is above the regional water table and is not considered a major aquifer. Where saturated, it yields water freely to wells.

Gravity Survey

Knowledge of the areal extent and thickness of the alluvial deposits is important because they contain most of the ground water in storage in the study area. Wells drilled in areas of thick alluvial fill will produce larger quantities of water than wells drilled outside these areas. The alluvial deposits are generally one to two orders of magnitude more permeable than the weathered or fractured basement complex.

Gravity measurements were made at 258 stations throughout the Anza-Terwilliger area during 1973 to determine differences in the attraction of gravity caused by differences in density of the material beneath the surface of the earth. These differences in gravity, measured in milligals (mgal),[1] may be used to indicate the geologic structure and the general shape of the surface of the basement complex beneath the alluvial basins. In general, a gravity low corresponds to a relatively thick alluvial section within an area covered by alluvium.

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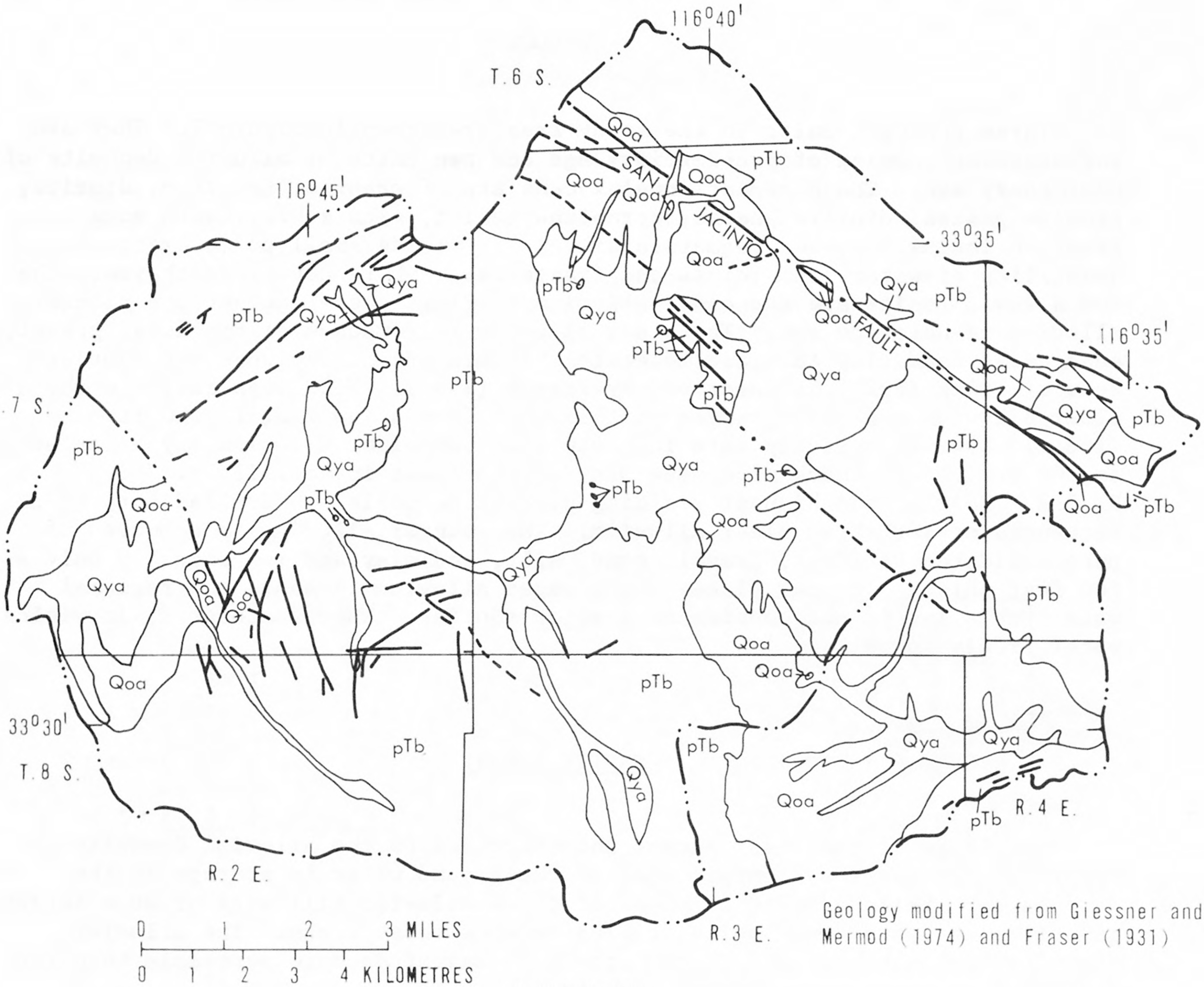
[1]A gal is the acceleration of gravity of 1 cm/sec. A milligal is 0.001 gal or 1/1000 cm/sec.



EXPLANATION

QUATERNARY

Holocene

Qya

Younger alluvium

Boulders, gravel, sand, silt, and clay. Generally a few feet thick. Where saturated, yields water freely to wells

Pleistocene

Qoa

Older alluvium

Boulders, gravel, sand, silt, and clay, moderately indurated. Includes the Bautista Beds of Frick (1921). Ranges in thickness from a few feet to as much as 800 feet (244 metres)

PRE-TERTIARY

pTb

Basement complex

Igneous and metamorphic rocks composed of granite, tonalite, diorite, gneiss, hornblend and mica schist, xenolith, inclusions and pegmatite dikes. Yields small to moderate quantities of water from joints, fractures, or where deeply weathered

Contact

Fault
Dashed where approximately located, dotted where concealed

Surface-water basin boundary

FIGURE 2.--Geologic map.

All gravity measurements were tied to a local base station at the corner of Cahuilla Road (California Highway 71) and Cary Road (fig. 1). This local base was established relative to the California Base Station Network by tying to the network base at Oceanside (station 324, Chapman, 1966, p. 39) and is thus on the Woollard and Rose (1963) gravity datum.

After corrections were applied for meter drift, the data were entered into the computer to be corrected for latitude, altitude, free air, Bouguer effect, and terrain effects. A density of 2.67 g/cm^3 (grams per cubic centimetre) was used for the gravity reduction because this value is consistent with the approximate density of the basement rocks in the area. Terrain corrections were carried out from 1.42 to 55.9 mi (2.29 to 90 km) from each station using Plouff's (1966) program and previously digitized topography (Robbins and others, 1973). The 55.9-mi (90-km) distance was used instead of the normal 103.6-mi (166.7-km) distance because the latter would extend into Mexico where digitized topographic data are not available. Digitized terrain corrections were made only to the Mexican border.

Several inner-zone terrain corrections were made for the effects of topography to a distance of 1.42 mi (2.29 km) for several selected stations to determine the amount of correction in the study area. In the flat valley areas the corrections ranged from 0 to 0.62 mgal. In the steeply dipping mountainous area the corrections ranged from 0.62 mgal near the San Jacinto fault to 4.36 mgal on top of Thomas Mountain. The inner-zone terrain correction was small and could be neglected in the four small tributary alluvial valleys which are relatively flat.

The uncertainty arising from the nonlinear tide effect is probably less than 0.1 mgal, and the maximum altitude error is probably less than 0.6 mgal or 10 ft (3 m). Therefore, the total error in the values used to make the gravity anomaly map is probably less than 0.7 mgal.

One thousand milligals were added to all Bouguer anomaly values to make them positive. Thus, for example, the true Bouguer anomaly corresponding to a value of 920 mgal on the map is -80 mgal.

The values on the gravity map (fig. 3) range from a low of 902 mgal near the northeast edge of the study area along the San Jacinto fault to a high of 920 mgal on the southwest edge of the study area. The four areas of deep alluvial fill are outlined, and lines of geologic section (A-A' and B-B') are shown on the gravity map (fig. 3). These lines of geologic section correspond to the sections in figure 4, which show the estimated depth of alluvial fill based on well logs and gravity data. The basement complex is at or very near land surface everywhere within the study area except for the four areas of thick alluvial fill shown in figure 3.

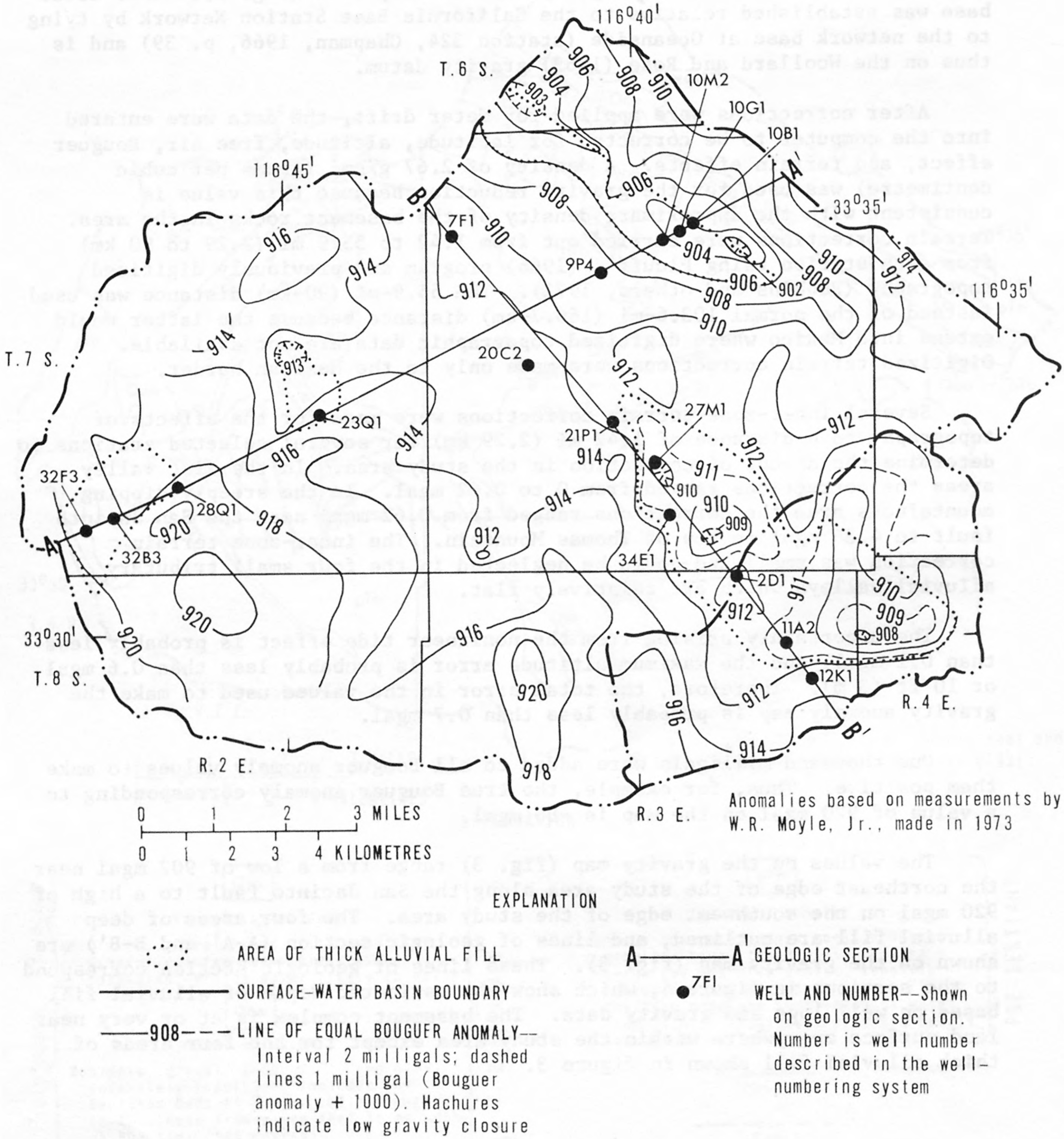


FIGURE 3.--Bouguer gravity anomalies, lines of geologic section, and areas of thick alluvial fill.

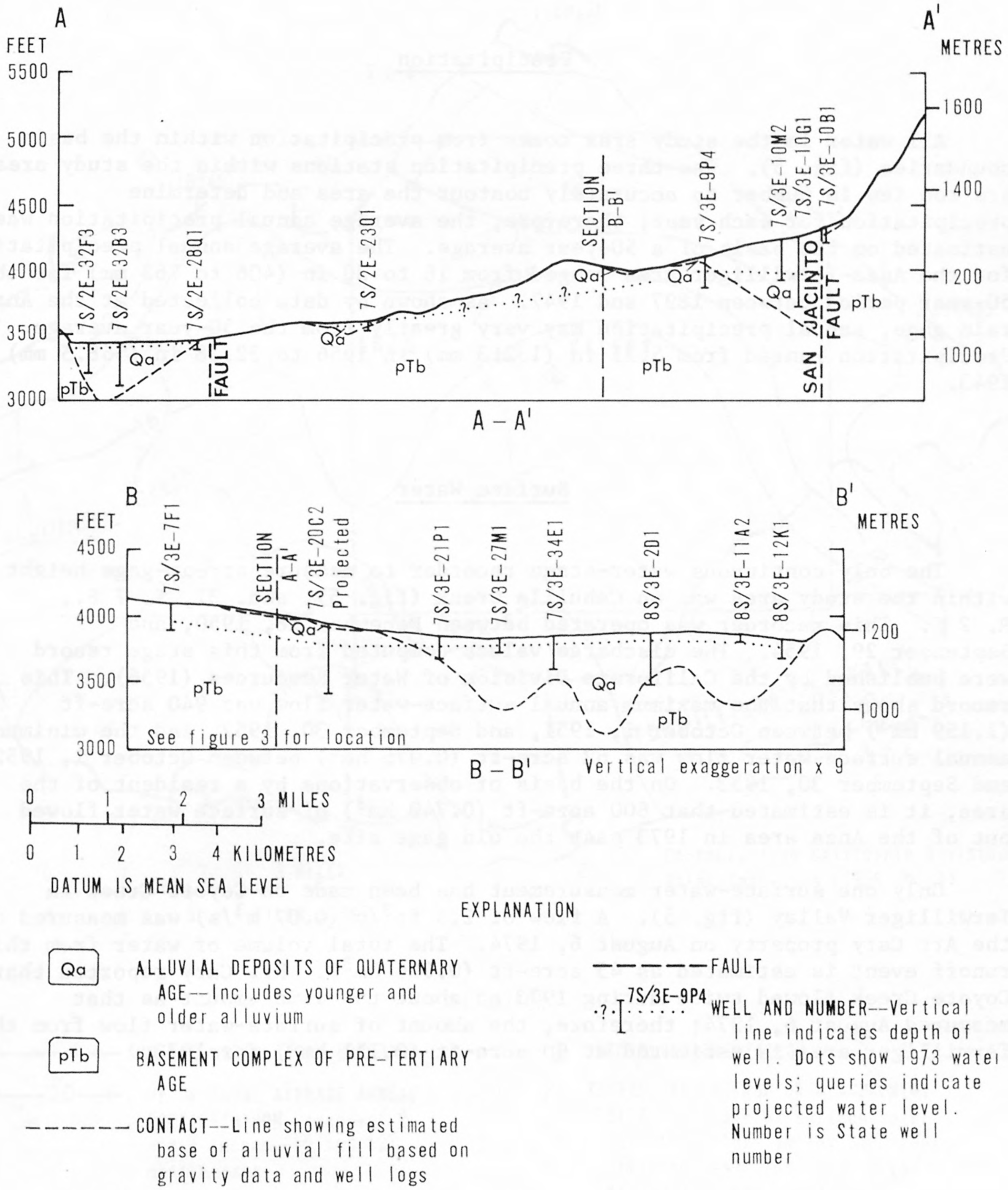


FIGURE 4.--Geologic sections.

HYDROLOGY

Precipitation

All water in the study area comes from precipitation within the basin boundaries (fig. 5). The three precipitation stations within the study area are too few in number to accurately contour the area and determine precipitation for each year; therefore, the average annual precipitation was estimated on the basis of a 50-year average. The average annual precipitation for the Anza-Terwilliger area ranged from 16 to 30 in (406 to 762 mm) for the 50-year period between 1897 and 1947. As shown by data collected at the Anza rain gage, annual precipitation may vary greatly from the 50-year average. Precipitation ranged from 5.21 in (132.3 mm) in 1956 to 22.38 in (568.5 mm) in 1943.

Surface Water

The only continuous water-stage recorder to measure stream-gage height within the study area was on Cahuilla Creek (fig. 5), sec. 31, T. 7 S., R. 2 E. This recorder was operated between December 18, 1950, and September 29, 1954. The discharge values computed from this stage record were published by the California Division of Water Resources (1956). This record shows that the maximum annual surface-water flow was 940 acre-ft (1.159 hm^3) between October 1, 1951, and September 30, 1952, and the minimum annual surface-water flow was 62 acre-ft (0.076 hm^3) between October 1, 1952, and September 30, 1953. On the basis of observations by a resident of the area, it is estimated that 600 acre-ft (0.740 hm^3) of surface water flowed out of the Anza area in 1973 past the old gage site.

Only one surface-water measurement has been made on Coyote Creek in Terwilliger Valley (fig. 5). A flow of 2.5 ft^3/s (0.07 m^3/s) was measured on the Art Cary property on August 6, 1974. The total volume of water from this runoff event is estimated as 45 acre-ft (0.056 hm^3). Mr. Cary reported that Coyote Creek flowed twice during 1973 at about the same amount as that measured August 6, 1974; therefore, the amount of surface-water flow from the Terwilliger area is estimated at 90 acre-ft (0.111 hm^3) for 1973.

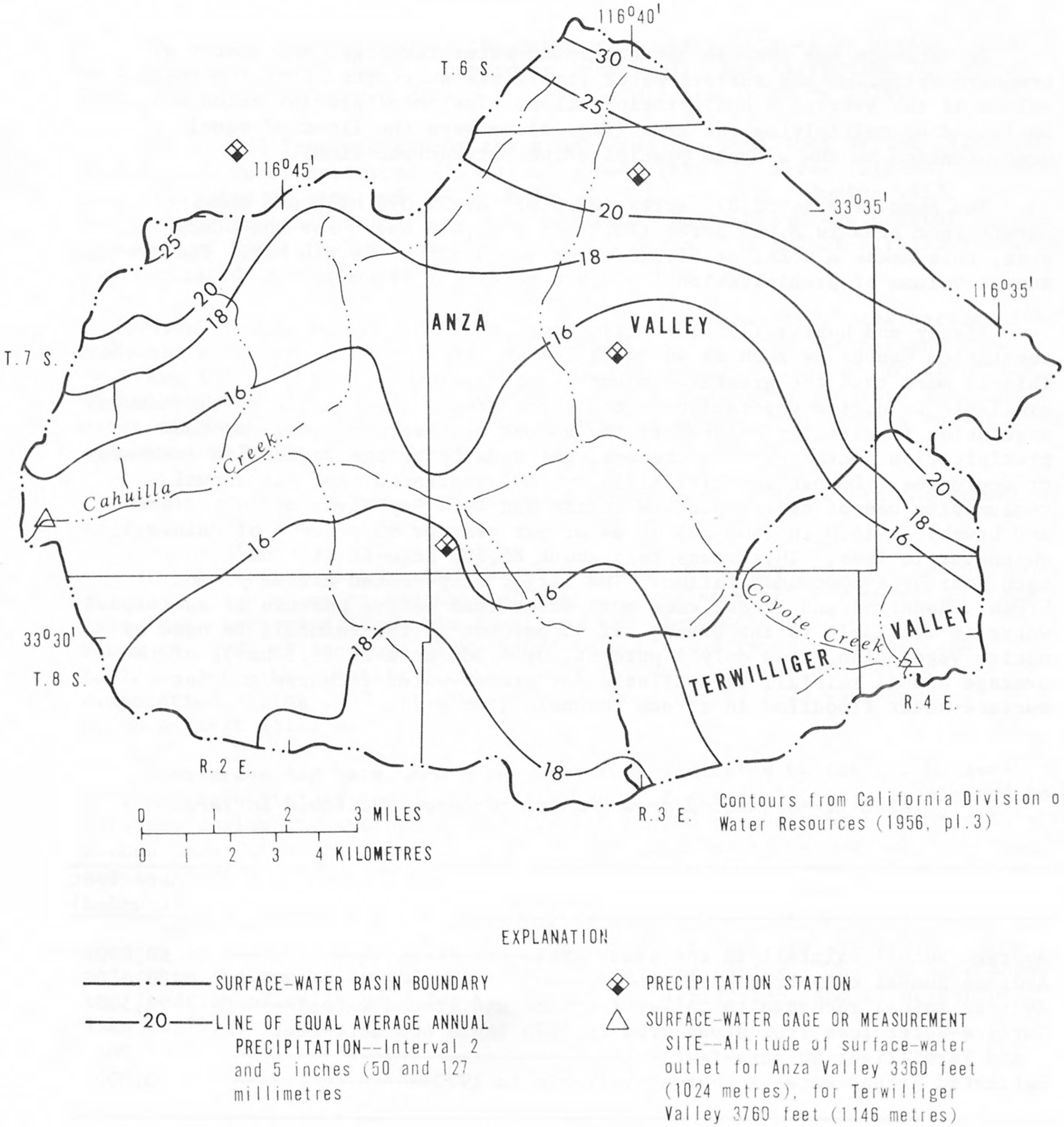


FIGURE 5.--Average annual precipitation, 1897-1947.

Ground-Water Recharge

To estimate the average annual ground-water recharge, the amount of evapotranspiration and surface-water runoff was subtracted from the total volume of the average annual precipitation. The total precipitation was estimated by multiplying the area (fig. 5) between the lines of equal precipitation by the average precipitation between the lines.

The Anza area is 52,875 acres (82.6 mi^2 or 21,398 ha), and the Terwilliger area is 8,445 acres (13.2 mi^2 or 3,418 ha). For the study area, this makes a total of 61,320 acres (95.8 mi^2 or 24,816 ha). The average annual volume of precipitation is 90,000 acre-ft (111 hm^3).

Blaney and Harris (1951, p. 31) showed that consumptive use by native vegetation can be as much as 46 in (1,168 mm) of water per unit area per year. This is more than the greatest amount of precipitation (30 in or 762 mm) available to native vegetation in the study area. The density of the natural vegetation is directly related to the amount of precipitation. As the precipitation increases or decreases, the density of the vegetation increases or decreases. Donnan and Litz (1954, p. 40) indicated that the annual consumptive use of native pasture in the San Luis Rey River drainage (grass and brush) is 16.0 in (406 mm) of water per year or 95 percent of rainfall, whichever is less. This means that about 85,500 acre-ft (105 hm^3) is lost each year by evapotranspiration. The larger deep-rooted native perennial brush (chaparral and trees) uses more water than native pasture if additional water is available to the brush. If 95 percent of the rainfall is used by native vegetation, then only 5 percent, or 4,500 acre-ft (5.5 hm^3), of the average annual rainfall is available for ground-water recharge and for surface-water floodflow in stream channels (table 1).

TABLE 1.--*Estimated ground-water recharge available in 1973*

	Acre-feet (rounded)
Average annual rainfall in the study area	90,000
Average annual evapotranspiration	85,500
Average annual recharge to valley (surface and ground water)	4,500
Surface-water loss from study area in 1973 (Anza 600 acre-feet and Terwilliger 90 acre-feet)	700
Estimated ground-water recharge available in 1973	3,800

Land and Water Use

The first land-use map of the study area was published by Waring (1919). He stated that water was not pumped in Anza Valley for irrigation in 1904 or 1915. Waring also listed data for 11 wells drilled prior to 1916.

The second land-use map of the study area was published by the California Division of Water Resources (1956) and showed that 535 acres (216 ha) of crops were irrigated in secs. 15, 21, and 22, T. 7 S., R. 3 E., during 1953. Partial records in the files of the California Water Resources Control Board, Division of Water Rights, indicate that 326 acres (132 ha) of alfalfa pastures was irrigated in these same three sections during 1953.

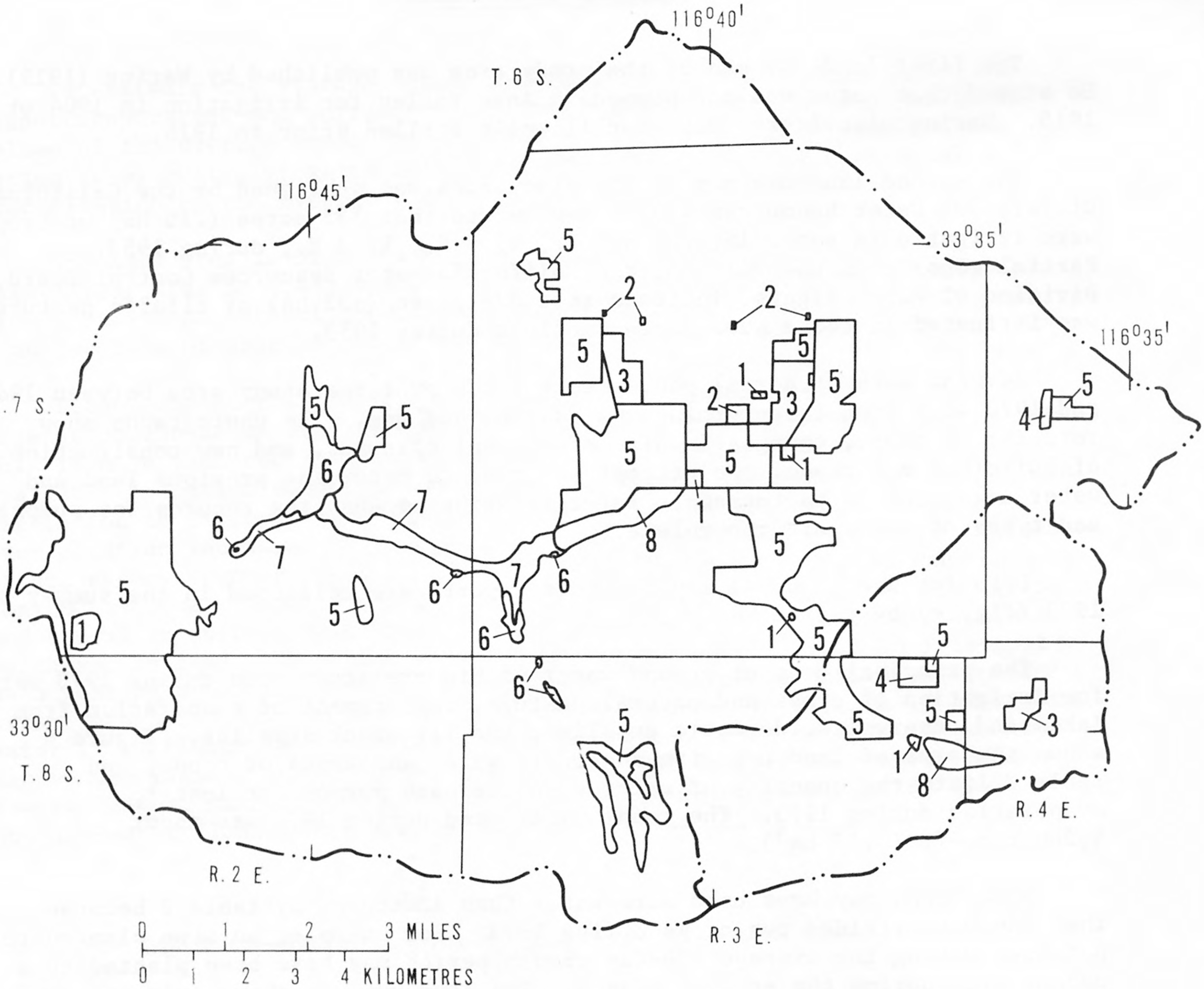
Several sets of aerial photographs taken over the study area between 1949 and 1970 were used to determine changes in land use. The photographs show rotation of crops, changes in size of natural pastures, and new construction of buildings and roads. No attempt was made to determine previous land and water use based on photographic interpretation because the records for pumpage and types of crops are incomplete.

Data for the land-use map for this report were collected in the summer of 1973 (fig. 6) by the author.

The principal uses of ground water within the study area during 1973 were for irrigation of crops and natural pasture, replacement of evaporation from lakes and reservoirs, domestic supplies, and livestock supplies. Figure 6 shows the area of land use with regard to water and types of crops, and table 2 lists the quantity of water used for each purpose or lost to evaporation during 1973. The total water used during 1973 was about 4,200 acre-ft (5.17 hm^3).

Some areas may have used more water than indicated by table 2 because they may have yielded two crops during 1973. For example, an area planted to potatoes during the average 120-day growth period may have been planted to a second crop during the growing season. The land-use map shows only one crop growing during the summer of 1973.

The well- and spring-location map (fig. 7) shows all the wells and springs in Anza and Terwilliger Valleys for which data are available. Some points on the map represent more than one well or spring. The map also shows the location of wells used for public supply, irrigation, and a recreational lake in 1973.



EXPLANATION

—·· SURFACE-WATER BASIN BOUNDARY

[1] LAKE OR RESERVOIR

[2] IRRIGATED TREES--Christmas trees or apples

[3] IRRIGATED POTATOES

[4] IRRIGATED PASTURE--Alfalfa or grass

[5] DRY-FARMED GRAIN--Rye or barley. Some additional irrigation locally

[6] GROUND WATER AT LAND SURFACE

[7] NATURAL PASTURE--Indicates ground water at or near land surface

[8] NATIVE PASTURE--Natural pasture that has dried up due to lowering of the water table

FIGURE 6.--Land use, 1973.

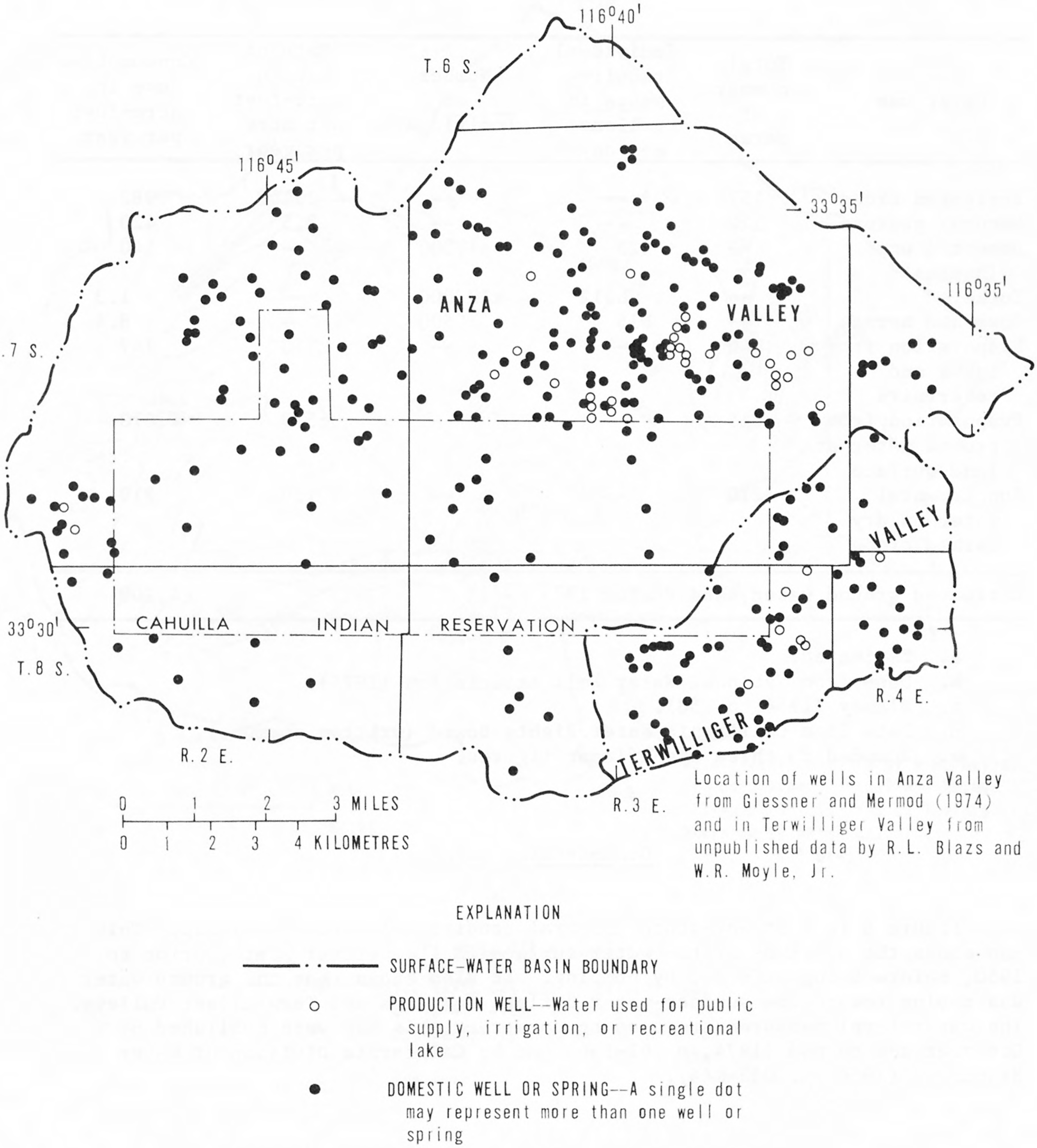


FIGURE 7.--Location of wells and springs.

TABLE 2.--*Estimated ground-water use during 1973*

Water use	Total number of acres	Individual require-ments in gallons per day	Number of individuals	Rate of use in acre-feet per acre per year	Consumptive use in acre-feet per year
Irrigated crops	457	--	--	2.148	982
Natural pasture	120	--	--	3.5	420
Domestic use (humans)	--	125	a1,000	--	140
Turkeys	--	b.12	a10,000	--	1.3
Cows and horses	--	b15	500	--	8.4
Evaporation from lakes and reservoirs	140	--	--	c5.3	747
Evaporation from ground water at land surface	315	--	--	c5.3	1,670
Supplemental water on dry farmed crops	d210	--	--	1.0	210
Estimated ground water used during 1973					e4,200

a. Estimated.
b. Data from National Water Well Association (1971).
c. Blaney (1954, p. 58).
d. Data from California Water Rights Board (written commun.).
e. Rounded to three significant figures.

Ground-Water Levels

Figure 8 is a steady-state (natural conditions) water-level map. This map shows the altitude of the water surface in its natural state, prior to 1950, before being affected by pumping. It also shows that the ground water was moving toward the surface-water outlets for Anza and Terwilliger Valleys. The water-level measurements used to construct this map were published by Giessner and Mermod (1974, p. 61-156) and by California Division of Water Resources (1956, p. G35-G44).

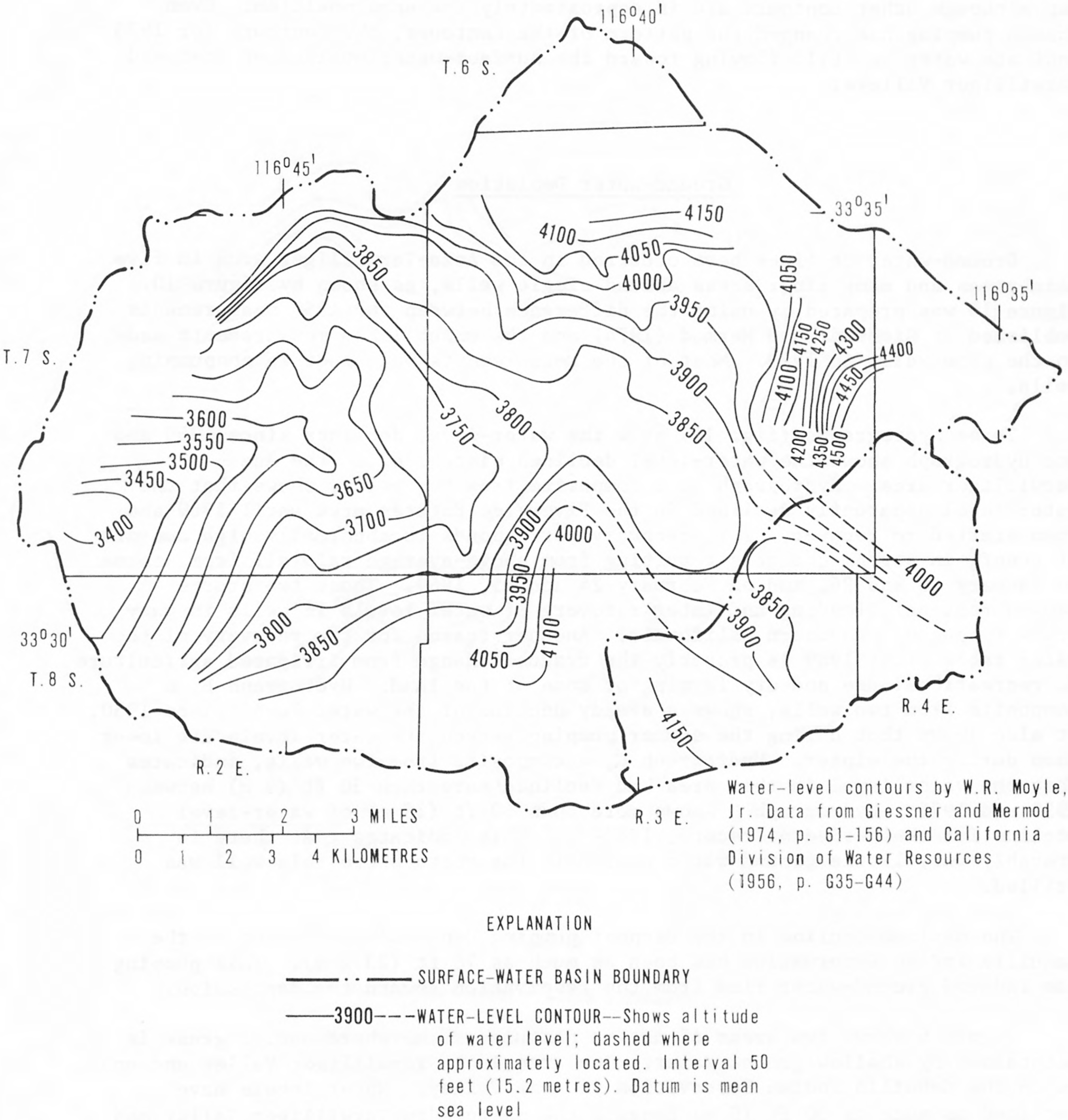


FIGURE 8.--Steady-state (1950) water levels.

Figure 9 is a water-level map based on measurements made in the summer of 1973. It shows that some contours have changed from those of the steady-state map although other contours are in approximately the same position. Even though pumping has changed the pattern of the contours, the contours for 1973 indicate water is still flowing toward the surface-water outlets of Anza and Terwilliger Valleys.

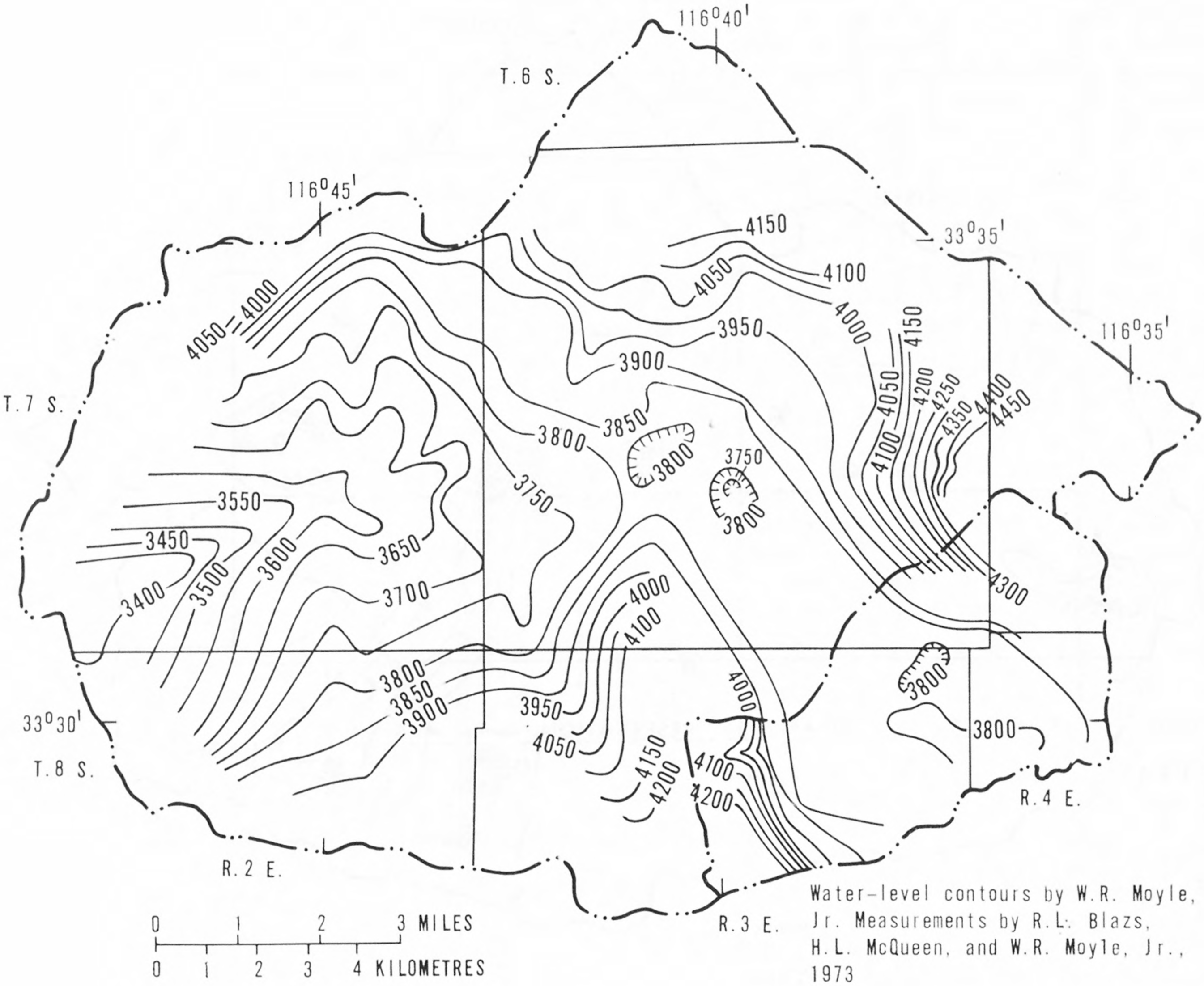
Ground-Water Depletion

Ground-water declines have occurred in the Anza-Terwilliger area in five main areas and many minor areas around single wells, as shown by figure 10. Figure 10 was prepared by using the difference between the 1950 measurements published by Giessner and Mermod (1974) and the unpublished measurements made in the same wells in 1973. Most of the measurements were made in nonpumping wells.

Three hydrographs (fig. 11) show the water-level declines since 1950 and one hydrograph shows the water-level declines since 1962 in the Anza-Terwilliger area. Hydrograph A, a composite from two wells, shows that the water level apparently declined in the Riverside Estates area until 1969 and then started to recover. This recovery corresponds to abnormally high amounts of runoff in stream channels resulting from above-average rainfall from storms on January 25 and 26, and on February 24 and 25, 1969. These two storms caused regional flooding and later recovery of water levels in wells in many areas throughout southern California. Another reason for the recovery of the water table after 1969 is probably the gradual change from irrigated agriculture to recreational use and dry farming of some of the land. Hydrograph B, a composite from two wells, shows a steady decline of the water level since 1950. It also shows that during the summer pumping season the water levels are lower than during the winter. Hydrograph C, a composite from two wells, indicates that the water level in this area had declined more than 30 ft (9 m) between 1950 and 1975. Hydrograph D shows more than 60 ft (18 m) of water-level decline for the period of record, 1962-73. This indicates that there is probably very little ground water stored in the rocks where this well was drilled.

The maximum decline in the deepest pumping depression adjacent to the Cahuilla Indian Reservation has been as much as 76 ft (23.2 m). This pumping has induced ground-water flow from the reservation toward the depression.

Figure 6 shows two areas of native pasture--areas where native grass is maintained by shallow ground water. One area is in Terwilliger Valley and one is on the Cahuilla Indian Reservation in Anza Valley. Water levels have declined as much as 30 ft (9 m) beneath the pasture in Terwilliger Valley and less than 10 ft (3 m) in Anza Valley. This native pasture has dried up in both areas because of water-level declines.



EXPLANATION

SURFACE-WATER BASIN BOUNDARY

3900 WATER-LEVEL CONTOUR--Shows altitude of water level. Interval 50 feet (15.2 metres). Datum is mean sea level

FIGURE 9.--Water levels, summer 1973.

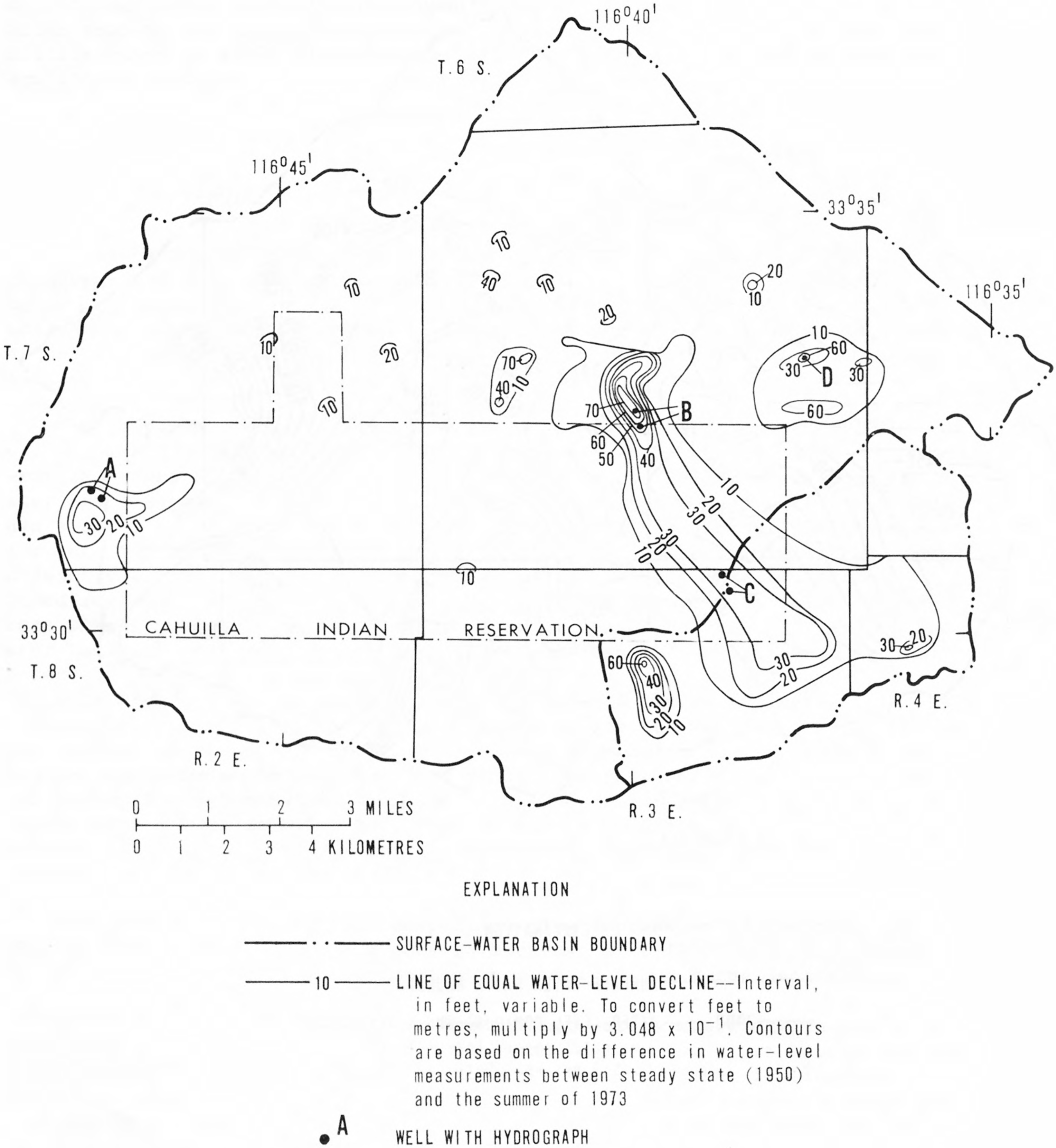


FIGURE 10.--Water-level decline between steady state (1950) and 1973.

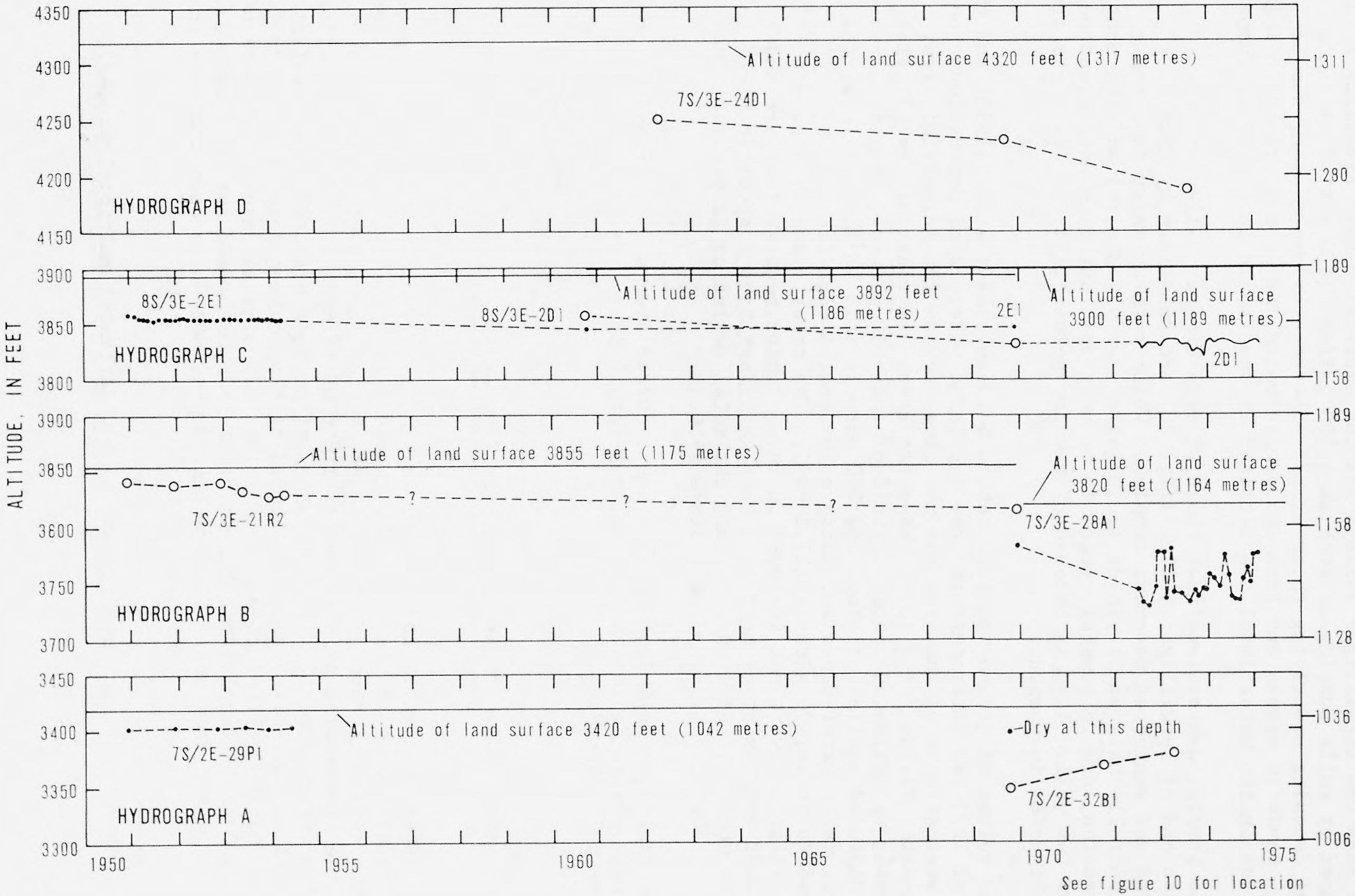


FIGURE 11.--Hydrographs of wells.

The large pumping depression that extends across the drainage divide between Anza and Terwilliger Valleys and the depression near Riverside Estates are caused by wells pumping as much as 1,000 gal/min (630 l/s) from thick alluvial deposits underlying these areas. The cone of depression, due to pumping, tends to spread out from the pumped wells for long distances. This is the reason the water level has declined in some wells that are not pumped.

The pumping depressions near the east edge of Anza Valley and the southwest end of Terwilliger Valley (fig. 10) are underlain by highly fractured and weathered basement complex. Wells pumping water from these rocks generally have small yields (1-50 gal/min or 0.6-32 l/s) and the cone of depression, due to pumping, tends to be very deep but does not spread out far from the well. This is because of the low permeability of the rocks from which the water is pumped.

The volume of ground-water depletion between steady state (1950) and the summer of 1973 was determined for the two large water-level depressions, one in the western part of the area and the other across the Anza-Terwilliger surface-water divide (fig. 10). These two areas are underlain by alluvial fill having an estimated specific yield of about 10 percent. The total volume of the depleted aquifer is about 144,000 acre-ft (178 hm^3); therefore, the total volume of water depleted, using a 10-percent specific yield, is estimated to be 14,000 acre-ft (17.3 hm^3). The other areas of water-level decline (fig. 10) were not included in the estimate because they are underlain by basement complex at or near land surface. They have a specific yield that ranges between 0.1 and 1 percent, and the total depletion is probably less than about 300 acre-ft (0.37 hm^3) since 1950.

The depletion in the study area has occurred over a 23-year period; thus, the average annual depletion for the Anza-Terwilliger area is about 600 acre-ft (0.74 hm^3).

Chemical Quality of Ground Water

The water from wells and springs in the study area is generally of good chemical quality, as indicated by the chemical analyses tabulated by Giessner and Mermod (1974); however, nitrate concentration in water in five wells exceeds the recommended drinking water limit of 44 mg/l (milligrams per litre) for public water supply. A concentration of 44 mg/l nitrate[1] is equivalent to the 10-mg/l nitrate-nitrogen limit listed by the Environmental Protection Agency in "Water Quality Criteria," 1972, p. 73. The nitrate concentrations range from 0 to 128 mg/l (fig. 12) in water from wells and springs sampled. Analyses of water from many of the wells sampled more than once indicate that

[1]To convert N (nitrate-nitrogen) to NO_3 (nitrate) multiply by 4.427.

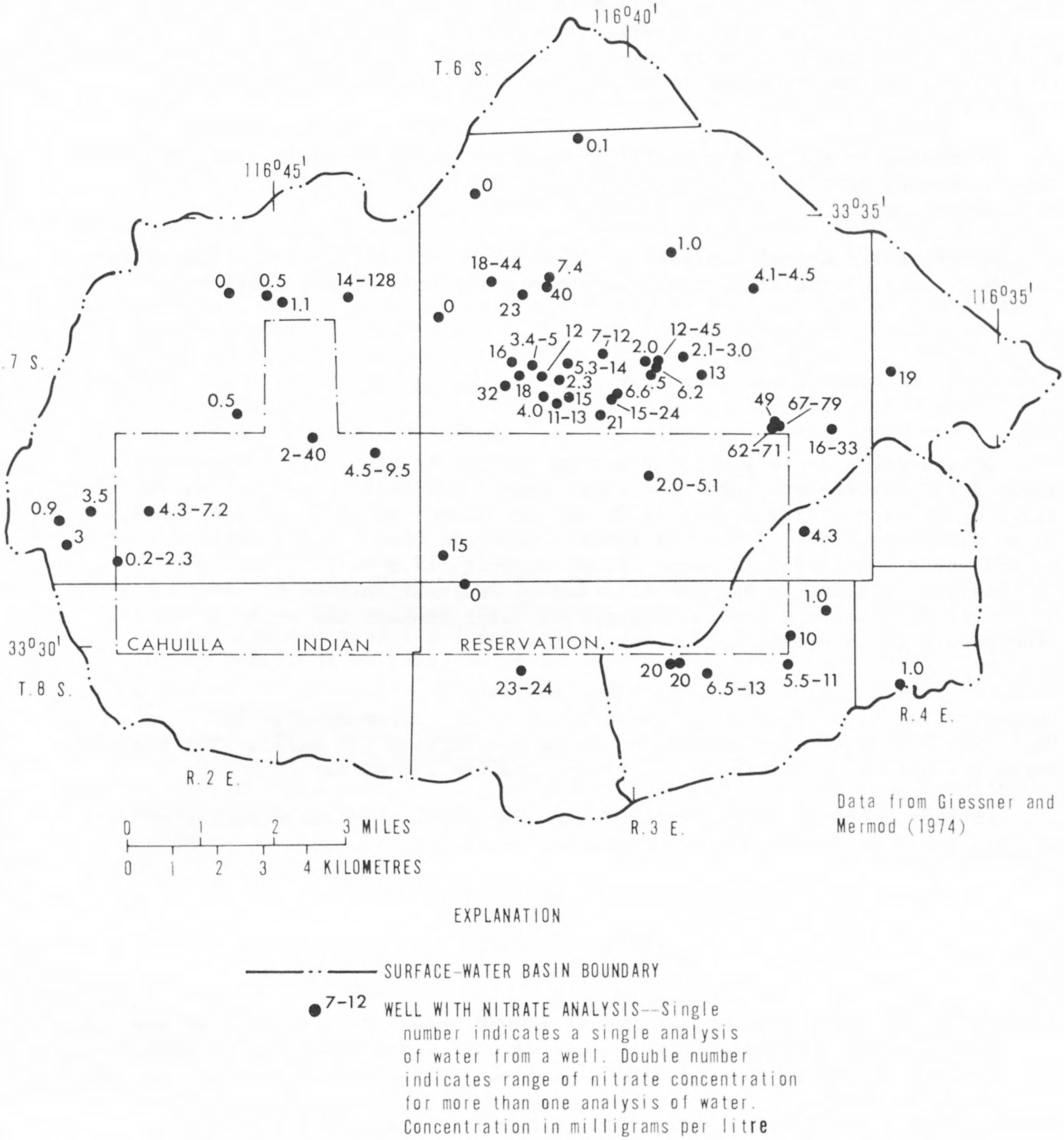


FIGURE 12.--Nitrate concentration in ground water.

nitrate concentrations change drastically with time. Many wells were sampled more than 10 times between 1950 and 1973. The wells that usually contain high concentrations of nitrate are drilled in thin alluvial deposits overlying basement complex. The water levels in these wells are generally near land surface. The nitrate probably comes from chemical fertilizer placed on crops, from animal wastes, from septic tanks, and from decomposition of native vegetation.

According to the Environmental Protection Agency (1972, p. 73), high concentrations of nitrate in drinking water may cause infantile methemoglobinemia.

Additional chemical analyses could show whether nitrate problems exist in other parts of the study area where presently no data are available.

SUMMARY AND CONCLUSIONS

Ground-water depletion is occurring locally in several places within the study area. Water-level declines range from a few feet to as much as 76 ft (23.2 m) between steady state (1950) and the summer of 1973. During 1973, about 4,200 acre-ft (5.2 hm^3) of ground water was used. Total depletion of ground water since 1950 is about 14,000 acre-ft (17.3 hm^3). Pumping depressions adjacent to the Cahuilla Indian Reservation have increased the hydraulic gradient and are causing ground water beneath the reservation to flow toward these depressions.

Chemical analyses of ground water indicate that some areas contain a concentration of nitrate which exceeds the limit recommended by the Environmental Protection Agency for human consumption (44 mg/l). The highest value for nitrate analyzed in the study area was 128 mg/l.

Further declines in water level and changes in the concentration of nitrate could be detected by a continuing monitoring program.

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