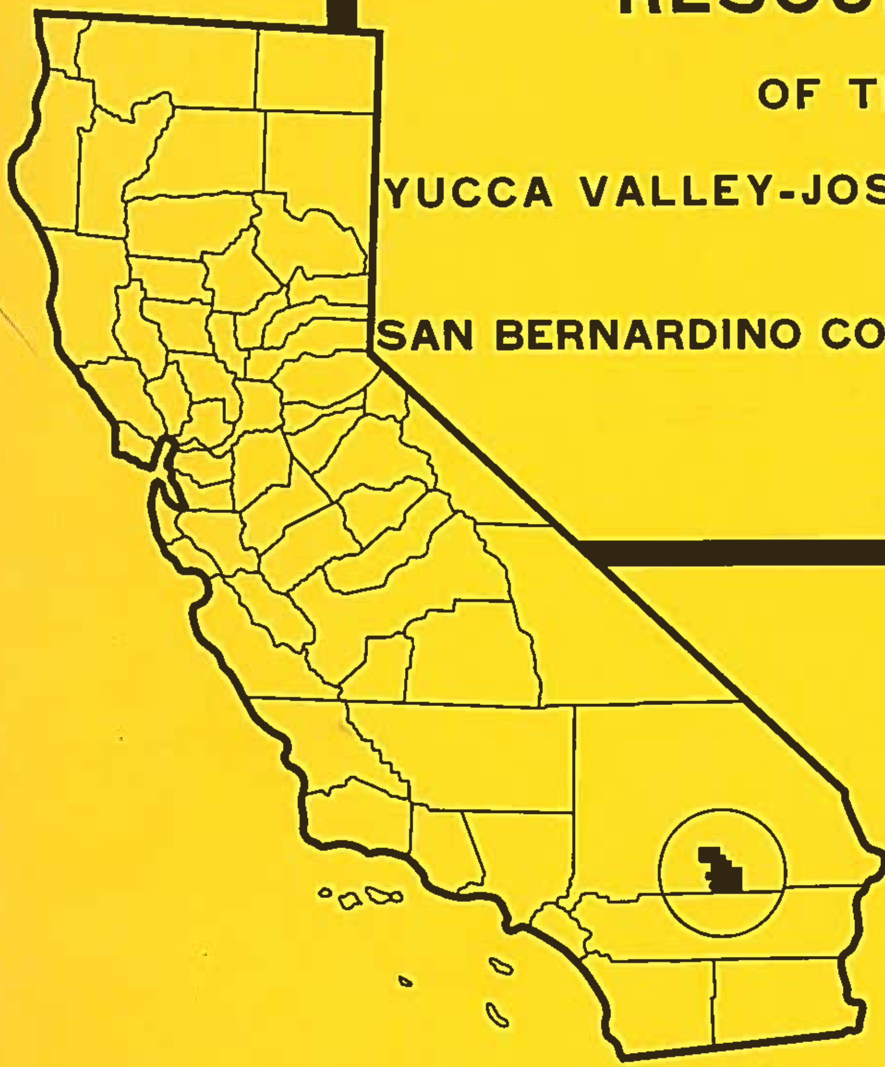
GROUND-WATER RESOURCES OF THE YUCCA VALLEY-JOSHUA TREE AREA SAN BERNARDINO COUNTY, CALIFORNIA



Lewis--GROUND-WATER RESOURCES, YUCCA VALLEY-JOSHUA TREE AREA, CALIFORNIA

OPEN—FILE REPORT
U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
Menlo Park, California, 1972
PREPARED IN COOPERATION WITH THE
MOJAVE WATER AGENCY

UNITED STATES
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By
Robert E. Lewis

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SAN BERNARDINO COUNTY, CALIFORNIA

By R. E. Lewis

ABSTRACT

The southeastern part of the Mojave Water Agency area included in this report comprises about 600 square miles. Recharge into the area is almost exclusively from precipitation in the San Bernardino and Little San Bernardino Mountains. About 500 acre-feet per year of recharge enters the western part of the area as underflow through Pipes Wash. Little direct recharge occurs as a result of precipitation directly on the unconsolidated deposits.

Presently about 11,000 persons reside in the area and current gross pumpage is about 1,600 acre-feet annually. By the year 2000 the population is estimated to be 62,000 and annual gross pumpage is expected to be nearly 11,000 acre-feet. Although over 1,200,000 acre-feet of ground water are presently in storage, most of the population is centered in the southern part of the area around the towns of Yucca Valley and Joshua Tree. About 70 percent of the population resides in the vicinity of Yucca Valley and is supplied by ground water pumped from the Warren Valley basin. Of the 96,000 acre-feet of ground water in storage in that basin in 1969, about 80,000 acre-feet will be necessary to sustain projected growth there until 2000. Assuming negligible recharge and only about 50 percent recovery of the ground water in storage, if imported water from northern California is not available before about 1990, additional local supplies will have to be developed, possibly in the adjacent Pipes subbasin to the north.

Ground water in the southern part of the study area generally contains less than 250 mg/l (milligrams per liter) dissolved solids and 1.0 mg/l fluoride. A general degradation of ground-water quality occurs northward toward the dry lakes where the concentrations of dissolved solids and fluoride approach 2,000 and 5.0 mg/l, respectively. In Reche subbasin some isolated occurrences of fluoride exceeding 1.5 mg/l were noted. The chemical character of ground water in Johnson Valley and Morongo Valley basins differs from well to well and, in general, water from these basins is less desirable for use.

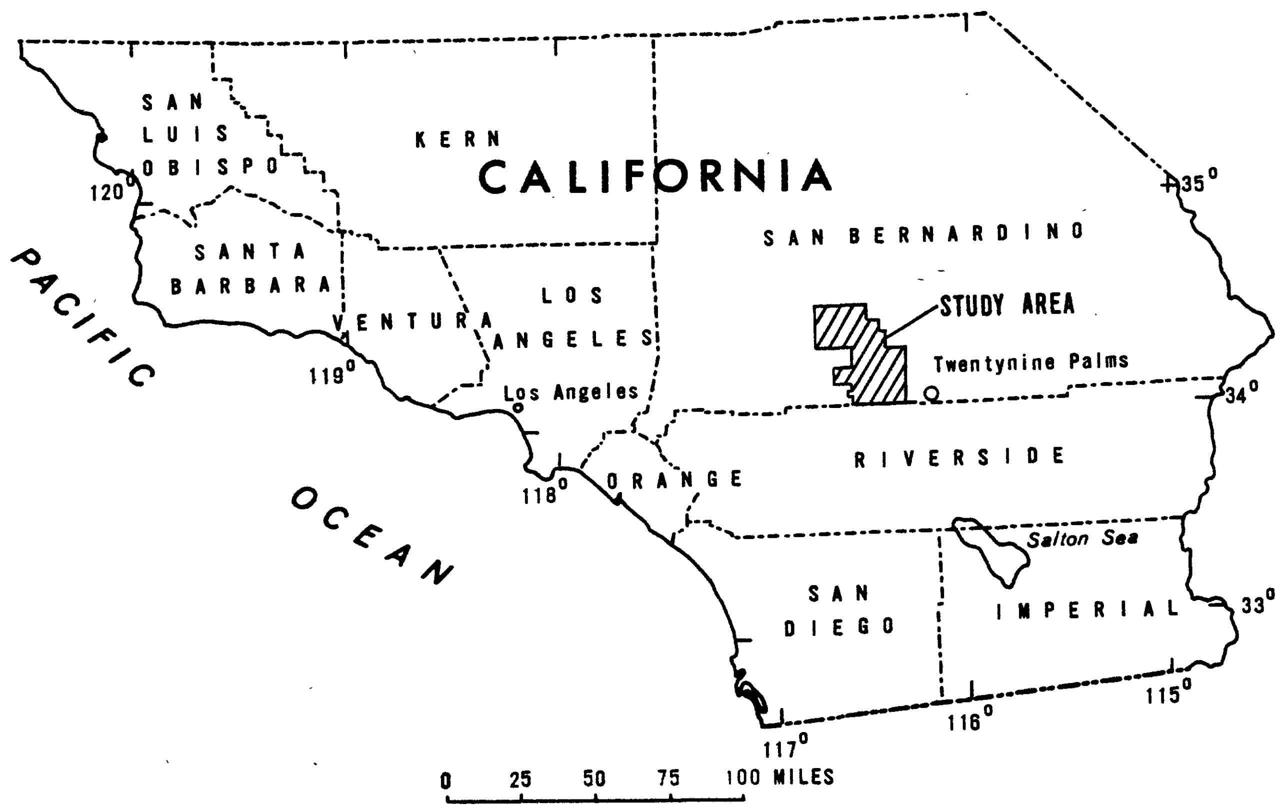

FIGURE 1.--Index map.

Description of the Area

The Mojave Water Agency area covers about 4,800 square miles of desert lands north and east of the San Bernardino Mountains. Within the agency boundary the water-resources study area (fig. 2), referred to in this report as the Yucca Valley-Joshua Tree area, consists of about 600 square miles along the southern part of San Bernardino County in the southeastern part of the Mojave Desert between long 116°12' E. and 116°40' E. extending northward about 32 miles to lat 34°30' N. in Johnson Valley. The drainage area outside the agency boundary to the south and west comprises an additional 150 square miles.

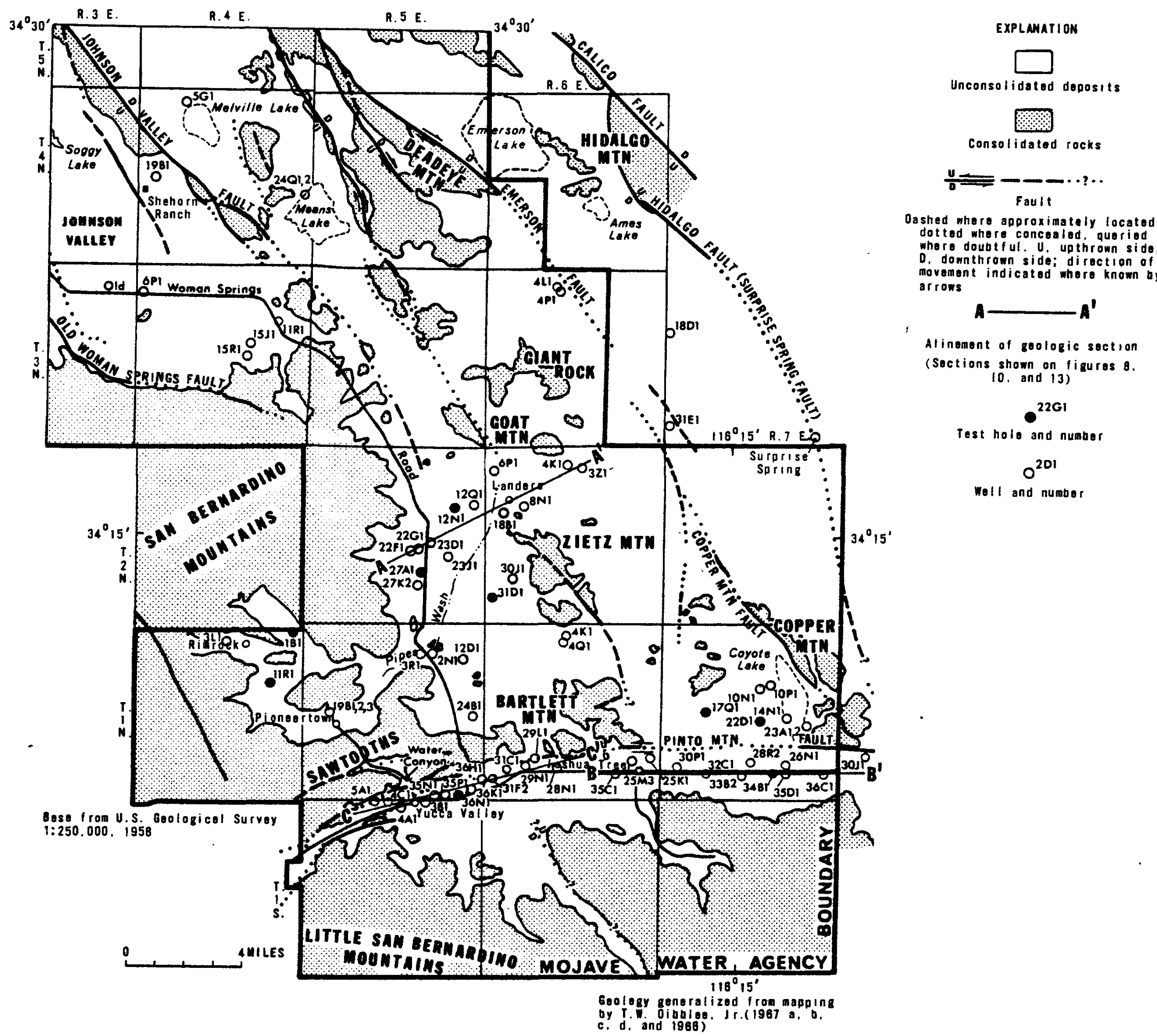

FIGURE 2.--Generalized geology and location of selected wells.

The study area is a broad, generally northeast sloping high-desert alluvial plain. Elevations on the basin floor range from about 2,500 to 3,400 feet above mean sea level in the southern part; from 2,600 to 3,600 feet through the central part near Landers; and from 2,300 to 3,200 feet in the northern part across Johnson Valley to Emerson Lake.

Physiographically, the study area is bounded on the south by the Little San Bernardino Mountains, which rise from the alluvial plain to an elevation of more than 5,800 feet. The San Bernardino Mountains form the western physiographic boundary of the southern part of the study area and southern physiographic boundary of the northern part of the area in Johnson Valley. Elevations in the higher San Bernardino Mountains are more than 9,000 feet.

No distinct physiographic boundaries exist to the east and north. The agency boundary extends irregularly north, then west, and, in this report, delineates the eastern and northern limits of the study area.

Many bedrock hills protrude from the alluvium forming natural barriers to ground-water movement. These hills and associated northwest-trending faults divide the study area into units that will be referred to in this report as ground-water basins and subbasins.

The climate, which is typical of the southern Mojave Desert, is characterized by abundant sunshine and little rainfall, high summer temperatures and relatively cool winters. The average annual precipitation at Yucca Valley is about 6.75 inches;[1] at Joshua Tree, about 4.65 inches;[2] most of this, however, is lost through evaporation, and little is recharged to the ground-water reservoir. Most of the recharge to the basin is from precipitation runoff from higher elevations migrating downward into the basin as underflow through locally fractured and weathered bedrock and along the permeable stream channels. In the headwaters of the Pipes Wash drainage system in the San Bernardino Mountains, elevation 8,400 feet, the average annual precipitation is 25 inches. This high area and other areas in the Little San Bernardino Mountains to the south where elevations approach 6,000 feet are the primary sources of recharge derived from precipitation.

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[1]Average for 1883 through 1962 derived from precipitation at Morongo Valley, from Warren O. Wagner and Associates (1963).

[2]Average for 1952-53 and 1968-69, from National Weather Service (U.S. Weather Bureau) data.

Prior to the end of World War II, the area included in this report was sparsely populated. There was little irrigation, and only a few cattle were grazed on ranches in Johnson Valley and in the vicinity of the towns of Yucca Valley and Joshua Tree. Water was obtained from a few wells pumped by windmills or by small gasoline engines. During that time, water levels in wells fluctuated and generally reflected the trends in precipitation. From 1936 to 1945 precipitation was generally greater than the long-term average, and although water-level measurements are generally unavailable prior to 1941, a hydrograph of well 1N/5E-35N1 (fig. 3) reflects the increase in the quantity of ground water in storage from 1942 to 1946. Periodic measurements of water levels indicate that water levels were lower in 1917 and had recovered by 1946. Thompson (1929, p. 643) indicated the depth to water in well 1N/5E-36H1 in 1917 was 130 feet; measurements in 1946 made in the same well indicated a water level of about 105 feet (Bader and Moyle, 1960, p. 60). This probably reflects the above-average wet period in California from 1940 through 1945.

Throughout most of the study area, water levels in wells have remained fairly constant for the period 1958 through 1969 and the withdrawals of ground water from storage have been small. In the southern part of the area, however, around the town of Joshua Tree and particularly around the town of Yucca Valley, water levels declined as pumpage increased to serve the influx of new residents. Almost all ground-water pumpage is used for public or domestic supply. Industrial water use is minor, and the only irrigation is water applied to the golf course west of Yucca Valley.

Previous Work and Acknowledgments

Previous work by the Geological Survey included a compilation of measurements of water level in wells, chemical analyses, and drillers' logs and a geologic map for the Yucca Valley-Twentynine Palms area (Bader and Moyle, 1960) and Morongo Valley and vicinity (Bader and Moyle, 1958). Work done by agencies other than the Geological Survey include mimeographed reports by Warren O. Wagner and Associates (1963), Albert A. Webb Associates (1964), and Koebig and Koebig (1966). Geologic mapping was done by Dibblee (1967a,b,c,d and 1968) at a scale of 1:62,500. Also, pertinent unpublished data on the geology and ground-water resources of the Marine Corps base at Twentynine Palms (written commun., F. S. Riley and G. F. Worts, Jr., 1953) were used in this report.

The writer acknowledges the cooperation of the many well owners and residents who provided information used in the study. Mr. Ron Fick and Mr. Fred Tripp, successive managers of the Yucca Valley County Water District, Mr. Herman Deich of the Joshua Basin County Water District, Mr. T. W. Jurling of the Yucca Water Co., Inc., Mr. Boyd Jensen of the Desert View County Water District, and Mr. Ion Lachman of the Panorama Heights Water Co., Inc. provided hydrologic information on wells under their jurisdiction. Special thanks go to Lt. Col. F. W. Pickett (U.S. Army, Retired) for supplying historic and recent data on wells in the study area.

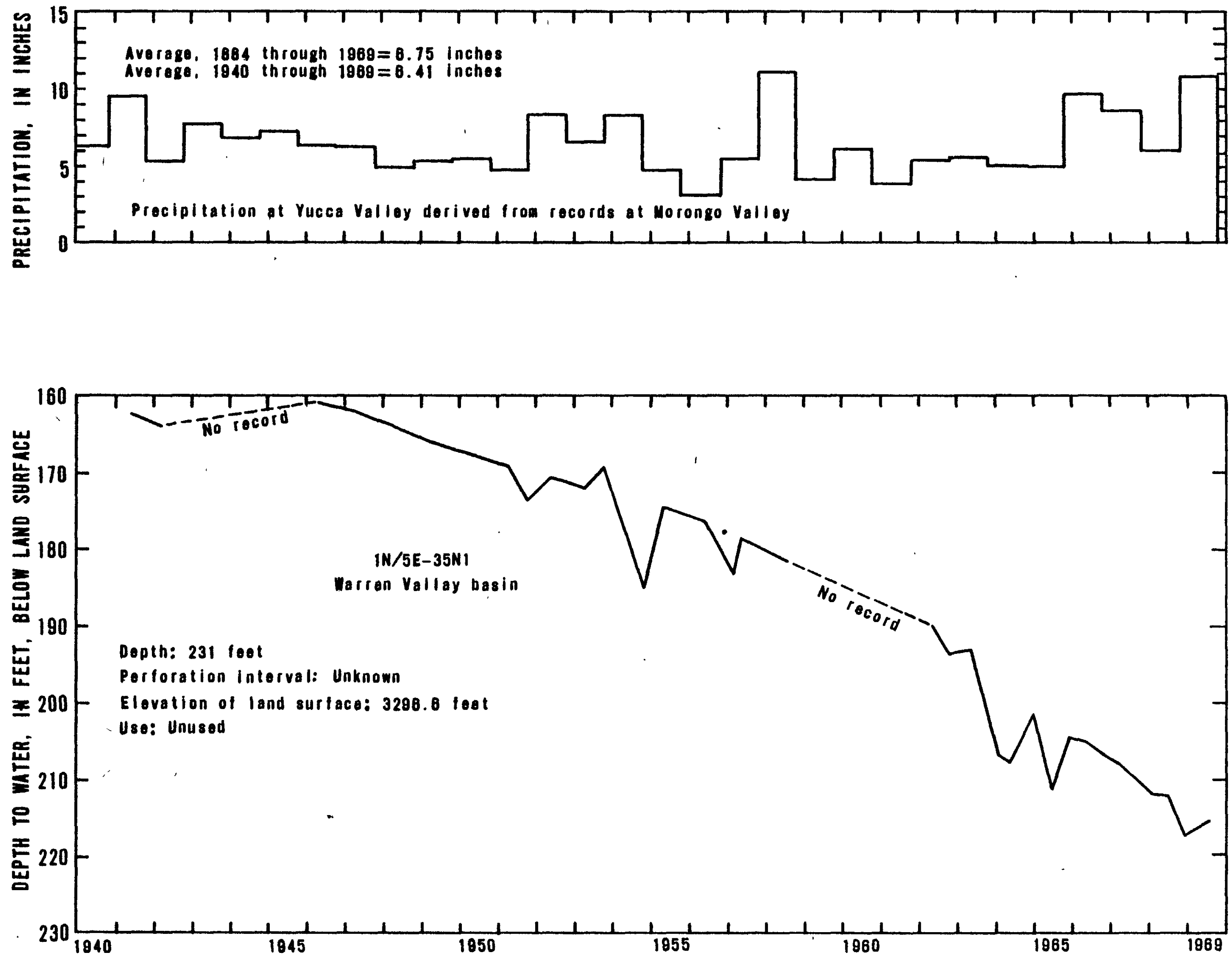
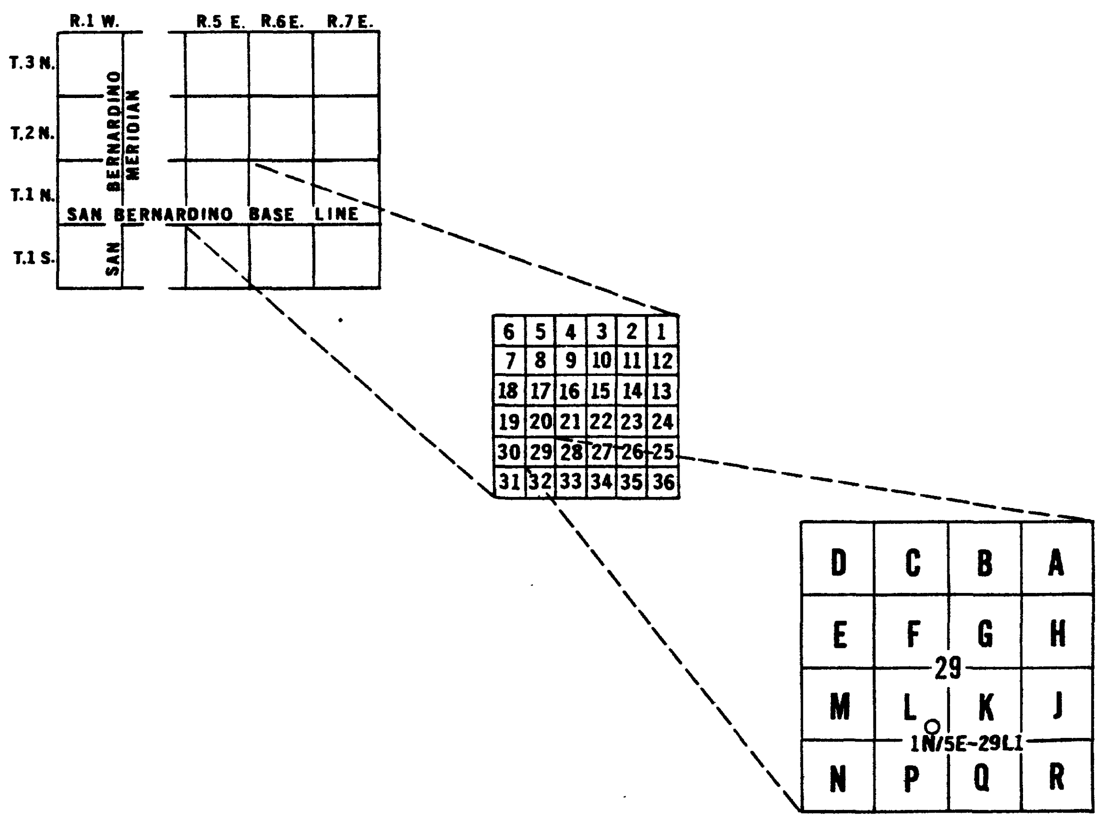


FIGURE 3.--Hydrograph of well 1N/5E-35N1 and annual precipitation at Yucca Valley.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public land. For example, in the well number 1N/5E-29L1 the first two segments designate the township (T. 1 N.) and the range (R. 5 E.); the third number gives the section (sec. 29); and the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram. The final digit is a serial number for wells in each 40-acre subdivision.



GEOLOGY

For this report the geology as mapped by Bader and Moyle (1958 and 1960) and by Dibblee (1967a,b,c,d and 1968) has been generalized to show consolidated rocks and unconsolidated deposits and to identify the principal faults that may affect the hydrology of the area (fig. 2).

Lithologic Units

The consolidated rocks consist primarily of igneous and metamorphic rocks of pre-Tertiary age, but also include, locally, flows of basalt of Tertiary and Quaternary age, and a buff sandstone beneath the basalt, probably correlative with the Old Woman Sandstone, named by Shreve (Richmond, 1960, p. 16). Collectively these rocks form the mountains south and west of the study area, the hills that protrude through the unconsolidated deposits, and the bedrock beneath the alluvium.

Because of their low permeability the consolidated rocks are considered to be virtually non-water-bearing. Locally, however, joints, fractures, and deeply weathered zones probably conduct some water to the ground-water system. Domestic wells drilled into the consolidated rock south of Yucca Valley yield quantities of water sufficient for household use.

The unconsolidated deposits consist, for the most part, of intercalated lenses of clay, silt, sand, and gravel, of Tertiary and Quaternary age. The thickness of these deposits is variable but is reported by Dibblee (1968) to be 1,000 feet or more east of the study area near Twentynine Palms. In the central part of the various basins few wells have been drilled through the full thickness of the unconsolidated deposits. Therefore their total thickness cannot be determined. An exploratory well, Onoco No. 1, drilled in sec. 28, T. 2 N., R. 8 E., east of the study area, was reportedly bottomed in granite wash basement at a depth of 2,106 feet (Smith, 1959, p. 17). Test holes drilled in the area near the towns of Yucca Valley and Joshua Tree have penetrated more than 750 feet of unconsolidated deposits without reaching bedrock.

Beneath the beds of Emerson, Melville, Means, and other unnamed dry lakes, the unconsolidated deposits may consist almost exclusively of clay and silt, are commonly micaceous, and generally alkaline. The playa clays and silt deposits are known from test borings to be 45 to 50 feet thick beneath Mesquite Lake (north of Twentynine Palms, east of the study area) and are probably of the same magnitude of thickness beneath some of the other dry lakes (written commun., F. S. Riley and G. F. Worts, Jr., 1953). Deposits beneath Emerson Lake may be somewhat thicker. Physiographic evidence indicates that the ancestral Pipes Wash drainage probably deposited a large volume of fine-grained sediments in Emerson Lake. Locally the unconsolidated deposits consist of fine, loose sand laid down by the prevailing westerly winds.

The unconsolidated deposits constitute the major aquifer system in the study area. Large-capacity wells which supply water for municipal purposes or golf-course irrigation and wells which supply water for domestic use tap these unconsolidated deposits. Although the water table is close to the land surface at the dry lakes, production wells are seldom drilled on these lakes because the deposits beneath them are fine grained and yield water very slowly, and the water quality is poor.

Faults and Ground-Water Barriers

The geologic structure of the study area is dominated by extensive faulting in the consolidated rocks and in the unconsolidated deposits. Most of the faults trend northwest; however, one major fault, the Pinto Mountain fault, crosses the southern part of the study area in a westerly direction. Some of the faults have uplifted the bedrock or displaced the overlying unconsolidated deposits so as to interrupt the subsurface movement of ground water. Thus the faults subdivide the study area into a number of distinct, separate basins and subbasins.

The principal faults in the area as mapped by Dibblee (1967a,b,c,d and 1968) are shown in the geologic map (fig. 2). Several measurements of water level in wells near known faults have indicated differences in water-table elevations from one side of the fault to the other. In these places, known faults mapped from physical evidence have been projected to show their most probable location and are identified in figure 5 as barriers to ground-water movement.

HYDROLOGY

This section of the report includes an explanation of the method used to compute specific yield of the unconsolidated deposits and to estimate the quantity of ground water in storage, a brief presentation of water-quality criteria for domestic use, and the hydrologic conditions in each basin or subbasin.

Computation of Specific Yield and Estimation of the Quantity of Ground Water in Storage

The specific yield of an unconfined aquifer is the ratio of the volume of water which the aquifer, when saturated, will yield by gravity to the total volume of the aquifer, all expressed quantitatively as a percentage. Generalized specific-yield values (table 1) were applied to sediment descriptions from drillers' logs.

TABLE 1.--*Estimated specific yield of unconsolidated deposits*

[After Poland and others, 1949]

Material	Specific yield (percent)
Gravel, clean	25
Sand, gravel and sand, sand and gravel	20
Sand, hard; sand and clay; sand with clay streaks	15
Clay and sand	10
Clay, sandy	5
Clay	3

To compute the specific yield of each basin or subbasin, the specific-yield values obtained from available drillers' logs and lithologic logs from the test holes were combined and an arithmetic average specific-yield value was determined for each basin or subbasin.

The quantity of ground water contained in storage was determined by multiplying the surface area of the water-bearing deposits in each basin or subbasin by the estimated saturated thickness of the unconsolidated deposits, and multiplying this product by the average specific-yield value that was computed for each basin or subbasin. Briefly, surface area (acres) times saturated thickness (feet) times average specific yield (percent) equals quantity of ground water in storage (acre-feet).

With the exception of the test holes, most of the wells are not sufficiently deep or accurately logged to permit precise determination of the thickness, specific yield, or hydrologic properties of the aquifer. In order to obtain estimates of the volumes of ground water stored in six of the storage units, estimates of thickness and specific yield of the aquifer were made using available data. The boundaries used in determining the surface area of the unconsolidated deposits in each of the six storage units were located to include in the calculation only that part of the alluvium from which ground water can probably be extracted.

Water Quality

In general, ground water in the southern part of the study area contains less than 250 mg/l (milligrams per liter) dissolved solids increasing to more than 1,000 mg/l northward in parts of Johnson Valley and to nearly 2,000 mg/l near the dry lake beds. The nature and concentration of the dissolved constituents in ground water, as revealed by chemical analyses of water samples obtained from wells, define the chemical character of the water and in part determine its suitability for various uses. Most of the chemical analyses used in this study are tabulated in two reports by Bader and Moyle (1958, 1960).

Recommended limits for the concentration of various ions in water for different uses have been established by the U.S. Federal Water Pollution Control Agency (1968) and by the U.S. Public Health Service (1962). The recommended limits for the concentration in drinking water of some of the more common constituents are listed in table 2.

TABLE 2.--*Recommended limits for the concentration of various ions*

[U.S. Public Health Service, 1962, p. 7]

Constituents[1]	Concentration[2] (mg/l)
Chloride (Cl)	250
Fluoride (Fl)	(See table 3)
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Dissolved solids	500

[1]Not a complete list.
[2]Concentrations should not exceed those listed unless suitable supplies are not available.

Fluoride in varying concentrations is generally present in all ground water. The potentially beneficial effects of fluoride ion in drinking water supplies are recognized by the U.S. Federal Water Pollution Control Agency (1968, p. 23). Recommended limits of fluoride ion concentration have been established by the U.S. Public Health Service (1962, p. 8) and are shown in table 3. Average concentrations greater than two times the optimum values in table 3 constitute grounds for rejection of the supply.

TABLE 3.--*Recommended limits of fluoride ion concentration in drinking water*

[U.S. Public Health Service, 1962, p. 8]

Annual average of maximum daily air temperature at Twentynine Palms, Calif. °F	Recommended control limits of fluoride concentration in mg/l		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	.8	1.1	1.5
58.4-63.8	.8	1.0	1.3
63.9-70.6	.7	.9	1.2
70.7-79.2	.7	.8	1.0
79.3-90.5	.6	.7	.8

On the basis of temperature data from the National Weather Service (U.S. Weather Bureau), the average maximum daily temperature at Twentynine Palms, the nearest National Weather Service station with sufficient data, is about 83°F. Therefore the upper recommended limit is 0.8 mg/l of fluoride, and the rejection level would be concentrations in excess of 1.4 mg/l.

The maximum recommended concentration of fluoride in drinking water depends on the annual average maximum daily air temperature (U.S. Public Health Service, 1962). The reason is that individuals, and particularly children, drink more water in warm climates; hence, the fluoride content of the water should be lower to prevent excessive total fluoride consumption (McKee and Wolfe, 1963, p. 190).

Hydrologic Conditions of the Basins

Six ground-water basins (fig. 4) lie wholly or partly within the study area (California Department of Public Works, Division of Water Resources, 1952, p. 35). Warren Valley, Means Valley, and Copper Mountain Valley basins are entirely within the study area. Means Valley basin is divided into Pioneertown, Pipes, and Reche subbasins, and Copper Mountain Valley basin is divided into Giant Rock, Coyote Lake, and Joshua Tree subbasins. Morongo Valley and Johnson Valley basins are only partly within the study area. The western part of Deadman Valley basin is designated Surprise Spring subbasin and is partly within the study area. Each of the basins and subbasins is separated from others by bedrock hills, by buried bedrock ridges, by faults, or by postulated barriers of undetermined origin. In this section of the report each basin or subbasin is discussed separately, boundaries separating each basin and subbasin are delineated, the direction of ground-water movement is indicated from a water-level contour map (fig. 5), ground-water pumpage is tabulated and the amount of water-level decline is indicated (fig. 6), storage capacity is estimated, and chemical analyses of ground water are discussed.

Means Valley Basin

Means Valley basin is an elongate, northwest-trending basin in the western part of the study area and is divided into Pioneertown, Pipes, and Reche subbasins (fig. 4).

Pioneertown subbasin.--The Pioneertown subbasin, except for about 1 mile on the east side, is bounded by consolidated rocks of the San Bernardino Mountains (fig. 4). Recharge is from precipitation and runoff in the surrounding mountains. Most of the recharge entering the subbasin moves east as subsurface flow through the unconsolidated deposits in Pipes Wash toward Pipes subbasin.

Pumpage is not metered but probably does not exceed 25 acre-feet per year. Water levels in wells have been relatively unchanged during the period 1958 through 1969.

Several water wells have been drilled into the unconsolidated deposits. Wells 1N/5E-19B1, 19B2, and 19B3 (fig. 2) were drilled near Pioneertown to depths of 208, 325, and 220 feet. Well 19B2 penetrated about 240 feet of saturated deposits and reached consolidated bedrock at a depth of 320 feet. The other wells did not reach bedrock.

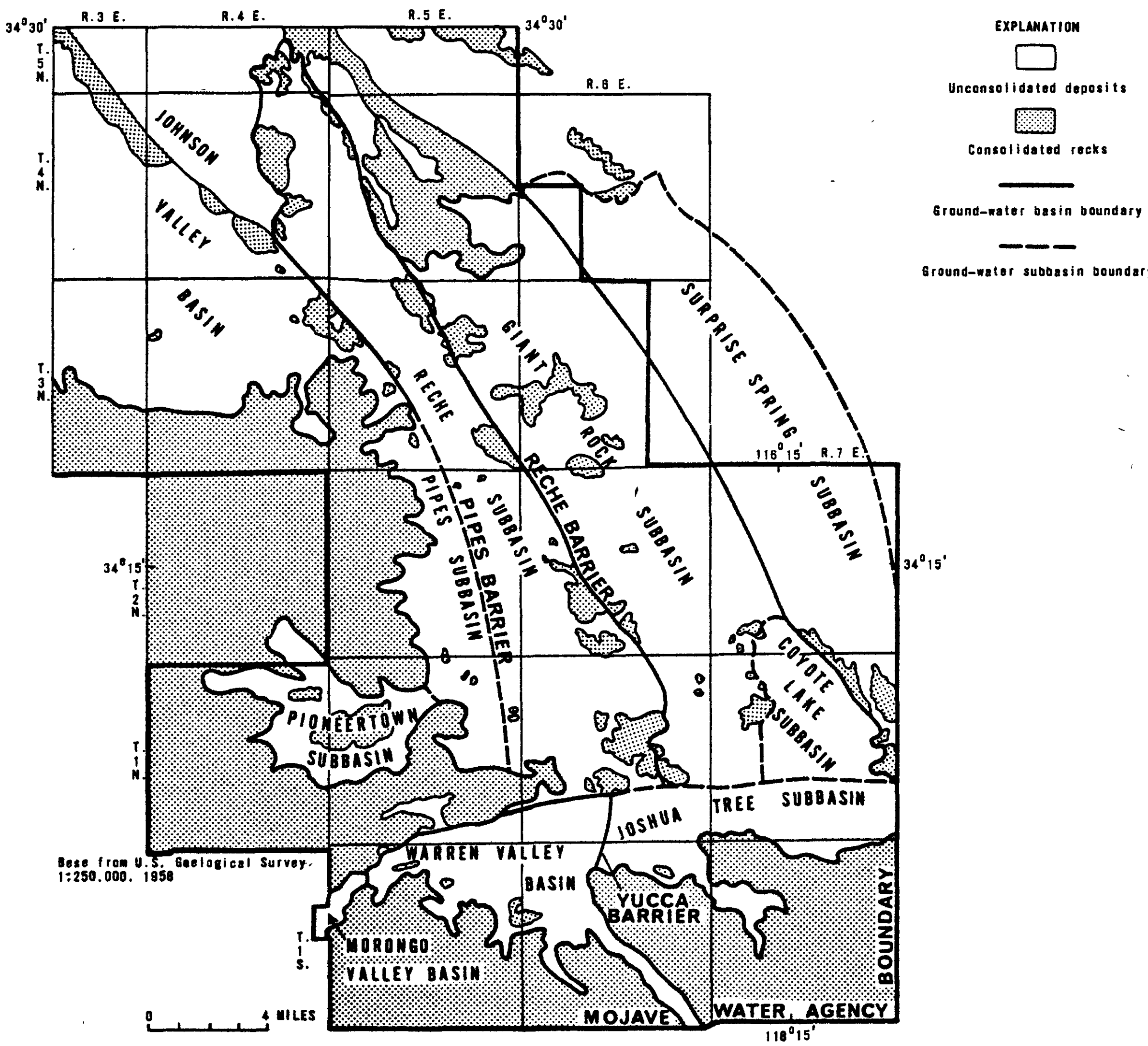


FIGURE 4.—Ground-water basins and subbasins.

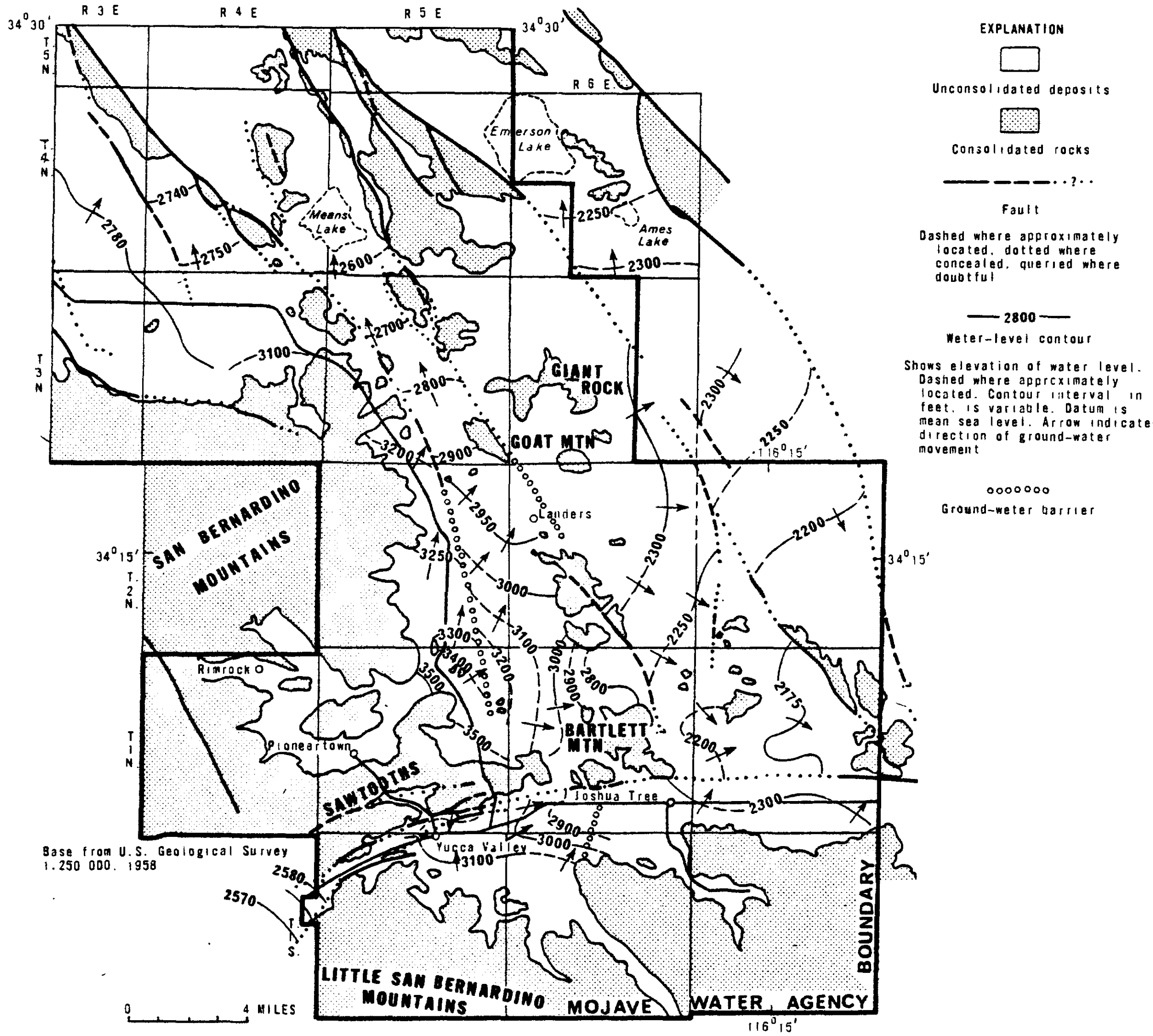


FIGURE 5.--Water-level elevation, spring 1969.

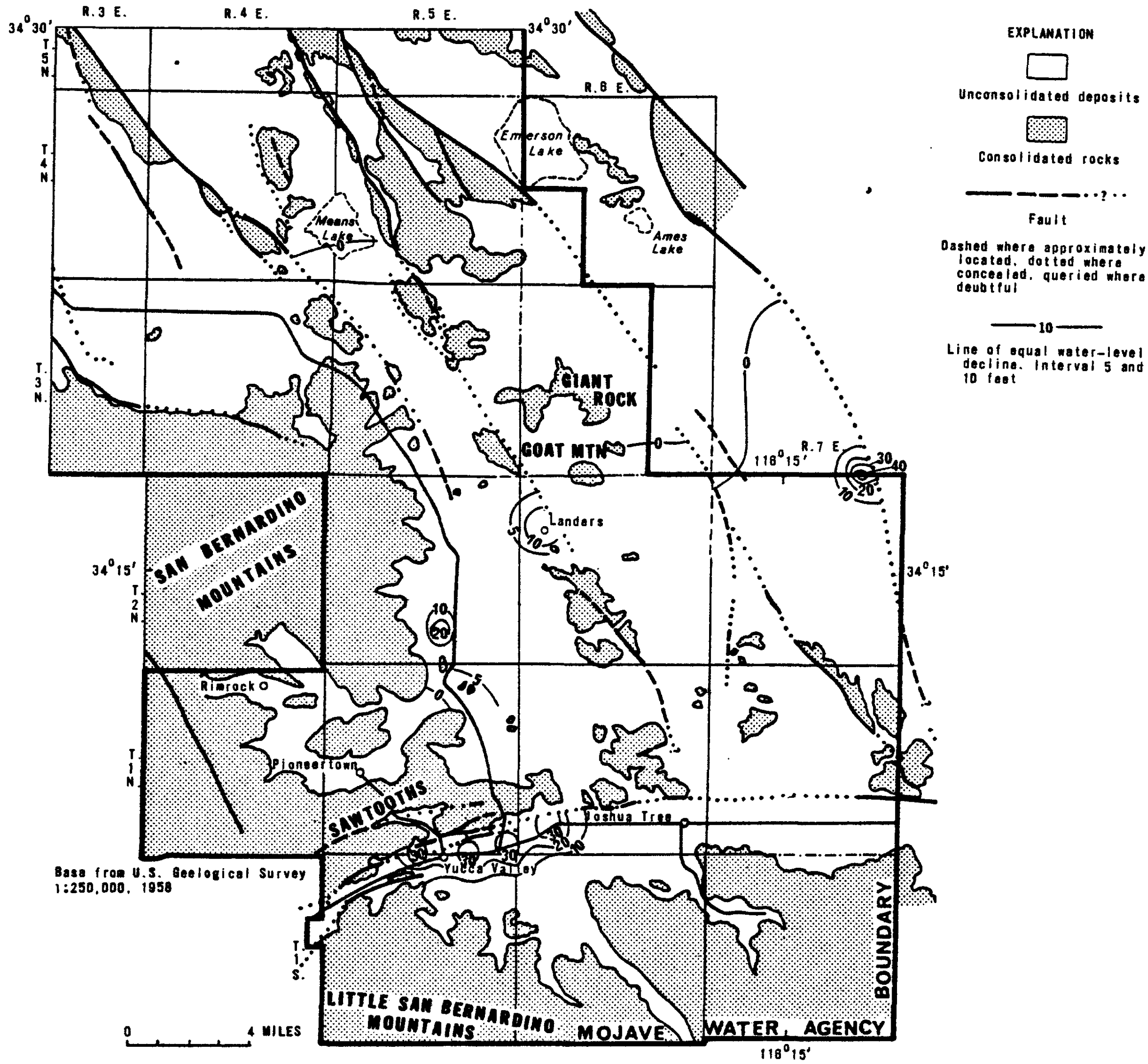


FIGURE 6.--Water-level decline 1958-69.

Well 1N/4E-3L1, drilled farther northwest near Rimrock, penetrated about 35 feet of saturated deposits and reached bedrock at a depth of 177 feet. Two test holes were drilled in the subbasin. Test hole 1N/4E-1B1 was drilled to a depth of 180 feet and penetrated 80 feet of saturated material; test hole 1N/4E-11R1 was drilled to a depth of 255 feet and penetrated 100 feet of saturated material. In both test holes, the water-bearing material was fine grained and very tight and did not yield water readily. Neither test hole was drilled to bedrock.

Because of insufficient data, ground-water storage in the Pioneertown subbasin was not estimated. It does not seem likely, however, that any substantial supply of ground water could be developed in the subbasin.

Between 1954 and 1960, seven analyses of water from one well near Pioneertown showed that dissolved solids ranged from 162 to 243 mg/l and averaged 204 mg/l. Fluoride concentrations ranged from 0.3 to 0.8 mg/l in six analyses and averaged 0.6 mg/l.

Pipes subbasin.--Pipes subbasin (fig. 4) is bounded on three sides by consolidated rock. The eastern boundary is the Johnson Valley fault and the Pipes barrier. Water levels on the western or Pipes subbasin side of the barrier are 100 to 175 feet higher than those on the eastern side.

Pipes subbasin receives runoff from approximately 70 square miles of surface drainage in the San Bernardino Mountains to the west. Runoff from the consolidated rock enters the unconsolidated deposits in the eastern part of the Pioneertown subbasin, moves downgradient as underflow, and enters Pipes subbasin through Pipes Wash near well 1N/5E-2N1 (fig. 2). Small additional quantities of underflow undoubtedly enter the subbasin along its western flank through fractures in the consolidated rock.

Estimates of underflow indicate that between 100 and 1,000 acre-feet per year could enter the subbasin through Pipes Wash. These estimates were based on a hydraulic gradient of 0.03 foot per foot, a cross-sectional area of 3×10^5 square feet, and a coefficient of permeability between 10 and 100 gpd (gallons per day) per square foot. The hydraulic gradient of 0.03 foot per foot was estimated from the 1969 water-level contour map (fig. 5). The cross-sectional area of 3×10^5 square feet was estimated from the saturated thickness indicated in the driller's log of well 1N/5E-3R1 and the width of the unconsolidated deposits shown by Dibblee (1967b). The coefficient of permeability between 10 and 100 gpd per square foot is described by Todd (1964, p. 53) as 10 gpd per square foot equals the upper limit of a poor aquifer and 100 gpd per square foot equals the lower limit of a good aquifer. Available data for Pipes Wash area indicate that the aquifer consists of a mixture of sand, gravel, silt, and clay.

Probably about 500 acre-feet of underflow are recharged into the subbasin through Pipes Wash annually. From Pipes Wash the ground water moves east and northeast through Pipes subbasin and crosses Pipes barrier into Reche subbasin.

Twenty-eight wells are in Pipes subbasin and ground-water pumpage is small. Of these wells, one is owned by the Desert View County Water District, 18 by full-time residents, three by part-time residents, and six are unused. Ground water pumped by the water district is metered, but pumping records are available only for 1966 through 1969. Pumpage from domestic wells operated by residents and part-time residents was estimated. On the basis of estimates of 0.2 acre-foot per person per year, owners of domestic wells would pump less than 8 acre-feet of ground water per year. For Pipes subbasin, total ground-water withdrawal for 1966 through 1969 was estimated to be 240 acre-feet, or an average of about 60 acre-feet per year.

The thickness of the unconsolidated deposits diminishes southward in the subbasin. In the central part of the subbasin test hole 2N/5E-27A1 was drilled to a depth of 705 feet without reaching consolidated rock and penetrated about 300 feet of saturated deposits. In well 1N/5E-3R1 in Pipes Wash east of Old Woman Springs Road, bedrock was penetrated at a depth of 270 feet, and the saturated thickness of the unconsolidated deposits was about 150 feet. In the southernmost part of the subbasin, in well 1N/5E-24B1, the depth to bedrock was 192 feet, and the saturated thickness of the unconsolidated deposits was about 30 feet. A conservative estimate of the average saturated thickness of the unconsolidated deposits in Pipes subbasin is about 150 feet.

Specific-yield values estimated from drillers' logs of 13 water wells and one test hole ranged from 10 to 22 percent and averaged about 14 percent for the entire subbasin.

The surface area of the water-bearing deposits in Pipes subbasin is about 9 square miles or about 5,800 acres. Using a saturated thickness of 150 feet and an average specific-yield value of 14 percent, the volume of ground water contained in storage in Pipes subbasin as of 1969 was estimated at 120,000 acre-feet.

Chemical analyses of water from three wells and one test hole in Pipes subbasin were all within the recommended limits for drinking water for concentration of ions established by the U.S. Public Health Service (1962). The analysis of water from well 2N/5E-27K2 is shown in figure 7. Concentration of dissolved solids in water from wells in the subbasin ranged from 250 to 314 mg/l; fluoride concentration ranged from 0.4 to 1.0 mg/l.

Prospects for the development of additional water supplies from Pipes subbasin seem good.

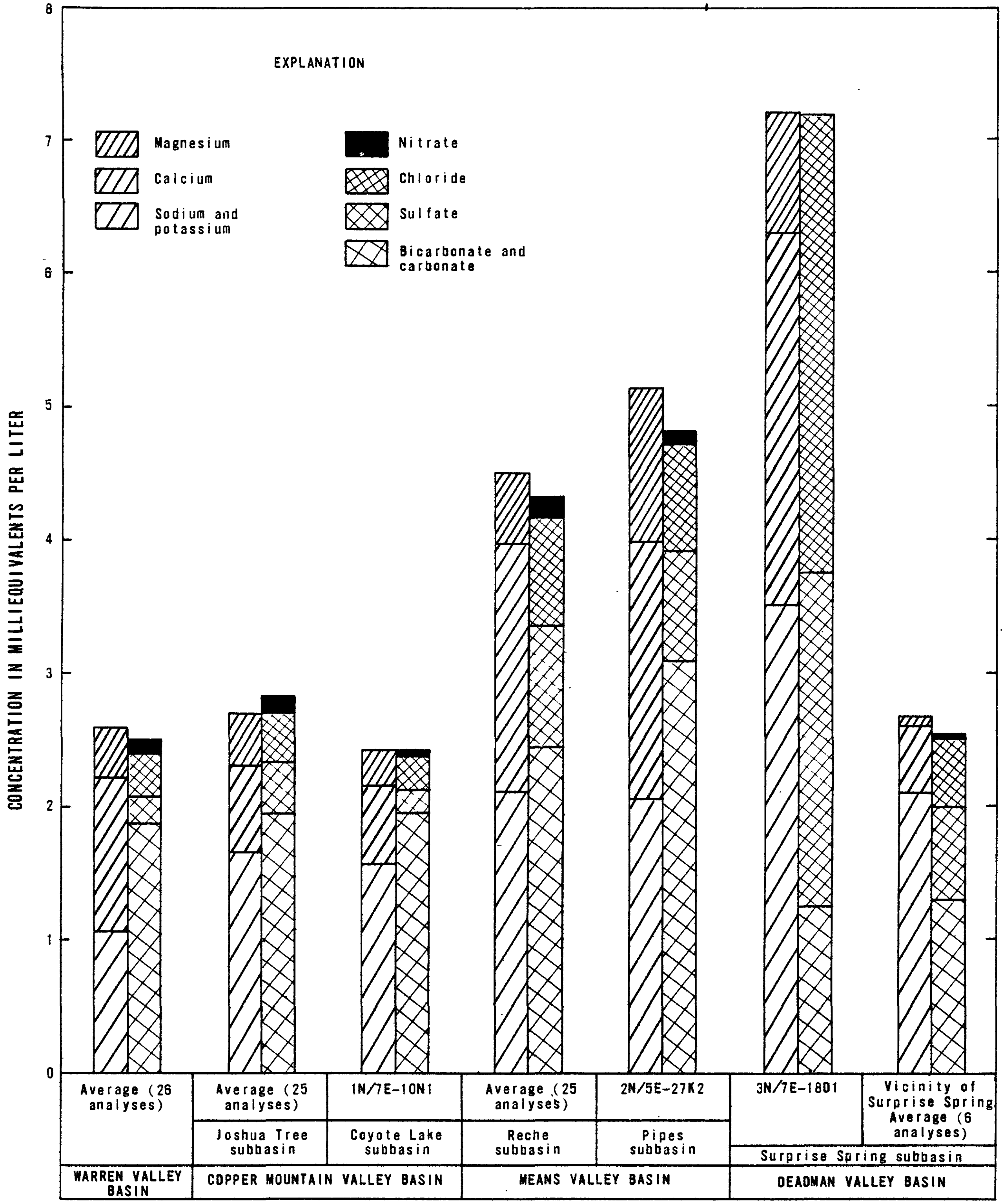


FIGURE 7.--General chemical composition of ground water.

Reche subbasin.--Reche subbasin has a surface area of about 51 square miles and is bounded on the east, west, and south by faults (fig. 2) or postulated barriers (fig. 5). The northern boundary is a concealed fault or bedrock ridge north of Means Lake. The western boundary, in common with Pipes subbasin to the west, is formed by the Johnson Valley fault and the postulated Pipes barrier. The effectiveness of the Pipes barrier on the migration of ground water is indicated by a difference in water-table elevation on either side of the barrier (fig. 5); water-level measurements in wells on the west, or Pipes subbasin side, are 100 to 175 feet higher than those on the east, or Reche subbasin side. The southern boundary of the subbasin is the Pinto Mountain fault and consolidated rocks of the Bartlett and Sawtooth Mountains. As a barrier to ground-water movement the effectiveness of the Pinto Mountain fault cannot be determined from available water-level measurements. However, chemical analyses of ground water sampled from the subbasin and from the Warren Valley basin south of the fault indicate two different water types (fig. 7). This implies that movement of ground water across the fault is restricted. The east side of the subbasin is bounded by the Reche barrier and a series of in-line faults and bedrock hills. The Reche barrier is postulated on the basis of a difference in water-table elevation of about 240 feet in wells that are separated by the barrier. Means Lake, in the northern part of the subbasin, is a ground-water sink and probably is a discharging playa.

Because no streams enter the subbasin, all recharge is from subsurface flow across Pipes barrier. The water-level contour map (fig. 6) indicates that ground-water movement in the subbasin is generally northwest toward Means Lake. Some ground water probably moves east across the Reche barrier and also across the unnamed fault in the Bartlett Mountain area. Where the southern end of Reche subbasin is terminated by the Pinto Mountain fault, data are insufficient to determine if outflow crosses the fault into Warren Valley basin to the south.

Ground-water withdrawals from Reche subbasin are from privately owned wells, and pumpage is not metered. Of the 43 existing wells only 22 are regularly in use, seven are owned by part-time residents, and 14 are unused. The total annual pumpage from domestic wells is probably less than 10 acre-feet. Most of the ground water is pumped by three water haulers who deliver water to residents of the area. The volume of ground water pumped for this purpose is not metered and is difficult to estimate. One water hauler estimated that he delivered 7.3 million gallons (22.4 acre-feet) of water annually. Two other water haulers operate on a smaller scale but could not provide an estimate of the quantity of water hauled. The total volume of ground water extracted from the Reche subbasin in 1969 probably did not exceed 75 acre-feet. Water levels were generally lower in the subbasin since previous water-level measurements in 1958. The greatest decline is in the Landers area (fig. 6).

The total thickness of the unconsolidated deposits in the deeper part of Reche subbasin may exceed 1,300 feet. An exploratory hole was drilled in sec. 25, T. 2 N., R. 5 E., in 1953 by the Retari Oil Co. The total depth of the hole was 1,311 feet and the well reportedly terminated in sediments of Tertiary age (Smith, 1959, p. 17). No lithologic or geophysical logs were available for the well, so the thickness of the unconsolidated deposits could not be determined. Test hole 2N/6E-31D1, however, about 0.1 mile south of the Retari hole, encountered extremely hard material at a depth of about 360 feet, and drilling was terminated at 383 feet. The deepest known wells in the southern part of the subbasin are in sec. 4, T. 1 N., R. 6 E.; well 1N/6E-4K1 is 780 feet deep and has a saturated thickness of 320 feet, and well 1N/6E-4Q1 is 726 feet deep and has a saturated thickness of 280 feet. Both wells, now unused, were reported to have yielded only small quantities of water.

To the north near Landers, well depths range from 200-300 feet with saturated thicknesses ranging from about 60-150 feet. Test hole 2N/5E-12N1 encountered what appeared to be consolidated rock at about 460 feet. The saturated thickness in the test hole was about 130 feet. In the central part of the subbasin well depths are 300-400 feet with saturated thicknesses of 50-75 feet. Test hole 2N/6E-31D1, 383 feet deep, had a saturated thickness of about 60 feet. Geologic section A-A' (fig. 8) across Reche subbasin was constructed using available drillers' logs and the composite log of test hole 2N/5E-12N1. For the Reche subbasin, 100 feet of saturated thickness is probably a reasonable average.

Lithologic descriptions of the unconsolidated deposits were obtained from drillers' logs for 16 wells and from two test holes. Calculated specific-yield values for the saturated deposits in the wells and test holes ranged from 6 to 20 percent and averaged about 12 percent.

As data are totally lacking for the northern part of the subbasin, any computation of the quantity of ground water in storage within the entire 51-square mile subbasin at this time (1969) would be subject to large errors. Also, the deterioration in the quality of the shallow ground water near dry lake beds generally renders some of the ground water in the immediate area not potable. A chemical analysis of ground water from a shallow well near Means Lake (4N/4E-24Q1) showed a dissolved-solids concentration of nearly 1,300 mg/l and concentrations of fluoride, chloride, and nitrate which exceeded the limits for drinking water recommended by the U.S. Public Health Service (1962). Because of the lack of data and the probable high concentration of dissolved solids in the northern part of the subbasin, the quantity of ground water in storage is computed for only about the southern three-fourths of the Reche subbasin, or within an area of about 32 square miles. For computing storage for this area of about 20,000 acres, a saturated thickness of 100 feet and an average specific yield of 12 percent were used; from these values the quantity of ground water in storage in the Reche subbasin, as of 1969, was estimated as 240,000 acre-feet.

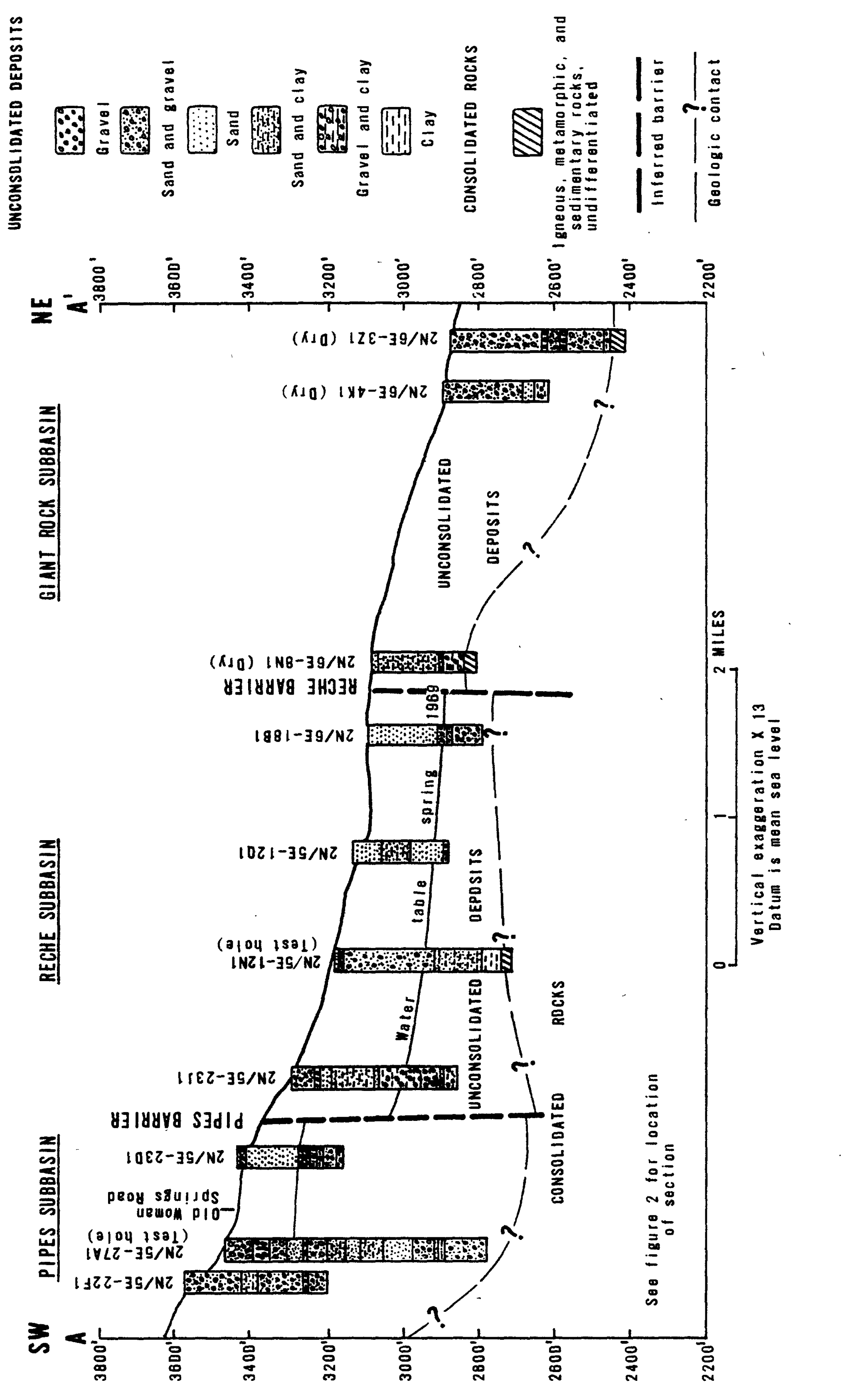


FIGURE 8.--Generalized geologic section A-A'.

Analysis of 32 samples of ground water from 10 wells and two test holes in Reche subbasin showed that the dissolved solids ranged between 220 and 450 mg/l and averaged about 280 mg/l. Except for fluoride, all chemical constituents are below the limits recommended by the U.S. Public Health Service (1962). Figure 7 shows the average chemical composition of ground water in Reche subbasin in comparison with the average composition of ground water in other basins and individual wells in the study area.

Available analyses indicate that, for the most part, the concentration of fluoride in ground water of the subbasin is below the limits recommended for the area by the U.S. Public Health Service (1962). However, a fluoride concentration of 3.0 mg/l was found in a water sample from well 2N/6E-30J1 and 1.9 mg/l in a sample from unused well 1N/6E-4Q1. The fluoride concentration in water from test hole 2N/5E-12N1 was 2.4 mg/l. The highest concentration of fluoride was found in well 1N/5E-12D1 near Pipes barrier along the western boundary of the subbasin. Ground water sampled from that well had a temperature of 42°C (108°F) and a fluoride concentration of more than 10 mg/l. The high fluoride content in water from the wells may be due to subsurface inflow through fractures in the consolidated rock. Future wells drilled in the subbasin could encounter high-fluoride water. The abnormally high temperature of the water from well 1N/5E-12D1 probably is indicative of deep circulation in a nearby fault.

Copper Mountain Valley Basin

Copper Mountain Valley basin is the largest of the ground-water basins described in the report area. For this report, the basin is divided into Giant Rock, Coyote Lake, and Joshua Tree subbasins (fig. 4).

Giant Rock subbasin.--Giant Rock subbasin is the largest of the subbasins in the report area, and yet is one from which the least data are available. To the north the subbasin is terminated by Deadeye Mountain. The eastern boundary is the Emerson fault and several small in-line faults that may be part of the Emerson fault system. A difference in the water-level elevations is a result of the barrier action of the faults. Water levels east of the fault system are 25-50 feet lower than those to the west. From the topography it seems likely that the subbasin may extend as far west as the Reche barrier and the series of in-line faults and bedrock hills, and as far south as the Pinto Mountain fault. Because of the lack of data, however, arbitrary western and southern boundaries similar to those used by F. S. Riley and G. F. Worts, Jr. (written commun., 1953) are used for computing ground-water storage capacity and encompass only about 22 square miles of the nearly 90 square miles of the whole subbasin.

Recharge to Giant Rock subbasin is from ground water crossing Reche barrier from Reche subbasin near Landers. Most of the ground water moves east toward the series of faults that form the eastern boundary of the subbasin and southeast toward Coyote Lake subbasin (fig. 4).

Available water-level measurements from wells in the subbasin indicate no apparent change in the water-table elevation during the period 1958 through 1969. Little or no ground water was extracted from the subbasin during the period 1958 through 1969.

Average specific-yield values for the Giant Rock subbasin are not available because of inadequate data on the unconsolidated deposits. However, F. S. Riley and G. F. Worts, Jr. (written commun., 1953) estimated the quantity of ground water in storage in 1953 for the 22-square-mile area called the Giant Rock subbasin in this report as 180,000 acre-feet. They used an average specific-yield value of 13 percent obtained from test-drilling results in Deadman Valley basin, and a saturated thickness of 100 feet.

Few chemical analyses are available for ground water sampled from wells in the Giant Rock subbasin. Because ground water apparently moves across the Reche barrier from the Reche subbasin into the Giant Rock subbasin, the water quality in the two subbasins probably is similar.

In the northern part of the subbasin, just west of the Emerson fault, the analyses of water sampled from well 3N/6E-4L1 were similar to those sampled from the Reche subbasin, although somewhat higher in calcium and bicarbonate ions. Analysis of water from well 3N/6E-4P1, a short distance south of well 4L1, showed a much higher concentration of calcium and bicarbonate, and an increase in the fluoride concentration from 0.7 to 5.0 mg/l. These quality differences, in conjunction with a water-level difference of about 7 feet between wells 4P1 and 4L1, and a much higher reported yield from well 4L1, suggest that these wells tap different aquifers.

Coyote Lake subbasin.--Coyote Lake subbasin, in the eastern part of the study area (fig. 4), is the smallest of the subbasins described in this report. The southern boundary of Coyote Lake subbasin is formed by the Pinto Mountain fault. The fault is an effective barrier to ground-water movement, as water levels on the north side of the fault are from 100 to 170 feet lower than on the south side. The eastern and northeastern boundary of the subbasin is formed by Copper Mountain. Part of the western boundary is formed by several isolated bedrock hills, and the northern boundary is arbitrarily defined.

A water-level contour map for spring 1969 (fig. 5) shows that the ground-water surface in Coyote Lake subbasin is nearly flat at an elevation of about 2,175 feet. Recharge to the subbasin is primarily from ground water leaking north across the Pinto Mountain fault from the Joshua Tree subbasin. Some recharge probably enters Coyote Lake subbasin from the north and west from the Giant Rock subbasin. The total annual recharge to the subbasin cannot be determined but probably is small. Some ground-water outflow might occur eastward through the very narrow gap between the Pinto Mountain fault and

Copper Mountain, but this could not be determined from the available data. On the other hand, no other natural outlet for ground-water discharge could be found; and because the water levels are fairly deep, discharge by evaporation from the dry Coyote Lake was unlikely even under undeveloped conditions.

Some recharge to the subbasin probably occurs from storm runoff in the Little San Bernardino Mountains when the runoff is of sufficient duration to maintain flow in the washes that cross Pinto Mountain fault. Although this is probably not a common occurrence, it did occur in 1962 when runoff was of sufficient duration and intensity to fill Coyote Lake to an estimated depth of 1 foot; water in the lake then reportedly flowed into several nearby crevasses in the unconsolidated deposits, and the water level in well 1N/7E-10P1 rose several feet (oral commun., F. W. Pickett, 1969). Several of these crevasses were visited by the author in 1969. The crevasses are fairly extensive and do not seem to be associated with faulting. They are most likely desiccation cracks similar to those described on Emerson and Soggy dry lakes by Neal and others (1968, p. 73) and may provide channels for small quantities of recharge to the ground-water reservoir.

Ground-water withdrawal from Coyote Lake subbasin is chiefly by domestic wells. Two public supply wells have been drilled in the area but neither is heavily pumped. Only 37 acre-feet of ground water were pumped from 1965 to 1969, or an average of about 7 acre-feet per year. Nineteen domestic wells were inventoried in the subbasin, but only seven are currently being pumped. As of 1970, the gross pumpage from Coyote Lake subbasin probably does not exceed 25 acre-feet per year.

The development of a 14-acre lake and park in the southeastern part of sec. 14, T. 1 N., R. 7 E., was started in 1969. Two wells, 1N/7E-23A1 and A2, were drilled in 1969 to supply water to the proposed 14-acre lake. When excavation of the lakebed is completed to an estimated average depth of 5 feet, a well pumping 300 gallons per minute will fill the lake in 53 days, excluding evaporation and seepage losses. Seepage losses can be held to a minimum with proper lining of the lake bottom. Evaporation losses would be about 75-100 acre-feet per year for a lake of this size in this area.

Including the additional demands placed on the subbasin by the new park, ground water extracted from the Coyote Lake subbasin in the ensuing years probably will be about 200 acre-feet annually.

There is no report of any well penetrating the entire sequence of unconsolidated deposits in the subbasin. At the west end of the subbasin, test hole 1N/7E-17Q1 was drilled to a depth of 347 feet and may have encountered bedrock at about that depth. The deepest well in the area is test hole 1N/7E-22D1 which is 750 feet deep and penetrated about 310 feet of saturated sediments above some very tight silty sand and clay. Other wells in the area were drilled to depths of between 230 and 508 feet and have saturated thicknesses between 65 and 181 feet. From available data, an average saturated thickness of 100 feet for the subbasin seems reasonable and is probably conservative.

Specific-yield values estimated from 10 drillers' logs and two test holes ranged from 8 to 23 percent and averaged about 14 percent.

The surface area of the unconsolidated deposits in Coyote Lake subbasin is about 14 square miles, or about 9,000 acres. Using an estimated saturated thickness of 100 feet and an average specific yield of 14 percent, the volume of ground water in storage in 1969 is about 126,000 acre-feet.

Chemical analyses of nine ground-water samples taken from well 1N/7E-10N1 between 1954 and 1967 (fig. 7) were below the limits recommended for drinking water by the U.S. Public Health Service (1962).

The concentration of dissolved solids ranged from 145 to 260 mg/l and averaged about 180 mg/l for all analyses from the subbasin. In 14 analyses of ground-water samples from three wells and one test hole, concentrations of fluoride were between 0.2 and 0.8 mg/l and averaged about 0.6 mg/l.

Joshua Tree subbasin.--The southern boundary of Joshua Tree subbasin (fig. 4) is formed by the Little San Bernardino Mountains. The northern boundary of the subbasin is formed by the hydrologic barrier effect of the Pinto Mountain fault. Water levels in Joshua Tree subbasin are about 100-170 feet higher than those in Coyote Lake subbasin to the north. Some ground water probably moves northward across the fault. The western boundary is formed by the Yucca barrier (fig. 4), a discontinuity in the ground-water surface between Joshua Tree subbasin and Warren Valley basin. Water levels on the west side of the barrier are about 400 feet higher than water levels on the east side. No evidence of faulting exists in this area, and the barrier probably is caused by a bedrock high that extends above the water table. Some ground water probably enters Joshua Tree subbasin near the Yucca barrier. At the east end of Joshua Tree subbasin, some ground water probably moves eastward out of the subbasin toward Twentynine Palms. The surface area of the water-bearing unconsolidated deposits is about 10 square miles, or about 6,400 acres.

Recharge to Joshua Tree subbasin from precipitation on the unconsolidated deposits is minor. Replenishment to the ground-water reservoir is from precipitation on more than 110 square miles of higher elevation terrain in the Little San Bernardino Mountains to the south. Precipitation infiltrating below the surface migrates downward through unconsolidated deposits in stream channels and along fractures in the bedrock.

Water levels in wells in the Joshua Tree subbasin have remained fairly constant since 1941 and have shown only minor fluctuations corresponding to variations in rainfall and pumping (fig. 9). Since 1958, water levels in wells have declined about 1-3 feet, an average of less than half a foot per year over the entire basin for 1958 through 1969.

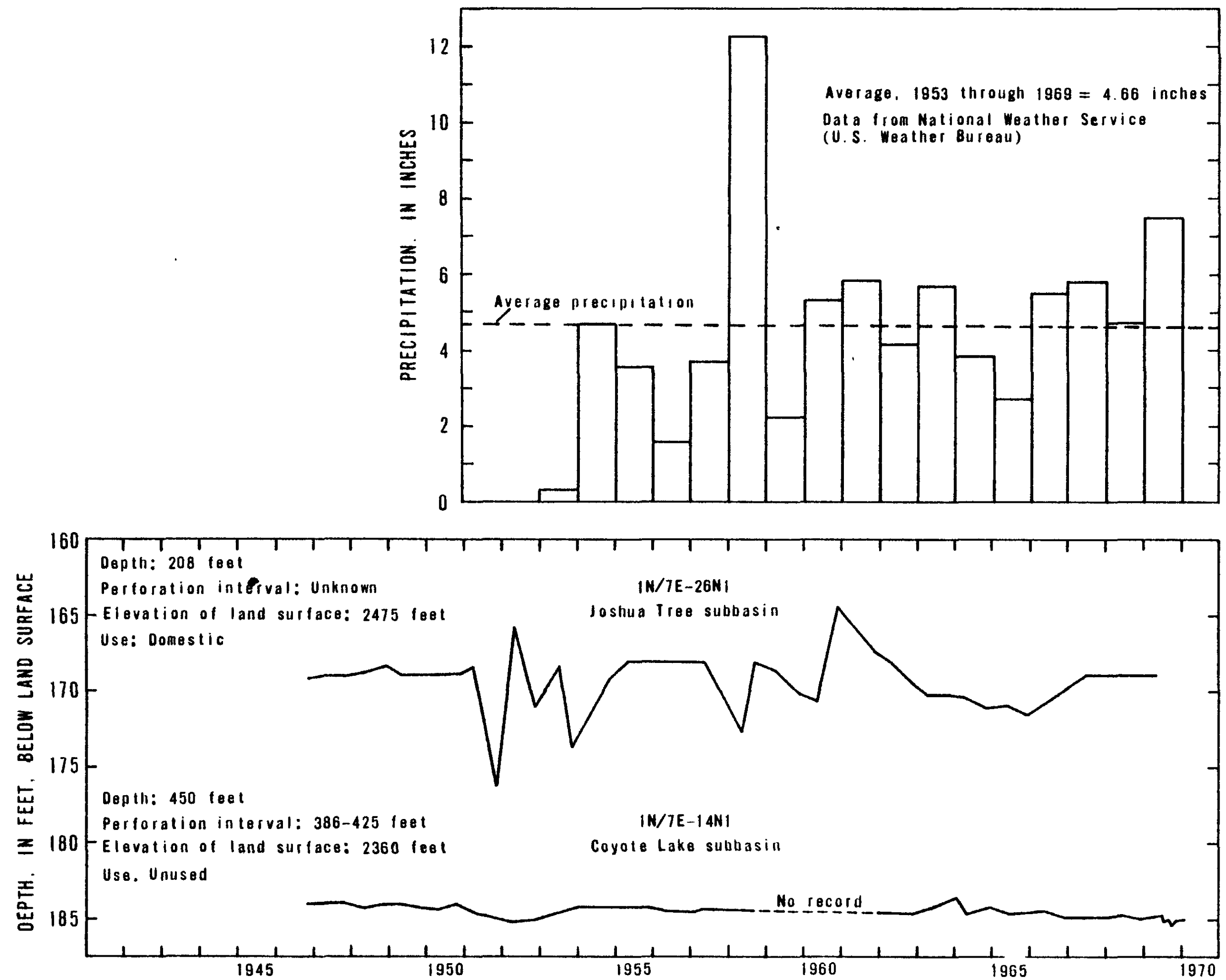


FIGURE 9.--Hydrographs of wells in Joshua Tree and Coyote Lake subbasins and annual precipitation at Joshua Tree.

All ground-water withdrawals from Joshua Tree subbasin are for domestic use. Most of the ground water is extracted by wells owned by the Joshua Basin County Water District and the Panorama Heights Water Co., Inc. Table 4 shows ground-water withdrawals from Joshua Tree subbasin for 1964 through 1969. The average annual ground-water withdrawal for the 6-year period is about 360 acre-feet.

TABLE 4.--*Ground-water withdrawals from Joshua Tree subbasin*

[From data supplied by Joshua Basin County Water District and Panorama Heights Water Co., Inc.]

Year	Ground-water withdrawals (acre-feet)
1969	415.2
1968	358.2
1967	382.4
1966 (estimated in part)	345.8
1965	309.1
1964	371.8
Total (rounded)	2,180
Average (rounded)	360

The maximum depth of the unconsolidated deposits in the Joshua Tree subbasin cannot be determined from available data. Well 1N/6E-25M3 was drilled in alluvium to a depth of 704 feet, and test hole 1N/7E-34B1 was drilled to a depth of 785 feet. Neither hole encountered bedrock. Other wells drilled within the subbasin range in depth from about 250 to 600 feet. Well 1N/8E-30J1, about a mile east of the eastern boundary of the Mojave Water Agency, was drilled to a depth of 785 feet without penetrating bedrock; the well was grouted back to 390 feet because of reported poor quality water at depth.

Figure 10 is a geologic section through Joshua Tree subbasin constructed from available drillers' logs and data from test hole 1N/7E-34B1. In well 1N/8E-30J1 the saturated thickness of sediments above the extensive clay interval is about 150 feet. Well 1N/6E-25M3, about 10 miles west at the other end of the subbasin, has about 280 feet of saturated gravels. Between these two wells, test hole 1N/7E-34B1 has about 320 feet of saturated deposits above the hard, predominantly fine-grained material. For computation of the quantity of ground water in storage, an average value of 150 feet of saturated thickness is used although this is probably conservative.

Specific-yield values were obtained using the method outlined previously from drillers' logs for 17 wells and one test hole in the subbasin. Values ranged from 12 to 21 percent and averaged about 15 percent for Joshua Tree subbasin. Using the determined variables the total volume of ground water in storage was estimated as 144,000 acre-feet as of 1969.

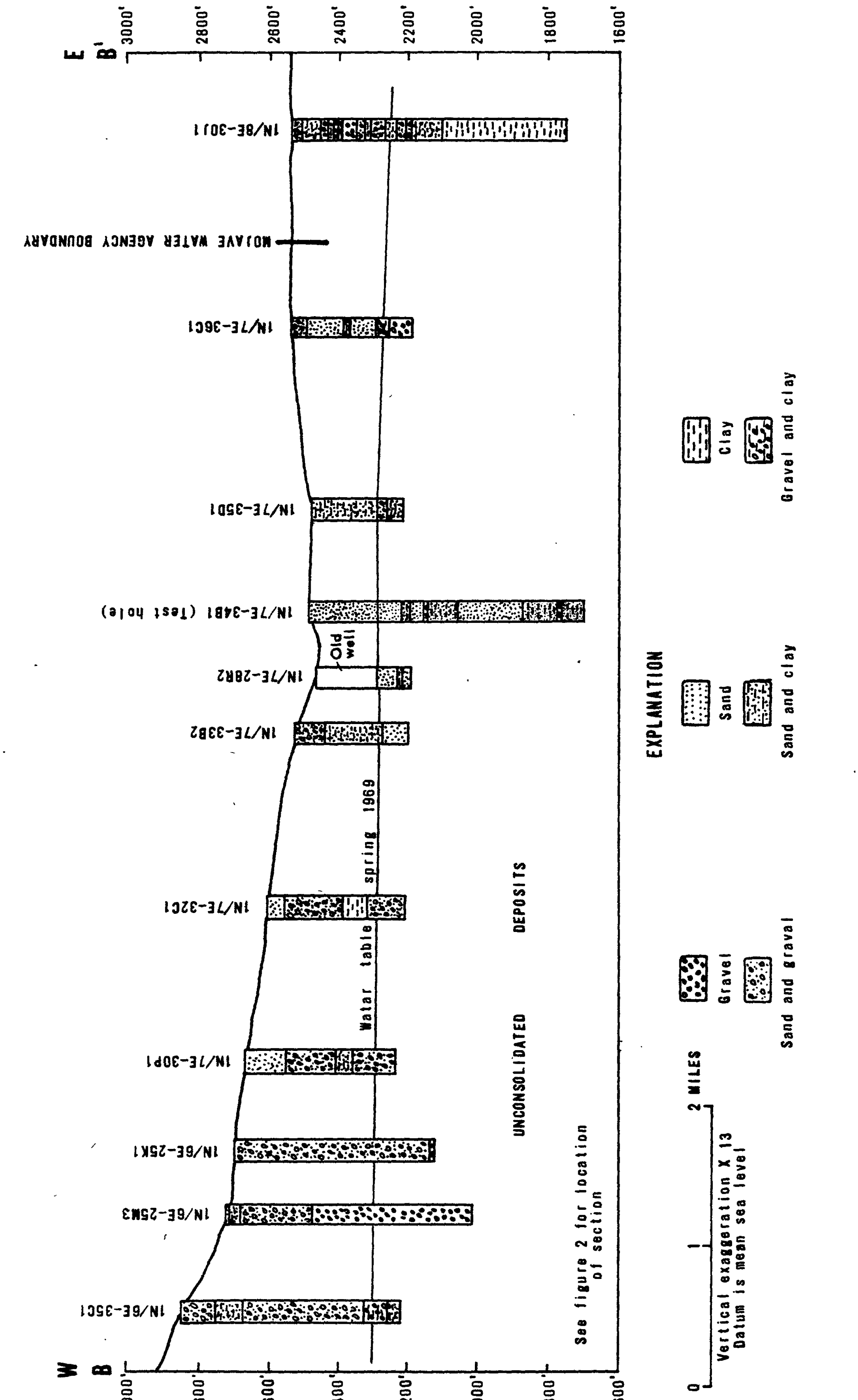


FIGURE 10.--Generalized geologic section B-B'.

Chemical analyses for 29 samples from seven wells and one test hole in Joshua Tree subbasin indicated that the quality of ground water is good, and none contained concentrations of ions exceeding the limits recommended by the U.S. Public Health Service (1962). Concentrations of dissolved solids ranged from 124 to 268 mg/l and averaged about 180 mg/l for the subbasin. Fluoride concentrations ranged from 0.3 to 1.4 mg/l. The average fluoride concentration was about 0.6 mg/l.

Deadman Valley Basin

Deadman Valley basin is an elongate, northwest-trending basin bisected by the Hidalgo (Surprise Spring) fault and lying almost entirely outside the Mojave Water Agency boundary. A part of the western half of the basin is partly within the agency boundary, and in this report is called the Surprise Spring subbasin. No test holes were drilled in this basin.

Surprise Spring subbasin.—The subbasin is bounded along its eastern side by the Hidalgo fault (also known as the Surprise Spring fault). To the north the subbasin is terminated by Emerson Lake and Hidalgo Mountain. The western boundary is along the Emerson fault system and the southern boundary of the subbasin is Copper Mountain.

Recharge to the Surprise Spring subbasin is, apparently, from underflow from the Giant Rock subbasin along most of the length of the Emerson fault system. Water levels on the eastern side of the fault are about 50 feet lower than those on the western side. In the Surprise Spring subbasin some ground water moves north toward Emerson Lake, some moves southeast toward Copper Mountain, and some moves east across the Hidalgo (Surprise Spring) fault into the eastern part of Deadman Valley basin. The high water table was evidenced in 1953 in the wash near Surprise Spring by the growth of phreatophytes. The spring discharge and the plant growth indicated that some water was spilling over the top of the fault barrier and that water was discharging into the eastern half of Deadman Valley basin (written commun., F. S. Riley and G. F. Worts, Jr., 1953). Ground water probably flows out from the Surprise Spring subbasin along most of the length of the Hidalgo (Surprise Spring) fault.

Water-level measurements made in the spring of 1958 and the spring of 1969 indicate no appreciable decline of the water table except near Surprise Spring. A water-level change map for 1958-69 (fig. 6) shows 10-40 feet of decline near Surprise Spring caused by pumping from several supply wells operated by the nearby U.S. Marine Corps Base. Pumping started about 1953, and during 1954-65 inclusive about 1,530 acre-feet was withdrawn annually by U.S. Marine Corps supply wells (Giessner and Robson, 1966, p. 18) in Surprise Spring subbasin. In 1966 and 1967, 2,070 and 2,220 acre-feet was withdrawn (written commun., J. A. Westphal, 1967).

Prior to 1950 pumpage from the northern part of the subbasin was small. In 1950 there was some irrigation in sec. 27, T. 4 N., R. 6 E., and pumpage from that area for 1950-52 may have been about 3,000 acre-feet (written commun., F. S. Riley and G. F. Worts, Jr., 1953). After 1953, land in that area was acquired by the Marine Corps Base Training Center near Twentynine Palms, and no appreciable quantities of ground water have been withdrawn since. During 1958-69 water levels in that area showed no appreciable change.

Average specific-yield values for Surprise Spring subbasin are not available because of inadequate data for the unconsolidated deposits, and no test holes were drilled in the subbasin. Lithologic logs are available for only two supply wells 800 feet deep and four test wells (drilled in 1952) 400 to 500 feet deep, all in the eastern part of the subbasin. Ground water in storage was computed for the subbasin using a specific-yield value of 13 percent (written commun., F. S. Riley and G. F. Worts, Jr., 1953) and a saturated thickness of 100 feet. Using the boundaries for the subbasin established by Riley and Worts, and estimates of pumping by Westphal (written commun., 1967) about 322,000 acre-feet of ground water remained in storage in 1967.

Wells in the eastern part of the subbasin near Surprise Spring tap ground water similar to that at well 3N/7E-31E1. Fluoride concentrations in all samples were less than 1.0 mg/l.

In the northwestern part of the subbasin, quality of the ground water is the poorest in the area. Water from well 3N/7E-18D1 showed a greater concentration of all ions except bicarbonate and carbonate, and a dissolved-solids content of 444 mg/l (fig. 7). The fluoride concentration was 0.3 mg/l. Farther north, in sec. 27, T. 4 N., R. 6 E., the quality of the ground water is even poorer, as shown by analyses of samples from wells in the area. Near Emerson dry lake, dissolved-solids and fluoride concentrations are about 2,000 and 5.0 mg/l.

Warren Valley Basin

Warren Valley basin is in the southwestern part of the study area (fig. 4). A natural topographic and ground-water divide exists at the west end and forms the basin boundary. The southern limit of the basin is the Little San Bernardino Mountains. To the east, ground-water flow is restricted by the Yucca barrier; on the western or Warren Valley basin side of the barrier, water levels are about 400 feet higher than those on the eastern or Joshua Tree subbasin side. The northern boundary of the basin is formed by the San Bernardino Mountains and by the Pinto Mountain fault.

Recharge to Warren Valley basin is small and may not exceed 200 acre-feet per year (Koebig and Koebig, 1966). Precipitation directly on the unconsolidated deposits contributes negligible quantities of recharge, and no perennial streams empty into the valley. Some flows of short duration occur during runoff from brief storms in the surrounding hills. The small quantity of recharge to the basin is from precipitation in the higher mountains and underflow in unconsolidated deposits along stream channels and through locally fractured and weathered bedrock.

The largest drainage area is in the Little San Bernardino Mountains to the south and consists of about 18 square miles with a maximum elevation of about 5,200 feet above mean sea level. No precipitation records are available, but an isohyetal map of the general area by Walter Hofmann (written commun., 1953) indicated annual precipitation of about 8 inches. Small quantities of recharge probably are contributed from precipitation in the San Bernardino Mountains and Water Canyon area north and northwest of the basin. Here the contributory drainage area is about 11 square miles, the maximum elevation is about 5,000 feet, and the average annual precipitation is about 7-8 inches.

Prior to 1958, ground-water conditions in Warren Valley basin were probably static, and ground-water movement was, at least in the western two-thirds of the basin, as shown in figure 11. Recharge entering the basin from the Little San Bernardino Mountains flowed north and then northeast. Recharge from the San Bernardino Mountains and Water Canyon moved south into the basin and then east. Some ground water probably moved eastward along the Pinto Mountain fault across the Yucca barrier into Joshua Tree subbasin.

Figure 12 is a water-level contour map constructed from water-level measurements made in spring 1969. The change in the general pattern of ground-water movement caused by the creation of pumping depressions in the basin is made evident by comparing figures 11 and 12. Because of the numerous pumping holes in the area (fig. 12) and resulting complexity of the water table in 1969, the water-level measurements for 1958 were used in computing average saturated thickness of unconsolidated deposits, and ground-water storage estimates. The storage figure was then updated to reflect the volume of ground water that was subsequently pumped.

Ground water pumped from wells in Warren Valley basin is chiefly for domestic use. Some ground water is pumped for irrigation of a golf course at the west end of the basin, but there is no agriculture in the area. With the increasing availability of water supplied by the two local water companies in recent years, most of the small individual domestic wells have been phased out of use by their owners. A few low-capacity wells are still pumped by small-horsepower submersible pumps or windmills at residences in the lower foothills of the Little San Bernardino Mountains southwest of Yucca Valley. These wells penetrate a few tens of feet of unconsolidated deposits and extract ground water from locally fractured bedrock.

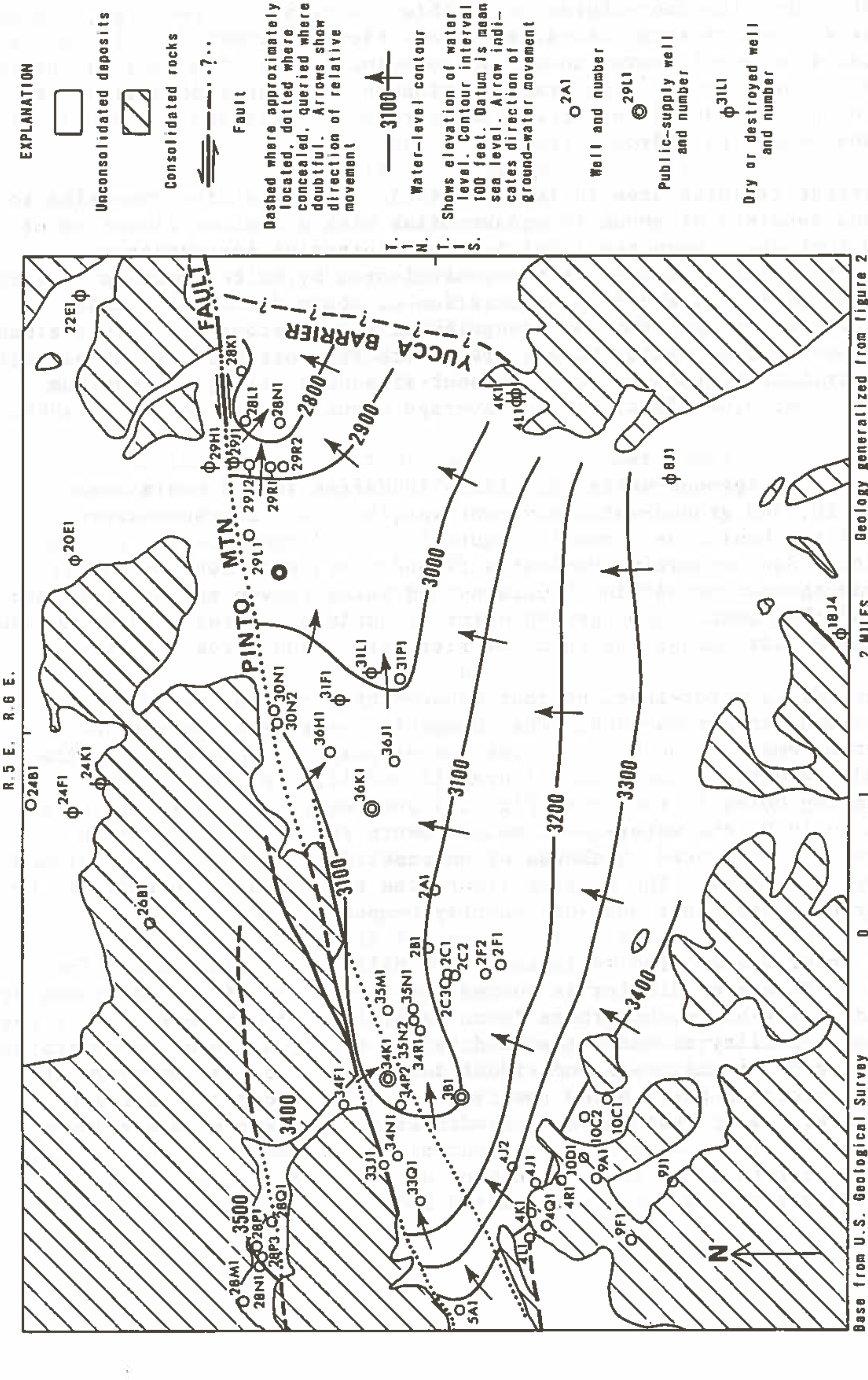


FIGURE 11.--Water-level elevations in Warren Valley basin, spring 1958.

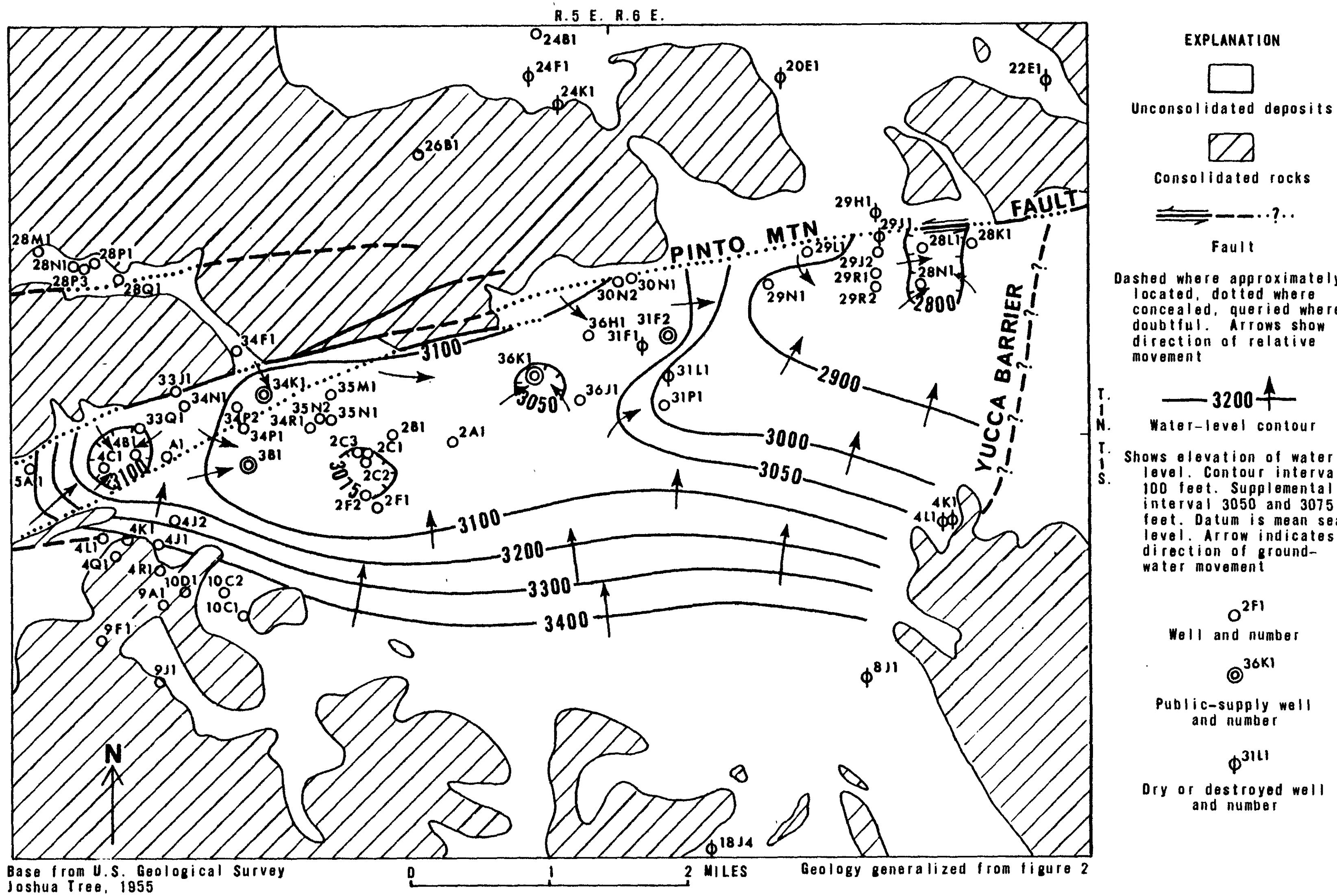


FIGURE 12.--Water-level elevations in Warren Valley basin, spring 1969.

Nearly all the ground water extracted from Warren Valley basin is pumped by the two water-service companies in the area and from golf course wells at the west end of the basin. Ground water pumped by the local water companies is metered and is included in pumpage totals for the basin shown in table 5. The water pumped by the local golf course is not metered but was estimated by using an applied water figure of 5 acre-feet per acre per year, interpolated from data of the Coachella Valley County Water District as an average applied water figure for local golf courses. Ground water pumped for irrigation of the golf course has probably been fairly constant since its construction in 1956 and, unless expansion of the golf course is undertaken, should remain constant in the ensuing years.

Ground water extracted by the water-service companies since 1949 has shown a marked increase during the 21-year period through 1969. Although the population in the Yucca Valley area has increased since 1945, some of the increase in pumpage after 1960 probably can be attributed to the normal expansion of the water-service companies, who extended their system of water mains and made water available to more residents. From 1949 through 1969, gross ground-water extraction from Warren Valley basin for all uses has ranged from 30 to 1,500 acre-feet per year and averaged about 680 acre-feet per year.

A geologic section C-C' (fig. 13) along the central part of the basin was constructed using lithologic descriptions from drillers' logs of eight wells and one test hole in Warren Valley basin. Specific-yield values ranged from 7 to 15 percent and averaged about 11 percent for the entire basin. Test hole 1N/5E-36N1 was drilled to a depth of 750 feet in the central part of the basin without encountering bedrock, and had a saturated thickness of 330 feet. Other wells in the basin range in depth from about 200 to 540 feet and, although not penetrating the entire sequence of unconsolidated deposits, have a saturated thickness between 60 and 300 feet. The average basin saturated thickness of the unconsolidated deposits was probably at least 150 feet in 1958. This figure is probably conservative, but because of the lack of data from depths several hundred feet below the water table, it seems inadvisable at this time (1970) to assume a greater or more optimistic depth figure for the saturated deposits in 1958.

The surface area of the saturated unconsolidated deposits in Warren Valley basin is about 10 square miles or about 6,400 acres. Using an average saturated thickness of about 150 feet in 1958 and an average specific yield of about 11 percent, the volume of ground water in storage in 1958 was computed to be 106,000 acre-feet. This 1958 estimate was used because the presence of numerous pumping holes in the basin in 1969 made it difficult to estimate the average basin-wide saturated thickness of the water-bearing deposits. Large errors might be introduced in the storage computations because of interpretations regarding the shape and depth of the pumping holes around pumped wells. Subtracting the consumptive-use figure in the basin since 1958, at least 96,000 acre-feet of ground water remained in storage in Warren Valley basin at the beginning of 1970.

TABLE 5.--*Ground-water withdrawals from Warren Valley basin*

[Acre-feet]

Year	Ground-water withdrawals				
	Gross pumpage			Consumptive use[1]	
	Public supply[2]	Golf course irrigation[3]	Total	Total	Cumulative total
1949	30		30	20	20
1950	30		30	20	40
1951	40		40	30	70
1952	60		60	40	110
1953	70		70	50	160
1954	100		100	70	230
1955	100		100	70	300
1956	120	530	650	440	740
1957	120	530	650	440	1,180
1958	120	530	650	440	1,620
1959	140	530	670	460	2,080
1960	160	530	690	470	2,550
1961	230	530	760	520	3,070
1962	320	530	850	580	3,650
1963	[4]420	530	950	650	4,300
1964	560	530	1,090	710	5,010
1965	[4]650	530	1,180	800	5,810
1966	810	530	1,340	910	6,720
1967	820	530	1,350	920	7,640
1968	980	530	1,510	1,030	8,670
1969	[4]1,000	530	1,530	1,040	9,710
Total:	6,880	7,420	14,300	9,710	
Average:			680	460	

[1]Based on consumptive-use value of 68 percent for all uses (Koebig and Koebig, 1966).

[2]From data supplied by the Yucca Valley County Water District and Yucca Water Co., Inc.

[3]Based on estimate of 5 acre-feet per acre for 105-acre golf course.

[4]Estimated in part.

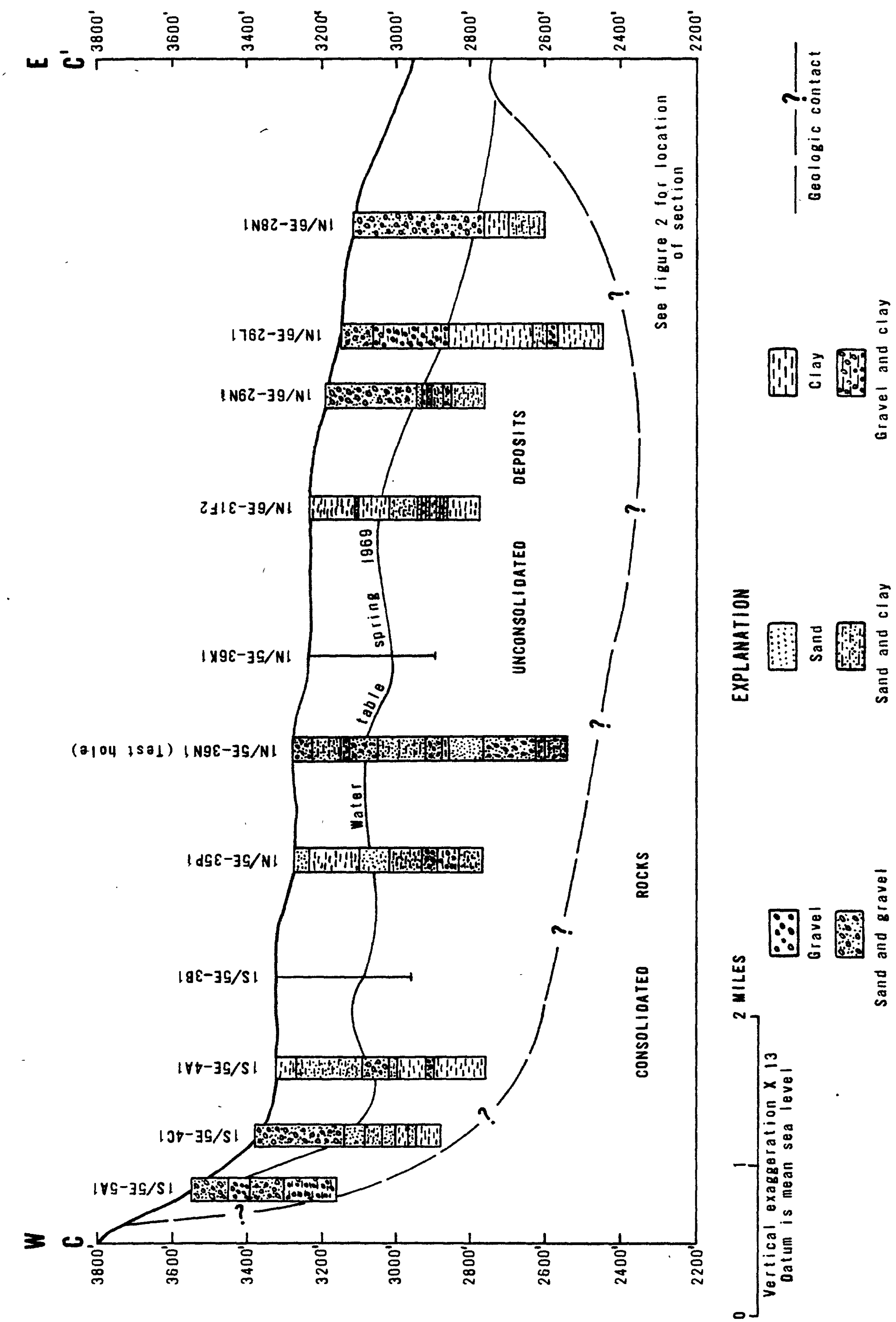


FIGURE 13.--Generalized geologic section C-C'.

From the water-level decline map (fig. 6) the volume of deposits dewatered from 1958 through 1969 was computed to be 103,000 acre-feet. Applying the average specific-yield factor of 11 percent to the volume of dewatered sediments indicates that about 11,000 acre-feet of net depletion of ground water had occurred during that period. Metered pumpage from two water companies in the area and estimated pumpage from the golf course wells and a few domestic wells indicate that about 12,500 acre-feet of ground water was pumped during that period and about 8,500 acre-feet consumptively used. Because the ground water in the basin is considered unconfined, and assuming inflow and outflow to be insignificant, or at least equal, this apparent imbalance of about 2,500 acre-feet might imply (1) that the specific-yield value used as an average for the entire basin is too high, or (2) that the contours of water-level decline constructed from available data are insufficiently accurate to warrant computation of dewatered sediment volume, or (3) that consumptive-use figures used might not be applicable for this particular basin because of the large volume of unsaturated deposits overlying the ground-water reservoir. In any case additional data are needed to more accurately determine the storage capacity of the basin.

Ground water in Warren Valley basin is low in dissolved solids. In 27 samples from nine wells in the basin, concentrations of dissolved solids ranged from about 120 to 250 mg/l and averaged about 160 mg/l. Concentrations of fluoride ranged from 0.2 to 1.0 mg/l and averaged about 0.4 mg/l. No concentrations of ions in excess of the limits recommended by the U.S. Public Health Service (1962) were reported in the analyses.

Morongo Valley Basin

Morongo Valley is a northeast-trending valley west of Warren Valley basin and is almost entirely outside the study area. A natural drainage divide exists between the two valleys. The Morongo Valley ground-water basin is bounded on the northwest by the San Bernardino Mountains and on the southeast by the Little San Bernardino Mountains.

Recharge to the basin is from precipitation runoff and underflow emanating from the higher San Bernardino Mountains to the northwest. Some recharge probably enters the basin from the Little San Bernardino Mountains to the south. Water-level contours based on measurements in spring 1969 (fig. 5) indicate that in the eastern part of the valley ground water moves toward the southwest.

Many small domestic wells extract ground water from the basin, but most of the pumping is by the water service company in that area. Measurements of water level in wells in spring 1958 and spring 1969 indicate a decline in four wells of 8 to 18 feet.

Descriptions from drillers' logs of the unconsolidated deposits were published by Bader and Moyle (1958). The deepest well for which records are available is 280 feet, and no contact with bedrock was reported. No attempt was made to assign specific-yield values to the sediments described in the drillers' logs, and the quantity of ground water in storage was not computed for this investigation. Previous investigators estimated the quantity of ground water in storage in the Morongo Valley basin as 120,000 acre-feet (U.S. Bureau of Reclamation, 1967).

Analyses of 14 water samples from nine wells in the Morongo Valley basin were published by Bader and Moyle (1958). Concentrations of dissolved solids in ground-water samples ranged from 212 to 670 mg/l and averaged about 507 mg/l in 13 samples. Fluoride concentrations ranged from 0.6 to 3.18 mg/l and averaged about 1.3 mg/l. Analyses of ground water from wells in sec. 29, T. 1 S., R. 4 E., and one well in sec. 7, T. 1 S., R. 5 E., showed concentrations of sulfate in excess of the 250 mg/l limit for drinking water recommended by the U.S. Public Health Service (1962).

Johnson Valley Basin

Johnson Valley basin is in the northwest part of the study area. Only the southeast part of the basin is within the area included in this report. The basin is bounded on the south and southeast by the San Bernardino Mountains and along the east and northeast by a concealed fault and outcrops of bedrock (fig. 2). Within the study area the basin is divided into two parts by the Johnson Valley fault. No data are available from the northeastern or upper part of the basin, and in this section of the report all references to the Johnson Valley basin pertain to that part which is southwest of the Johnson Valley fault.

The ground-water surface in the Johnson Valley basin is relatively flat (fig. 5). Southeast of the unnamed northwest-trending fault near the Shehorn Ranch (fig. 2), water-level elevations in wells in the spring of 1969 ranged between 2,776 and 2,785 feet, and there is a slight northeast gradient. Water levels northeast of the fault are about 30 feet lower. Some ground water probably moves northeast across the Johnson Valley fault toward Melville Lake. The water-level elevation in wells 3N/4E-11R1 and 15J1 in the southeast corner of the basin near the bedrock boundary is about 3,100 feet; this is about 350 feet higher than other water-surface elevations in the basin 1 or 2 miles to the west and northwest. The difference in the water-surface elevation may be representative of a steep water-table gradient in this area, or may indicate a locally confined aquifer with pressure heads analogous to those in fractured bedrock to the south. No evidence is available to substantiate either hypothesis.

Records of 29 wells in the Johnson Valley basin indicate that only about half of the wells are pumped regularly for domestic purposes. The water-level change in wells for 1958-69 in that part of the Johnson Valley basin included in this report has averaged less than 0.5 foot, and ground-water withdrawals probably have averaged less than 10 acre-feet per year.

Only two wells drilled in the area were reported to penetrate all the unconsolidated deposits. Well 3N/4E-15R1, within half a mile north of the exposed bedrock, was reported to have reached bedrock at a depth of 297 feet. Well 4N/4E-19B1 penetrated 120 feet of unconsolidated deposits overlying the bedrock and might indicate relatively thin unconsolidated deposits in that area. Other wells in the basin were drilled to depths between 160 and 540 feet without reaching bedrock. Saturated thicknesses in wells ranged from 33 to 192 feet. Specific-yield values computed from descriptions in five drillers' logs ranged between 8 and 18 percent and averaged 13 percent. From the available data, and because only a part of the Johnson Valley basin is within the study area boundary, no attempt was made to compute the quantity of ground water in storage.

Water quality in the Johnson Valley basin differs from well to well and is generally poorer than in the basins to the south and east. Should a shortage of water eventually become a problem, or if a source of supply becomes necessary for some other subbasin in this vicinity, poorer quality ground water from the basin could be blended with ground water of better quality from one of the adjacent subbasins to yield an acceptable blend for domestic use.

On either side of the unnamed fault near the Shehorn Ranch in Johnson Valley, fluoride concentrations were slightly above the limits recommended for drinking water by the U.S. Public Health Service (1962). The fluoride concentration in 26 analyses from four wells averaged about 0.9 mg/l. In the southern part of the basin, in T. 3 N., R. 4 E., fluoride values ranged from 1.3 to 9.0 mg/l.

Concentrations of dissolved solids in the southeastern part of the basin were between 300 and 500 mg/l; in three analyses of water from well 3N/4E-6P1 concentrations ranged from about 1,200 to 1,300 mg/l. In the central part of the basin, southwest of the unnamed fault, concentrations of dissolved solids in ground-water samples from two wells were about 520 and 860 mg/l. East of the unnamed fault, concentrations of dissolved solids ranged from about 640 to 3,130 mg/l and averaged about 1,560 mg/l in 25 samples from three wells.

Concentrations of sulfate and chloride in excess of the recommended limits were noted in the analyses of water from several wells. Available ground-water analyses indicated sulfate concentrations in excess of the recommended 250 mg/l limit in sec. 6, T. 3 N., R. 4 E., and secs. 22, 23, and 24, T. 4 N., R. 3 E. Analyses of ground water from wells in sec. 19, T. 4 N., R. 4 E., indicated concentrations of both sulfate and chloride in excess of the recommended limits.

TEST-DRILLING PROGRAM

Nine 4-3/4-inch test holes (fig. 2) were drilled by the hydraulic rotary method in May and June of 1971 to obtain information about the water-bearing properties of the deeper aquifers in the various basins and subbasins. Depth of the test holes ranged from 180 to 785 feet, and the aggregate depth of the test holes is 4,635 feet. Spontaneous potential and resistivity (16- and 64-inch normal) geophysical logs were obtained in six of the test holes and on two of these gamma and neutron logs were obtained. Three test holes were not logged geophysically. For each test hole samples of drill cuttings were obtained and examined and drilling-rate logs were kept.

Two-inch steel pipe casing was set in each test hole and perforated at a depth interval which included the effective bottom of the aquifer as determined from the logs or from drill cuttings. To insure hydraulic conductivity of the test hole with the aquifer, each hole was developed by pumping fresh water down inside the casing with a centrifugal pump. Further development was effected when compressed air was forced through a hose suspended inside the pipe to clean out the hole and obtain a water sample for chemical analysis. Data from the nine test holes are summarized in table 6.

TABLE 6.--*Summary of data on rotary test holes*

	Well number	Depth (feet)	Depth cased (feet)	Perforated interval (feet)	Chemical quality (mg/l)		Depth to water from land surface (feet)	Date measured	Aquifer thickness[1] (feet)	Specific yield[2]	Logs[3]
					Dissolved solids	Fluoride					
Means Valley basin Pioneertown subbasin	1N/4E-1B1	180	168	147-168	-	-	76 78	6-14-71 9-23-71	80	0.08	-
	1N/4E-11R1	255	190	169-190	-	-	44 48	6- 1-71 9-23-71	100	.07	-
Pipes subbasin	2N/5E-27A1	705	485	443-485	314	0.4	190	6-14-71	300	.15	E,R
Reche subbasin	2N/5E-12N1	480	358	337-358	450	2.4	272	6-14-71	130	.08	E
	2N/6E-31D1	383	358	337-358	220	.7	298	5-28-71	60	.15	E,R
Copper Mountain Valley basin Coyote Lake subbasin	1N/7E-17Q1	347	316	253-316	-	-	284	6-14-71	20	.10	-
	1N/7E-22D1	750	504	464-506	177	.8	235 240	6-14-71 9-28-71	310	.10	E
Joshua Tree subbasin	1N/7E-34B1	785	590	527-590	268	1.4	201	6-14-71	320	.14	E
Warren Valley basin	1N/5E-36N1	750	590	548-590	[4]227	1.0	190 186	6- 1-71 9-28-71	330	.15	E

[1]Based on maximum depth from which ground water can be readily extracted as interpreted from geophysical and drilling time logs.
[2]From water table to bottom of aquifer.
[3]E = Spontaneous potential, resistivity (16 inchee, 64 inches normal); R = Gamma, neutron.
[4]Test hole vandalized before sample could be obtained; analysis from nearby well 1N/6E-31C1, 730 feet deep.

ADEQUACY OF THE LOCAL SUPPLY

Prior to 1956, withdrawals from the ground-water reservoir did not exceed natural recharge in any of the basins included in this study, and fluctuations in water level generally reflected extended wet or dry periods. Although population has increased steadily in most of the basins since 1956, the decline of water levels since 1956 has been slight, and no alarming overdraft is evident. Pumping depressions have developed in Pipes subbasin, in Reche subbasin, and in Surprise Spring subbasin. However, the available ground water contained in storage in each of these subbasins probably is adequate to supply anticipated future needs of each area, at least during the remainder of this century.

The total ground-water storage of all the basins except Johnson Valley and Morongo Valley was conservatively estimated as more than 1,200,000 acre-feet (table 7). If 50 percent of the available ground water could be feasibly and economically extracted, more than enough ground water is available to meet the estimated consumptive use of 120,000 acre-feet to sustain the area until the year 2000 (table 8). The problem which may arise, however, is that the center of population growth has been, and will probably continue to be, in the southern part of the study area centered around the towns of Joshua Tree and Yucca Valley.

TABLE 7.—*Estimated ground-water storage in 1969*

Ground water storage unit	Surface area		Saturated thickness (feet)	Specific yield (percent)	Storage (acre-feet)
	Square miles	Acres			
Pipes	9	5,800	150	14	120,000
Pioneertown	9	5,800	--	--	--
Reche	32	20,000	100	12	240,000
Surprise Spring[1]	41	26,000	100	13	340,000
Giant Rock[1]	22	14,000	100	13	180,000
Coyote Lake	14	9,000	100	14	126,000
Joshua Tree	10	6,400	150	15	144,000
Warren Valley	10	6,400	150	11	96,000
Johnson Valley	--	--	--	--	--
Morongo Valley[2]	8.5	5,500	200	11	(120,000)
					1,246,000

[1]Data from written commun., F. S. Riley and G. F. Worts, Jr., 1953.
[2]U.S. Bureau of Reclamation, 1967, p. 38. (Not included in total.)

TABLE 8.--*Annual and cumulative consumptive-use requirements in the Yucca Valley-Joshua Tree area*

Year	Population[1]	Per capita[2] (gallons per day)	Gross (acre-feet)	Consumptive-use[3] (acre-feet)	Cumulative consumptive-use (acre-feet)
Estimated use prior to 1958			-	-	1,700
1958	3,327	116	430	290	2,000
1959	3,507	117	560	310	2,300
1960	3,687	118	490	330	2,600
1961	4,312	119	570	390	3,000
1962	4,934	120	660	450	3,500
1963	5,556	121	750	510	4,000
1964	6,178	122	840	570	4,600
1965	6,800	122	930	630	5,200
1966	7,920	123	1,100	740	5,900
1967	9,040	124	1,300	850	6,800
1968	10,160	125	1,400	970	7,700
1969	11,280	126	1,600	1,100	8,800
1970	12,400	127	1,800	1,200	10,000
1971	13,300	128	1,900	1,300	11,000
1972	14,200	129	2,100	1,400	13,000
1973	15,100	130	2,200	1,500	14,000
1974	16,000	131	2,300	1,600	16,000
1975	16,900	132	2,500	1,700	18,000
1976	18,240	133	2,700	1,800	19,000
1977	19,580	134	2,900	2,000	21,000
1978	20,920	135	3,200	2,200	24,000
1979	22,260	136	3,400	2,300	26,000
1980	23,600	136	3,600	2,400	28,000
1981	25,300	137	3,900	2,600	31,000
1982	27,000	138	4,200	2,800	34,000
1983	28,700	139	4,500	3,000	37,000
1984	30,400	140	4,800	3,240	40,000
1985	32,100	141	5,100	3,400	43,000
1986	33,620	142	5,300	3,600	47,000
1987	35,140	143	5,600	3,800	51,000
1988	36,660	144	5,900	4,000	55,000
1989	38,180	145	6,200	4,200	59,000
1990	39,700	146	6,500	4,400	63,000
1991	41,620	147	6,900	4,700	68,000
1992	43,540	148	7,200	4,900	73,000
1993	45,460	149	7,600	5,200	78,000
1994	45,380	150	8,000	5,400	83,000
1995	49,300	150	8,300	5,600	89,000
1996	51,840	151	8,800	6,000	95,000
1997	54,380	152	9,300	6,300	101,000
1998	56,920	153	9,800	6,600	108,000
1999	59,460	154	10,000	7,000	115,000
2000	62,000	155	11,000	7,300	122,000

[1]Population 1970-2000 based on estimates by Koebig and Koebig (1966) updated for most recent census.

[2]Koebig and Koebig (1966).

[3]Net pumpage is about 68 percent of the gross pumpage (Koebig and Koebig, 1966).

In the Joshua Tree subbasin, population has increased from a few hundred in 1950 to about 4,000 in 1969. No obvious pumping depressions have developed although the water surface has declined an average of 1-3 feet since 1958, and some overdraft now exists which will increase with continued urban growth. Present ground-water withdrawals of about 400 acre-feet per year will increase to about 3,200 acre-feet per year by the year 2000 and by that time will have consumed about 36,000 acre-feet from the ground-water storage. Estimates of ground-water storage of Joshua Tree and Coyote Lake subbasins, however, indicate that sufficient ground water is available to sustain predicted urbanization in those subbasins beyond the year 2000.

In the Warren Valley basin, the population has increased from about 350 in 1950 to about 8,900 in 1969 (oral commun., Larry Fine, 1970), and ground water has been depleted from storage in Warren Valley basin at the rate necessary to sustain this growth. Declines of 4 to 40 feet have occurred near several of the more heavily pumped wells in the basin, and declines will continue as water service is expanded to accommodate the increasing population.

From available data, it seems that public-supply wells in Warren Valley basin are adequate to extract sufficient ground water from storage to meet demands in the near future. Assuming future water-level declines at the present rate, probably no immediate danger to the present supply wells exists. It is recommended that static and pumping water-level measurements be obtained in the spring and autumn at each of the public-supply wells. When it appears from the measurements that a particular well will be unable to meet immediate future demands because of anticipated pumping drawdown, consideration should be given by the well owner to reducing the pumping capacity in the well and to constructing a replacement well.

Currently about 70 percent of the expansion occurs in the vicinity of the town of Yucca Valley, and some concern exists as to the adequacy of the local water supply to accommodate long-term future growth in that area. Figure 14 shows the projected population figures from several sources for the Yucca Valley-Joshua Tree area updated and extended to reflect current population figures. Figure 15 indicates the anticipated water consumption for that area. Assuming a continuing growth factor of 70 percent of the population occurring in the Yucca Valley area, additional withdrawals from Warren Valley basin of about 80,000 acre-feet of ground water will be necessary to sustain the projected growth to the year 2000. This figure is less than the estimated ground-water storage of the Warren Valley basin. However, in order to extract the maximum quantity of ground water from any basin, many properly spaced wells must be drilled for optimum pumping efficiency; this is generally not economically feasible.

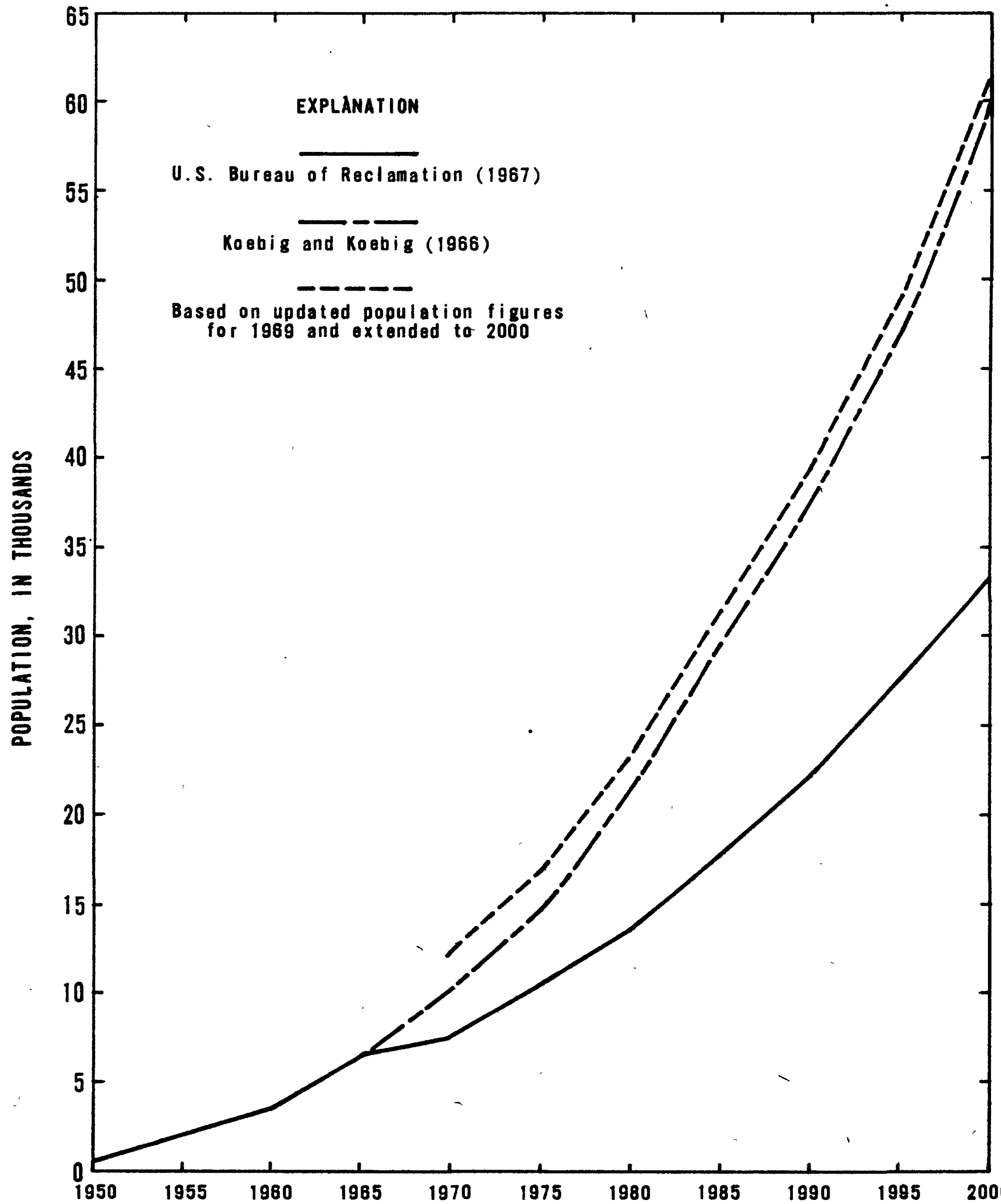


FIGURE 14.--Projected population figures for the Yucca Valley-Joshua Tree area.

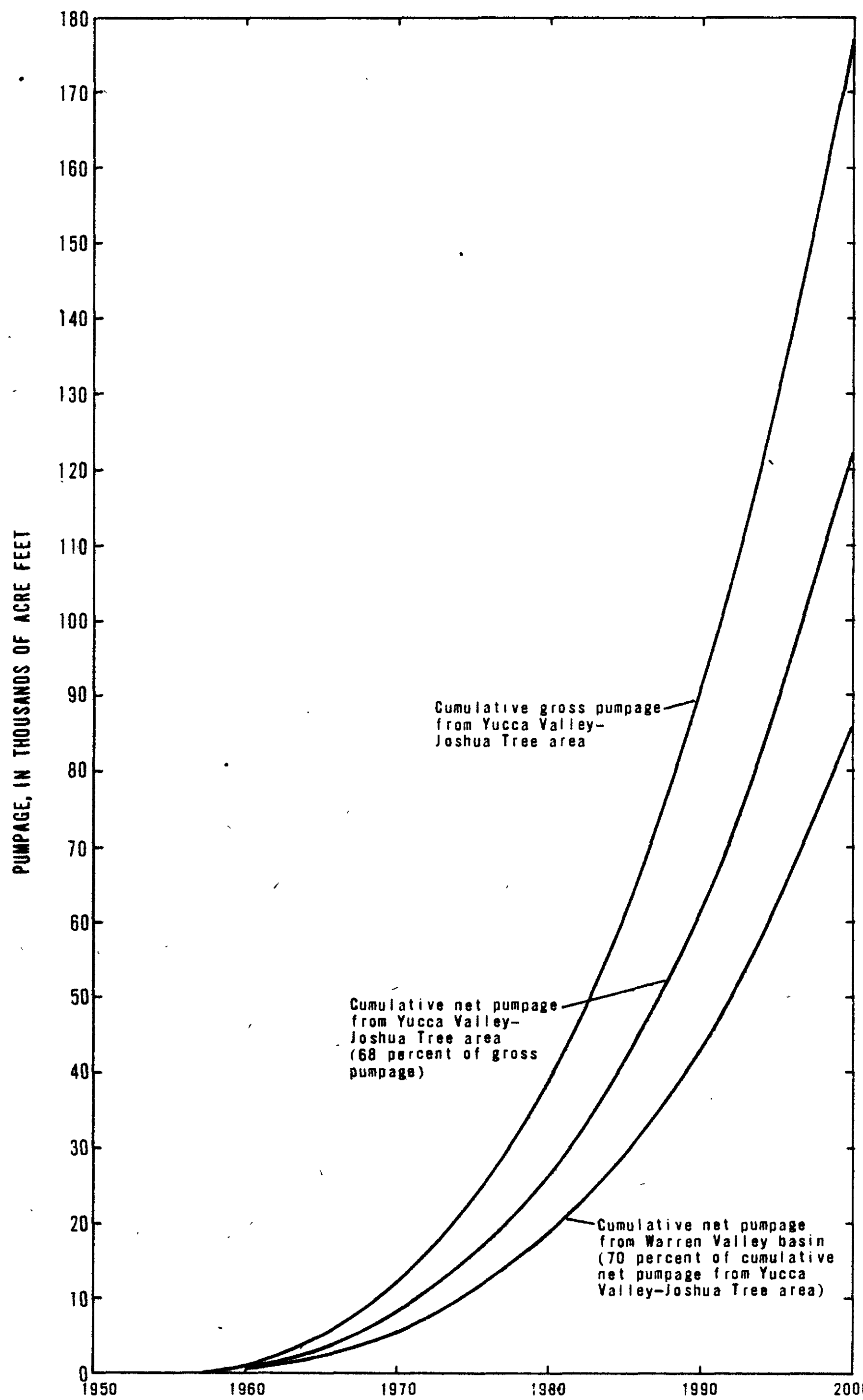


FIGURE 15.--Present and projected ground water pumpage requirements in the Yucca Valley-Joshua Tree area.

If 50 percent of the ground water in storage can be economically extracted, and considering inflow and outflow of the basin inconsequential, and if the consumptive-use and average specific-yield values are valid, then from estimates based on available population-growth data, the Warren Valley basin supply should be adequate until about 1990 although additional wells will be required. However, indefinite long-term urban growth cannot be sustained in the area utilizing the available Warren Valley basin ground-water supply. A substantial increase in population beyond that predicted for the Yucca Valley-Joshua Tree area would create an additional demand on the ground-water supply and hasten the time when a supplemental source of water is needed. The eventual importation of northern California water would insure an adequate supply to the area. However, until a firm target date can be established for its arrival, some consideration should probably be given to developing the ground-water resources in the nearby subbasins.

Results of test drilling in the study area indicate that future supply wells drilled in the Warren Valley basin should be drilled to depths sufficient to utilize the deeper saturated deposits--this is generally in excess of 600 feet. Test holes drilled in Pioneertown, Pipes, and Reche subbasins indicate that: (1) Saturated deposits in Pioneertown subbasin are probably too consolidated and fine grained to yield sufficient water for anything other than domestic use; (2) Saturated deposits in Reche subbasin are locally thin and may yield water which is high in fluoride; and (3) The greatest potential for water-supply development exists in Pipes subbasin.

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