GEOLOGICAL SURVEY CIRCULAR 404

WATER RESOURCES SUMMARY FOR SOUTHERN CALIFORNIA, 1957

UNITED STATES DEPARTMENT OF THE INTERIOR
FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY
Thomas B. Nolan, *Director*

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By William C. Peterson

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ABSTRACT

Current water requirements for southern California are more than 2 million acre-feet per year. These requirements are being satisfied by supplementing limited local water reserves with imported water.

The average annual precipitation ranges from about 2 inches in parts of the desert to about 50 inches in the higher mountains. Also, there is a great variation in annual precipitation at any one place.

The annual variation is not entirely random in that the annual precipitation tends to occur in sequences of wet and dry years. Records of the 1956–57 climatological year indicate that the dry period which began in 1944 continues unabated.

Runoff follows the same cyclic pattern of wet and dry periods established by precipitation, but with even greater variability. Annual runoff for the 1956–57 water year at 15 selected gaging stations ranged from 0.0 to 5.0 inches with departures from the average annual runoff for the 35-year base-mean period, 1920–55, ranging from minus 100 to minus 52 percent. The average annual runoff for the 1956–57 water year was 1.41 inches, a departure of minus 65 percent from the base mean. The average annual runoff for the 13-year dry period 1944–57 ranged from 0.24 to 6.9 inches with an average departure of minus 44 percent.

As result of these continuing dry years, most of the reservoirs storing natural runoff were practically dry. The combined contents of 12 selected reservoirs in September 1957 was only 7.5 percent of total capacity.

The trend in ground-water depletion that began in 1944 continued during the year. Although the increased use of imported water for recharge of ground-water basins reduced the rate of decline in some areas, water levels in most observation wells were the lowest of the period of record. In areas entirely dependent on local ground-water reserves for their supply, the problem of obtaining sufficient water became more critical.

The rapid increase in requirements of water stepped up the importation of water from the Colorado River from 20,000 acre-feet in 1944 to 597,000 acre-feet in 1957. During the same period, importations from Owens Valley were running close to aqueduct capacity; 331,000 acre-feet was imported from this source during 1957.

Annual runoff data for the 1955–56 water year from all currently published gaging-station records establish that year as one of the driest in recent years in southern California.

INTRODUCTION

This water-resources summary is the 15th in a series issued annually since June 1944. Its main purpose is to present a brief analysis of those phases of local water supply associated with the work of the Geological Survey in southern California.

The first part of this summary deals with water resources for the water year ending September 30, 1957. It contains a brief analysis of annual precipitation, annual runoff (provisional) at selected gaging stations, water reserves in both surface and underground reservoirs, and supplemental imported water.

The second part of this summary gives, in detail, annual runoff for the preceding water year ending September 30, 1956. A period of about 1 year, beginning at the end of the water year, is usually required to complete computations of daily discharge for all the gaging stations. An additional 6 months to a year is required to process and present the data in published form in the annual Geological Survey water-supply papers. Consequently, this summary represents the first opportunity to release data on magnitude of runoff for all stations now operated in southern California for the water year 1955–56.

Some of the information presented in this summary was included in previous issues. The repetition is made so that each summary will be complete and entirely independent of previous issues.

For the purpose of this summary, southern California is that part of the State extending southward along the coast from the Arroyo Grande basin to the international boundary and inland to include all the area to the Colorado River and Nevada State line south of the Tehachapi Mountains and Inyo County. The inland part of this 47,000-square-mile area is predominantly an arid desert. Consequently most of the population centers and agricultural areas of the region are concentrated in the long narrow band of coastal land. The chief exceptions are Antelope Valley in the Mojave Desert and Coachella and Imperial Valleys in the Colorado Desert. The area covered in this summary is shown in figure 1.

Because of many desirable climatic and economic factors, the population growth of southern California has been phenomenal, probably the greatest in the Nation. A population of about 300,000 in 1900 increased to about 5.7 million by 1950. About 80 percent of this population increase occurred in the three decades since 1920. Since 1950 the population growth has continued, and it is estimated that the present population of southern California is about 8 million.

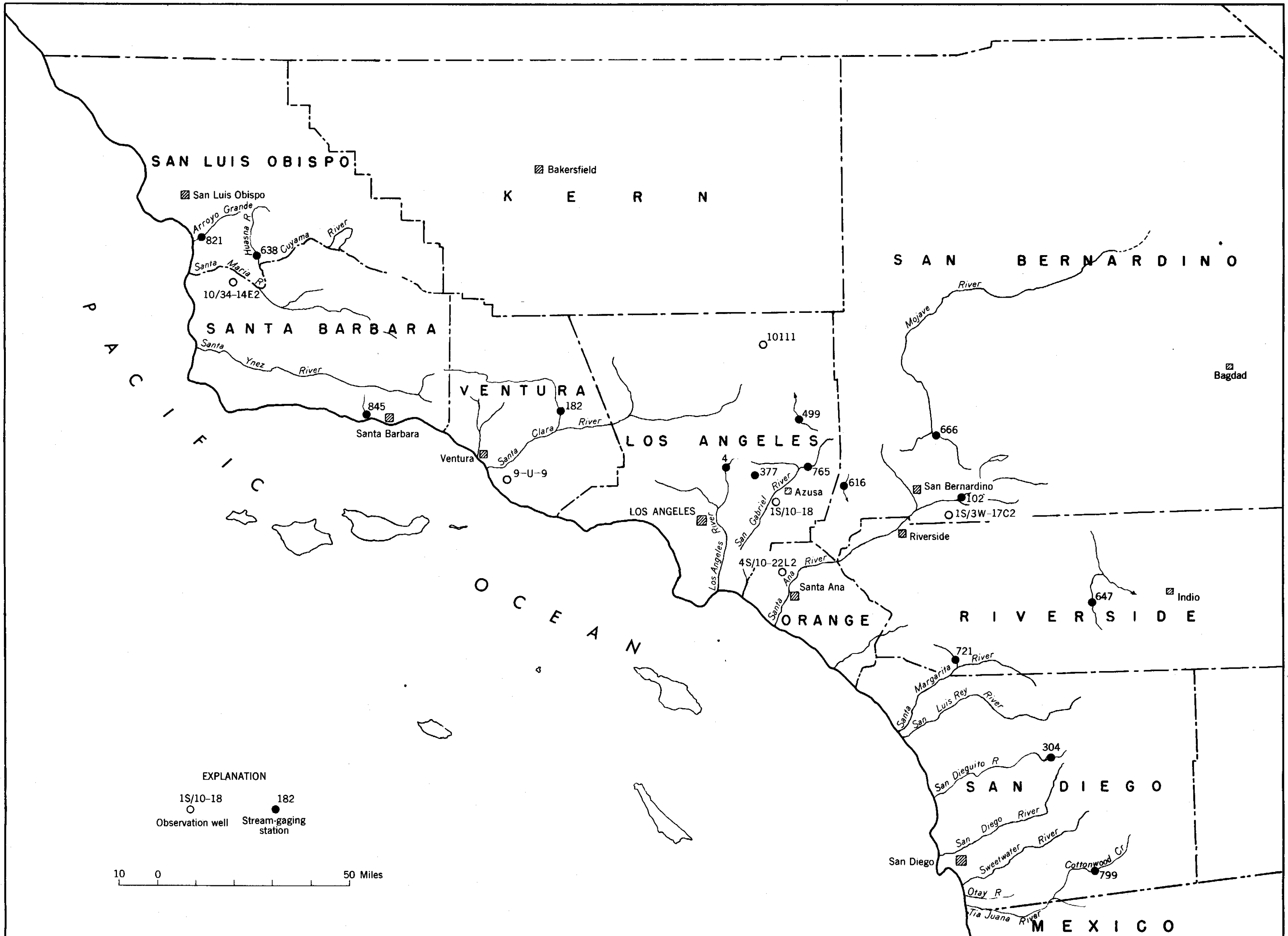

Figure 1.—Location of selected gaging stations and observation wells.

Such a vast increase in population greately intensifies the water problems in these arid and semiarid regions of limited water reserves. It has been estimated that the water requirements for urban and agricultural purposes in the coastal areas were about 1.8 million acre-feet in 1950 and have been steadily increasing at a rate of about 40,000 acre-feet per year. As a result, the water situation has changed from good to extremely critical in many areas. Just how critical the situation is depends largely upon the magnitude of the local ground-water reserves and the ability of the community to import water from outside the basin.

Southern California has been forced to obtain its water supply from distant sources because of its limited local water reserves; as a result this area pays more for its water than any other area of comparable size in the Nation.

WATER RESOURCES FOR THE WATER YEAR 1956–57

Precipitation

Very few areas in the United States experience ranges in average annual precipitation that are as wide as those observed in southern California. Because of modifications in the atmospheric-moisture circulation by local physiographic features, the observed average annual precipitation ranges from 2.24 inches at Bagdad in the Mojave Desert to 51.53 inches at Morse near Squirrel Inn in the San Bernardino Mountains.

On an areal basis the average annual precipitation of southern California is about 9.5 inches, or only about 32 percent of the national average of 30 inches. Not more than 2 percent of southern California has an average annual precipitation equal to or larger than that of the United States. More than 50 percent of southern California is arid, with an average annual precipitation of 5 inches or less.

In addition to the great range in average annual precipitation from place to place, there is often an even greater variation in annual precipitations at any one locality. For instance, the annual precipitation at Los Angeles for the climatological year, July 1 to June 30, has ranged from 5.59 inches in 1898–99 to 38.18 inches in 1883–84, and averaged 14.99 inches for a 80-year period of record ending in 1957. At Indio, in the desert area of southern California, the annual precipitation has ranged from 0.40 inch in 1879–80 to 11.50 inches in 1939–40, and averaged 3.16 inches for a 79-year period of record ending in 1957.

The variation in annual precipitation is not entirely random as the annual precipitation occurs in sequences of wet and dry years. The sequences represent a time distribution in which the wet years predominate, alternating with other periods in which dry years predominate—resulting in an irregular cyclic pattern. This distribution in time is most pronounced on the coastal side of the mountains and least defined in the arid desert regions.

Possibly the longest existing record of these wet and dry sequences is to be found in the growth of annual tree rings in certain types of trees growing in the mountains of southern California. Schulman[1] has been able to measure the annual tree-ring growth in big-cone spruce for the 560-year period of 1385 to 1944. These records indicate a definite cyclic pattern, with the average length of dry periods amounting to 14.5 years and wet periods amounting to 12.5 years, giving an average cyclic period of 27 years. Not all the individual years within a wet period are wet, but the wet years predominate; likewise, not all the individual years within a dry period are dry, but the dry years predominate.

A diagram showing the progressive 10-year means (fig. 2) is frequently used to show the existence of the alternating wet and dry periods. Points used to define these three curves represent the departures of the 10-year mean annual precipitation from the average annual precipitation for the period of record at Los Angeles, Santa Barbara, and San Diego for successive 10-year periods. The three pronounced highs in this diagram represent wet periods; the lows represent dry periods. Final points for the last 10-year period of these curves represent the mean annual precipitation from July 1, 1947, to June 30, 1957.

The observed 1957 annual (climatological year, July 1 to June 30) precipitation at these three typical southern California stations is given in table 1. During this year, the 13th year of a predominately dry period, the annual precipitation at all three stations was less than the average for the period of record; in fact, during the 10-year period 1948–57 there was only 1 year with above-average precipitation at each location. The influence of the 1957 precipitation is such as to reverse the trends at San Diego and Los Angeles and to continue the upward trend at Santa Barbara. (See fig. 2.)

Runoff

The precipitation, after first satisfying the soil-moisture deficiencies in the root zone of the native vegetation in mountain and foothill areas and of the agricultural crops in the valley-floor areas, recharges the ground-water reservoirs or drains into the stream channels as runoff. That part of the precipitation appearing as runoff follows the same cyclic tendency shown in figure 2. However, this cyclic tendency is often more pronounced because the annual runoff may represent only a very small part of annual basinwide precipitation. For example, the annual runoff for San Gabriel River near Azusa has ranged from as little as 0.86 inch throughout the basin for the water year ending September 30, 1899 to a maximum of 36.4 inches for the water year ending September 30, 1922, with an average of 9.7 inches for a 62-year period of record.

This range in annual runoff, together with its time sequence, is shown in figure 3 for the gaging station on San Gabriel River near Azusa and the gaging station on Santa Ana River near Mentone. Both stations reflect the runoff from rugged mountain basins within the San Bernardino and the Angeles National Forests where efforts are made to protect and maintain a native vegetative cover. The records for these two

[1] Schulman, Edmund, 1947, Tree-ring hydrology in southern California: Univ. Ariz., Lab. of Tree-ring Research, Bull. 4.

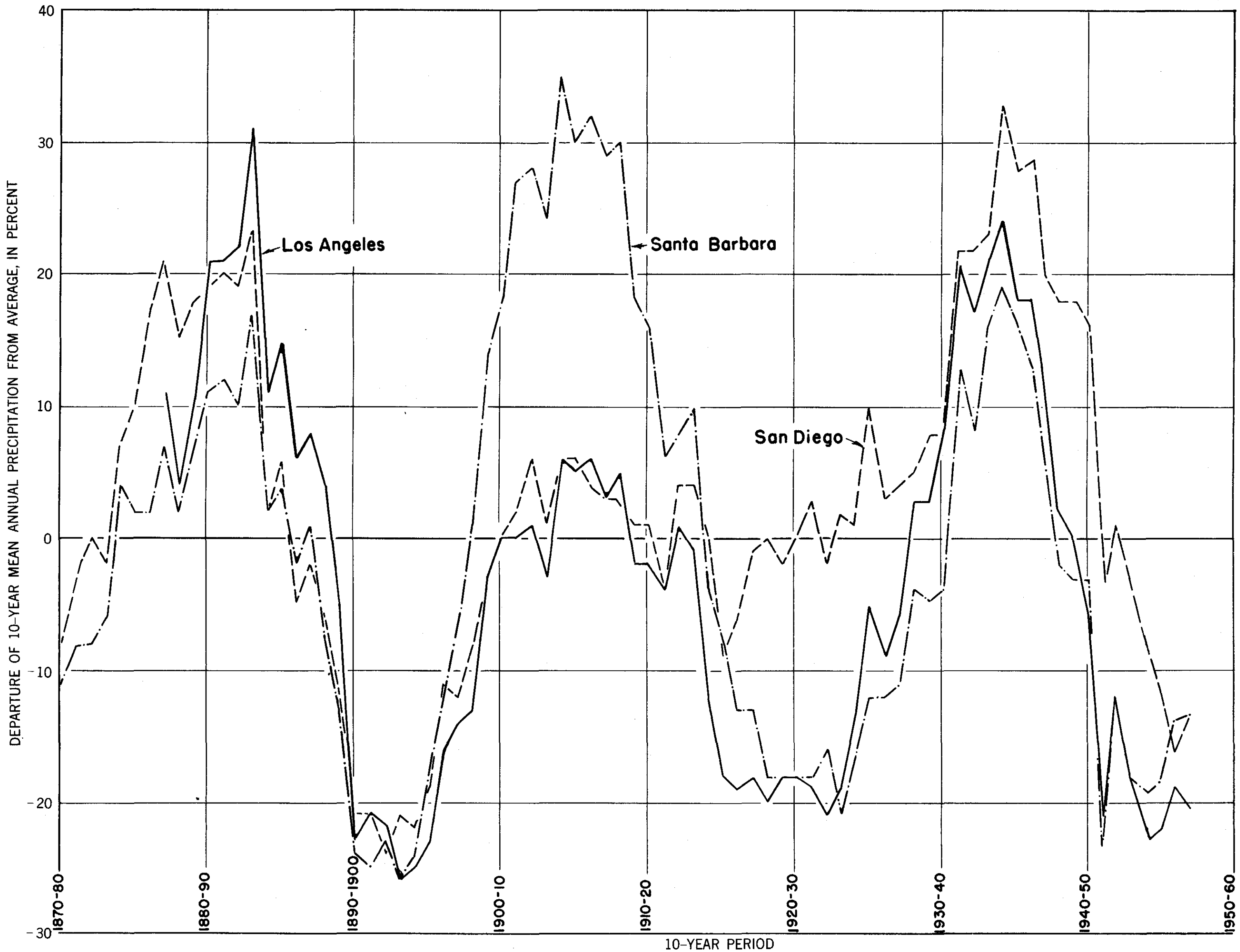

Figure 2.—Progressive 10-year mean annual precipitation.

Table 1.—Annual precipitation

Station	Period of record		1957 annual precipitation		10-year period 1948-57 mean annual precipitation	
	Length (years)	Average annual precipitation (inches)	Inches	Departure from average (percent)	Inches	Departure from average (percent)
San Diego	107	9.94	8.89	-10.6	8.62	-13.3
Los Angeles	80	14.99	9.54	-36.4	11.92	-20.5
San Barbara	90	17.91	13.86	-22.6	15.53	-13.3

stations are assumed to be typical of the mountain runoff in those areas where the basinwide average annual precipitation ranges from 30 to 40 inches. Both records display the same cyclic tendencies shown by the annual precipitation. To accentuate this distribution, the records have been segregated into the generally accepted wet and dry periods of the region, with the average annual runoff for each of these periods shown by the crosshatched area.

One of the methods used for determining wet and dry periods is that of cumulative departures as shown in figure 4. The diagrams show cumulative departures of annual runoff from the mean annual runoff, in percent, from 1895 to 1954 for San Gabriel River near Azusa and from 1896 to 1954 for Santa Ana River near Mentone. A continuously downward trend represents a dry period; a continuously upward trend represents a wet period.

It is evident from an inspection of figure 4 that both records contain 3 dry and 2 wet periods and consequently the means for the periods of record tend to be biased because of the greater number of dry years. On the basis of the records for San Gabriel River near Azusa, the 49-year period of 1896—1944 and the 50-year period of 1905—54 represent the least biased records because each contains 2 wet and 2 dry periods. For Santa Ana River near Mentone, the least biased records are those for the 47-year period 1897—1943 and for the 49-year period 1906—54. As there are but a few gaging stations in southern California where records are of sufficient length to contain these optimum time periods, it is necessary to consider the use of shorter periods, each containing a single wet and dry sequence. The beginning and the ending of each of these periods, together with the mean annual runoff for each period, are included in figure 4.

The obvious variability of the short-period data suggests that it is doubtful that the longtime mean can be used as a direct measure of dependable runoff for any randomly selected period. Consequently the longtime mean annual runoff becomes merely an indirect measure of the relative runoff among basins rather than a measure of usable or available water during extended critical periods.

Despite the shortcomings of the longtime mean in reference to most of southern California's water problems, the use of mean values as a measure of central tendency is desirable for brevity. Furthermore, mean values based on a common time period are more suitable for the purpose of the water resources summary than longtime means based on periods of varying length. Admittedly, any selected time period will be arbitrary because of areal differences in the beginning and ending dates of the sequences of wet and dry groups of years and lack of definition of the sequences in drainage areas of meager precipitation. But base means developed from a common time period are more directly comparable between basins that are longtime means developed from different length periods and, when properly interpreted, have considerable significance in many parts of southern California.

For the water resources summary, the 30-year period beginning October 1920 and ending September 1950 was initially selected for a base mean, and was used in recent editions of the summary. October 1920 was chosen as the beginning date so that the base period would conform closely to that of the standard period October 1920 to September 1945 for which median monthly discharge is computed and used for national coverage in the Water Resources Review of the U. S. Geological Survey and the Canadian Water Resources Division. The choice of this beginning date also enabled the inclusion, in the base-mean period, of many shorter runoff records that could be extended back to October 1920 with a minimum loss of accuracy.

Beginning with this edition of the summary, the 35-year period from October 1920 to September 1955 is used for computing base means. It is contemplated that the 35-year period will be used through the 1961 edition of the summary. The base means for the 35-year period are a few percent lower than those for the 30-year period, which should be borne in mind when comparing percentage departures in this edition of the summary with those in Circular 399 and earlier editions.

Annual runoff for the water year 1956—57

Annual runoff for the water year 1956—57 at the 15 gaging stations shown on figure 1 is briefly summarized in table 2 and compared to the average-annual runoff for the 35-year base period of 1920—55.

The intent of table 2 is to provide a general index of the surface runoff throughout southern California for the water year ending September 30, 1957. The wide range of the 1956—57 runoff, 0.0 to 5.0 inches, is typical of the region and is due largely to the areal distribution of precipitation. Departures of the 1956—57 runoff from the 35-year base means were about the same as those of the preceding 1955—56 water year, with the exception of the Huasna River in the Santa Maria basin and Arroyo Grande in the Arroyo

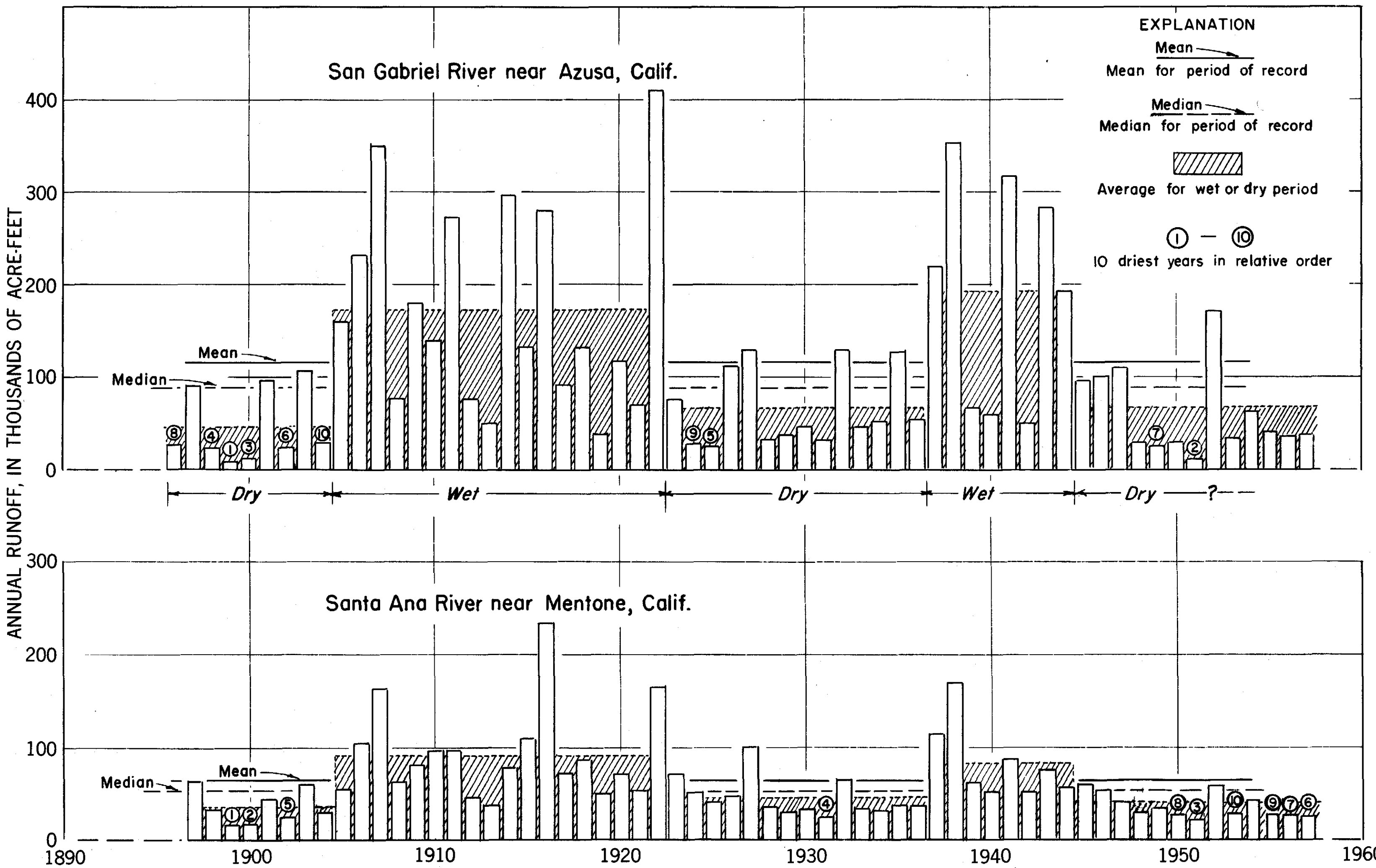

Figure 3.—Annual runoff distribution, 1896–1957.

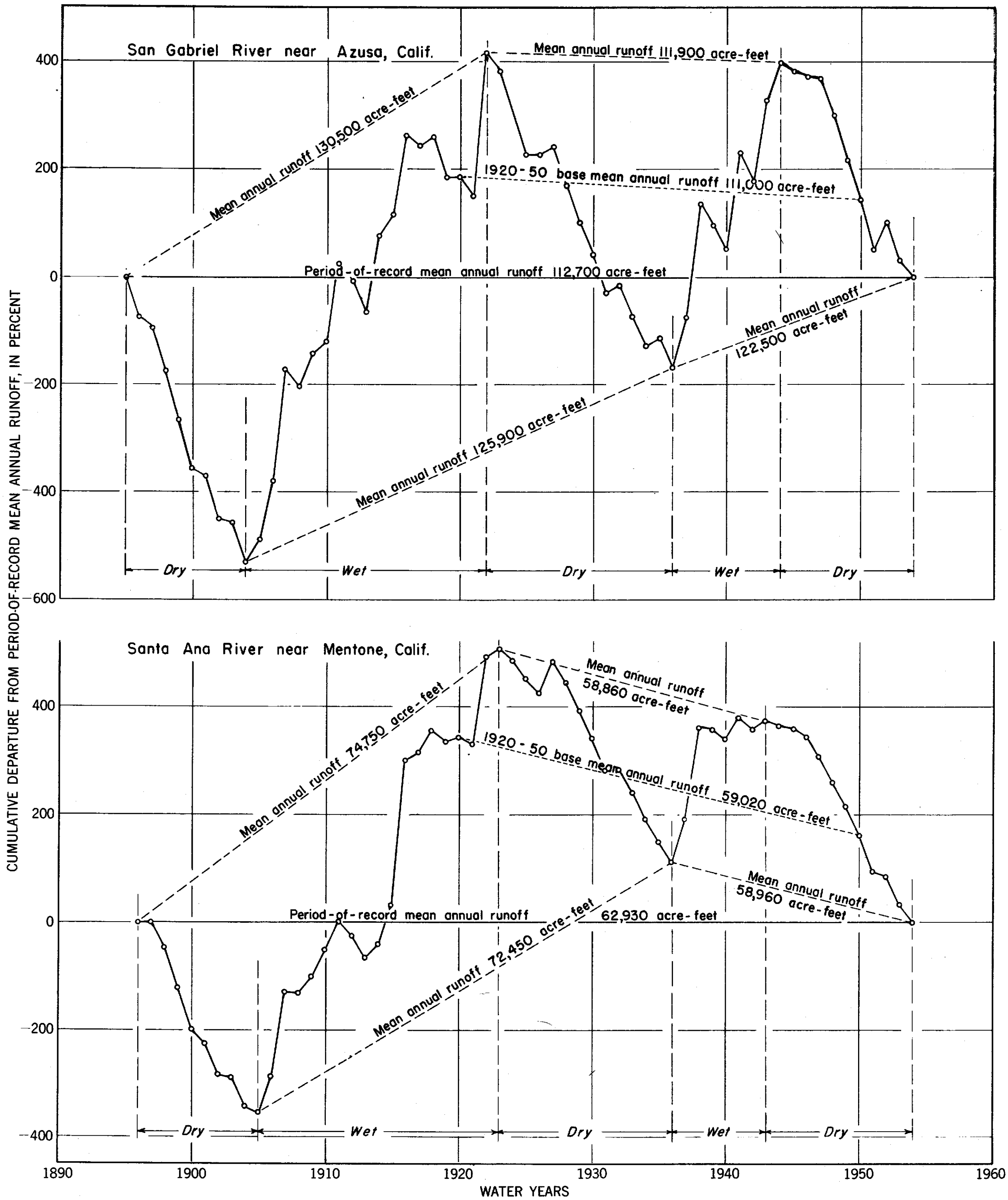

Figure 4.—Mean annual runoff for different periods, 1896–1954.

Table 2.—Annual runoff for the water year 1956-57, and the average annual runoff for the dry period 1944-57 at selected gaging stations

Locality no. on fig. 1	Station	Drainage area (square miles)	1920-55 base mean annual runoff (acre-feet)	1956-57 runoff			Average annual runoff for 1944-57 dry period		
				Acre-feet	Inches	Departure from base mean annual runoff (percent)	Acre-feet	Inches	Departure from base mean annual runoff (percent)
	Pacific Slope Basins:								
799	Cottonwood Creek at Morena Dam	120	11,250	263	0.04	-98	2,970	0.46	-74
304	Santa Ysabel Creek at Sutherland Dam-------------	58	12,340	940	.30	-92	4,410	1.4	-64
721	Murrieta Creek at Temecula----	220	9,380	997	.08	-89	3,390	.29	-64
102	Santa Ana River near Mentone--	202	55,680	26,400	2.5	-53	36,910	3.4	-34
616	Cucamonga Creek near Upland---	10.1	5,710	1,840	3.4	-68	3,730	6.9	-35
765	East Fork San Gabriel River near Camp Bonita-----------	88.2	48,910	23,630	5.0	-52	31,390	6.7	-36
4	Arroyo Seco near Pasadena-----	16.4	6,270	1,150	1.3	-82	3,220	3.7	-49
377	Santa Anita Creek near Sierra Madre-----------------------	10.5	4,360	1,570	2.8	-64	2,580	4.6	-41
182	Sespe Creek near Fillmore-----	254	70,980	23,540	1.7	-67	36,710	2.7	-48
845	San Jose Creek near Goleta----	5.54	--	784	2.7	--	836	2.8	--
638	Huasna River near Santa Maria-	119	12,540	681	.11	-95	6,130	.97	-51
821	Arroyo Grande at Arroyo Grande	106	14,940	3,320	.59	-78	8,700	1.5	-42
	The Great Basin:								
647	Palm Canyon Creek near Palm Springs--------------------	94.0	4,390	9.2	0	-100	1,260	.24	-71
666	Deep Creek near Hesperia------	137	44,271	20,450	2.8	-54	26,000	3.6	-41
499	Big Rock Creek near Valyermo--	23.0	12,100	4,420	3.6	-63	7,620	6.2	-37

Grande basin. Runoff in these excepted basins at the extreme northern end of coastal southern California decreased a small percent of the base mean to magnitudes roughly comparable to those of the 1954–55 water year.

The average annual runoff for the 1956–57 water year was 1.41 inches over the 1,464 square miles of mountain drainage listed in table 2, or about 35 percent of the 35-year base runoff. During the 1955–56 water year the average annual runoff for this group of basins was 1.77 inches, or about 1.25 times that of 1956–57.

Current dry period

The typical southern California runoff distribution shown on figure 3 indicates that the water year ending September 30, 1957 was among the driest during the observational period. Furthermore, this dry year was the 13th in a predominately dry period that has persisted since October 1944—and may not end for some time. The tree-growth studies by Schulman suggest that southern California may have experienced dry periods of more than 40 years.

A measure of the relative dryness of the dry periods is afforded by numbering the 10 driest years, for each of the stations shown in figure 3, in their order of dryness. Of these 20 years at both stations, 9 occurred in the very dry 9-year period ending September 30, 1904. The current dry period is next in order with 8 years, and the 14-year period ending September 30, 1936 was the least dry, containing only 3 of the 20 years.

The average runoff for the current dry period and its relation to the base mean is included in table 2.

At most of the stations the average runoff for the period 1944–57 was less than that for the period 1944–56. The average departure of the runoff from the 35-year base mean during the 13-year dry period for the basins listed was minus 44 percent.

Surface storage

Currently there exists about 1.5 million acre-feet of surface storage in southern California for municipal, domestic, and irrigational uses. Most of this storage has been obtained by building dams across mountain stream channels. However, because of the many adverse topographic features, such as steepness of the stream channels and narrowness of the canyons, construction costs are high and reservoir capacities small. Only 5 reservoirs of 115 built have a capacity in excess of 100,000 acre-feet. Because of these relatively small reservoir capacities, it is impossible in many instances to carry over the excessive flood runoff occurring during wet periods for use in the following dry periods. Furthermore, some of these reservoirs were not built for the purpose of storing local flood runoff but were intended for the storing and distribution of imported waters from Owens Valley and the Colorado River.

Because of the necessity for flood control in the valley-floor areas, additional storage of more than 400,000 acre-feet has been developed. Even though these flood-control reservoirs are primarily for retarding the flood runoff, a certain amount of water conservation is accomplished because provision is made, when possible, to control releases for efficient recharge of ground-water basins.

Data regarding the behavior of 12 reservoirs during the current dry period are given in table 3. These

Table 3.—Storage in selected surface reservoirs

Reservoir	Average annual 1920-55 inflow (acre-feet)	Present capacity at spill-way level (acre-feet)	Storage ratio (years)	Storage Sept. 30, 1956 Acre-feet	Storage Sept. 30, 1956 Percent of capacity	Storage Sept. 30, 1957 Acre-feet	Storage Sept. 30, 1957 Percent of capacity	Change in storage (acre-feet)	Storage on Sept. 30, 1944 Acre-feet	Storage on Sept. 30, 1944 Percent of capacity	Change in storage 1944-57 (acre-feet)
Morena and Barrett	24,800	94,970	3.8	1,410	1.5	1,270	1.3	-140	89,900	86	-88,630
El Capitan	38,600	112,810	2.9	6,690	5.9	2,540	2.2	-4,150	79,700	68	-77,160
Lake Hodges	33,280	33,550	1.0	[a]2,640	7.9	[a]3,460	10	+820	31,100	93	-27,640
Lake Henshaw	24,410	194,300	8.0	[b]1,800	1.0	[b]1,080	.6	-720	144,000	74	-142,300
Vail Lake	9,810	49,370	5.0	810	1.6	560	1.1	-250	--	--	--
Big Bear Lake	--	72,200	--	2,830	3.9	1,950	2.7	-880	47,600	66	-45,650
Santiago	11,220	25,000	2.2	2,830	11	3,700	15	+870	20,400	82	-16,700
Matilija	20,910	7,020	.34	5,560	79	5,250	75	-310	--	--	--
Jameson Lake	3,840	6,760	1.8	3,030	45	[b]1,260	19	-1,770	6,050	89	-4,790
Gibraltar	30,540	14,780	.48	11,660	79	10,340	70	-1,320	6,120	38	+4,220
Cachuma	60,700	210,000	3.5	36,600	17	30,150	14	-6,450	--	--	--
Total	[c]268,000	820,760	3.1	75,860	9.2	61,560	7.5	-14,300	424,870	78	-398,650

[a] Mostly Colorado River water. [b] Approximately. [c] Includes estimate for Big Bear Lake.

reservoirs were built for the purpose of supplying domestic, municipal, or irrigational water. Except for Lake Hodges, the only source of inflow to each reservoir during 1957 was from local runoff. The combined capacity of these 12 reservoirs is about 55 percent of their total capacities thus far developed for the purposes they were built.

The Morena and Barrett Reservoirs in the Tia Juana River basin are the most southerly of this group. At the end of the preceding dry year—on September 30, 1956—these reservoirs were almost empty. At the end of the equally dry 1957 water year the reservoirs were still almost empty. This is typical of the larger reservoirs where the average annual inflow is small in comparison with storage capacity and where the holdover storage from the preceding wet period has long been exhausted. Farther north, however, at the Matilija Reservoir, the storage at the end of the 1956 water year amounted to 79 percent of capacity, and at the end of the 1957 water year amounted to 75 percent of capacity. This relatively large retention is typical of those reservoirs in which the average annual inflow is large in terms of the reservoir's capacity.

Column 4 of table 3 gives storage ratio, which is defined as the ratio of usable capacity to average annual runoff. It is expressed in years and is the time required, assuming average runoff, to impound a volume of water equal to the usable capacity of the reservoir.

Ground water

Over a large part of southern California, the most readily available and best distributed water reserve is the water stored in the deep alluvial deposits of the valley-floor area. A major part of the water requirements of the region has been and is being supplied by pumping from this source. The magnitude of these water reserves is difficult to measure; however, they have been estimated by Eckis[2] to be about 7.5 million acre-feet in the alluvial deposits in the basins of the Los Angeles, San Gabriel, and Santa Ana Rivers in a zone 100 feet thick extending from 50 feet above to 50 feet below the January 1933 water levels.

The rapid growth of the industrial and urban developments has overtaxed these reserves. As a consequence the current rate of extraction often exceeds the average rate of recharge, creating an overdraft. Currently, many ground-water basins in southern California now have, or are threatened by, overdrafts.

The usefulness of a ground-water reservoir, like a surface-water reservoir, is dependent upon its size, the magnitude of the annual increments of recharge, and the annual rate of withdrawal. Also, like a surface reservoir, the ground-water reservoir must capture its water in the wet periods and retain it in storage to meet the needs of the following dry periods.

The valleys of southern California contain a large number of ground-water basins, many of which have complex geologic and hydrologic features. Changes in water levels differ considerably from basin to basin, depending upon the relationship between natural recharge and pumping draft. Consequently it has been necessary to confine the detailed analysis of the changes in water levels to the few observation wells indicated on figure 1.

The records of change in water level in six selected observation wells for their period of record are shown on figure 5. The division of wet and dry periods is based arbitrarily on figure 4. A light dashed line indicates the rate of decline during each dry period and is based chiefly on the group of years having the least precipitation during the period. Assuming that ground-water recharge during all dry periods is small and of about the same magnitude, an increase in the rate of decline becomes a measure of the increase in ground-water extractions.

At the end of the 1957 water year, almost all water levels were the lowest for the period of record—a reflection of the great increase in regional water requirements and the excess of withdrawals over the small increments of recharge during the current 13-year dry period.

Western San Diego County

Ground-water levels in the coastal alluvial valleys of western San Diego County, including the basins of the Tia Juana, Otay, Sweetwater, San Diego, San Dieguito, and San Luis Rey Rivers, declined during the 1957 water year, continuing a downward trend which began about 13 years ago. By September 30,

[2] Eckis, Rollin, 1934, Geology and ground-water storage capacity of valley fill (South Coastal Basin Investigation): California Dept. Public Works, Div. Water Resources, Bull. 45.

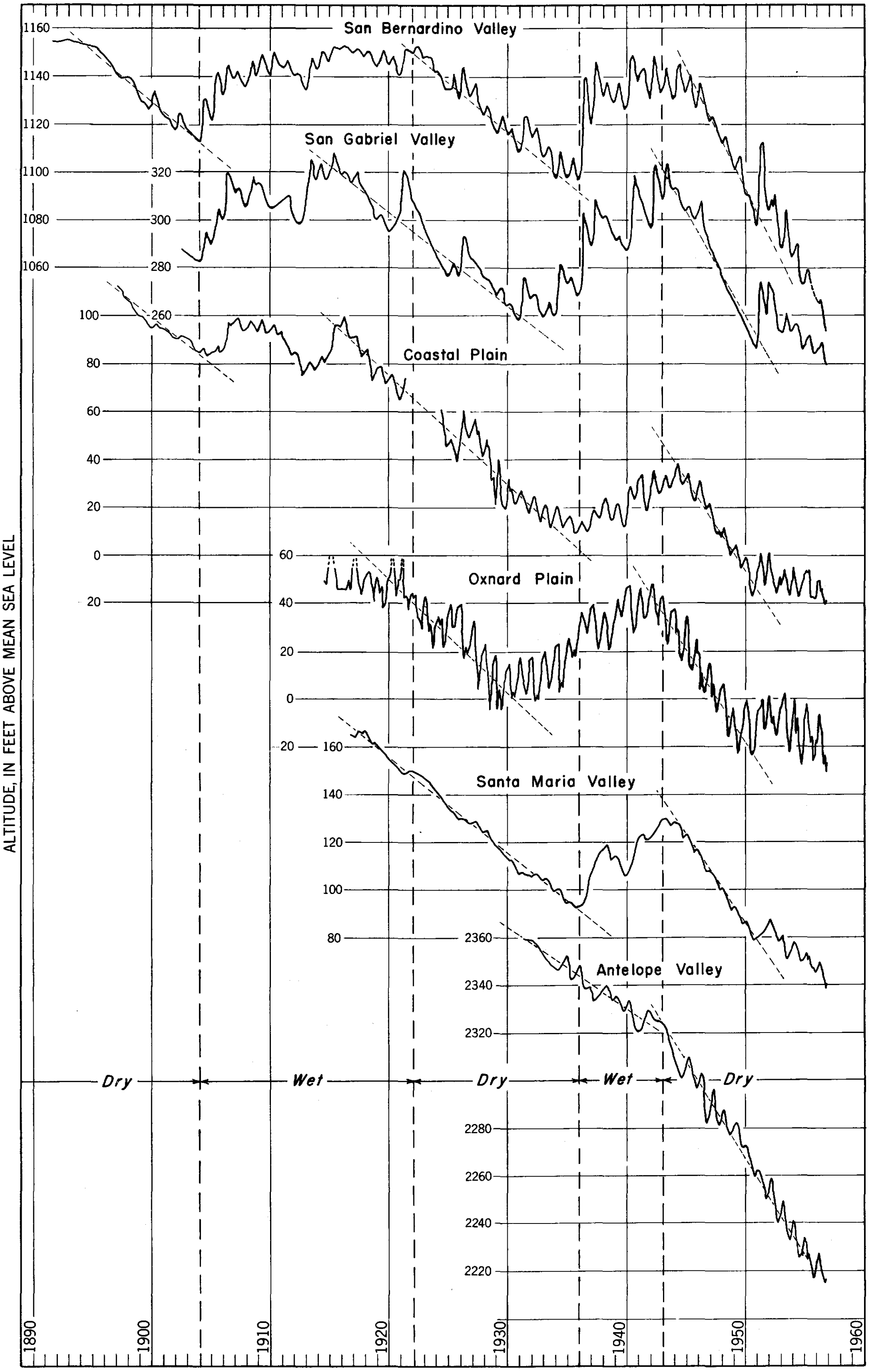

Figure 5.—Water-level fluctuations at selected observation wells.

1957, the levels in many wells were the lowest of the entire period of record. Near the coast in the San Luis Rey and Otay River basins, the water levels were below sea level during all or part of the year. At the present time, areas of known or threatened sea-water intrusion exist in the basins of the Tia Juana, Otay, San Diego, and San Luis Rey Rivers.

Riverside County

The ground-water levels in the arid and semiarid San Jacinto basin have declined steadily since the first observations of 1904. The Riverside County Flood Control and Water Conservation District reports that the water level in the observation well 4S/1W-35RI, near the city of San Jacinto, was about 200 feet below land surface in September 1957; this well was flowing in 1917. Similarly the water level in a second well 4S/3W-33RI, near the city of Perris, was about 186 feet below the land surface during September 1957 in an area where the water level was about 20 feet below the land surface during March 1904. Both areas now are using a limited amount of Colorado River water—at double the cost of locally pumped water—in an effort to supplement the declining water reserves.

At the end of the 1957 water year, ground-water levels in certain areas of the Riverside and Whitewater basins were about 7 feet below those observed during the fall of 1956; and at the Wildomar School in the Murrieta-Temecula basins, the ground-water level declined almost 14 feet during the year. A reversal of the general downward trend was observed in the Elsinore basin where ground-water levels rose 2–10 feet. The rise was generally attributed to the importation of Colorado River water to the valley area of the basin.

San Bernardino Valley

The San Bernardino Valley is a relatively deep alluvial valley in the upper Santa Ana River basin east of metropolitan Los Angeles. The water needs of the valley's prominent agricultural and urban developments are supplied from local surface and ground-water sources.

The longest available record of changes in ground-water levels is that for the Williams well (1S/3W-17C1). This record (fig. 5) began in 1892 and indicates the response to seasonal changes caused by pumping and recharge and to the long-term changes associated with wet and dry periods tending to give the water-level fluctuation a general cyclic time distribution that coincides closely with the wet and dry periods shown on figure 4.

The rate of decline during the first and second dry periods amounted to about 4.2 feet per year. However, during the current dry period the rate of decline increased to about 10 feet per year. This increase in rate of decline reflects an increase in ground-water use that, when contrasted with the average rate and duration of recharge during wet periods of record, forecasts a condition of overdraft in the near future.

The San Bernardino Valley Water Conservation District reports that the valley's ground-water levels at the end of the 1957 water year averaged about 110 feet below the levels at the beginning of the current dry period. Owing to the increasing export of water from the area above the San Jacinto fault, many wells have either gone dry or the yields have diminished to the point where the wells have become unusable. Among these was the Williams well, which went dry in July 1956 and was still dry in January 1957. Water-level records obtained since March 1957 are from a companion well (1S/3W-17C2) drilled to replace the Williams well. Deepening of wells, lowering of pumps, and increased pumping costs are imposing serious economic hardships on water users, particularly those in the fringe areas of the valley.

San Gabriel Valley

The San Gabriel Valley is a deep alluvial valley in the San Gabriel River basin along the toe of the San Gabriel Mountains. The ground-water-storage capacity of these deposits is believed to be about 1.2 million acre-feet in a zone 100 feet thick, ranging from 50 feet above to 50 feet below the January 1933 water level.[2] The once extensive agricultural acreage in this valley is rapidly being converted into an urban area. Most of the valley's water requirements are met from local ground-water reserves.

The record obtained at the Baldwin Park observation well 1S/10-18 (fig. 5) is assumed to represent ground-water conditions throughout the valley. During the dry period 1922–36, the average rate of water-level decline was about 3.9 feet per year and increased to 8.8 feet per year during the current dry period. During the last few years, this rate of decline has moderated, owing partly to the wet year 1951–52 and partly to the increased use of imported Colorado River water in the area.

Coastal plain

The coastal plain is the broad, flat area extending along the coast from Santa Monica to Newport Beach and inland to the Santa Monica and Santa Ana Mountains, the Puente and San Jose Hills, and lesser foothills. Three major streams—the Santa Ana, San Gabriel, and Los Angeles Rivers—cross this plain to discharge into the ocean. The rich agricultural lands of the plain have been converted gradually into extensive urban and suburban areas. Currently, the coastal plain is the most densely populated and industrialized section of southern California.

The fresh-water-bearing deposits underlying the plain are composed of marine and alluvial material that locally attain a thickness of 2,500 feet or more. Less than 20 years ago the water stored in these deposits was the principal source of water for the area. Because of the rapid increase in water needs during recent years, it has been necessary to import a substantial part of the water requirements from Owens Valley and the Colorado River. Even with these imported waters, the ground-water reserves have been so depleted that sea water has intruded these deposits along many sections of the coast.

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[2] See footnote p. 9.

Systematic observations of change in ground-water level in the coastal plain have been noted at the Neff well 4S/10-22L2 and its companion wells near Anaheim since 1898. These records (fig. 5) have been used as an index of changes in the water level of the coastal plain. During the 59-year period of record at this site, a net decline of 132 feet (from 112 feet above sea level to 20 feet below sea level) was observed. This decline, which has not been uniform, was concentrated largely in the three dry periods. An average rate of decline of 3.9 feet per year in the first dry period increased to 4.6 feet per year during the second dry period and to 7.6 feet per year in the current dry period. During the last few years, this rate of decline has moderated owing partly to the wet year 1951–52 and partly to greater use of imported waters.

The Orange County Water District reports an average rise in ground-water level of 15.5 feet throughout the eastern part of the coastal plain during 1957. This level is about 5.5 feet higher than the average level at the end of the 1956 water year and reflects the spreading of 102,000 acre-feet of Colorado River water to replenish the underground basin. In addition to the water purchased by the Orange County Water District, about 46,000 acre-feet of Colorado River water was purchased by cities and other water users for direct use in areas previously supplied from the district basin.

Oxnard plain

The Oxnard plain is one of the most important agricultural and urban areas in Ventura County. Water-level observations made by Ventura County Water Resources Division, at well 9-U-9 in the city of Oxnard (fig. 5) are assumed to represent changes in the ground-water reserves beneath this broad coastal plain. Since 1943 the water level at this site has declined almost continuously. Between 1943 and 1951 the average rate of decline was about 7.4 feet per year. This trend was reversed temporarily by recharge in the wet year 1951–52. However, since 1953 the decline in water level has resumed at a rate somewhat less than that before 1952.

The Ventura County Water Resources Division reports that the ground-water levels of the Oxnard plain were generally about 25 feet below sea level in the fall of 1957. At this same time the water levels were about 63 feet below sea level in Pleasant Valley, an eastward extension of the Oxnard plain. There is evidence of sea-water intrusion in wells near the ocean.

Santa Maria Valley

Changes in water level in well 10/34-14E2 (fig. 5), near the center of the Santa Maria Valley, generally reflect the status of ground water in storage for a large part of the valley. The records from this well show a continuous and almost uniform decline in water level at a rate of 4.0 feet per year during the dry years 1917–36. As a result of the large ground-water recharge during the wet period extending through 1944, the water level in this well rose about 35 feet. During the current dry period, the water level declined at an average rate of 7.4 feet per year to the lowest level on record, indicating a substantial increased draft on the ground-water reserves.

Antelope Valley

Antelope Valley is in the extreme west end of the Mojave Desert in Los Angeles and Kern Counties. Parts of this arid valley have been farmed successfully for more than 60 years. However, the steadily increasing water needs for agricultural and other uses have created a critical overdraft in the valley.

Figure 5 shows the changes in water level in a well near Lancaster; they are assumed to be an index of changes in the large, heavily pumped part of the valley. During the last 26-year period the water level in this and nearby wells has declined about 145 feet. This decline, which persisted even during the wet years, clearly indicates that extractions exceeded the recharge. A rate of decline of about 3.4 feet per year during the 1922–36 dry period has increased to 8.1 feet per year during the current dry period.

Artificial recharge of ground water

The Metropolitan Water District of Southern California reported that it sold about 152,000 acre-feet of Colorado River water at a cost of more than $1.5 million to the people of Los Angeles and Orange Counties during the 1957 water year for the major purpose of retarding the rapid rate of decline in ground-water levels. This water was permitted either to infiltrate into the stream-channel deposits or to spread into highly permeable specially prepared basins overlying the main ground-water bodies.

About 3,500 acre-feet of Colorado River water was put into injection wells along the coast in the vicinity of Manhattan Beach to maintain a fresh-water barrier against sea-water intrusion.

An additional 9,000 acre-feet of local storm runoff from the mountain and foothill areas during the 1957 water year was diverted from natural stream channels into specially prepared basins for the purpose of recharging the ground-water reservoirs in Los Angeles County.

Imported water

Southern California extends over a predominately arid region which has less than 2 percent of the State's natural water supplies. Consequently, to satisfy the ever-increasing water requirements of the area, water must be imported from distant sources.

Since 1913 the city of Los Angeles has diverted water from the Owens Valley east of the Sierra Nevada for use in the city some 250 miles to the south. During the 1957 water year the Owens River aqueduct, operating at full capacity as in previous years, delivered 331,000 acre-feet to the Los Angeles area.

By means of a 1,617-foot pumping lift and a 242-mile aqueduct from the Colorado River, the Metropolitan Water District of Southern California delivered 597,000 acre-feet to the greater Los Angeles and San Diego areas during the 1957 water year.

As indicated on figure 6, these annual imports have increased from 329,000 acre-feet in 1945 to 928,000 acre-feet in 1957—a net increase of 182 percent. About

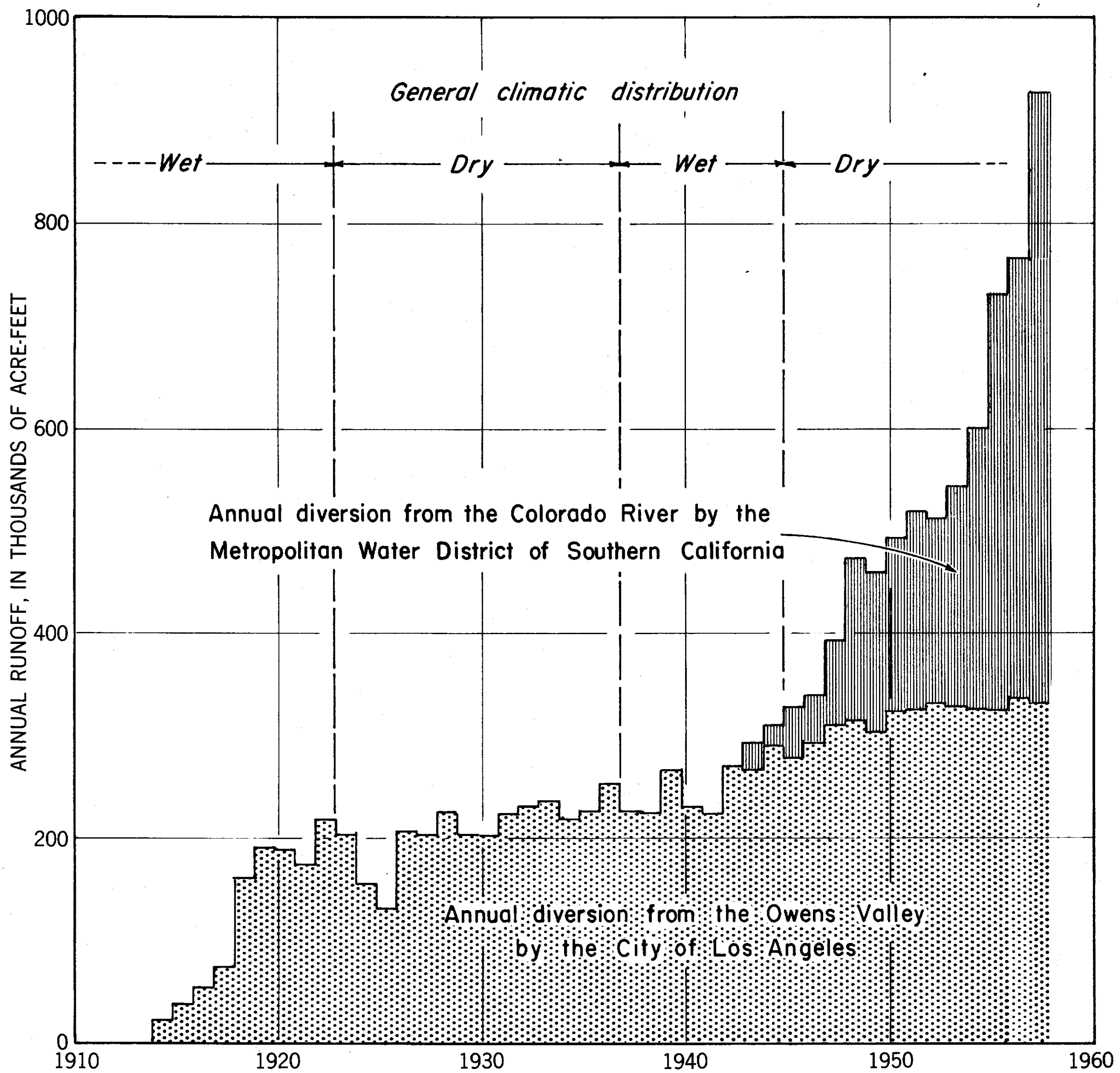

Figure 6.—Water imported into southern California.

45 percent of the annual water requirements in the coastal areas are now met by imported water.

ANNUAL RUNOFF FOR THE WATER YEAR 1955–56

Annual runoff data for the water year ending September 30, 1956, for all southern California gaging-station records currently published by the Geological Survey, are presented in table 4. The mean and median values of the annual runoff for the period of record and the relation of the annual runoff to the base mean are included for the stations with a record of sufficient length.

Areal distribution

The normal storm tracks moving over southern California are such that the precipitation along the coast generally decreases from north to south. The eastward movement of these storms is blocked by the high mountain barriers which cause the greatest precipitation on the windward side of these barriers. Across the barriers the precipitation decreases rapidly to near zero in the desert areas.

A generalized areal distribution of the annual runoff for the water year ending on September 30, 1956, is shown on figure 7. The runoff quantities used to

Table 4.—Annual runoff for the water year 1955-56

[Basic data furnished by: [a]city of San Diego; [b]California Water and Telephone Co.; [c]Helix Irrigation District; [d]Vista Irrigation District; [h]Montecito County Water District; [i]city of Santa Barbara.
Records furnished by: [e]Orange County Flood Control District; [f]Los Angeles County Flood Control District; [g]Ventura County Water Resources Division.
Imported water: *Adjusted for 21,690 acre-ft of Colorado River water; **Adjusted for 31,590 acre-ft of Colorado River water; †Adjusted for 12,770 acre-ft of Colorado River water; ††Adjusted for 4,005 acre-ft of Owens River water]

Basin and stream	Drainage area (square miles)	1955-56 annual runoff: Acre-feet	1955-56 annual runoff: Acre-feet per square mile	1955-56 annual runoff: Departure from base mean (percent)	Period of record: Length (years)	Period of record: Mean annual runoff (acre-feet)	Period of record: Median annual runoff (acre-feet)	Base mean: Mean annual runoff 1920-55 (acre-feet)
PACIFIC SLOPE BASINS								
Tia Juana River basin:								
Cottonwood Creek at Morena Dam [a]	120	131	1.09	-99	20	10,910	6,100	11,250
Cottonwood Creek at Barrett Dam, near Dulzura	250	1,380	5.52	----	11	9,240	4,200	------
Cottonwood Creek above Tecate Creek, near Dulzura	316	0	0	----	20	7,750	1,880	------
Campo Creek near Campo	84	22	.26	----	20	2,310	1,520	------
Tia Juana River near Dulzura	478	44	.09	----	20	12,520	4,200	------
Tia Juana River near Nestor	1,668	0	0	----	21	38,300	8,690	------
Otay River basin:								
Jamul Creek near Jamul	72	1,140	1.58	----	16	------	------	------
Otay River at Savage Dam	98	1,047	10.7	----	20	------	------	------
Sweetwater River basin:								
Sweetwater River at Loveland Dam, near Alpine [b]	100	542	5.42	----	12	4,310	2,000	------
Sweetwater River at Sweetwater Dam [b]	181	1,172	6.48	----	69	------	------	------
San Diego River basin:								
Boulder Creek at Cuyamaca Reservoir, near Julian [c]	12.0	398	33.2	-91	12	2,090	1,060	4,360
San Diego River at El Capitan Dam [a]	190	1,801	9.48	----	11	10,980	5,000	------
San Diego River near Santee	380	178	.47	-99	41	20,920	3,620	20,410
San Dieguito River basin:								
Santa Ysabel Creek at Sutherland Dam	58	860	14.8	-93	35	15,570	8,500	12,340
Santa Ysabel Creek near Ramona	110	792	7.20	----	23	------	------	------
Guejito Creek near San Pasqual	24	564	23.5	----	9	731	------	------
Guejito Creek at San Pasqual	28	412	14.7	----	11	557	140	------
Santa Maria Creek near Ramona	58	.2	0	----	17	4,060	650	------
San Dieguito River at Lake Hodges [a]	303	-699	-2.31	----	40	------	------	------
San Luis Rey River basin:								
San Luis Rey River at Lake Henshaw, near Mesa Grande [d]	209	1,782	8.53	-93	34	22,030	12,700	24,410
San Luis Rey River at Monserate Narrows, near Pala	383	1,150	3.00	----	13	8,470	2,820	------
San Luis Rey River near Bonsall	514	0	0	-100	27	18,530	7,170	21,970
San Luis Rey River at Oceanside	557	0	0	----	24	15,930	1,450	------
Santa Margarita River basin:								
Temecula Creek at Vail Dam, near Temecula	319	1,370	4.29	-86	33	8,900	4,940	9,810
Murrieta Creek at Temecula	220	997	4.53	-89	26	7,750	2,170	9,380
Santa Margarita River near Temecula	592	3,750	6.33	-80	33	17,490	7,190	19,030
Santa Margarita River near Fallbrook	645	1,750	2.71	-92	31	22,160	8,460	23,090
Santa Margarita River at Ysidora	740	0	0	-100	32	25,390	9,390	27,450
San Juan Creek basin:								
San Juan Creek near San Juan Capistrano	110	5,710	5.19	----	28	------	------	------
Trabuco Creek near San Juan Capistrano [e]	36.5	1,360	37.3	-61	26	3,740	580	3,530
Aliso Creek basin:								
Aliso Creek at El Toro [e]	8.5	427	50.2	-17	26	550	220	514

Table 4.—Annual runoff for the water year 1955-56—Continued

Basin and stream	Drainage area (square miles)	1955-56 annual runoff: Acre-feet	1955-56 annual runoff: Acre-feet per square mile	1955-56 annual runoff: Departure from base mean (per cent)	Period of record: Length (years)	Period of record: Mean annual runoff (acre-feet)	Period of record: Median annual runoff (acre-feet)	Base mean: Mean annual runoff 1920-55 (acre-feet)
Peters Canyon Wash basin:								
San Diego Creek near Irvine	--------	987	------	---	7	1,220	------	-------
Santa Ana River basin:								
Santa Ana River near Mentone	202	26,890	133	-52	60	61,750	51,700	55,680
Mill Creek near Yucaipa	39.9	9,870	247	-60	28	23,960	17,400	24,500
Mill Creek near Mentone	--------	351	------	---	17	1,980	510	-------
Plunge Creek near East Highlands	16.9	2,910	172	---	37	-------	------	-------
Santa Ana River near San Bernardino	--------	2,950	------	---	11	6,430	1,010	-------
Little San Gorgonio Creek near Beaumont	2.61	23	8.81	---	8	65	------	-------
San Timoteo Creek near Redlands	123	194	1.58	-85	30	1,090	430	1,300
San Timoteo Creek near Loma Linda	--------	1,170	------	---	2	-------	------	-------
East Twin Creek near Arrowhead Springs	8.6	1,660	193	-51	36	3,390	2,460	3,420
Waterman Canyon Creek near Arrowhead Springs	4.55	896	197	-53	38	1,970	1,300	1,900
City Creek near Highland	19.8	2,860	144	-62	37	7,450	5,600	7,530
Devil Canyon Creek near San Bernardino	6.16	1,410	229	-40	37	2,330	1,650	2,340
Lytle Creek near Fontana	46.9	13,450	287	-55	52	31,560	25,900	29,730
Cajon Creek near Keenbrook	40.9	2,110	51.6	-69	36	6,540	4,270	6,720
Lone Pine Creek near Keenbrook	15.0	199	13.3	-83	25	956	360	1,160
Lytle Creek (east channel) at San Bernardino	--------	311	------	---	27	-------	------	-------
Warm Creek near Colton	--------	19,630	------	---	36	-------	------	-------
Santa Ana River at Riverside Narrows, near Arlington	--------	*26,440	------	-51	26	40,650	29,900	53,860
Day Creek near Etiwanda	4.8	1,300	271	-67	27	3,920	2,960	3,950
Cucamonga Creek near Upland	10.1	2,100	208	-63	27	5,550	4,130	5,710
San Jacinto River near San Jacinto	140	4,800	34.3	-80	36	24,000	13,600	24,550
Bautista Creek near Hemet	39.4	56	1.42	---	9	449	------	-------
San Jacinto River near Elsinore	717	0	0	---	40	-------	------	-------
Temescal Creek near Corona	--------	35	------	---	27	2,800	43	-------
San Antonio Creek near Claremont	16.9	6,820	404	-58	39	15,710	11,600	16,120
Santa Ana River below Prado Dam	--------	72,440	------	---	16	-------	------	-------
Santa Ana River at county line, below Prado Dam	--------	71,310	------	---	37	-------	------	-------
Santiago Creek at Santiago Dam, near Villa Park	63	7,683	122	-32	25	12,970	7,800	11,220
Santiago Creek near Villa Park	83.8	628	7.49	---	36	-------	------	-------
Santiago Creek at Santa Ana	--------	1,290	------	-73	27	3,970	580	4,750
Santa Ana River at Santa Ana	2,418	3,810	1.58	-80	33	14,760	2,080	19,300
San Gabriel River basin:								
East Fork San Gabriel River near Camp Bonita [f]	88.2	22,200	252	-55	23	51,470	34,800	48,910
West Fork San Gabriel River at Camp Rincon [f]	102	12,350	121	-75	29	46,910	26,100	49,640
San Gabriel River near Azusa	211	36,380	172	-65	61	110,000	79,600	104,200
Rogers Creek near Azusa	6.4	772	121	-66	39	2,130	1,090	2,240
Fish Creek near Duarte	6.5	1,100	169	-63	39	2,860	1,810	3,010
San Gabriel River below Santa Fe Dam, near Baldwin Park	231	0	0	---	14	-------	------	-------
San Dimas Creek near San Dimas	18.3	799	43.7	-76	39	3,140	1,880	3,290
Dalton Creek near Glendora	7.5	356	47.5	---	36	-------	------	-------
Little Dalton Creek near Glendora [f]	2.7	211	78.1	---	18	492	220	-------
San Jose Creek near Whittier [f]	85.2	4,990	58.6	-15	27	6,040	3,840	5,860
San Gabriel River above Whittier Narrows Dam	--------	**8,960	------	---	1	-------	------	-------
San Gabriel River at Pico [f]	--------	†11,280	------	-67	28	32,120	14,000	34,270
San Gabriel River at Spring Street, near Los Alamitos	584	9,390	16.1	---	29	19,020	1,990	-------
Brea Creek below Brea Dam, near Fullerton	23.4	378	16.2	---	14	492	220	-------
Brea Creek at Fullerton [e]	26.2	551	21.0	---	26	849	364	-------
Fullerton Creek below Fullerton Dam, near Brea	--------	310	------	---	15	-------	------	-------
Fullerton Creek at Fullerton [e]	6.2	1,100	177	---	21	543	220	-------
Coyote Creek near Artesia [f]	110	7,280	66.2	+30	27	5,840	3,150	5,620
Carbon Creek near Yorba Linda	20.4	206	10.1	---	7	188	------	-------

Table 4.—Annual runoff for the water year 1955-56—Continued

Basin and stream	Drainage area (square miles)	1955-56 annual runoff			Period of record			Base mean
		Acre-feet	Acre-feet per square mile	Departure from base mean (percent)	Length (years)	Mean annual runoff (acre-feet)	Median annual runoff (acre-feet)	Mean annual runoff 1920-55 (acre-feet)
Los Angeles River basin:								
Los Angeles River at Sepulveda Dam	155	††13,405	86.5	---	13	12,770	9,260	-----
Pacoima Creek near San Fernando [f]	28.2	1,250	44.3	-82	39	6,650	3,110	6,920
Tujunga Creek below Mill Creek, near Colby Ranch [f]	64.9	1,810	27.9	---	8	4,000	------	------
Tujunga Creek near Sunland [f]	106	4,700	44.3	-78	39	20,270	10,900	21,190
Haines Creek near Tujunga	1.2	31	25.8	---	24	282	140	------
Little Tujunga Creek near San Fernando [f]	21.0	381	18.1	-81	28	1,860	510	2,020
Tujunga Creek below Hansen Dam	148	25	.17	---	16	15,020	2,900	------
Los Angeles River at Los Angeles [f]	510	35,890	70.4	-12	27	41,770	25,300	40,790
Arroyo Seco near Pasadena	16.4	2,160	132	-66	42	6,660	3,620	6,270
Los Angeles River near Downey [f]	614	66,440	108	---	28	69,860	44,900	------
Sawpit Creek near Monrovia	5.3	835	158	-56	39	1,820	1,300	1,880
Santa Anita Creek near Sierra Madre	10.5	2,230	212	-49	40	4,140	2,610	4,360
Little Santa Anita Creek near Sierra Madre	1.9	278	146	-58	39	637	360	665
Eaton Creek near Pasadena	6.5	895	138	-68	38	2,690	1,710	2,820
Rio Hondo near Montebello [f]	------	16,180	------	-59	28	38,010	26,800	39,240
Mission Creek near Montebello [f]	------	2,310	------	---	26	11,510	10,900	------
Rio Hondo near Downey [f]	------	14,540	------	---	28	19,550	7,960	------
Los Angeles River at Long Beach [f]	822	96,820	118	+10	27	102,800	69,500	88,040
Ballona Creek basin:								
Ballona Creek near Culver City [f]	88.6	34,590	390	---	28	-------	------	------
Topanga Creek basin:								
Topanga Creek near Topanga Beach [f]	17.9	1,030	57.5	-72	25	3,920	1,450	3,690
Malibu Creek basin:								
Malibu Creek at Crater Camp, near Calabasas [f]	103	4,680	45.4	-63	25	14,050	4,630	12,760
Santa Clara River basin:								
Santa Clara River at Los Angeles—Ventura county line [g]	------	5,510	------	---	4	-------	------	------
Piru Creek above Piru Reservoir	------	10,850	------	---	1	-------	------	------
Piru Creek below Santa Felicia Dam	------	8,100	------	---	1	-------	------	------
Piru Creek near Piru	432	8,400	19.4	-79	29	39,700	18,100	40,600
Hopper Creek near Piru [g]	23.0	1,640	71.3	---	24	3,480	1,590	------
Sespe Creek near Wheeler Springs	50	2,550	51.0	---	8	3,460	------	------
Sespe Creek near Fillmore	254	29,600	117	-58	29	70,660	39,800	70,980
Santa Paula Creek near Santa Paula	39.8	5,260	132	-60	29	13,320	6,950	13,330
Ventura River basin:								
Matilija Creek above reservoir, near Matilija Hot Springs	51	7,940	156	---	8	9,630	------	------
Matilija Creek at Matilija Hot Springs	55	6,600	120	-68	29	20,910	10,000	20,910
North Fork Matilija Creek at Matilija Hot Springs [g]	15.5	2,500	161	-57	27	6,150	2,970	5,860
San Antonio Creek at Casitas Springs [g]	------	1,150	------	---	7	2,440	------	------
Coyote Creek near Ventura	41.1	6,180	150	-28	28	8,980	3,550	8,620
Ventura River near Ventura	187	15,040	80.4	-68	29	47,470	23,750	46,590
Carpinteria Creek basin:								
Carpinteria Creek near Carpinteria	13.8	357	25.9	---	15	1,070	290	------
Atascadero Creek basin:								
Atascadero Creek near Goleta	18.3	2,640	144	---	15	1,520	580	------
San Jose Creek basin:								
San Jose Creek near Goleta	5.54	2,230	392	---	15	992	580	------

Table 4.—Annual runoff for the water year 1955-56—Continued

Basin and stream	Drainage area (square miles)	1955-56 annual runoff: Acre-feet	1955-56 annual runoff: Acre-feet per square mile	1955-56 annual runoff: Departure from base mean (percent)	Period of record: Length (years)	Period of record: Mean annual runoff (acre-feet)	Period of record: Median annual runoff (acre-feet)	Base mean: Mean annual runoff 1920-55 (acre-feet)
Santa Ynez River basin:								
Santa Ynez River at Jameson Lake, near Montecito[h]	13.8	752	54.5	-80	25	4,320	2,010	3,840
Santa Ynez River above Gibraltar Dam, near Santa Barbara[i]	216	12,654	58.6	-59	36	30,040	11,500	30,540
Santa Ynez River below Gibraltar Dam, near Santa Barbara[i]	216	3,480	16.1	---	36	25,850	7,960	------
Santa Ynez River below Los Laureles Canyon, near Santa Ynez	277	9,780	35.3	---	9	17,380	------	------
Santa Cruz Creek near Santa Ynez	73.8	9,410	128	---	14	7,380	5,430	------
Cachuma Creek near Santa Ynez	20.5	1,750	85.4	---	6	2,220	------	------
Santa Ynez River near Santa Ynez	435	1,900	4.37	---	26	63,400	14,500	------
Santa Agueda Creek near Santa Ynez	56.4	1,200	21.3	---	15	1,680	720	------
Zanja Cota near Santa Ynez	--------	1,380	------	---	2	------	------	------
Santa Ynez River at Grand Avenue, near Santa Ynez	--------	4,760	------	---	2	------	------	------
Santa Ynez River at Solvang	579	12,140	21.0	---	18	31,220	9,920	------
Santa Ynez River at Buellton	--------	15,820	------	---	2	------	------	------
La Zaca Creek at Buellton	39.5	76	1.92	---	15	188	22	------
Santa Ynez River near Buellton	668	16,620	24.9	---	4	------	------	------
Santa Ynez River at Santa Rosa Damsite, near Buellton	--------	16,930	------	---	2	------	------	------
Santa Ynez River at Cooper's Reef, near Lompoc	--------	15,710	------	---	2	------	------	------
Santa Ynez River below Santa Rita Creek, near Lompoc	--------	16,940	------	---	2	------	------	------
Salsipuedes Creek near Lompoc	47.0	15,610	332	---	15	5,300	2,170	------
Santa Ynez River at narrows, near Lompoc	790	28,760	36.4	---	4	------	------	------
Santa Ynez River near Lompoc	790	28,860	36.5	---	31	85,950	30,900	------
Santa Ynez River at H Street, near Lompoc	816	26,700	32.7	---	9	------	------	------
Santa Ynez River at 13th Street, near Lompoc	--------	23,670	------	---	2	------	------	------
Santa Ynez River at barrier, near Surf	895	27,310	------	---	9	------	------	------
San Antonio Creek basin:								
San Antonio Creek near Casmalia	--------	3,970	------	---	1	------	------	------
Santa Maria River basin:								
Cuyama River near Ventucopa	90	2,630	29.2	---	11	3,850	2,750	------
Cuyama River near Santa Maria	912	3,730	4.09	-73	26	14,770	7,240	13,970
Alamo Creek near Santa Maria	87.7	3,330	38.0	---	13	3,210	1,520	------
Huasna River near Santa Maria	119	10,430	87.6	-17	26	13,830	5,600	12,540
Sisquoc River near Sisquoc	290	14,060	48.5	---	13	17,190	11,200	------
La Brea Creek near Sisquoc	86.7	2,070	23.9	---	13	2,820	580	------
Tepusquet Creek near Sisquoc	28.9	1,160	40.1	---	13	760	430	------
Sisquoc River near Garey	442	8,360	18.9	---	15	16,430	6,660	------
Santa Maria River at Guadalupe	1,763	4,200	2.38	---	15	14,120	2,100	------
Arroyo Grande basin:								
Arroyo Grande at Arroyo Grande	106	17,320	163	+16	16	16,100	8,690	14,940
THE GREAT BASIN								
Salton Sea basin:								
Whitewater River at Whitewater	57.4	5,320	92.7	---	7	5,320	------	------
Tahquitz Creek near Palm Springs	--------	538	------	---	9	1,770	------	------
Palm Canyon Creek near Palm Springs	94.0	.2	0	-100	21	3,490	940	4,390
Andreas Creek near Palm Springs	8.78	946	108	---	8	1,450	------	------
Coyote Creek near Borrego Springs	--------	1,580	------	---	6	1,930	------	------
Palm Canyon Creek near Borrego Springs	21.7	267	12.3	---	6	391	------	------
Mojave River basin:								
Deep Creek near Hesperia	137	16,980	124	-62	43	55,110	41,700	44,270
West Fork Mojave River near Hesperia	74.8	2,120	28.3	-91	44	31,650	20,300	24,510
Mojave River at lower narrows, near Victorville	530	21,740	41.0	-63	31	56,580	33,400	58,270
Mojave River at Barstow	--------	0	------	-100	26	21,430	72	25,690
Mojave River at Afton	--------	902	------	---	6	2,110	------	------
Antelope Valley:								
Big Rock Creek near Valyermo	23.0	4,800	209	-60	33	11,090	6,780	12,100
Little Rock Creek near Little Rock[f]	49.0	5,470	112	-59	24	12,670	6,810	13,500

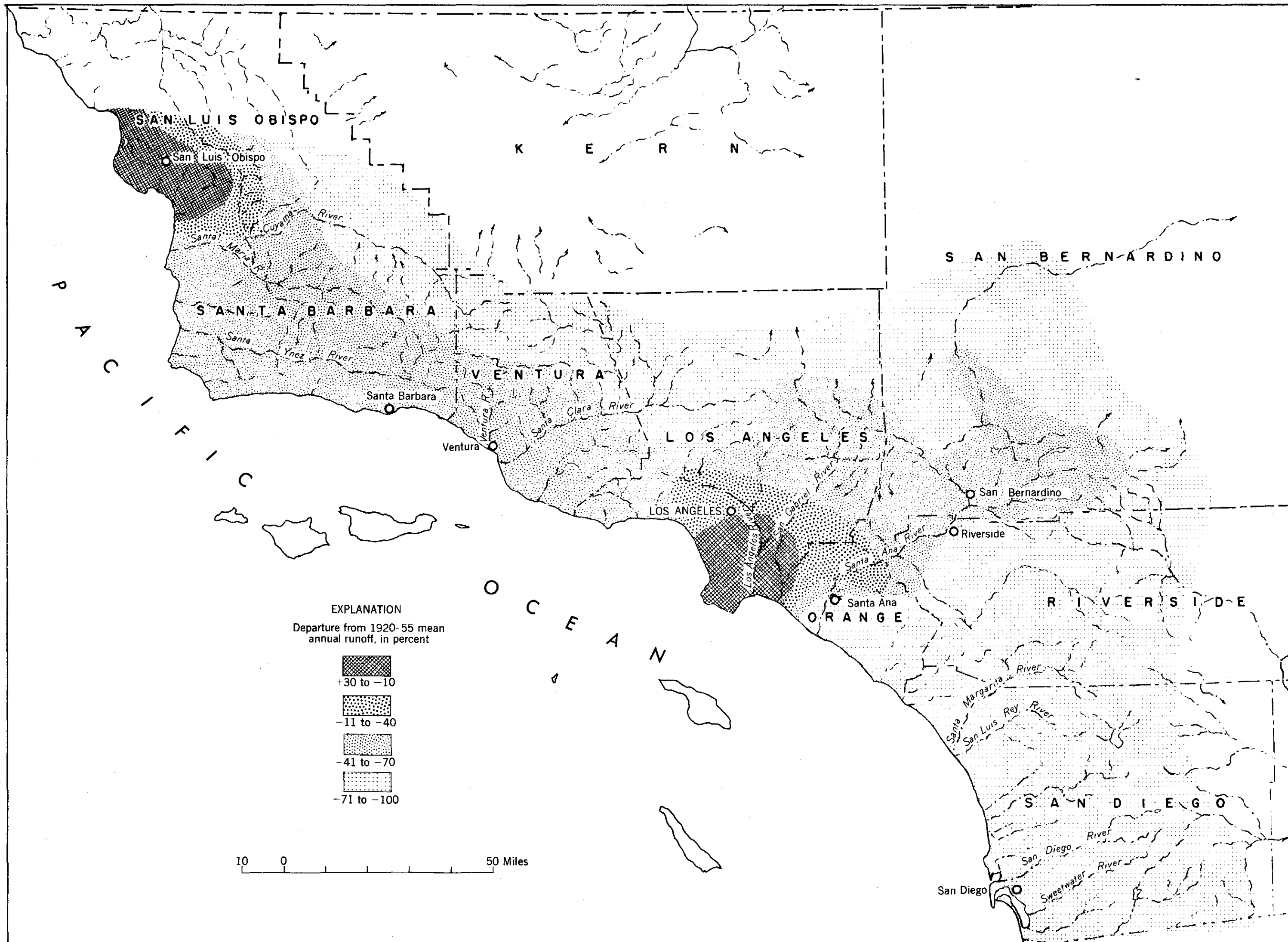

Figure 7.—Areal distribution of annual runoff for the water year 1955–56.

define this distribution were obtained from table 4; the quantities are relative as they express the departure, in percent, of the runoff for the 1956 water year from the mean of the 35-year period 1921–55.

The 1956 water year was a very dry year—the 12th year in a series of dry years—and the annual runoff from many valley streams in the agricultural areas was zero or nearly zero, representing departures as much as 100 percent below the 35-year base mean.

In sharp contrast, and reflecting precipitation on the paved streets and roofs of buildings, annual runoff in many highly urbanized valley-floor areas in or near metropolitan Los Angeles exceeded the base mean by as much as 30 percent. Departures of this magnitude are (fig. 7) quite comparable to the departures experienced in the relatively natural areas at the extreme northern end of coastal southern California.

Unit runoff

Unit rates of runoff generally decrease rapidly as the streams cross the valley-floor areas and discharge into the ocean. In the predominantly agricultural areas, the 1956 runoff into the ocean was zero from the basins of the Tia Juana, San Luis Rey, and Santa Margarita Rivers. In contrast, the highly urbanized areas tributary to the Los Angeles River discharged into the ocean the equivalent of 118 acre-feet per square mile, or 2.2 inches, over the basin. The street drainage in the Beverly Hills and Hollywood areas produced a 1956 runoff of 390 acre-feet per square mile, or 7.3 inches, over the Ballona Creek basin.

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