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SOME ASPECTS OF THE WATER SUPPLY IN THE SOUTH COASTAL BASIN, CALIFORNIA

By

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Introduction

The South Coastal Basin is drained by the San Gabriel, Santa Ana, and Los Angeles Rivers. The area encompasses the San Fernando Valley, the San Gabriel Valley, the San Bernardino (or upper Santa Ana) Valley, the San Jacinto Valley, and the Coastal Plain. Figure 1 shows an outline map of this area, in which the mountain and foothill areas are segregated from the alluvial valley floor area. The metropolitan and urban communities, as well as the agricultural areas of this basin, are entirely dependent upon the water supply originating in this 4, 550 square mile area, except for the importations of water through the Owens Valley and Colorado River aqueducts. This report is preliminary and is subject to revision.

Precipitation in Mountain and Foothill Areas Tributary to Valley Floor

The foothill and mountain areas, as much as 10, 000 feet in altitude in northern and eastern parts of the basin, represent barriers to the incoming moisture-laden maritime air. The lifting of this moist air results in considerable precipitation over the higher mountain areas, amounting to as much as a mean annual precipitation of 40 to 60 inches locally. However, the average annual precipitation is reduced to about 24 inches when the entire foothill and mountain area of 2, 410 square miles is considered. During the 28-year period of 1920-48 this basin-wide mountain and foothill precipitation has ranged from about 38 inches during the 1940-41 climatic (July 1 to June 30) year to about 13 inches during 1927-28. This variability of precipitation is of considerable significance in that it has a major influence on runoff and recharge of the ground-water bodies.

The basin-wide annual precipitation and runoff for the South Coastal Basin is shown graphically in terms of acre-feet on figure 2 for the period of 1920-48. The upper part of this figure giving the total precipitation in the mountain and foothill areas tributary to the valley floor indicates that the mean annual precipitation amounts to 3, 100, 000 acre-feet or about 24 inches over the entire area, and the median value amounts to 3, 000, 000 acre-feet. However, the precipitation for individual years ranged from 5, 100, 000 acre-feet to 1, 800, 000 acre-feet. Certain cyclic tendencies are

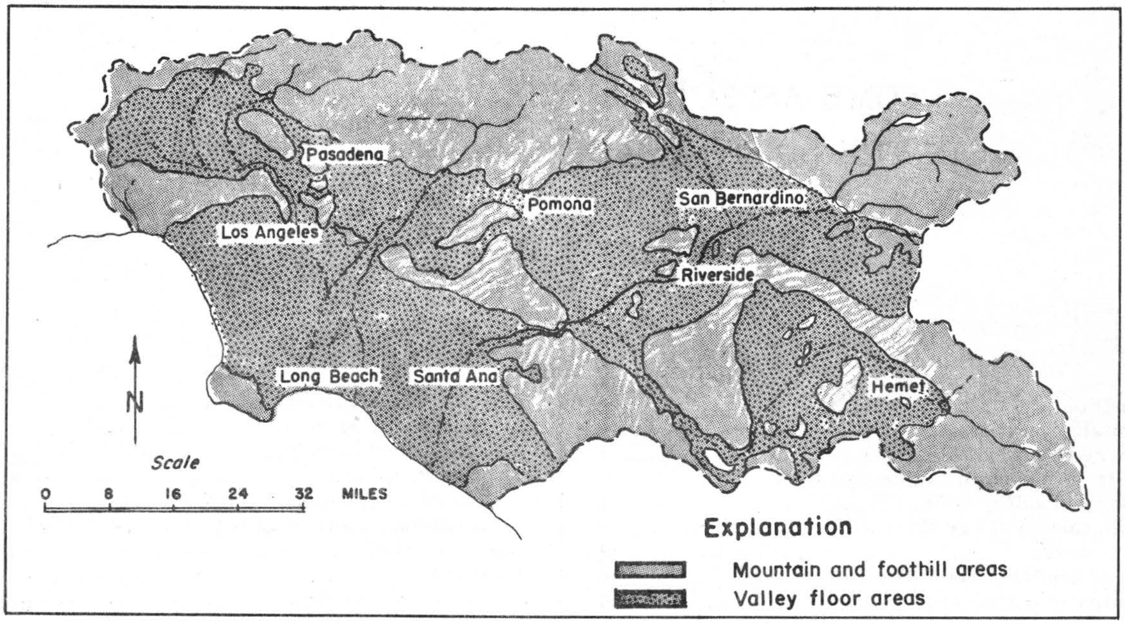

Figure 1.--South Coastal Basin (including San Jacinto River Basin).

indicated by extended wet, as well as dry, periods. Not all the years within an extended wet period are above normal, but they greatly predominate. Likewise in an extended dry period not all the years are dry, but they tend to predominate. Within the 28-year period of 1920-48 the driest 10-year period was that of 1923-33 when the average annual mountain and foothill precipitation amounted to 2,600,000 acre-feet or 84 percent of the mean value for the 28-year period. In contrast, the wettest 10-year period of 1936-46 produced an average precipitation of 3,600,000 acre-feet or 116 percent of the 28-year value.

Runoff From Mountain and Foothill Areas Tributary to Valley Floor

Of the precipitation in the mountain and foothill areas, that portion reaching the land surface at rates of rainfall in excess of rates of infiltration tends to produce surface overland flow, or, basically, the flood runoff. However, in southern California major portions of the precipitation generally occur at lesser rates of rainfall, enter the soil mantle, and satisfy the soil moisture deficiencies resulting from the preceding season's evapotranspiration losses. After satisfying this soil moisture deficiency, the residual recharges the mountain ground-water bodies, from which water seeps into the stream channel to appear as surface flow. As a result the mean annual precipitation of 3,100,000 acre-feet produces only about 500,000 acre-feet of runoff, which includes both surface flood runoff and the more stabilized ground-water seepage. This runoff amounts to 3.9 inches over the entire mountain and foothill areas, or 16 percent of the precipitation. The natural water loss therefore is indicated to be 20.1 inches annually. A part of this may be considered as the cost in water of maintaining the native vegetation, which serves to retard erosion of the relatively steep slopes. Although the loss seems large, actual experience has shown that only a small amount of this water could be salvaged by removal of the vegetation, at the expense of accelerated erosion.

The distribution of the annual runoff from the mountain and foothill areas is shown graphically as the second part of figure 2. Because of its method of origin, the annual runoff shows even greater variability than the precipitation. While the mean annual runoff amounted to 500,000 acre-feet, the annual runoff has been less than this amount in 71 percent of the years. In fact, 47 percent of the entire runoff for the 28-year period occurred in the five wet or flood years of 1921-22, 1936-37, 1937-38, 1940-41, and 1942-43, a condition typical of most semiarid areas. Because of the unusually high discharges occurring during these years, and the lack of suitable surface reservoir storage facilities, a sizable portion of this runoff wasted into the ocean. Under these conditions of extreme variability, the median runoff of 370,000 acre-feet (by definition -- half the years have a greater runoff and half the years have a lesser runoff) is by far a better estimate of the normal runoff. During the driest 10-year period of this relatively short record, the mean annual runoff amounted to 280,000 acre-feet, while the wettest 10-year period had a mean annual runoff of 740,000 acre-feet or 2.6 times greater.

Precipitation on Valley Floor

In addition to runoff from the mountain areas, the valley floor receives about 1,800,000 acre-feet annually in the form of precipitation as shown in the third part of figure 2. This represents an annual valley-floor precipitation of about 16 inches. Because of the flatter ground surface and the generally high rates of infiltration of the soil mantle, very little of this water results in flood runoff. However, as the area becomes more urbanized a portion of this precipitation finds its way

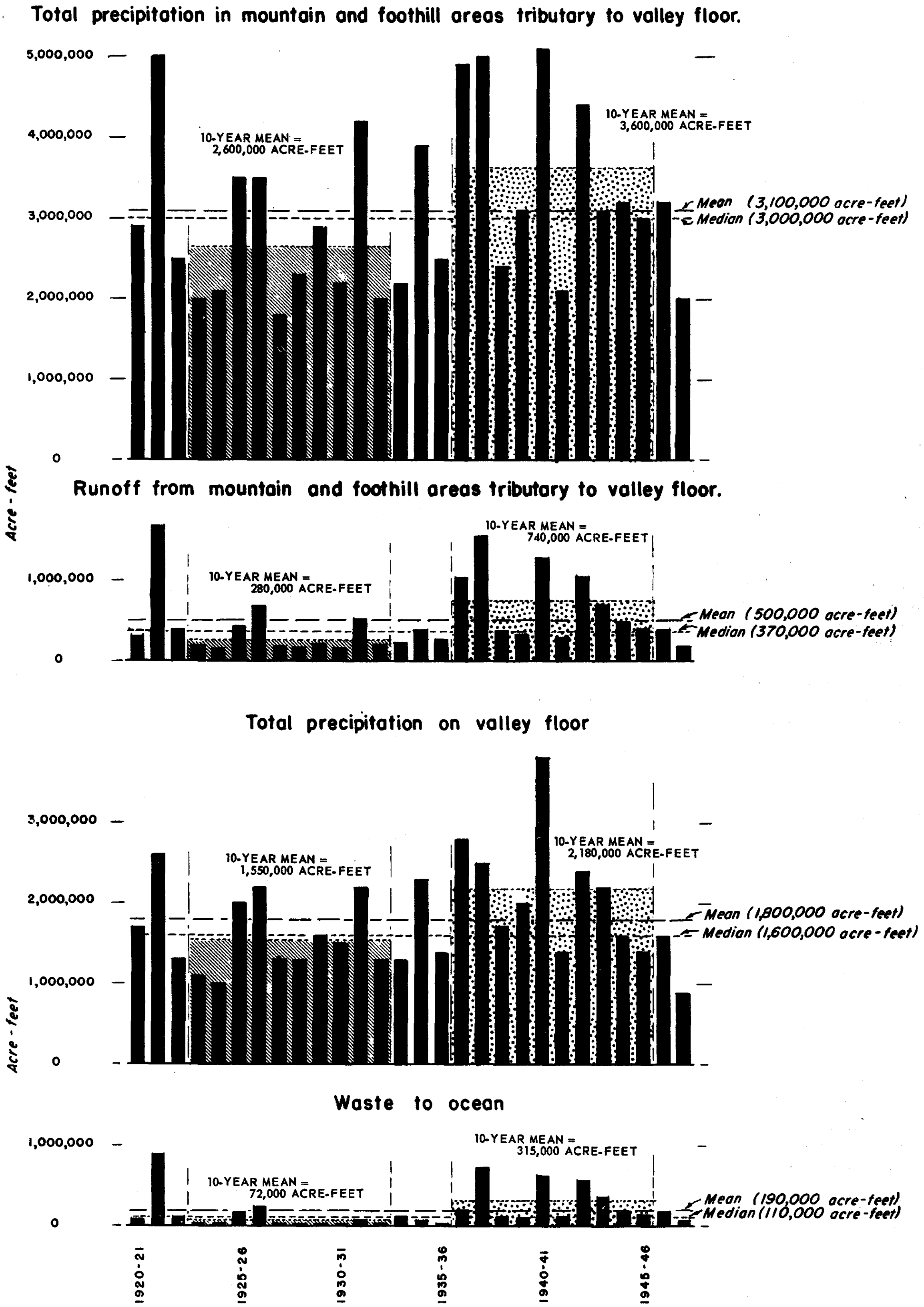

Figure 2. --Precipitation and runoff in the South Coastal Basin, Calif. (including the San Jacinto River Basin).

to the stream channels as a result of street drainage. The disposition of valley precipitation which does not run-off is first to satisfy soil-moisture deficiencies and for the remainder to penetrate the ground-water zone.

The diagrams on figure 2 indicate that the median annual precipitation amounts to 1,600,000 acre-feet or about 89 percent of the mean. During the driest 10-year period of 1923-33 the mean annual precipitation amounted to 1,550,000 acre-feet, while during the wettest 10-year period of 1936-46 the precipitation amounted to 2,180,000 acre-feet.

Waste to Ocean

Of the 1,800,000 acre-feet of precipitation falling annually on the valley-floor areas and the 500,000 acre-feet of the annual runoff reaching the valley floor from the mountain and foothill areas, only 190,000 acre-feet or 8 percent wastes to the ocean. In this instance the four wet years, 1921-22, 1937-38, 1940-41, and 1942-43 produced 52 percent of the total runoff wasted to the ocean during this entire 28-year period. The amount of wastage was greatest in 1922 although 1941 was the year of highest precipitation. The influence of this flood runoff on the total waste to the ocean is clearly suggested by the lower diagram on figure 2. Effective conservation of this excessive runoff is extremely difficult because of its infrequent occurrence and the lack of natural storage sites in the steep and rugged mountain areas.

Although the mean annual wastage to the ocean amounts to 190,000 acre-feet, the median value amounts to only 110,000 acre-feet or about 58 percent of the mean. Because of the very irregular distribution of the annual precipitation, the drier 10-year period of 1923-33 wasted annually only 72,000 acre-feet to the ocean while the wet 10-year period of 1936-46 wasted annually 315,000 acre-feet or 4.4 times that for the drier period.

By way of summary: the 24 inches of annual precipitation on 2,410 square miles of mountain and foothill areas and the 16 inches of annual precipitation on the 2,140 square miles of valley lands results in a waste to the ocean of runoff equivalent to 0.8 inch over the entire basin. Consequently the natural water losses of the mountain and foothill areas, together with the use on the valley floor, results in consumption of all but 4 percent of the annual precipitation.

Length of Available Records

In an analysis such as this the investigator is always hampered by the shortness and incompleteness of the records. It was for this reason that it was necessary to confine this analysis to the 28-year period of 1920 to 1948. The shortness of the record, coupled with the extreme variability of the precipitation, mountain runoff, ground-water recharge, and other factors affecting water supply, might have an effect on this report. Consequently there is included figure 3 which gives the annual runoff distribution of some long-term records: namely, the San Gabriel River near Azusa, the Santa Ana River near Mentone, and the Santa Ysabel Creek near Mesa Grande.

During the entire period of record from 1895 to 1948, an interval of 53 years, the mean annual runoff of the San Gabriel River near Azusa amounts to 119,000 acre-feet, which is substantially in agreement with the mean of 117,000 acre-feet for the 28-year period of 1920-48. However, the median for the entire period of record of 93,000 acre-feet is considerably larger than the median of 76,000 acre-feet for the period of 1920-48 and the normal annual runoff for the standardized base period of 1921-45 shown on figure 3. The wettest 10-year period of the entire record was in 1906-16 and produced 7 percent more runoff than the 10-year period of 1936-46, while the driest 10-year period of the entire record, which included the driest three years of record, was in 1895-1905 and had a runoff of materially less than the driest 10-year period within the recent 28-year interval.

Variability of Annual Runoff

As the San Gabriel River is an important source of water supply, the extreme variability of annual runoff, which ranged from 14 percent of normal for the water year of 1898-99 to 577 percent of normal for the water year of 1921-22, is of vital concern to the local water user. This variation in runoff is due to a combination of influences, paramount of which is the general magnitude of the mean annual precipitation and the absorptive and retentive qualities of the mantle rock. In the nearby Santa Ana River, with somewhat less mean annual precipitation, the extremes of annual runoff range from 32 percent of normal in 1898-99 to 462 percent of normal in 1915-16. This relatively greater annual runoff during extremely dry periods and smaller annual runoff during flood years suggest a much more absorptive and retentive mantle rock than that in the San Gabriel River drainage. Although the mean annual precipitation is almost identical to that of the Santa Ana River the annual runoff distribution shown by the Santa Ysabel Creek record exhibits even greater extremes with 13 percent of normal runoff in 1947-48 and 1,019 percent of normal runoff in 1915-16. It is quite evident from the above that only with a sufficient length of record and with a complete understanding of the mountain mantle rock characteristics is it possible to predict or estimate the extreme conditions of flow which could occur in the many mountain and foothill areas tributary to the South Coastal Basin.

Surface Reservoir Storage

Efforts have been made since the first settlement of this area to develop mountain reservoir storage. The first of these structures is believed to be Bear Valley dam completed in 1884 followed by Lake Hemet dam in 1893. These reservoirs were developed by the agricultural groups as conservation measures. It was not until 1920 when the urban areas began to encroach on natural stream courses that the first flood control dam at Devils Gate was built. The following table gives the capacity of the existing reservoirs in the South Coastal Basin.

Reservoir capacity, in acre-feet, in the South Coastal Basin

Period in which built	Flood Control	Conservation	Total
Prior to 1930	7,000	120,000	127,000
1931 to 1950	356,000	76,000	432,000
Total	363,000	196,000	559,000

In the case of multiple-purpose reservoirs it is often extremely difficult to separate the gross storage capacity of a reservoir into flood control and conservation, because most reservoirs are operated on a day-to-day schedule to give the maximum conservation with the minimum risk to possible flood damage. This generally means the assigning of greater and greater portions of the storage to conservation as the threat of floods diminishes with the advancement of the rainy season.

As indicated in the above table, the existing storage capacity prior to 1930 was largely intended for water conservation. However, with the great increase in the population and industrial activities during the last 20 years, flood control problems have become acute. As a result the major part of the reservoir capacity developed during these years was for flood control purposes. Because of unfavorable mountain sites, it has been necessary to create this storage capacity largely in the valley floor area, thereby practically eliminating the usefulness of the reservoir for conservation.

At the present time the reservoir capacity allotted to flood control is almost equal to the median annual runoff from the mountain area, although during flood years such as those of 1937-38 this volume would amount to less than 25 percent of the annual runoff. The conservation facilities as furnished by reservoir capacity are of little value for long term carry-over because of the limited amount of capacity and the relatively protracted "dry" periods.

Another problem encountered in management of storage reservoirs is that movement of heavy debris during floods reduces storage capacities. Some of this debris can be removed by sluicing, but some can be removed only by hauling.

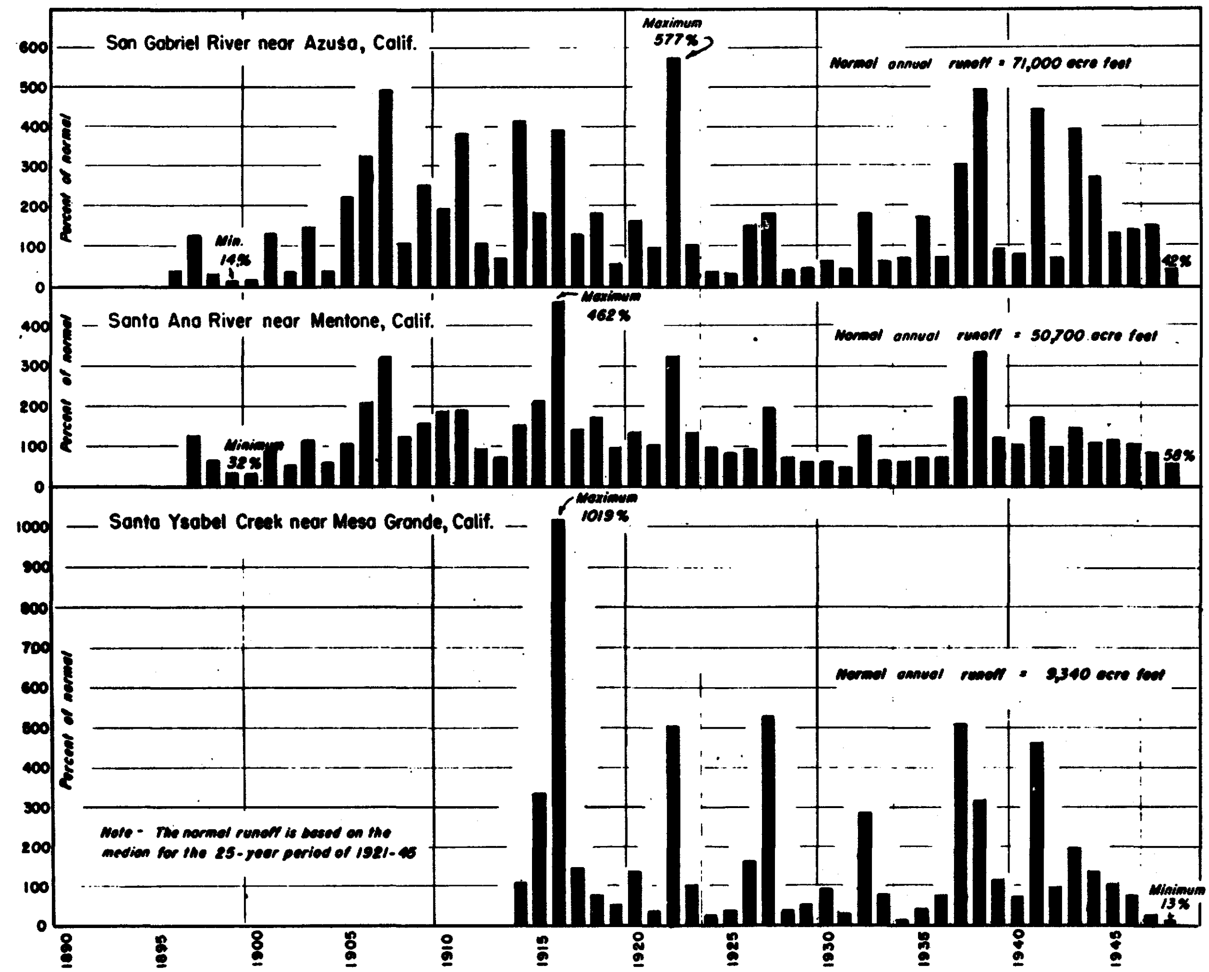

Figure 3. —Seasonal runoff distribution.

Ground-Water Storage

Fortunately for the South Coastal Basin considerable ground-water storage capacity does exist in the deep alluvial-filled valley floor areas, where the depth of aquifers is as much as 3,000 feet or more in certain places. The California Division of Water Resources in Bulletin 45, published by that agency, estimates the ground-water storage capacity for a zone 100 feet thick, 50 feet above and 50 feet below the water table of January 1933, to be 6,860,000 acre-feet. With the inclusion of the San Jacinto River Basin, this storage capacity increases to about 7,500,000 acre-feet. However, the usable storage volume in this tremendous reservoir is limited to that portion which can be dewatered economically and then replenished effectively, either by natural or artificial means. Under present conditions these ground-water bodies are the principal source of the water requirements for the agricultural, industrial and a considerable portion of the municipal and domestic demands of the South Coastal Basin.

As a result of these great extractions the ground-water storage has become depleted locally. In some basins, long-time perennial yields have not been exceeded; in others, however, alarming overdrafts have been developed. These two conditions are best illustrated by fluctuations of the ground-water level at key wells as shown in figure 4. The upper part of this figure shows the altitude of the ground water in the Bunker Hill and San Gabriel ground-water basins, which are two of a group of more than 60 identifiable ground-water basins within the South Coastal Basin. In the Bunker Hill ground-water basin near San Bernardino the water level of less than 1,130 feet above sea level in January 1900 dropped to 1,110 feet in the early spring of 1905; thereafter it rose to an altitude of greater than 1,150 feet in 1916 and 1923. As a result of the dry 10-year period of 1923-33, the ground-water level dropped steadily to a minimum elevation of about 1,095 feet in the fall of 1936. However, during the subsequent wet 10-year period of 1936-46 the level rose to an elevation slightly less than 1,150 feet. Thus the ground-water storage, depleted as a result of an extended dry period, was completely recharged during a subsequent period of above-normal precipitation. The ground-water extractions in this basin are less than the natural recharge and the record of ground-water fluctuation is assumed to be typical of those areas considered not to be overdrawn. The records obtained in the San Gabriel Basin near Azusa are included in this figure as confirmation of ground-water behavior in areas where the extractions are well within the limits of the recharge.

The remaining records of ground-water fluctuation are obtained from key observation wells in ground-water basins showing various degrees of overdraft. The record of ground-water fluctuations beginning in 1904 for the well in the West Coastal Basin located in the vicinity of Gardena and about 5 miles from the ocean shows the progressive depletion of the ground-water storage. From an altitude of about 10 feet above sea level in the fall of 1923 it dropped to 10 feet below sea level in 1933 the end of the dry 10-year period. However, during the subsequent wet period, in which the annual recharge would be at its greatest, the altitude of the ground water shows continual decline so that by the end of the wet 10-year period in 1946 the ground-water altitude was about 20 feet below sea level. It must be assumed that during this period the pumping demand not only used all the accelerated annual recharge, but continued to draw on hold-over storage.

The records for the remaining wells show the same typical pattern found in areas where the pumping draft exceeds the natural recharge. The overdraft in the South Coastal Basin is believed to be on the order of 100,000 acre-feet annually.

This depletion of ground-water storage becomes extremely serious in those ground-water basins adjacent to the ocean. In the West Coastal Basin, an area of 175 square miles along the coast between Redondo Beach and Santa Monica and inland to Beverly Hills and Inglewood, the ground-water level in the main water-bearing deposits in November 1945 was below sea level in at least 75 percent of the area, was 20 feet below sea level in at least half the area, and 50 feet below in nearly 10 percent of the area. Since that time the average water levels have been drawn down several feet more. This condition fosters sea-water encroachment, and as has been pointed out by Poland and others (1948)1/ this condition has actually existed for more than 20 years in this area. Sea-water encroachment has also occurred or is occurring in parts of the coastal plain in Orange County.

Ground-Water Recharge

The ground-water reservoirs of the valley-floor areas are recharged mainly by deep penetration of the precipitation falling on the valley floor, by absorption of surface runoff in the natural stream channels and by artificial means, such as water spreading. It is quite obvious from figure 4 that in many parts of the South Coastal Basin the present rate of extraction exceeds the combined rate of recharge from all three of these sources.

Deep Penetration

Deep penetration is first influenced by the land slope and permeability of the surface soil mantle. Highly permeable soils having moderate land slopes are generally conducive to minimum flood runoff and maximum absorption of the storm precipitation. However, soils of low permeability will produce the reverse effect with a greatly reduced opportunity for deep penetration. After moisture enters the soil mantle it must first satisfy the existing soil moisture deficiencies. In the fall just prior to the winter precipitation period these deficiencies may be as great as 18 inches in the chaparral or native brush-covered areas and as little as 3 inches in the frequently irrigated citrus areas. Because of the many phases or influences affecting deep penetration, its evaluation is always quite complex. However, Muckel (Muckel and Aronovici, 1948) did estimate the deep penetration centered around the towns of Chino and Ontario in the Chino Basin and in an integral part of the South Coastal Basin. He found the average annual deep penetration over this 237-square-mile valley-floor area to amount to about 4.5 inches or about 240 acre-feet per square mile. However, in the wet year 1940-41, Muckel found that the deep penetration amounted to 3.8 times the average value or over 900 acre-feet per square mile of area. In fact the recharge for this single season ac-

1 See selected references, p.

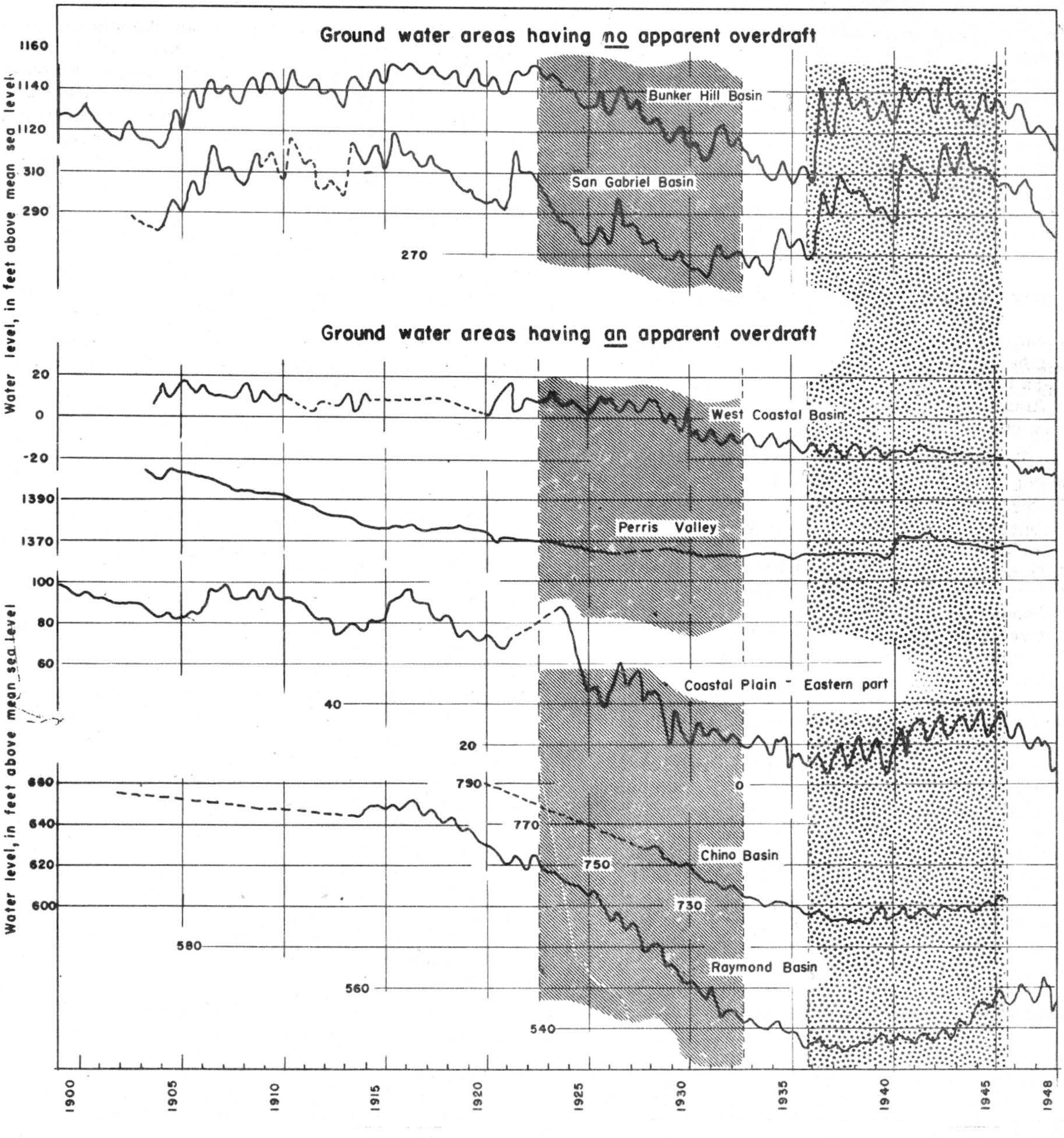

Figure 4. --Fluctuation of ground-water level at key wells in the South Coastal Basin.

counted for 19 percent of the total recharge by deep penetration for the period of 1927-47 (the period of the Muckel Investigations), with the four wettest years of 1936-37, 1937-38, 1940-41, and 1942-43 producing about 59 percent of the total recharge from this source. This distribution in regard to time is believed to be typical of that occurring over the entire area.

It cannot, however, be safely assumed that all parts of the South Coastal Basin received a recharge of a magnitude similar to that for Chino ground-water basin. As already indicated this type of recharge is dependent upon the precipitation, topography, soil type, type of culture, geology, and many other features of a less-controlling nature.

Natural Absorption of Surface Runoff

The natural absorption of the surface runoff along the bottom of the stream channels represents an important contribution to valley floor ground-water recharge. Of course, substantial absorption occurs only when the altitude of the water table is well below that of the stream-bed. However, this condition exists in many of the valley areas of the South Central Basin and conditions for recharge are very favorable.

The large recharge from this source during flood periods is often surprising to many observers. During the month of March 1938 when most of the streams were in extreme flood the runoff absorption in the valley floor areas amounted to 400,000 acre-feet or slightly more than 40 percent of the flood waters discharging into the area from the many streams in the tributary mountains and foothills. An equally large portion of the extreme flood runoff for shorter intervals of time such as the maximum day is often absorbed over large sections of the valley floor. During such wet 10-year periods as 1936-46 at least 425,000 acre-feet was absorbed annually into valley-floor ground-water storage or diverted for irrigation.

Artificial Means of Ground-Water Recharge

The means of recharge generally known as water spreading has been practiced for many years in parts of southern California. The oldest organized spreading operation for which factual data are available is that on the cone of the Santa Ana River east of San Bernardino. Records of spreading at this location are continuous since 1912; annual amounts of spread range from 68,000 acre-feet in 1921-22 to none in the dry years of 1924-25, 1928-29, 1930-31, and 1932-33. In more recent years this has been augmented by spreading in other parts of the Santa Ana River Basin as well as in other portions of the South Coastal Basin. The annual distribution of this spreading by organized groups is shown on figure 5 for the Santa Ana and San Gabriel River Basins.

In the Santa Ana River Basin this annual spreading has a mean value of 15,200 acre-feet and a median of 10,000 acre-feet. Of the total amount of the water spread since 1912, 17 percent was spread in 1921-22 and together with that spread in four of the other wettest years represents 41 percent of all the water spread. During the very dry 10-year period of 1923-33, 12,400 acre-feet was spread annually, increasing to 21,300 acre-feet during the wet 10-year period of 1936-46. However, because of certain legal requirements, these upstream spreading operations of the Santa Ana River are greatly restricted under all but extreme flood conditions.

The second part of figure 5 gives the annual distribution of the organized spreading in the San Gabriel River Basin sponsored by the Los Angeles County Flood Control District and its associates. As in the preceding case the major portion of this increment to ground-water recharge occurred during the wetter years. For example, 33 percent of the entire recharge from this source since 1920 occurred in the four years 1936-37, 1937-38, 1940-41, and 1942-43.

It should be fully understood that the above values represent gross spreading, as a sizable portion of those quantities would have been absorbed naturally in the river channels further downstream. While the net contribution to ground-water recharge from this source may not be large, it does show that this means of water conservation is effective.

Local Supply

The gross average annual local supply of this basin, as shown on figure 2, is essentially the precipitation on the alluvial valley-floor areas of 1,800,000 acre-feet, plus the runoff from the mountain and foothill areas tributary to the valley-floor area of 500,000 acre-feet. However, not all of this water is available for the support of the agricultural crops or the demands of the domestic and industrial requirements of the South Coastal Basin. Immediately following and during a storm, there is a considerable loss by evaporation from the interception on the leaves of vegetative cover and from the surface of the soil. This evaporation represents an unrecoverable water loss to the atmosphere estimated by Blaney (1933) to be equivalent to about 0.5 inch per storm and ranging from 3 to 8 inches per year dependent on the wetness of the year. The average annual evaporation from precipitation at the land surface is roughly calculated to be on the order of 500,000 acre-feet. In addition to this unrecoverable loss, mean annual waste to the ocean is 190,000 acre-feet. The following table gives the estimated total recoverable water supply.

Estimated total recoverable and available local annual water supply, in acre-feet, of the South Coastal Basin

	Mean 1920-48	Median 1920-48	10-year Mean 1923-33	10-year Mean 1936-46
Mountain and foothill runoff a/	500,000	370,000	280,000	740,000
Precipitation on the valley floor a/	1,800,000	1,600,000	1,550,000	2,180,000
Unrecoverable water losses of 4 inches over valley floor area b/	-500,000	-500,000	-500,000	-500,000
Waste to ocean b/	-190,000	-110,000	-72,000	-315,000
Change in ground-water storage	0	0	0	0
Total recoverable water supply b/	1,600,000	1,400,000	1,300,000	2,100,000
Soil mosture available only to vegetative cover b/	-900,000	-900,000	-900,000	-900,000
Available surface and ground-water supply a/	700,000	500,000	400,000	1,200,000

a Reasonably accurate
b Rough approximation only

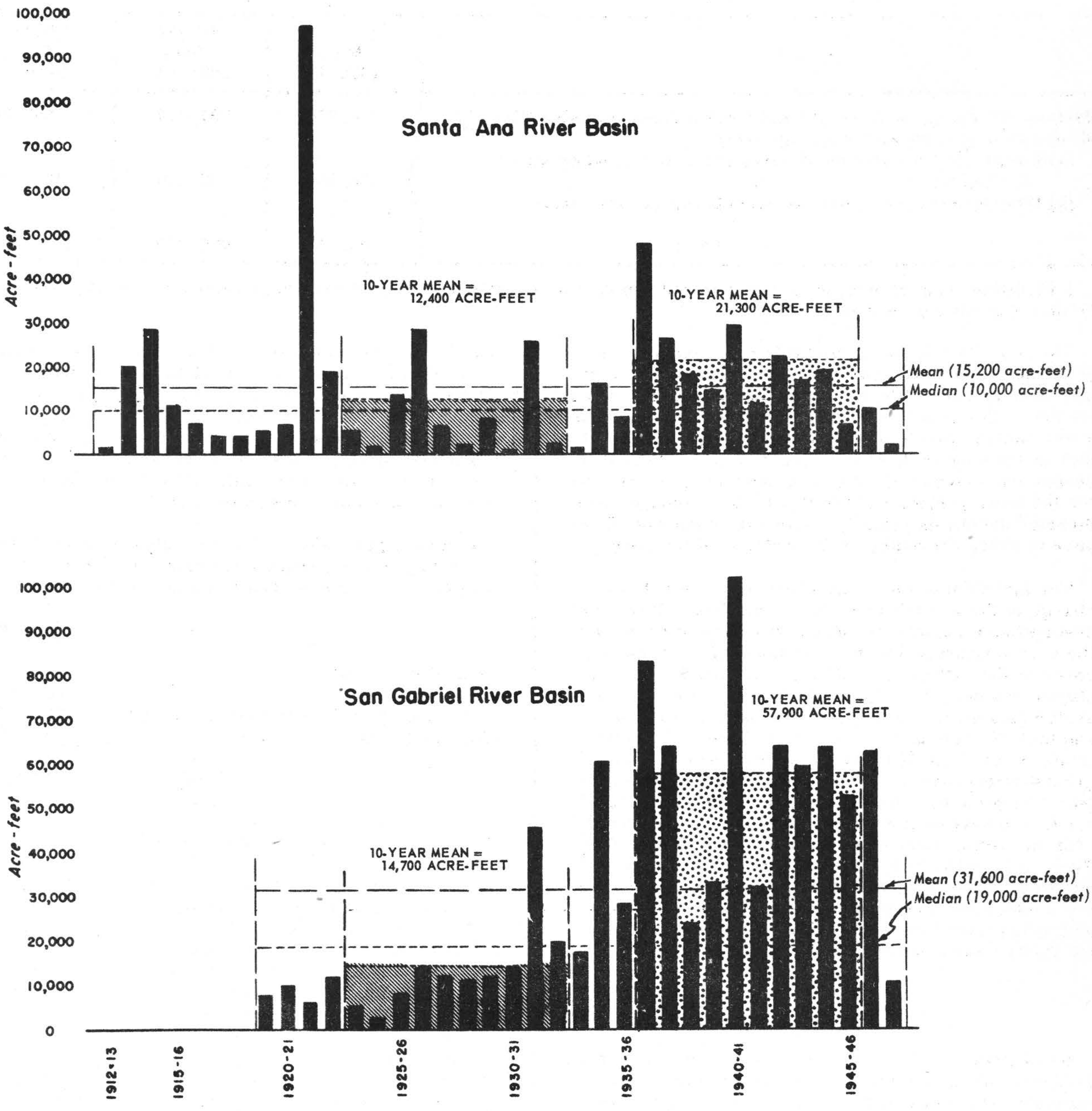

Figure 5. —Annual water spreading in the South Coastal Basin.

However a portion of this recoverable water is in the form of soil moisture available only to vegetative cover. This soil moisture represents a first claim against the recoverable water, as it is first necessary for the precipitation to satisfy the existing soil-moisture deficiencies developed by transpiration from native or agricultural crops during the preceding growing season before recharge to the ground-water reservoir occurs by deep penetration. These deficiencies, ranging from about 3 inches in the shallow-rooted citrus grove to 18 inches in the deep-rooted native chaparral, are estimated to be about 900,000 acre-feet or almost 8 inches over the valley-floor area. Furthermore, these deficiencies should remain fairly constant from year to year, as long as there is little change in type of land use. As shown by the table, the available mean annual supply of surface and ground water is estimated to be 700,000 acre-feet. This supply can be increased only to the extent that the average waste to the ocean (190,000 acre-feet) can be reduced by additional conservation structures.

The following table shows the present source of the surface- and ground-water supply available to the South Coastal Basin for the mean period of 1920-48, as well as for the dry 10-year period of 1923-33 and the wet 10-year period of 1936-46.

Estimated sources of the available surface- and ground-water supply, in acre-feet

Source	Mean 1920-48	10-year Mean 1923-33	10-year Mean 1936-46
Surface diversions of mountain and foothill runoff to valley floor 1/	200,000	200,000	200,000
Recharge to ground-water storage (net) (a) Stream-bed absorption of surface runoff (including water spreading) (b) Deep penetration of precipitation below the root zone	500,000	200,000	1,000,000
Total	700,000	400,000	1,200,000

1 Probably about 25 percent of the diverted runoff subsequently moves downward to ground-water storage from the irrigated areas where it is applied.

The first item in the above table represents the diversions of surface runoff from the mountain and foothill streams for use in the valley-floor areas. In most instances this runoff is seepage from mountain ground-water bodies, which in turn have a very stabilizing effect on the magnitude of this diverted water. For this reason the amounts diverted are assumed to be constant for the mean periods used in this table, although these diverted quantities actually would vary somewhat from year to year, depending on the wetness of the year.

The last item of this table represents the net recharge to the ground-water reservoir from stream bed absorption of surface runoff and deep penetration from the precipitation below the root zones of the vegetative cover in the valley-floor areas. Each phase of this recharge has been developed separately, but is here presented as a single item due to the many uncertainties and lack of reasonable accuracy in these determinations. It will be noted that this annual recharge to ground-water storage ranges from about 200,000 acre-feet during the dry 10-year period of 1923-33 to about 1,000,000 acre-feet during the wet 10-year period of 1936-46 with a mean value of about 500,000 acre-feet. Thus, it is possible to create a considerable apparent overdraft of the ground-water supply during extended dry periods and to replenish storage in the more favorable subsequent wet years. (See fig. 4, hydrographs for Bunker Hill and San Gabriel Basins.)

Demand

As of 1949, the estimated mean annual water demand of plants and man for the entire South Coastal Basin amounted to about 2,100,000 acre-feet. The sources from which this demand was taken are shown as follows:

	Acre-feet
Mean annual total recoverable water supply	1,600,000
Importations by Owens Valley and Colorado River aqueducts	400,000
Overdraft of the valley floor ground-water storage as of 1944-45	100,000
Mean annual demand	2,100,000

The first item, mean annual total recoverable, was derived in the tabulation on page 8. The importations given as the second item are measured by the city of Los Angeles and the Metropolitan Water District of Southern California. The overdraft of the ground-water storage is largely based on the work of Gleason (1947) and Young, Ewing, and Blaney (1941) and relates chiefly to average conditions as of 1944-45.

In a very general way the mean annual demand can be segregated into vegetal demands and those of the municipal, industrial, and domestic needs as indicated:

	Acre-feet
Vegetal demands	
Soil moisture	900,000
Developed surface and ground-water	500,000
Municipal, industrial, domestic	700,000
Total use	2,100,000

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