51-7

UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
Water Resources Division

WATER SUPPLY OF THE SOUTH COASTAL BASIN

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By letter of March 13, 1951, to William E. Wrather, Director U. S. Geological Survey, Mr. J. Richard Queen, Staff Consultant, Committee on Interior and Insular Affairs, House of Representatives, indicated that the South Coastal Basin of southern California has been selected as a "guinea-pig" area to evaluate the results of specialized work carried out by various agencies concerned with water-resources data and development. For purposes of the study, the Committee has asked 24 questions relating to water resources in the South Coastal Basin.

In the following pages, the Geological Survey makes reply to as many of the questions as fall within its field of work.

Introductory Statement

The South Coastal Basin of southern California comprises the mountain-slope, valley, and plain areas between the crests of the San Gabriel and San Bernardino Mountains and the Pacific Ocean. It includes the drainage basins of the Los Angeles, San Gabriel, and Santa Ana Rivers. The valley and plain area consists of four inland valleys --- San Fernando, San Gabriel, Upper Santa Ana, and San Jacinto Valleys --- and the coastal plain. These are all major ground-water basins; their location in relation to other major basins of California is shown on plate 1 (Nos. 19, 20, 21, 22, and 33), and their general geologic setting is shown on plate 2.

The South Coastal Basin as here defined 1/ embraces 4,550 square

_/ As defined by the State Division of Water Resources, the South Coastal Basin does not include the San Jacinto Valley. This must be kept in mind in comparing information in State bulletins with data given here.

miles of which 2,410 is mountain and foothill area and 2,140 is valley land (Troxell and Poland, 1951). The city of Los Angeles and its suburbs occupy about half of the San Fernando and San Gabriel Valleys and the coastal plain, and about all the remainder is developed agricultural land, most of it under irrigation. In the Upper Santa Ana and San Jacinto Valleys about 35 percent of the valley lands is irrigated and about 8 percent is occupied by domestic and industrial area.

Except for the importations from Owens Valley, all of the South Coastal Basin has been supplied with local water until 1941. Since that time, some water has been imported from the Colorado River. As of 1950, the gross local diversions of surface water and pumping of ground water by man were about twice as great as the importation.

Although the South Coastal Basin comprises five major ground-water basins or valleys, these basins are cut up into many sub-basins by faults or bedrock outcrops which act as barriers to ground-water movement. The major faults of the area are shown on plate 2.

The four inland valleys of the South Coastal Basin —— the San Fernando, San Gabriel, Upper Santa Ana, and San Jacinto Valleys —— all contain relatively coarse permeable valley fill in which confining beds are not sufficiently abundant or restrictive, in general, either to prevent free percolation from the stream channels or penetration of water from the land surface. However, each contains several fault barriers which affect the circulation of ground water, and which locally have produced areas of artesian flow. Probably the best known examples are the Bunker Hill dike

(San Jacinto fault) west of San Bernardino and the Raymond fault at the lower edge of the Raymond Basin in the Pasadena area. Both produced artesian flow under the initial conditions of high head.

Each of the inland valleys discharges to the coastal plain through a narrow throat at its lower end. The bedrock constrictions impede water flow and cause the ground water to rise to the land surface where it escapes in the stream channels, later to sink below the surface once again in the intake areas of the coastal plain.

Underflow through the passes to the coastal plain is only a few second-feet at the lower ends of the San Fernando and Upper Santa Ana Valleys but at Whittier Narrows, the pass from the San Gabriel Valley to the coastal plain, it has been estimated as on the order of 32 second-feet.

The coastal plain differs from the inland valleys in that it is chiefly an area of confined water --- that is, circulation from the land surface to the principal ground-water body is not free, except in the relatively small intake areas adjoining the passes from the inland valleys.

Thus, it should be understood that the South Coastal Basin is an area with a complex geologic history which has produced a series of free water-table ground-water basins in the inland valleys and a great confined basin in the coastal plain. Water which sinks freely through the permeable deposits of the inland basins locally is forced to the surface by faults or bedrock barriers and reappears in the streams where it is chiefly diverted for irrigation but in part passes again to the ground-water reservoirs downstream. The natural complexity of water movement within the South Coastal Basin has been greatly increased by the diversions, extractions, and transportation of water by man. There is no clear separation of ground water and surface water; together with soil moisture, however, they constitute the local water supply.

Replies to the 24 Questions

1. How many underground reservoir basins have been identified in the South Coastal Basin? (Prepare a map of this area and identify each basin by number and name.)

In the principal part of the South Coastal Basin (exclusive of the San Jacinto Valley) 50 ground-water basins or sub-basins have been identified and described by the California Division of Water Resources (Eckis, 1934). A print of the State base map showing location, name, and number assigned by the State to these 50 basins (Gleason 1947) is attached to this memorandum (pl. 3).

For the San Jacinto River Basin, which was included with the South Coastal Basin in the recent report by Troxell and Poland (1951), the California Division of Water Resources in a recent investigation has identified two principal ground-water basins, separated by the Casa Loma fault which extends northwesterly near Hemet and separates the main San Jacinto Valley from the Perris-Lakeview-Winchester area to the southwest.

The map of the San Jacinto River Basin attached herewith (pl. 4) is from the mimeographed report by Young, Ewing, and Blaney (1941) entitled "Utilization of the Waters of Beaumont Plains and San Jacinto Basin, California". This map shows six sub-basins rather than the two identified by the State. The San Jacinto sub-basin (1) constitutes the area northeast of the Casa Loma fault; sub-basins 2 to 6 comprise the area to the southwest.

II. Give the characteristics of each basin, i.e., the size (in acres), shape, depth and capacity of the water-bearing formation to store and transmit water.

III. What is your department's estimate in acre-feet of the storage capacity of each identifiable basin? What is your Department's estimate in acre-feet of the total storage capacity for all of the underground basins?

The U. S. Geological Survey made detailed investigations of wells and irrigation systems in the South Coastal Basin in 1903-6 (Mendenhall, 1905a, 1905b, 1905c, 1905d, 1908) and in the San Jacinto Valley in 1904-16 (Waring, 1919). However, these early studies were made prior to the drilling of many of the deeper water wells and information on depth and character of the water-bearing deposits and on the geology was of a reconnaissance nature. No estimates were made at that time of storage capacity of the underground basins.

In the forties the Geological Survey made detailed studies of much of the coastal plain with specific reference to salt-water contamination of the ground-water supplies and the geologic and hydrologic conditions controlling ground-water occurrence (Poland and Piper, 1945; Poland and Sinnott, 1945; Piper and Garrett, 1946; Poland, 1946; Poland, Garrett, and Sinnott, 1948; Garrett, 1949).

The hydrologic characteristics of each of the larger ground-water basins of the South Coastal Basin have been studied by the California Division of Water Resources in the past three decades. Information on and estimates of thickness of water-bearing deposits, specific yield of deposits, and ground-water storage capacity have been presented in State Bulletin 45 (Eckis, 1934). The ground-water storage capacity as estimated in Bulletin 45 is for a zone approximately 100 feet thick, the top of which is 50 feet above and the base 50 feet below the water table of January 1933.

The following table is chiefly a tabulation of pertinent material from Bulletin 45, largely from Table 1, page 121, of that bulletin. However, information on thickness of water-bearing deposits in the coastal-plain area is based on the recent work by the Geological Survey.

For the San Jacinto River Basin, the estimate of storage capacity has been supplied by the California Division of Water Resources based on a current study of the area, and relates to the zone whose top and bottom are respectively 50 feet above and 50 feet below the water table of January 1947. This estimate is preliminary.

It will be noted that the ground-water storage capacity has been estimated for a zone 100 feet thick for the purpose of obtaining an approximation of the usable storage capacity. The usable underground reservoir is the part of the basin that can be dewatered economically by pumping from wells. The part of the basin lying below the depth of economic pumping lift is, in effect, dead storage, and the magnitude of its volume has no bearing on usable storage.

Table 1. Areas, depth of deposits, specific yields, and ground-water storage capacities for 37 ground-water basins of the South Coastal Basin

[Data chiefly from Bulletin 45, California Division of Water Resources, 1934]

Ground-water basin	Surface area (acres)	Thickness of water bearing beds 1/ (feet)	Storage capacity in acre-feet: 50-foot zone above water table	50-foot zone below water table	Total 100-foot zone	Approximate specific yield of 100-foot zone (percent)
San Fernando Valley						
1. San Fernando	96,200	200-500+	405,000	412,000	817,000	9.0
2. Sylmar	6,700	100-500	20,000	24,000	44,000	7.0
3. Tujunga	7,330	150	23,000	20,000	43,000	8.0
4. Pacoima	2,870	100-600	11,000	12,000	23,000	8.0
5. Verdugo	3,840	150-400	8,900	7,600	17,000	5.5
Subtotal	116,940		468,000	476,000	944,000	
San Gabriel Valley						
6. Main San Gabriel	73,400	800-2,000	422,000	419,000	841,000	11.5
7. Monk Hill	4,990	100-1,000	18,000	17,000	35,000	7.5
8. Raymond						
8a. Pasadena	15,000	100-1,200	65,000	62,000	127,000	9.0
8b. Santa Anita	2,900		9,500	9,500	19,000	7.0
9. Upper Canyon	1,260	100-300	6,000	5,100	11,000	11.0
10. Lower Canyon	1,580	100-300	9,200	9,000	18,000	11.5
11. Glendora	2,680	100-750+	10,000	9,300	19,000	8.0
12. Way Hill	1,700	100-300	7,300	4,500	12,000	10.5
13. San Dimas	5,000	100-900	17,000	15,000	32,000	7.5
14. Foothill	1,150	100-200	---	---	---	---
15. Puente	10,900	100-500	29,000	28,000	57,000	6.0
Subtotal	120,560		593,000	578,000	1,171,000	
Upper Santa Ana Valley						
16. Chino	129,500	100-1,500	536,000	583,000	1,119,000	9.0
17. Claremont Hts.	3,220	300-900	9,400	9,000	18,000	6.0
18. Live Oak	1,730	400-700	4,100	4,000	8,100	5.0
19. Pomona	5,540	700-1,100	16,000	17,000	33,000	6.5
20. Cucamonga	7,940	500-1,500	27,000	27,000	54,000	7.0
21. Rialto-Colton						
21a. Rialto	14,420	750-1,500+	60,000	60,000	120,000	8.5
21b. Colton	8,210		50,000	43,000	93,000	11.5
22. Bunker Hill	50,950	100-1,500+	257,000	243,000	500,000	10.0
23. Lytle	3,940	1,000+	22,000	22,000	44,000	11.0
24. Devil Canyon	6,300	600	26,000	21,000	47,000	7.5
25. Yucaipa-Beaumont						
25a. Yucaipa	13,960	500-1,000	48,000	51,000	99,000	7.0
25b. Beaumont	13,060		29,000	31,000	60,000	5.0

Table 1. — Continued

Ground-water basin	Surface area (acres)	Thickness of water bearing beds 1/ (feet)	Storage capacity in acre-feet: 50-foot zone above water table	50-foot zone below water table	Total 100-foot zone	Approximate specific yield of 100-foot zone (percent)
26. San Timoteo						
26a. North area	15,180	500-1,000	----	48,000	48,000	6.5
27. Riverside	32,160	100-1,000	51,000	156,000	207,000	11.0
28. Arlington	14,180	50-200	14,000	22,000	36,000	9.5
29. Temescal	16,170	100-400	34,000	36,000	70,000	9.0
30. Spadra	4,200	100-550	15,000	11,000	26,000	7.5
Subtotal	340,700		1,198,000	1,384,000	2,582,000	
Coastal Plain						
31. West						
31a. Northern	26,750	100-400	144,000	144,000	288,000	---
31b. Southern	62,070	100-1,200	201,000	201,000	402,000	---
32. Hollywood	9,450	100-700	20,000	18,000	38,000	5.0
33. Central						
33a. Los Angeles River area	31,030	200-1,500	152,000	152,000	304,000	---
33b. San Gabriel River area	24,830	300-3,000	142,000	162,000	304,000	12.0
33c. Santa Ana River area	46,130	300-3,000	261,000	231,000	492,000	11.0
33d. Irvine area	24,940	100-1,500	64,000	62,000	126,000	5.5
34. LaHabra						
Upper zone	21,000	0-1,350	40,000	40,000	80,000	4.5
Lower zone	---		33,000	40,000	73,000	12.0
35. Yorba Linda	11,100	200-700	30,000	27,000	57,000	5.0
Subtotal	257,400		1,087,000	1,077,000	2,164,000	
San Jacinto Valley, Winchester-Perris-Lakeview area	150,000				920,000	
TOTALS	985,600				7,781,000	

1/ Thickness of alluvial water-bearing beds actually ranges from a feather edge to a maximum in about all basins. However, the range given in the table is an attempt to approximate the average depth. The last figure is maximum known or estimated thickness and for most basins the average thickness is approximately one-half the range given.

The total ground-water storage capacity of the 35 larger basins of the South Coastal Basin, plus the San Jacinto River Basin, as estimated for the 100-foot zone of water-level fluctuation, is 7,780,000 acre-feet. Because there are several small basins for which the estimate of storage has not been included, and because the economic range of fluctuation of the water table under present conditions is believed to be somewhat in excess of the 100 feet utilized in the estimate, it is concluded by the Geological Survey that the usable ground-water storage capacity of the South Coastal Basin area as here defined is on the order of 10,000,000 acre-feet.

IV. What is your Department's estimate of the safe annual yield in acre-feet of all the underground reservoirs of this basin?

The average annual recharge to ground water is about 500,000 acre-feet and this is equivalent to the safe yield.

V. For the last 10 years of record give in acre-feet the average annual surplus or overdraft of water for the South Coastal Basin.

During the 10-year period 1940-50, the utilization of local water is estimated as on the order of 860,000 acre-feet a year. This has resulted in an estimated average annual depletion of 200,000 acre-feet of ground-water storage; in terms of the average longtime supply, the average annual overdraft during the 10 years has been 150,000 to 200,000 acre-feet.

VI. Give in acre-feet for this basin an estimate of the average annual water loss due to transpiration from swampy areas overgrown with water-loving vegetation.

A swampy or moist area of 300 square miles or more in the valley floor areas of the South Coastal Basin has during the last 100 years or so been reduced to about 25 square miles in the development of the area. These swampy or moist areas can be segregated into about 7 square miles of tidal swamp land and about 18 square miles of moist area in which the ground-water is only a few feet below the ground surface.

Whatever plant life that might exist in the tidal areas is tolerant to the high saline content of the water. Generally, the losses from these areas are not considered as suitable for salvage.

The remaining 18 square miles of moist areas generally is located along stream channels and is covered with grass and riparian trees. This land, however, is not without economic value as much of it is used for grazing. The largest single block of moist area is along the Santa Ana River just above Prado Flood Control Dam. An investigation in this area by Troxell (1933) for the Geological Survey indicated a loss of 2,700 acre-feet per square mile. On this basis the average annual water loss from the 18 square-mile area of moist land in the South Coastal Basin would be about 50,000 acre-feet.

VII Of the total amount of precipitation on the combined water-shed, what is the best estimate in acre-feet of the amount returned to the atmosphere by (a) evaporation and (b) transpiration?

Most investigators have found it quite impossible to completely segregate on an areal basis the water losses due to evaporation and those due to transpiration. Consequently, the term "evapotranspiration", or the more simple term "water losses", is generally used.

The Geological Survey estimates that as of 1949, about 4,700,000 acre-feet from the basin-wide average annual precipitation of 4,900,000 acre-feet and a 100,000 acre-feet annual overdraft of ground-water supply returns to the atmosphere as water vapor. This loss amounts to 94 percent of the precipitation and ground-water overdrafts as indicated in the following table:

Water losses

Natural water losses		
Mountain and foothill areas	2,600,000acre-feet	
Valley floor areas (includes unirrigated areas)	1,100,000	
		3,700,000 acre-feet
Economic use a/		
Agricultural crops	750,000	
Domestic and industrial	250,000	
		1,000,000
Total water loss (of water originating within the South Coastal Basin)		4,700,000

a/ Based on 1942 crop survey by Gleason (1947) and on 1939 crop survey by Young (1941)

VIII How many pumps are now operated in this basin for the purpose of withdrawing water from the underground by
(a) Individuals for agricultural or domestic use?
(b) Industrial plants?
(c) Municipalities?

The total number of pumps now operated in the area for the purposes listed is not known exactly. However, estimates can be given based on partial coverage or on U. S. Census count.

(a) Individuals or water companies for agricultural use: 4,532 plants in 1940, based on U. S. Census, (Irrigation of Agricultural Lands).

(b) Industrial plants: 250 to 350 pumps (estimate by U. S. Geological Survey).

(c) Municipalities: 520 pumps on municipal wells or water company wells for municipal supply in 1940 (from California Water Supply statistics, Special Bull. No. 63, California Department of Public Health, 1941).

IX. Give an average annual estimate in acre-feet of the water pumped from the various underground reservoirs that is used by
(a) Individuals for agricultural or domestic uses.
(b) Industrial plants.
(c) Municipalities.

It is estimated that in the 10 years 1941-50, the average yearly pumpage of water from all the underground basins for principal uses has been as follows:

(a) Individuals for agricultural or domestic uses: 550,000 to 600,000 acre-feet.

(b) Industrial plants: 100,000 to 150,000 acre-feet.

(c) Municipalities or water companies for municipal use: 200,000 acre-feet.

X. How much useful water in acre-feet furnished by nature not presently utilized can be made available to the inhabitants of this area by proper engineering investments other than aqueducts to import water?

From the earliest pioneer settlement to the present time the local water supply has been developed by a reduction of natural water losses within the South Coastal Basin as well as wastes from the area. The salvage or reclamation of these losses is governed largely by the cost of water obtained from competitive sources. As the value of water increases, projects once believed to be uneconomic may become feasible.

The early pioneers, when first occupying the South Coastal Basin, generally obtained their water supply by diversions from the nearest stream channel. However, as the demand for water became greater, individual diversions were consolidated and moved upstream in an effort to reduce the natural water losses by reducing the size of moist areas along the stream channels. In fact, at the present time, most diversion intakes have been moved well into the mountain area, with the flow being carried in subsurface pipe lines to the point of usage. In addition, infiltration galleries have been developed in the alluvial deposits at the point of diversion to salvage most of the subsurface flow, so that in most instances all the water within the capacity of the diversion leaving the mountain basin is available for direct use in the area of service.

There are, however, many riparian trees and shrubs along the banks of the many mountain streams above the point of diversion. Taylor (1933) found that the riparian plants (alder, bay, maple, sycamore, etc.) along Coldwater Canyon near San Bernardino consumed about 105 acre-feet per 1,000 feet of canyon during the 4-month period of July through October 1932. Typical data such as these are not always applicable to other areas due to differences in altitude and the cross-sectional area of the canyon. Consequently, the amount of water salvageable can be estimated only after detailed investigations. Furthermore, it is doubtful if more than 50 percent of this water could actually be salvaged by removal of the vegetation. Many of the water companies have given this problem considerable thought, but have thus far failed to develop a satisfactory method for salvaging these particular water losses.

In the valley-floor areas salvage operations are generally accomplished by merely lowering the ground-water to a point well below the root zone of the riparian plant life. Above Prado Flood Control Dam on the Santa Ana River, the Orange County Flood Control District has spent almost $500,000 in the last few years in attempting to lower the ground water below the root zones of this plant life, thereby hoping to recover annually about 8,000 acre-feet or more of water now lost through uneconomic natural water losses. Thus far the project has not been developed far enough to know how much can be salvaged.

As indicated by Troxell and Poland (1951) most of the average waste to the ocean of 190,000 acre-feet is not generally considered to be economically salvageable, because of its irregularily in occurrence. However, this waste to the ocean is somewhat reduced by the operation of the Corps of Engineers flood control reservoirs on the lower Santa Ana, San Gabriel and Los Angeles Rivers. Whenever possible, the flood waters are released from the reservoir in such magnitude that much of the flow would be absorbed into the ground-water storage along the river channels before reaching the ocean. The concrete-lined flood control channel ways considered necessary for the protection of life and property are in some instances being designed to include supplemental spreading grounds so that a portion of this flood runoff may be salvaged.

Situated along the coast in the South Coastal Basin are several outfall sewers serving the coastal communities. The largest of these systems is that operated by the city of Los Angeles in which case most of the water originates in the Owens Valley outside of the local area. The same is true of those coastal communities using Colorado River water. The combined wastage from this source in 1949 amounted to about 346,000 acre-feet. This outflow has been considered by Troxell and Poland (1951) as a water loss to the basin and as such was included in the 2,100,000 acre-feet annual water demand of 1949 for the vegetative cover and man.

Means for the economic reclamation of some of this water have been under consideration for some time in this area by such men as the late R. F. Goudey, A. M. Rawn and others. One of the coastal oil refineries now has under consideration a plan to use some of this reclaimed sewage.

XI. Give an average annual estimate in acre-feet of the amount of water consumed by vegetative cover in (a) the mountain and foothill areas tributary to valley floor and (b) valley floor area.

This question differs only slightly from question VII. In this instance that portion of the imported water believed to be consumed by the vegetative cover is included so as to give the total losses for the South Coastal Basin.

The Geological Survey estimates the average amount of water consumed by the vegetative cover to be 2,600,000 acre-feet in the mountain and foothill areas and 2,300,000 acre-feet in the valley floor areas. This is itemized in the following table.

Water losses a/

Natural water losses		
Mountain and foothill areas	2,600,000 acre-feet	
Valley floor areas(including unirrigated areas)	1,100,000	
		3,700,000 acre-feet
Economic use b/		
Agricultural crops	820,000 acre-feet	
Domestic and industrial	340,000	
		1,160,000
Total water losses (including imported waters)		4,860,000

a/ Includes imported waters as of 1949.
b/ Based on 1942 crop survey by Gleason (1947) and 1939 crop survey by Young (1941).

XII. For the last 10 years of record give in acre-feet the average amount of water that has wasted to the ocean.

The waste to the ocean for the 10-year period of 1940-50 amounted to 2,380,000 acre-feet. Fifty percent of this runoff occurred in the two water years of 1941 and 1943. Although the average annual waste to the ocean during the 10-year period was 238,000 acre-feet, seven of the 10 years had an average annual waste of less than 120,000 acre-feet. This wastage to the ocean does not include the flow through the outfall sewer systems.

XIII. Give in acre-feet for the last 10 years of record the average annual mountain and foothill runoff.

The average annual runoff from the mountain and foothill areas for the 10-year period (1940-50) amounted to 499,000 acre-feet.

XIV. According to your records, how much water in acre-feet has been available and utilized on an average annual basis for the last 10 years of record from all surface and ground-water sources?

The Geological Survey estimates the average annual utilized surface and ground-water in the South Coastal Basin to be 860,000 acre-feet for the 10-year period (1940-50), as indicated in the following table. This data does not include the importations from the Owens Valley or Colorado River.

Estimated available annual surface and ground-water supply for the 10-year period 1940-50

Precipitation on the valley floor	1,700,000 acre-feet
Runoff from mountain and foothill areas	500,000
Depletion of ground-water storage	200,000
Unrecoverable water losses on the valley floor	-500,000
Waste to ocean	-240,000
Total recoverable water supply	1,660,000 acre-feet
Soil moisture available only to the vegetative cover	-800,000
Utilized surface and ground-water supply	860,000

XV. Give an estimate in acre-feet of the average annual amount of precipitation that is unrecoverable. Explain.

Unrecoverable water was assumed by Troxell and Poland (1951) to be that portion of the precipitation not available for the use of man or the vegetative cover. In any area where the land surface is covered with vegetation, the amount of precipitation reaching the ground is often very much less than that recorded in a rain gage. Observations obtained in a southern California chaparral forest by the San Dimas Experiment Station (Hamilton 1949) indicate that practically all of the precipitation is lost by evaporation from the leaves of the plant if the storm precipitation amounted to 0.10 inch or less. However, if the storm precipitation were as much as 10 inches, almost 1.0 inch would be lost in this manner. These same investigators found that about 3.1 inches were lost out of an annual precipitation of 27.7 inches by this interception. The residual of 24.6 inches is subject to further reduction by evaporation from the litter or the soil below the vegetative cover. This evaporated moisture never has an opportunity either to runoff over the surface of the ground or enter the root zone in the mantle rock. While this loss is almost impossible of measurement, it is believed to amount to at least one or more inches each year. Consequently, in the mountain areas, the amount of moisture available for surface runoff, soil moisture and deep penetration to ground water storage is likely to be at least 4 or 5 inches less than that measured in a rain gage. This would amount to about 500,000 to 600,000 acre-feet in the mountain and foothill areas.

In the valley floor areas, Blaney (1930) found that after each storm there was a loss by evaporation of .1 to .8 inch. During a year this loss in moisture would range from 3 to 8 inches. Consequently in the valley floor areas, the amount of moisture available for surface runoff, soil moisture and deep penetration would be from 3 to 8 inches less than shown in a rain gage. On an areal basis, this loss has been estimated as 500,000 acre-feet in the valley floor areas.

XVI. Give a brief summary of the results obtained in this basin as a result of your sedimentation surveys and studies.

The Geological Survey is not at this time making sedimentation surveys or studies in this area. However, our interest in the subject is very great. At the present time there is no organized sedimentation work in the South Coastal Basin. Some information on basinwide rates of erosion are available from the Los Angeles County Flood Control District, San Bernardino County Flood Control District, Soil Conservation Service, and others.

Geologically the mountain areas of the South Coastal Basin are young and rugged, consequently subject to considerable erosion. However, this being a semiarid area, the mode of transportation is considerably different than that in the more humid areas. The capacity of the water to transport debris is generally confined to those very large floods which occur at infrequent intervals.

For example, during the March 1938 flood, the mountain flood control reservoirs in Los Angeles County were partly filled with coarse debris. The Los Angeles County Flood Control District estimated this entrapped debris to be equivalent to a depth of 0.1 to 1.4 inches over the entire drainage area as a result of this single storm (Troxell, 1942). A debris load of this magnitude does not move as a suspended load, but rather as a bed load which can be measured only by entrapment in reservoirs or debris basins. However, not all the debris during this storm was entrapped in reservoirs or debris basins. For example, the Corps of Engineers estimated about 6,600,000 cubic yards was deposited in the Los Angeles-Long Beach harbor. (Corps of Engineers, 1938).

The excessive precipitation during the New Year 1934 storm in the mountains tributary to the La Canada Valley of the South Coastal Basin created debris waves of 10 feet or more in height in the valley-floor areas (Troxell, 1939). In moving across the valley, these waves took the lives of 40 persons, demolishing about 400 homes, and causing a property damage in excess of $5,000,000. Over 600,000 cubic yards of debris were deposited in this valley as a result of this storm. (Eaton, 1936).

Debris movements of these types and magnitudes requires analysis entirely different from that practiced by usual sedimentation survey.

XVII. Give an estimation in dollars and cents of the average yearly damage to reservoirs, bottom land and the water yield generally as a result of the sediments derived from various types of erosion.

This question is outside the scope of the Geological Survey's program.

XVIII. What is your Department's estimate of the annual amount of water in acre-feet in this basin that is presently not utilized that could be made available by artificial recharge?

In the opinion of the Geological Survey, only a small part of the water not now utilized could be made available for artificial recharge to ground-water storage.

In an effort to obtain the maximum benefits from the flood runoff, organized groups in nearly every part of the South Coastal Basin are actively engaged in water spreading. Although the net contributions from this source are believed to be small in terms of the total supply (Troxell and Poland, 1951), they represent a substantial part of the longterm overdraft.

It is the belief of many investigators that the only method by which the ground-water supply can be effectively recharged from now existing flood waste is through surface reservoir storage developed in the mountain areas. Unfortunately the mountain canyons are so steep that the available storage above the projected dams has not made the projects feasible. For example, the Santa Ana River Investigation found that it would require a 178-foot dam at the Filirea Reservoir site to store 4,000 acre-feet, it would require a 315-foot dam at the Forks Reservoir site to store 20,000 acre-feet and at the Turk Basin a dam 155 feet high to store 5,000 acre-feet. (Santa Ana River Investigation 1928, p. 62-64). However, were it possible to develop effective storage in the mountains, the flood flows could be released in such regulated volume during and immediately following each storm that a large portion of the flow could be absorbed into the valley-floor ground-water storage. At the present time, the local water users have not considered these projects economically feasible.

The reclamation of sewage now wasting to the ocean has been given considerable thought by many engineers. At the present time the point of recovery is at or near sea level. Thus, in addition to reclamation, the sewage has to be elevated to point of use or to the area of recharge. Competitive waters can be obtained at a cost that has made the development of this supply not economically feasible at the present time for wide distribution and use in the South Coastal Basin.

XIX. For the South Coastal Basin give an estimation per acre-feet of the cost of maintaining an adequate water supply through

(a) Artificial recharge
(b) Importation through the Owen's Valley and Colorado Aqueducts.

This question is entirely outside the scope of the Geological Survey program in the South Coastal Basin.

XI. What is your Department's estimate of the amount of water in acre-feet that could be saved annually from the runoff through stable water ways and the temporary detention of such runoff in small upland storage basins?

The Geological Survey is not in a position to answer this question except in a very general way. It is very doubtful if the now existing flood wastes to the ocean can be reduced economically by more than a few percent.

As indicated elsewhere, the flood runoff is largely confined to a few wet years (Troxell and Poland, 1951). Actually during these wet years, the excessive waste is generally confined to even a shorter time period. For example, the waste to the ocean amounted to 730,000 acre-feet in 1937-38 of which 550,000 acre-feet occurred in the month of March. The storage in the small upland storage basins in terms of this concentrated flood runoff would be very small. For this reason the effectiveness of small upland storage reservoirs may be small in reducing the waste to the ocean.

If stable water ways refer to the concrete-lined flood channels now crossing portions of the South Coastal Basin Valley floor areas, then the answer would be negative. Actually these flood control channels have greatly reduced the opportunity for recharge of the water supply. The stream flow which formerly meandered over the highly absorptive valley fill is now speeded to the ocean in an effort to reduce flood damage. Even if the stabilizing of the stream channels did not contemplate concrete lining, it would still tend to reduce the water supply due to a reduction in the opportunity for stream-bed absorption.

XXI. What is your Department's estimate in acre-feet of the amount of water that is lost by evaporation and transpiration that could be saved by methods more practical and economical than importation?

It is doubtful if appreciable water now lost through evaporation and transpiration could be further salvaged by more practical and economic methods than by importation. As indicated in some of the previous answers, the present water supply was developed by salvaging existing natural water losses and wastes. In most instances, the local water users have already reached the limits of feasible recovery of these losses.

XXII. What is your Department's estimate in acre-feet of the average annual amount of flood waters presently salvaged in the South Coastal Basin by various methods, such as intentionally leaking reservoirs, etc.

In the very broadest sense, flood waters are salvageable by both natural and artificial means. The salvage by natural stream-bed absorption is by far the larger of the two methods. Troxell and Poland (1951) estimated that during the month of March 1938 about 400,000 acre-feet of flood waters were absorbed into the ground-water storage in the valley floor stream channels. The average annual recharge from this source probably exceeds 200,000 acre-feet. Continual encroachment by urban development and the construction of concrete-lined flood control channel tends to reduce the opportunity for stream-bed absorption.

The Geological Survey's estimate of the average annual salvage of the flood runoff in such conservation reservoirs as Bear Valley Lake, Lake Hemet Railroad Canyon Reservoir and Santiago Reservoir amounts to about 30,000 acre-feet or 25 percent of their capacity.

The estimated salvage in the mountain flood control reservoirs built and operated by the Los Angeles County Flood Control District amounts to about 25,000 acre-feet or 30 percent of their present capacity. This salvage is accomplished by a combined flood-control and conservation program of operation.

The flood-control or detention reservoirs built by the Corps of Engineers in the valley-floor areas are primarily flood-control reservoirs. To be effective, these reservoirs must be emptied as quickly as possible after each storm. In order to guarantee this pattern of operation, some of the dams were built with ungated openings. The operation of these reservoirs have the effect of distributing the flow over a longer period of time, thereby enhancing the opportunity for stream-bed absorption. This opportunity for ground-water recharge varies greatly below each reservoir, making an estimation of the salvaged water difficult. In some instances, the flood waters discharge into an area of relatively high ground-water levels, or only short distances above concrete flood-control channels. It is doubtful if the average annual salvage from this source would exceed 5,000 acre-feet.

In addition, Troxell and Poland (1950) indicated that an annual gross recharge of about 46,800 acre-feet of mountain runoff are absorbed into ground-water storage through spreading operations. Because of the engineering difficulties involved and the risks to life and property, very few spreading grounds are operated during the period when flood waters are wasting to the ocean. Consequently, this method of ground-water recharge is not believed to measurably reduce the waste to the ocean during the flood period.

XXIII. What is your Department's estimate in acre-feet of the average annual amount of flood waters that presently waste to the sea?

The Geological Survey believes the average annual waste to the ocean to amount to 190,000 acre-feet (Troxell and Poland, 1951). Most of this runoff occurs as flood runoff.

XXIV. How much of the flood waters (in acre-feet) presently wasted to the ocean could be salvaged by various engineering methods?

It would be difficult, if not impossible, to estimate the amount of additional salvage that could be developed by various engineering methods. However, it is doubtful if an appreciable part of the flood waters now wasting to the ocean could be effectively salvaged.

The most productive possibilities for additional salvage would be in the form of mountain reservoirs. Investigations of these mountain reservoir sites ~~has~~ have indicated that the returns do not justify the expenditures of public funds.

The additional salvage of valley floor flood runoff is largely unfeasible due to the fact that the runoff originates at such low altitude above sea level and the lack of suitable reservoir sites in the highly populated urban areas.

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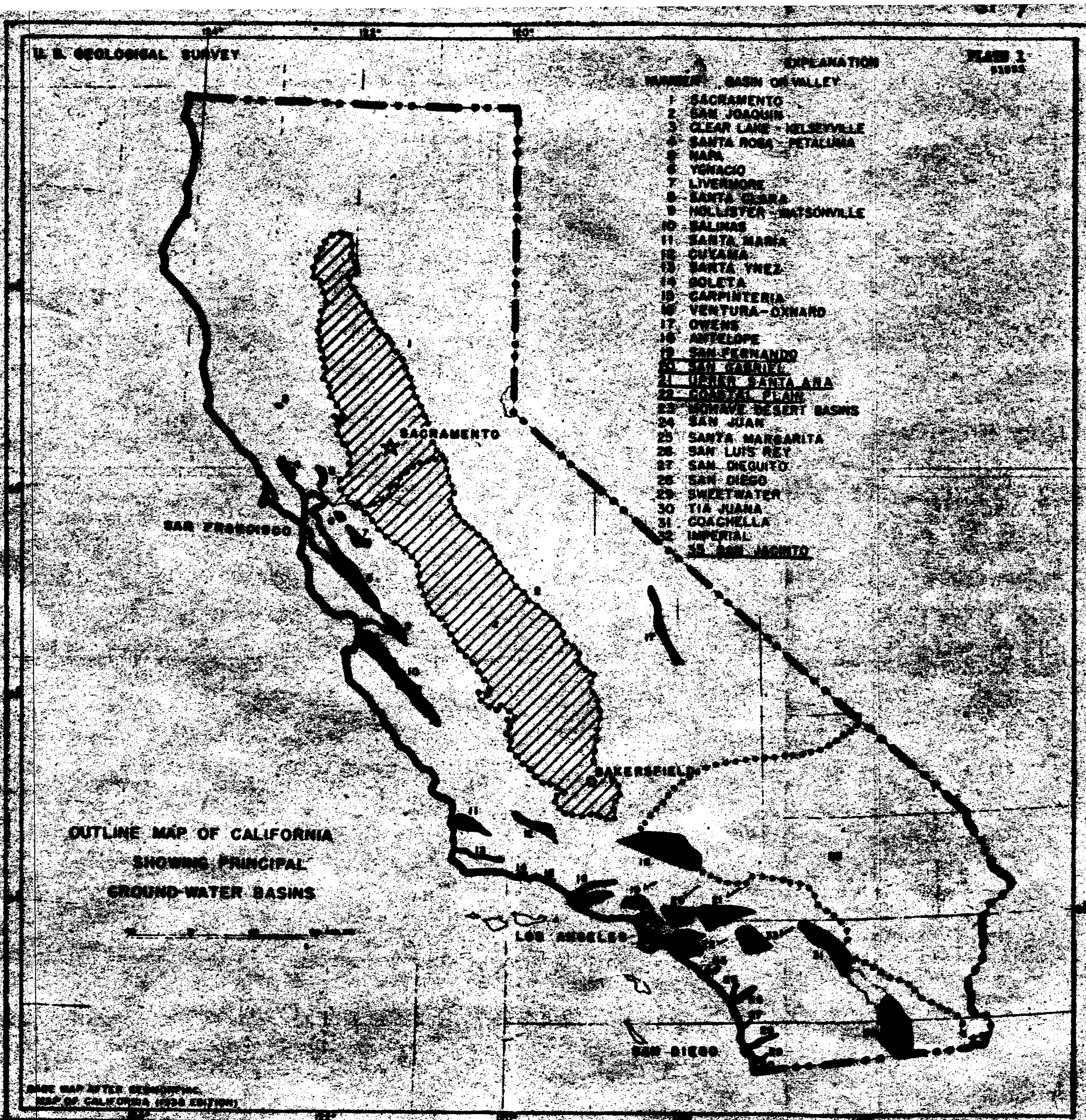

U. S. GEOLOGICAL SURVEY
EXPLANATION
NUMBER BASIN OR VALLEY
1 SACRAMENTO
2 SAN JOAQUIN
3 CLEAR LAKE - KELSEYVILLE
4 SANTA ROSA - PETALUMA
5 NAPA
6 YGNACIO
7 LIVERMORE
8 SANTA CLARA
9 HOLLISTER - WATSONVILLE
10 SALINAS
11 SANTA MARIA
12 CUYAMA
13 SANTA YNEZ
14 GOLETA
15 CARPINTERIA
16 VENTURA-OXNARD
17 OWENS
18 ANTELOPE
19 SAN FERNANDO
20 SAN GABRIEL
21 UPPER SANTA ANA
22 COASTAL PLAIN
23 MOHAVE DESERT BASINS
24 SAN JUAN
25 SANTA MARGARITA
26 SAN LUIS REY
27 SAN DIEGUITO
28 SAN DIEGO
29 SWEETWATER
30 TIA JUANA
31 COACHELLA
32 IMPERIAL
SACRAMENTO
SAN FRANCISCO
BAKERSFIELD
LOS ANGELES
SAN DIEGO
OUTLINE MAP OF CALIFORNIA
SHOWING PRINCIPAL
GROUND-WATER BASINS

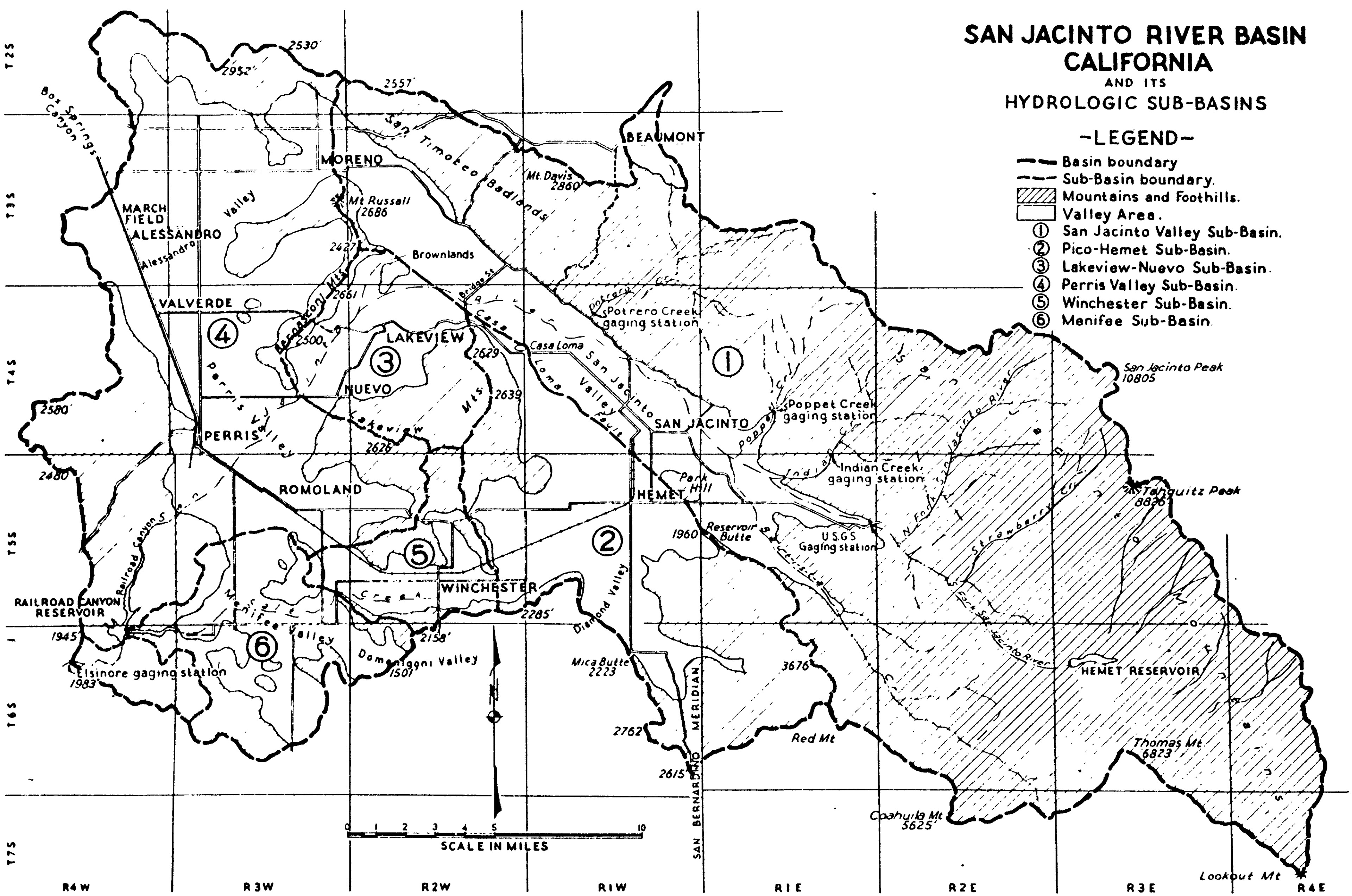

PLATE 4
Figure 8.

From report by Young, Ewing, and Blaney on "Utilization of the waters of Beaumont Plains and San Jacinto Basin, Calif."