
GEOGRAPHICAL DISTRIBUTION
OF
WATER RESOURCES
AND
AGRICULTURAL LANDS
IN
CALIFORNIA
LEGEND
Area of Basin in Per Cent of Area of State
Agricultural Lands in Per Cent of Total of State
Water Resources in Per Cent of Total of State
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
NORTH PACIFIC BASIN
AREA 11.0 %
LAND 1.9 %
WATER 37.6 %
SACRAMENTO BASIN
AREA 16.8 %
LAND 26.8 %
WATER 34.8 %
SAN FRANCISCO BAY BASINS
AREA 2.2 %
LAND 2.6 %
WATER 1.2 %
SAN JOAQUIN BASIN
AREA 20.6 %
LAND 36.3 %
WATER 16.8 %
CENTRAL PACIFIC BASINS
AREA 7.5 %
LAND 4.1 %
WATER 3.1 %
GREAT BASIN
AREA 35.1 %
LAND 18.3 %
WATER 5.1 %
SOUTH PACIFIC BASINS
AREA 6.8 %
LAND 10.0 %
WATER 1.4 %
Eureka
Red Bluff
Chico
Lake Tahoe
Stockton
Modesto
Merced
Fresno
Visalia
Bakersfield
Owens Lake
Needles
Yuma
Scale of Miles
0 20 40 60 80

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

PUBLICATIONS OF THE
DIVISION OF WATER RESOURCES
EDWARD HYATT, State Engineer

Reports on State Water Plan Prepared Pursuant to Chapter 832, Statutes of 1929

BULLETIN No. 29

SAN JOAQUIN RIVER BASIN

1931

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ACKNOWLEDGMENT

In the investigation of the water resources of the San Joaquin River Basin and in the preparation of a plan for their conservation, utilization and distribution, most valuable assistance and cooperation have been received.

Many individuals, irrigation districts and other public and private agencies, mutual water companies and public utilities have furnished data and information which were particularly useful in the preparation of this report.

Active and material aid in many phases of the investigation was received from departments of the Federal Government and the State.

The advice and assistance of the engineers of the Advisory Committee throughout the investigation and preparation of this report have been of inestimable value and their services are especially commended.

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Consulting geologists and engineers rendered reports on special features of the investigation as follows:

Hyde Forbes, Engineer-Geologist, made geologic investigations of dam sites on the Cosumnes, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, San Joaquin, Kings, Kaweah, Tule and Kern rivers and on Dry Creek, a tributary of Mokelumne River; and also made studies of the underground reservoirs and ground water conditions in the San Joaquin Valley. His reports, entitled "Geological Reports on Dam Sites in San Joaquin River Basin," and "Geology and Underground Water Storage Capacity of San Joaquin Valley" are presented in Appendixes C and B, respectively.

Lester S. Ready, Consulting Engineer, rendered a special report on the value of electric energy that would be developed at the Friant power plant and the cost of electric energy that would be required for the operation of the San Joaquin River Pumping System.

S. T. Harding, Consulting Engineer, classified the lands on the San Joaquin Valley floor and rendered a report thereon entitled "Classification of Valley Floor Lands in San Joaquin River Basin," which is presented as Appendix A.

S. K. Love, Chemist, United States Geological Survey, analyzed samples of water of various California streams, including some in San Joaquin River Basin, and rendered a report thereon, entitled "The Chemical Character of Some Surface Waters of California," which is presented as Appendix E.

Harry Barnes, Consulting Engineer, prepared an estimate of the water requirements and rights of certain irrigated areas on the San Joaquin Valley floor. He also collaborated with Mr. Harding in the classification of the lands on the valley floor and submitted valuable data on existing conditions of irrigation development in Madera County.

C. H. Holley, Consulting Engineer, classified a part of the lands in the upper San Joaquin Valley and furnished additional information on existing conditions of irrigation development in Tulare County.

FEDERAL AGENCIES COOPERATING IN INVESTIGATION

WAR DEPARTMENT

THOMAS M. ROBINS, *Lieutenant Colonel, Corps of Engineers, Division Engineer, Pacific Division*

J. R. D. MATHESON, *Major, Corps of Engineers, District Engineer, Sacramento District of Pacific Division*

W. A. WOOD, JR., *Captain, Corps of Engineers*

Under the general direction of Colonel Robins, the general supervision of Major Matheson and the immediate direction of Captain Wood, the War Department carried out an investigation of the water resources of the Sacramento, San Joaquin and Kern rivers with a view to the formulation of general plans for the most effective improvement of navigation and the prosecution of such improvement in combination with the most efficient developments of potential water power and supplies for irrigation, and the control of floods, and rendered a report thereon. The investigation was made under authority of the River and Harbor Act of January 21, 1927, and in accordance with the provisions of House Document No. 308, 69th Congress, 1st Session. The investigations of the State and War Department were coordinated effectively without duplication of effort. The work of the War Department covered special important phases of the investigation, particularly flood control and navigation. The War Department also has furnished valuable assistance by testing the soil conditions along the San Joaquin River for determining the best location of the conveyance channel for the San Joaquin River Pumping System.

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

ELWOOD MEAD, *Director*
R. F. WALTER, *Chief Engineer*
C. A. BISSELL, *Senior Engineer*
H. W. BASHORE, *Senior Engineer*

An investigation of the State Water Plan with particular regard to irrigation development was initiated in May, 1930, by the Bureau of Reclamation under the general direction of Dr. Mead and the immediate direction of Mr. Bissell and in cooperation with the State. The investigation was continued under the general direction of Mr. Walter and under the immediate direction of Mr. Bashore. This investigation deals principally with the formulation of a plan for the immediate relief of the improved lands with a deficient water supply in the upper San Joaquin Valley. A report on the State Water Plan and a relief project for the upper San Joaquin Valley is in course of preparation.

Geological Survey, Water Resources Branch

H. D. MCGLASHAN, *District Engineer*

Studies of the water supply of the San Joaquin River Basin were aided by the cooperation rendered by Mr. McGlashan in furnishing advance information on stream flows in the basin and in improving the installations of certain stream gaging stations maintained for this purpose. Chemical analyses of the waters of several streams of the San Joaquin River Basin also were made by this branch of the United States Geological Survey.

DEPARTMENT OF AGRICULTURE

Bureau of Public Roads, Division of Agricultural Engineering
W. W. McLaughlin, *Associate Chief*

Under cooperative agreement, the Division of Agricultural Engineering under the general direction of Mr. McLaughlin and the immediate supervision of Major O. V. P. Stout, made detailed measurements of the consumptive use of water by crops and natural vegetation in the Sacramento-San Joaquin Delta, covering a period of about six years. The Bureau in cooperation with the College of Agriculture of the University of California made a study of the cost of irrigation water in California which has been of much assistance in determining the value of irrigation supplies to be furnished under the State Water Plan. A report on this study has been published as Bulletin No. 36, Division of Water Resources. It is entitled:

"Cost of Irrigation Water in California"

by

H. F. Blaney, *Irrigation Engineer, U. S. Department of Agriculture*

and

M. R. Huberty, *Assistant Irrigation Engineer, Division of Irrigation Investigations and Practice, University of California, Agricultural Experiment Station*

Weather Bureau
E. H. Bowie, *in charge of Western States*

The Bureau cooperated in furnishing unpublished precipitation records which were of great value in the investigation.

Bureau of Chemistry and Soils
M. H. Lapham, *Inspector, District 5*

The Bureau furnished advance data on soil surveys which aided in the land classification. A. T. Strahorn of this Bureau, at the request of the Bureau of Reclamation, reviewed the State's classification of lands on the San Joaquin Valley floor.

FEDERAL POWER COMMISSION

F. E. Bonner, *Executive Secretary*
E. W. Kramer, *Regional Engineer, U. S. Forest Service, Representing the Commission in California*

In connection with the investigation of the War Department, Mr. Kramer and J. E. McCaffrey, Senior Hydroelectric Engineer, made a study of the growth of consumption of electric energy in California and the probable value of hydroelectric energy which could be generated at several units of the State Water Plan.

STATE AGENCIES COOPERATING IN INVESTIGATION

UNIVERSITY OF CALIFORNIA, COLLEGE OF AGRICULTURE

C. B. Hutchison, *Dean*

Two cooperative reports were prepared by the College of Agriculture on economic phases of the investigation, namely:

"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley"

by

Frank Adams, *Professor of Irrigation Investigations and Practice*

and

M. R. Huberty, *Assistant Professor of Irrigation Investigations and Practice*

and

"Permissible Economic Rate of Irrigation Development in California"

by

David Weeks, *Associate Professor of Agricultural Economics*

The data in these reports published respectively as Bulletin Nos. 34 and 35, Division of Water Resources, were of particular value in determining the rate at which additional water supplies would be needed in the San Joaquin Valley and the amount that the landowners could afford to pay for these supplies.

CHAPTER 832, STATUTES OF 1929

An act making an appropriation for work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development, and utilization of the water resources of California including the Santa Ana river, Mojave river, and all water resources of southern California.

(I object to the item of $450,000.00 in section 1 and reduce the amount to $390,000.00. With this reduction I approve the bill. Dated June 17, 1929. C. C. Young, Governor.)

The people of the State of California do enact as follows:

SECTION 1. Out of any money in the state treasury not otherwise appropriated, the sum of four hundred fifty thousand dollars, or so much thereof as may be necessary, is hereby appropriated to be expended by the state department of public works in accordance with law in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana river and its tributaries, the Mojave river and its tributaries, and all other water resources of southern California.

SEC. 2. The department of public works, subject to the other provisions of this act, is empowered to expend any portion of the appropriation herein provided for the purposes of this act, in cooperation with the government of the United States of America or in cooperation with political subdivisions of the State of California; and for the purpose of such cooperation is hereby authorized to draw its claim upon said appropriation in favor of the United States of America or the appropriate agency thereof for the payment of the cost of such portion of said cooperative work as may be determined by the department of public works.

SEC. 3. Upon the sale of any bonds of this state hereafter authorized to be issued to be expended for any one or more of the purposes for which any part of the appropriation herein provided may have been expended, the amount so expended from the appropriation herein provided shall be returned into the general fund of the state treasury out of the proceeds first derived from the sale of said bonds.

FOREWORD

This report is one of a series of bulletins on the State Water Plan issued by the Division of Water Resources pursuant to Chapter 832, Statutes of 1929, directing further investigations of the water resources of California. The series includes Bulletin Nos. 25 to 36, inclusive. Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," is a summary report of the entire investigation.

Prior to the studies carried out under this act, the water resources investigation had been in progress more or less continuously since 1921 under several statutory enactments. The results of the earlier work have been published as Bulletin Nos. 3, 4, 5, 6, 9, 11, 12, 13, 14, 19 and 20 of the former Division of Engineering and Irrigation, Nos. 5, 6 and 7 of the former Division of Water Rights, and Nos. 22 and 24 of the Division of Water Resources.

The full series of water resources reports prepared under Chapter 832, twelve in number, are:

Bulletin No. 25—"Report to the Legislature of 1931 on State Water Plan."
Bulletin No. 26—"Sacramento River Basin."
Bulletin No. 27—"Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay."
Bulletin No. 28—"Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers."
Bulletin No. 29—"San Joaquin River Basin."
Bulletin No. 30—"Pacific Slope of Southern California."
Bulletin No. 31—"Santa Ana River Basin."
Bulletin No. 32—"South Coastal Basin."
Bulletin No. 33—"Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain."
Bulletin No. 34—"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley."
Bulletin No. 35—"Permissible Economic Rate of Irrigation Development in California."
Bulletin No. 36—"Cost of Irrigation Water in California."

This bulletin presents detailed data and information on the water supplies and agricultural lands of the San Joaquin River Basin; the history and present status of irrigation, flood control, navigation and hydroelectric power developments; the utilization of water supplies from surface and underground sources; the irrigable lands and water requirements of the basin; the major units of a plan for the ultimate development and utilization of the water resources of the basin; and a proposed plan for initial development, comprising units of the ultimate plan immediately required to meet the deficiencies in water supply for present developments and needs in the San Joaquin Valley.

CHAPTER I

INTRODUCTION, SUMMARY AND CONCLUSIONS

The San Joaquin River Basin occupies that portion of California lying between the crests of the Sierra Nevada on the east, the Coast Range on the west, the San Emigdio and Tehachapi mountains on the south, and bounded on the north by the lower San Joaquin, the Mokelumne and Cosumnes rivers. It is approximately 290 miles long and 130 miles wide and embraces an area of 32,000 square miles or about one-fifth of the area of the State. In the central portion of the basin surrounded by mountainous areas lies the San Joaquin Valley, an area of 13,000 square miles of gently sloping plains with predominantly fertile soils well adapted to agriculture. The basin is drained by the San Joaquin River and its many tributaries, comprising one of the two largest stream systems within California.

The San Joaquin River Basin on the south and the Sacramento River Basin on the north together form the Great Central Basin of California, which reaches from near the northerly boundary of the State to the Tehachapi Mountains a distance of about 500 miles or nearly two-thirds the length of the State and occupies more than one-third of the State's area. The Sacramento River Basin includes in its central portion the Sacramento Valley which merges with the San Joaquin Valley on the south to form a practically continuous area of 18,000 square miles of plains designated the Great Central Valley. This northerly basin is drained by the Sacramento River and its many tributaries which comprise the largest stream system wholly within the State. The Sacramento and San Joaquin rivers flow toward each other and meet in a network of channels forming a common delta, finally combining to discharge through a common mouth into Suisun Bay and thence through San Francisco Bay into the Pacific Ocean.

The San Joaquin River Basin is devoted chiefly to agriculture. An area of about 8,500,000 acres of agricultural land or 36 per cent of the total agricultural area of the State lies in this basin. While the San Joaquin Valley in the early days of development was devoted largely to the raising of grain and cattle, the introduction of irrigation made possible the production of a great variety of crops. Irrigation development began in the decade following 1850 when diversions were made to lands lying adjacent to the streams, although areas of naturally overflowed lands had been used for pasturage prior to that time. Construction of the railroad through the valley during the period 1869 to 1875 resulted in an increase in population and a demand for suitable land for more intensive cultivation. Up to the present time more than two million acres have been placed under irrigation, more than one-third of the total area of irrigated lands in the State. The chief crops produced are deciduous and citrus fruits, olives, nuts, grapes, nearly every variety of vegetable, grain, alfalfa and cotton. Dairying and the raising of beef cattle, sheep, hogs and poultry also are important industries. It is estimated that in 1930 the value of the land, buildings, equipment and live stock utilized in the industry was about $912,917,000. The returns from crops and live stock products from the basin in 1929 amounted to $233,220,000 or about 30 per cent of the total return from these industries in the State.

Manufacturing, in the San Joaquin River Basin, is second only to agriculture as a source of income. The most important manufactured products are canned and preserved fruits and vegetables, dairy products and canned milk, lumber, lime, cement and marble. The income in the basin from the value added by manufacture, in 1929, amounted to about $68,740,000 or 5.1 per cent of the total for the entire State.

A large amount of both hydroelectric and steam-electric energy is also produced in the San Joaquin River Basin. A considerable portion of this energy is used within the basin and the remainder is transmitted to the metropolitan areas of Los Angeles and other nearby sections of southern California, and to those in the San Francisco Bay region. The power plants of the basin have an installed capacity of about 911,000 kilovolt amperes and in 1929 produced about 3,240,000,000 kilowatt hours of electric energy or about 37 per cent of the total production in the State.

Mineral production ranks third in source of income. The value of all mineral products from the San Joaquin River Basin in 1929 amounted to $54,730,000 or 12.7 per cent of the total for the entire State. This included $37,375,000 for petroleum, $3,015,000 for natural gas, $2,340,000 for gold and $12,000,000 for miscellaneous minerals. The latter item includes, silver, copper, lead, quicksilver, tungsten, gems, platinum, barytes, coal, manganese, chromite, gypsum, marble, magnesite, dolomite, silica, pumice, clay for pottery and bricks, slate, limestone, granite, borates, assorted building stone, volcanic ash, salt, diatomaceous earth, minerals for paint, lime and other materials for the manufacture of cement, and mineral water.

The present population of the San Joaquin River Basin is about 575,000, more than one-tenth of that of the entire State. It can be classed as about 40 per cent urban and 60 per cent rural. Over 95 per cent of the population resides in the San Joaquin Valley. During the last decade, the population increased about 28 per cent while during the previous decade it increased over 60 per cent. The largest cities in the basin are Fresno and Stockton, the industrial and commercial centers of the San Joaquin Valley and its environs. The former city has a population of 53,000 and the latter 48,000. The completion of the Stockton Deep Water Channel to San Francisco Bay in the near future will make this city a port of call for ocean-going vessels. Bakersfield and Modesto are the next important cities. The former has a population of 26,000 and the latter 14,000. Other incorporated cities and towns having a population of more than 2500 in order of size are: Visalia, 7300; Merced, 7100; Hanford, 7000; Lodi, 6800; Tulare, 6200; Porterville, 5300; Madera, 4700; Turlock, 4300; Lindsay, 3900; Tracy, 3800; Taft, 3400; Selma, 3000; Sanger, 3000; Dinuba, 3000; Coalinga, 2900; Exeter, 2700; Delano, 2600 and Reedley, 2600.

The basin, especially the San Joaquin Valley, is well served by transportation facilities. It is traversed from north to south by the

Southern Pacific Railroad, which has two main lines from Fresno north and one main line from Fresno south, and by the main line of the Santa Fe Railroad. There are also numerous branches from the main line railroads into the mountains and different parts of the valley. Electric lines connect urban areas in certain sections of the valley. A network of improved highways throughout practically the entire basin also provides facilities for rapid motor truck transportation, either for short or long hauls, and such transportation is now competitive with that by rail.

Water Problems in San Joaquin River Basin.

Irrigation development has been so rapid and extensive in the San Joaquin Valley that local water supplies are now insufficient to meet the needs of present irrigated areas, particularly in the southern or upper portion of the valley south of the Chowchilla River. On all of the streams tributary to the upper San Joaquin Valley, there long since has been effected a very high degree of utilization of run-off without surface storage regulation. For many years, while the irrigated areas devoted to annuals have varied from season to season with the available amount of surface water supplies, the expansion of irrigated areas devoted to permanent crops has occurred chiefly through the development of ground water supplies. With limited or no surface supplies, the replenishment of ground water storage, commonly resulting from the use of ample surface irrigation applications, is lacking in many of these areas. In some localities, expansion of irrigated areas has continued to such an extent that the net draft on ground water storage exceeds the average seasonal replenishment from whatever local sources are available. The result has been a depletion in ground water storage, which is indicated by a continuously receding water table. Out of a total irrigated area in the upper San Joaquin Valley of 1,200,000 acres drawing their supplies both from streams and wells, some 400,000 acres are now overdrawing the water supplies naturally available to them. Studies reveal that there is only about one- half the amount of water for their full requirements. With the recession of ground water levels, water supplies in some areas have become exhausted while in others pumping lifts have become so excessive as to be economically prohibitive. Farms and homes have already been abandoned for the lack of an adequate and dependable water supply. It appears probable that some 200,000 acres must go back to desert condition if a supplemental water supply is not obtained in the near future. These 200,000 acres are valued at more than $50,000,000 and yield annually under normal economic conditions $20,000,000 worth of agricultural products.

In the Sacramento-San Joaquin Delta, about two-thirds of which lies in the San Joaquin River Basin, the available inflow from the Sacramento and San Joaquin River systems during recent years of generally subnormal run-off has been insufficient during certain months of several years to meet the consumptive demands in the delta and adjacent delta uplands drawing their supplies from the delta channels, and to keep the water fresh against invasion of saline water from San Francisco Bay. Saline invasion has rendered the water unfit for irrigation and other uses, not only in the delta and adjacent delta uplands but also in the adjacent upper San Francisco Bay Basin in the area adjoining Suisun Bay. The resulting curtailment of irrigation in the delta has caused material losses in crop production which in 1931 is estimated to have been about $1,300,000. In addition, the salinity menace with a possibility of more extensive and prolonged invasion in future years than has occurred in the past has tended to depreciate land values in this most fertile and productive region. Moreover, industries and agricultural lands in the areas adjacent to Suisun Bay have been curtailed in their use of fresh water from the lower river and upper bay channels with losses resulting of substantial amount. Additional water supplies are urgently needed to prevent saline invasion into the delta channels and maintain continuous fresh water therein, and to provide for the full consumptive needs of the delta and adjacent upland areas and for the nearby industrial and agricultural areas in the upper San Francisco Bay region.

In addition to the problems of water shortage in the San Joaquin River Basin, there are problems of flood control and navigation which should receive attention. Disastrous floods have occurred in past years of large run-off and the possibility of their repetition is a menace to some of the improved valley lands and populated areas. Although works for flood protection have been provided for considerable portions of the areas subject to flood menace, there is a need for additional flood protection on many of the streams in the basin. The problem of navigation involves chiefly the upper San Joaquin River above Stockton. This waterway from Stockton to Mendota is potentially navigable and in former years was actually navigated by commercial craft operating as far upstream as Mendota and occasionally to Herndon. Because of deficient stream flow during several months of the year resulting in inadequate navigation depths, transportation by water has never been dependable on this stream. This waterway is worthy of improvement from Stockton to Mendota to provide cheap water transportation for the large volume of tonnage moving to and from the San Joaquin Valley.

Studies reveal that, even with a full practicable development of the water resources of the San Joaquin River Basin, additional water supplies will be needed to meet the full requirements in the basin. On the other hand, the water supplies in the Sacramento River Basin are in excess of its full requirements. The most logical and practical source of supplemental water supply for the San Joaquin River Basin is the surplus water which could be made available in the Sacramento River Basin. The adequate solution of the water problems of the San Joaquin River Basin, therefore, involves plans for development of water supplies not only in its own basin but also in the Sacramento River Basin.

A proper and coordinate solution of the water problems of the San Joaquin River Basin is highly desirable. The investigations upon which this report is based have been directed to this purpose together with the formulation of a general plan for the conservation, regulation, distribution and utilization of the water resources to provide for the ultimate needs of the basin.

Previous Investigations.

Investigations of the water resources of the Great Central Basin with a view of utilizing the water for the greatest beneficial uses have been made at various times over a long period of years. Some of the more important of these are enumerated in the following paragraphs.

In 1873 an investigation was made by the United States War Department and a plan was outlined for utilizing the water supply to the greatest advantage for irrigation purposes.

The first effort of the State to make an investigation of its water resources and offer a solution of the problem concerning water utilization was made in 1878 and resulted in "An act to provide a system of irrigation, promote rapid drainage and improve navigation on the Sacramento and San Joaquin rivers." Under this act, investigations were carried out by the State Engineer, William Ham. Hall. He, like the Army Engineers in 1873, suggested that the water of the Great Central Valley be developed in a systematic manner. Several reports and maps were published by the State Engineer between 1880 and 1888.

In 1900, the United States Department of Agriculture, Office of Experiment Stations, made an investigation of irrigation conditions and recommended certain changes in the water laws of the State.

In 1906, a report on hydrographic investigations in the Sacramento Basin, California, was prepared by S. G. Bennett, engineer for the United States Reclamation Service. This report summarized data on irrigation and reclamation from other reports and described a number of reservoir sites and possible storage and irrigation projects in the basin.

Another State investigation was made in 1911 through a special board called the "Conservation Commission," which issued a report on its findings.

In 1912, the United States Department of Agriculture made an investigation and issued a bulletin dealing with the irrigation resources and their development.

The State investigations known as "The California Water Resources Investigations" were initiated in 1921. These investigations have been carried on under the direction of the State Engineer in accord with successive authorizations of the Legislature in 1921, 1925, 1927 and 1929.

Scope of Present Investigation.

The present investigation has been directed to the formulation of plans for the ultimate conservation, regulation, distribution and utilization of the water resources of the San Joaquin River Basin for all necessary and desirable purposes and, of more immediate importance, to the solution of the present water problems in the basin involving the determination of a plan for initial development comprising units of the ultimate plan required to meet the immediate needs. Because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for supplemental waters to meet its full requirements, the plans for both initial and ultimate development in the two basins are interrelated and interdependent and, therefore, have been considered together as one unified project for the entire Great Central Valley.

In the formulation of the State Water Plan in the Great Central Valley, studies in addition to those presented in this report on the San Joaquin River Basin have been made covering the Sacramento River Basin, the Sacramento-San Joaquin Delta and upper San Francisco Bay Basin, including an investigation of the feasibility of constructing a barrier at some point below the confluence of the Sacramento and San Joaquin rivers to prevent invasion of saline water into the delta. The results of these investigations are presented in other reports.*

This bulletin presents the detailed data and studies of the water resources investigations for the State Water Plan in the San Joaquin River Basin. It sets forth the available water supply, the area, location and quality of agricultural lands, the history and present status of irrigation, flood control, navigation and hydroelectric power developments, the utilization of surface and ground water supplies, an estimate of the area of lands suitable for irrigation, the present and ultimate water requirements for all purposes, the major units of an engineering plan for the ultimate development, regulation and utilization of the water resources of the basin, and a plan for initial development comprising units of the ultimate plan immediately required to meet the deficiencies in water supply for present developments and needs in the San Joaquin Valley.

In the studies of water supply, estimates were made of the run-off at various points for the 40-year period 1889–1929. These estimates were based on records of precipitation in the basin for the entire period and on stream flow measurements which were started as early as 1893 and which are available for about 20 years on streams contributing approximately 90 per cent of the run-off from mountain areas. Estimates of full natural run-off were made for all of the major streams and groups of minor streams. Full natural run-offs and those under present and ultimate conditions of development, at the dam sites of the major reservoir units in the San Joaquin River Basin, also were estimated. Studies also were made of the distribution of the run-off and the occurrence and distribution of return waters and ground water. The present and ultimate net run-offs, estimated for the 40-year period 1889–1929,** were used in the reservoir studies to determine the required storage capacities, and to estimate the amounts of utilizable water supply obtainable through the operation of surface storage reservoirs, underground storage and pumping and conveyance units as proposed.

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* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.
Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.
Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

** Since the preparation of the water supply studies in this report based upon the run-offs for the 40-year period 1889–1929, on which the major units of the State Water Plan for initial and ultimate developments were proportioned and on which the utilizable water supply obtainable from each plan of development was determined to test its adequacy in meeting the requirements, two seasons of low run-off have occurred, 1929–30 and 1930–31. Therefore, it was deemed desirable to test the adequacy of the plans proposed for initial and ultimate development of the San Joaquin River Basin by the inclusion of these seasons in the water supply analyses, and if either plan were found inadequate, to point out wherein, if possible, a modification of it could be made which would assure dependable supplies to all areas served by the plan. The results of the supplemental analyses of water supply through the season 1930–31, which, with minor changes in the plan of operation, show that the proposed plans for both initial and ultimate developments would be adequate to meet the requirements, are presented in Appendix D.

A classification was made in the field of all agricultural lands in the San Joaquin Valley and adjacent foothills on the basis of their adaptability for irrigation, utilizing soil surveys, where available, as a guide. This classification covered an area of about nine million acres. A survey also was made of the crops now grown on the lands of various classes to obtain data on the areas and locations of the different kinds of crops both irrigated and nonirrigated, and to determine the adaptability of different localities and classes of land to the growing of different types of crops. Data also were obtained on the net water requirements for these irrigated lands and incidental information on conveyance losses and gross requirements. Based upon these data, the ultimate water requirements in the areas to be served were estimated for the mountain and foothill lands above the major reservoir units, and for the valley floor lands, by divisions or zones of service as related to source of supply including local streams and imported water from outside the basin. Estimates were made of the gross allowance or diversion, the net allowance or water delivered to the land, and the net use of water or the amount from which no return would be available.

An engineering plan for the ultimate development of all of the lands considered feasible of development was evolved. The location and extent of the developed lands now under irrigation and in need of a supplemental water supply were determined and the amount of the required supplemental supply estimated. An initial plan of development for furnishing a supplemental water supply to the developed lands in need of additional water was evolved, which would constitute the first progressive step in the plan for ultimate development.

Analyses were made of all phases of the coordinated operation of the major units of the State Water Plan in the Great Central Basin in accord with the plans for both initial and ultimate development, in order to test the adequacy of each plan in meeting the requirements and effecting all objectives sought and desired.

In the formulation of plans for storage and conveyance of water supplies, many studies were made to determine the best location for, and the most economic size of, each unit, and the most practicable plan of coordinated operation to meet the requirements for irrigation, salinity control, flood control, power development and navigation. Analyses were made of reservoirs at various sites on each major stream to determine the most feasible location and the economic capacity for the purposes to be served. Topographic surveys were made of all reservoirs and dam sites for which maps were not available. Field examinations of reservoir sites were made to appraise the values of lands and improvements which would be submerged and these values were checked by comparison with data from county assessors and other sources. Some of the dam sites were explored by shafts, tunnels and core drillings, and geologic studies by competent geologists were made of all sites. From these geologic data, estimates were made of the depths of excavation necessary to obtain satisfactory foundations for the dams. The economic installations of power plants at the dams of the major reservoirs also were carefully considered. Due to the importance of the utilization of underground reservoirs in the San

Joaquin Valley, a geologic study was made to locate underground storage areas, to estimate their capacity and determine the practicability of their utilization for the storage and extraction of water supplies. Detailed studies were made of the operation of underground reservoirs in combination with surface storage regulation. Many alternate plans were investigated for the conveyance from the Sacramento River of the water required to supplement the available local supplies in the San Joaquin River Basin, and the distribution and utilization of such imported supplies in coordination with local supplies in the basin. These investigations necessitated the making of numerous topographic and location surveys, explorations, and field examinations for valuation of right of ways.

Data also were obtained on unit costs of materials and all parts of the construction work and on the probable length of time required for construction. With these data and the estimated quantities involved in different parts of the construction, estimates were made of the costs of the dams, reservoirs, power plants and conduits. Data also were obtained on the costs of operation, maintenance and depreciation of the different features of the units and with these data and assumed interest and amortization charges, estimates were made of annual costs.

In the following chapters of this report, there are presented in detail the basic studies and investigations and the proposed plans of development and operation for the State Water Plan in the San Joaquin River Basin. These are briefly summarized with conclusions in the remaining portion of this chapter.

Water Supply.

Precipitation—The precipitation in the San Joaquin River Basin is extremely variable both geographically and seasonally. It ranges in seasonal average from 50 inches in the mountains to less than 10 inches on the valley floor and varies in different seasons and localities from a minimum of 25 to a maximum of 192 per cent of the mean. It occurs in the form of snow in the high mountains, which melts in the spring and early summer months to produce a large percentage of the run-off. On the average, about 90 per cent of the precipitation falls during the months of November to April inclusive, with little or no rainfall in the valley during the growing season when the moisture demands of crops are at their peak.

Run-off—The San Joaquin River Basin, while occupying 20.6 per cent of the total area of California, yields from its mountainous portion only 16.8 per cent of the total water supply from the entire mountainous area of the State. The basin is drained by the San Joaquin River and its numerous tributaries, comprising 13 major streams and 22 minor streams or stream groups. The following tabulation shows the areas of the drainage basins and the mean seasonal full natural run-offs from the mountain and foothill areas for each stream and stream group, with subtotals for the upper San Joaquin Basin, the lower San Joaquin Basin (south of the delta), and the tributaries discharging directly into the delta. The streams of the upper San Joaquin Basin include the Chowchilla River and all those to the south of that stream. The streams of the lower San Joaquin Basin include all those south of the delta from the Chowchilla River north to and including the Stanislaus River. The delta tributary streams include those north of the Stanislaus River to and including the Cosumnes River. The contributions to the surface run-off and possible ground water replenishment, from rainfall on the valley floor, are not included because of the lack of definite knowledge as to their amounts.

FULL NATURAL RUN-OFF OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	Seasonal full natural run-off, in acre-feet (Season October 1 to September 30)			
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929
Upper San Joaquin Basin—					
Panoche Creek	295	26,400	24,200	14,000	13,200
Cantua Creek group	208	12,600	11,300	6,100	5,500
Los Gatos Creek	119	9,400	8,400	4,800	4,300
Tejon Creek group	1,341	88,600	74,700	43,900	41,000
Caliente Creek	471	37,300	28,900	21,900	22,100
Kern River	2,410	725,000	691,000	505,000	466,000
Poso Creek group	576	45,500	38,600	32,300	35,300
Deer Creek	110	19,500	16,500	13,400	12,600
Tule River	390	135,000	113,000	87,200	77,600
Yokohl Creek group	98	14,200	12,000	10,000	10,900
Kaweah River	514	443,000	355,000	311,000	291,000
Lime Kiln Creek group	201	60,600	52,900	46,000	49,700
Kings River	1,694	1,889,000	1,580,000	1,321,000	1,226,000
Dry Creek	48	4,100	3,600	3,000	2,600
San Joaquin River	1,631	1,995,000	1,699,000	1,405,000	1,333,000
Cottonwood Creek	28	2,100	1,800	1,400	1,200
Fresno River	270	63,400	56,300	46,300	38,900
Daulton Creek group	66	4,600	3,900	3,200	2,700
Chowchilla River	238	70,900	56,200	56,900	55,100
Totals, Upper San Joaquin Basin	10,708	5,646,200	4,827,300	3,932,400	3,688,700
Lower San Joaquin Basin—					
Orestimba Creek group	1,340	120,000	102,000	87,200	78,600
Dutchman Creek group	72	8,600	6,000	5,700	5,900
Mariposa Creek	103	13,200	9,400	9,000	9,100
Owens Creek group	66	6,700	4,500	4,300	4,400
Bear Creek	71	7,800	5,300	5,100	5,200
Burns Creek group	171	25,400	18,700	18,300	18,800
Merced River	1,054	1,115,000	944,000	814,000	765,000
Tuolumne River	1,543	2,070,000	1,772,000	1,577,000	1,520,000
Wildcat Creek group	59	9,200	6,500	6,300	6,500
Stanislaus River	983	1,350,000	1,108,000	949,000	932,000
Totals, Lower San Joaquin Basin	5,462	4,725,900	3,976,400	3,475,900	3,345,500
Delta Tributaries—					
Littlejohns Creek	41	8,400	6,200	6,000	6,200
Martells Creek group	122	14,900	11,100	10,700	11,100
Calaveras River	394	227,000	191,000	131,000	115,000
Mokelumne River	632	853,000	726,000	626,000	618,000
Sutter Creek group	285	97,600	75,600	75,900	70,500
Cosumnes River	534	407,000	346,000	289,000	282,000
Totals, Delta Tributaries	2,008	1,607,900	1,355,900	1,138,600	1,102,800
Grand totals	18,178	11,980,000	10,159,600	8,546,900	8,137,000

All of the full natural run-off of most of the streams, at the sites for the major reservoir units of the State Water Plan, is not now available, and in the future probably even less will be available, for conservation by the reservoirs. The "present net run-offs" at any point are those which would occur under present conditions of development in the tributary basin. The "ultimate net run-offs" are those which would occur with ultimate instead of present conditions of development in the tributary drainage basin. These present and ultimate net run-offs were used in studies of water supply yield under present and ultimate conditions respectively. The mean seasonal net run-off from the San Joaquin River Basin into San Joaquin Delta for the 12-year period 1917–1929, under conditions of irrigation and storage development as of 1929 and municipal diversions out of the basin as of 1940, is set forth in the first of the following tabulations. The second tabulation sets forth the mean seasonal ultimate net run-off of each of the major streams at the reservoir sites considered in the ultimate State Water Plan, and the area of the drainage basin above each reservoir.

PRESENT NET RUN-OFF INTO SAN JOAQUIN DELTA

Mean for 12-Year Period 1917–1929

Stream	Present seasonal net run-off, in acre-feet (Season October 1 to September 30)
San Joaquin River at Newman	1,180,100
Tuolumne River at confluence with San Joaquin River	1,045,000
Stanislaus River at confluence with San Joaquin River	665,000
Calaveras River at Jenny Lind	135,000
Mokelumne River below Woodbridge	510,000
Dry Creek near Ione	64,800
Cosumnes River below Michigan Bar	269,000
Total	3,868,900
Pumping diversions below gaging stations	89,300
Net run-off into San Joaquin Delta	3,779,600

ULTIMATE NET RUN-OFF OF MAJOR STREAMS IN SAN JOAQUIN RIVER BASIN

Stream	Drainage area, in square miles	Ultimate seasonal net run-off, in acre-feet (Season October 1 to September 30)			
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929
Kern River	2,080	714,000	679,000	493,000	454,000
Tule River*	338	130,000	109,000	84,100	74,500
Kaweah River	514	443,000	355,000	311,000	291,000
Kings River	1,544	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	1,631	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	102	55,200	48,200	39,800	34,000
Chowchilla River	238	70,900	56,200	56,900	55,100
Merced River	1,034	989,000	825,000	705,000	659,000
Tuolumne River	1,536	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	900	1,239,000	997,000	839,000	820,000
Calaveras River	363	189,000	156,000	96,400	80,100
Mokelumne River	575	820,000	696,000	597,000	581,000
Cosumnes River	435	290,000	235,000	182,000	169,000
Totals	11,290	10,456,100	8,831,400	7,363,200	6,973,700

*Includes South Fork of Tule River, which enters the main Tule below the reservoir site of the State Water Plan.

There are wide variations in seasonal, monthly and daily run-off. The data on natural flow for the period 1889–1929 show that the seasonal run-off varies on different streams from maximums of 225 to 357 per cent to minimums of 10 to 28 per cent of the 40-year mean; and that, on most of the major streams, 75 to 80 per cent of the total seasonal run-off occurs on the average during about five months of the spring and early summer. Daily variations in flow range from practically nothing to several thousand second-feet.

Return Water—In the San Joaquin River Basin a substantial potential water supply is that from water which, once used for irrigation, domestic or other purposes, would return to the streams or accumulate in the various ground water basins. The return waters from irrigation would have their sources in the losses from canals or other conduits during conveyance of water from the points of diversion on the streams to points of use and in irrigation applications in excess of consumptive use. A large portion of the return waters from the mountain and foothill region would be available for storage in the major reservoir units of the State Water Plan in which they could be regulated to a supply conforming to the irrigation demand on the valley floor. In the upper San Joaquin Valley, which is that portion southward from Mendota and the Chowchilla River, most of the waters diverted to the valley floor in excess of consumptive use would be utilized by pumping from underground reservoirs. The efficient utilization of these ground water reservoirs would allow only a relatively small portion of this water to reach the valley trough channels. In the lower San Joaquin Valley, northward from Mendota and the Chowchilla River, the waters diverted to the valley floor in excess of consumptive use would enter the streams or artificial drains and finally reach the San Joaquin River or would replenish the underground basins. The return waters reaching the San Joaquin River could be made available for reuse on adjacent lands or exportation to other areas through the major conveyance units of the State Water Plan.

Agricultural Lands.

The agricultural lands in the San Joaquin River Basin comprise about 36.3 per cent of those in the entire State. The classification of agricultural lands on the basis of their adaptability for crop production and irrigation, made during the present investigation, covered all those lands lying in the San Joaquin Valley and adjacent foothills.

The lands were divided into five classes, the first four of which are considered as agricultural and the fifth as having no present or potential agricultural value. The character of the soil and topographic and surface features determined the class in which each parcel of land was placed. A certain percentage of each class of agricultural land was estimated to be capable of irrigation and these percentages applied to the areas of the respective classes of land in any tract, gave the irrigable area of that tract. The gross agricultural and net irrigable areas in the basin, estimated during this investigation, are shown in the following tabulation:

AREAS OF AGRICULTURAL AND IRRIGABLE LANDS IN SAN JOAQUIN RIVER BASIN

Section	Gross agricultural area		Net irrigable area	
	In acres	In per cent of total	In acres	In per cent of total
Upper San Joaquin Valley floor	4,881,800	57.4	3,648,000	61.2
Lower San Joaquin Valley floor	2,360,600	27.8	1,676,000	28.1
Foothill areas	977,000	11.5	380,000	6.4
San Joaquin Delta	279,000	3.3	257,000	4.3
Totals	8,498,400	100.0	5,961,000	100.0

Irrigation Development and Water Supply Utilization.

Favorable soil and climatic conditions, with the one exception of adequacy of rainfall, have made the San Joaquin Valley a pioner section in the irrigation development of California. Starting in the decade following 1850, the early irrigation enterprises were largely undertaken by individuals. Subsequently, larger enterprises were undertaken under various forms of organization including first, private and mutual water companies and later irrigation district and other similar forms of organization.

There are now 36 active irrigation districts embracing a gross area of 1,826,578 acres of which 1,143,840 acres were irrigated in 1929; 16 public utility water companies irrigating approximately 184,000 acres in 1929; and 48 mutual water companies irrigating in 1929 approximately 336,000 acres. There are also several water storage, conservation, reclamation and other forms of public district organization under which lands are irrigated in the San Joaquin Valley.

Irrigation development has been rapid and extensive, particularly in the last three decades. The area irrigated has increased from about 800,000 acres in 1900 to about two and one-quarter million acres in 1929, which comprises more than one-third of the irrigated land in the State and about two-fifths of the entire net acreage susceptible of irrigation in the San Joaquin River Basin. The following tabulation sets forth the areas of irrigated crops in the San Joaquin River Basin in 1929.

IRRIGATED CROPS IN THE SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS—1929

Portion of basin	Area of irrigated crops, in acres											
	Citrus orchards	Deciduous orchards, including figs, nuts and olives	Grape vineyards	Grain	Alfalfa	Field crops	Cotton	Irrigated pasture land	Truck crops	Rice	Unclassified	Totals
Upper San Joaquin Valley	41,600	122,600	349,700	64,300	174,200	123,000	212,500	62,900	6,500	1,000	43,500	1,201,800
Lower San Joaquin Valley and adjacent foothills	200	107,500	116,000	131,200	211,600	31,500	66,400	61,500	84,200	15,600	6,100	831,800
Totals, excluding delta	41,800	230,100	465,700	195,500	385,800	154,500	278,900	124,400	90,700	16,600	49,600	2,033,600
San Joaquin Delta,[1] in Contra Costa and San Joaquin counties	0	1,500	0	66,100	16,100	34,000	0	10,800	65,800	0	0	194,300
Totals	41,800	231,600	465,700	261,600	401,900	188,500	278,900	135,200	156,500	16,600	49,600	2,227,900

[1] The San Joaquin Delta also includes 24,500 acres of crops irrigated in 1929 in Sacramento County.

Irrigated crops comprise 79 per cent of all crops produced in the San Joaquin River Basin in 1929. Of the unirrigated crops, grain constitutes 97 per cent of the total acreage.

The early enterprises made use of the natural stream flow only. Due to the rapid reduction in stream flow following the melting of snow on the higher drainage areas, usually in June or early July, the lands which could be given full service without storage were limited. Many areas received only a partial service and either adjusted the crops to those of early maturity, or by excessive use of flood waters, while available, raised the ground water to provide at least partial subirrigation during the remainder of the season. Waterlogging was caused in many instances by such excessive applications, and continued high ground water resulted in soil injury through alkali accumulations in many areas.

In the southern or upper valley, the first irrigation developments were made by direct surface diversion to the lands, principally on the delta fans. For areas distant from streams, where surface supplies were not obtainable, ground water was found to be available and pumping began to be practiced in the early part of the present century. In many localities, where artesian wells first were secured, increased draft has resulted in a lowering of water levels and pumping is now required. Pumping from wells has been developed to a very large extent in this section of the valley, where stream flow is small in relation to the demand. On the Kings and Kaweah river deltas, pumping from wells, within the irrigated areas, is extensively used to supplement direct surface diversion. For areas further south, practice includes all variations from entire dependence on stream diversion to full pumping or combinations of these two practices.

Due to the low run-off of the 1928–1929 season, the irrigated areas for the upper San Joaquin Valley are somewhat below the average. None of the streams, tributary to this portion of the basin, are regulated by surface irrigation storage and the limit of utilization of their surface run-off under existing diversion rights has long since been reached. The cropped land, irrigated solely from surface diversion, varies through wet and dry periods. This is particularly true where lands are in large holdings. On the other hand, the extent of irrigated areas, entirely dependent upon a supply pumped from ground water, has been increasing rapidly even though the water levels underlying these areas have been receding steadily. It is estimated that the acreage so served, in 1929, is the maximum of record.

As a result of the increase in use of ground water supplies in the upper San Joaquin Valley during the period of generally subnormal run-off extending over the past decade or more, ground water levels have been depressed in the most of the irrigated areas of the upper San Joaquin Valley. In some areas lacking adequate sources of ground water replenishment, underground supplies either have become exhausted or ground water levels have dropped to such an extent that pumping lifts are now excessive. During the period 1921–1929 the lowering in areas of heavy pumping draft has varied generally from 25 to 50 feet where no direct sources of supply were available, with maximum lowering in one area of 85 feet. In the major portions of areas having direct sources of water supply such as the Kings and

Kaweah river deltas, a lowering from 5 to 10 feet has occurred. From the known extent of recession, it is estimated that the average seasonal depletion of ground water, in an area of about 400,000 acres in which the available supply even over a long period is insufficient to support present requirements, has amounted to 387,000 acre-feet over the 8-year period 1921–1929. Based upon records of ground water fluctuation, irrigated areas, and estimates of net inflow to the underground basins, the present net use requirements of the several absorptive areas of the upper San Joaquin Valley were found to average about 2 acre-feet per acre of area irrigated.

In the northern or lower valley, direct surface diversions were used until the developments had become sufficiently extensive to enable storage to be financed. These storage developments were made, to a large extent, economically feasible by the development and sale of hydroelectric energy in conjunction with the storage and release of irrigation water. Such storage is now in use on the Merced, Tuolumne and Stanislaus rivers. Pumping from wells is limited to drainage. However, drainage water, in most instances, is reused for irrigation. On the San Joaquin River, some storage for power is now available as a partial aid to irrigation. Supplies from the lower portions of the San Joaquin River have been obtained by pumping rather than by gravity diversion. A large area above the mouth of Merced River, including about 309,000 acres of land devoted to crops, is irrigated from the main San Joaquin River with diversion works at or near Mendota. Lands irrigated by the Merced, Tuolumne and Stanislaus rivers have a gross area of 621,275 acres of which 421,000 acres were irrigated in 1929. In the San Joaquin Delta, about 219,000 acres out of a total gross area of 279,000 acres were devoted to irrigated crops in 1929. The water supply for these delta lands, coming partly from the San Joaquin River system and partly from the Sacramento River, has been insufficient in certain months of several recent years to meet the net water requirements and to keep the water in the delta channels fresh as against invasion of saline water from the bay. It is estimated in another report* that the deficiency in supply for the entire delta for meeting the full consumptive demands and preventing saline invasion ranged from about 150,000 to 1,128,000 acre-feet per season with an average seasonal defficiency of 451,000 acre-feet during the period 1920 to 1929.

Except for the San Joaquin Delta the water supplies in the lower San Joaquin Valley under present conditions of development are adequate to meet the present requirements of the irrigated lands. The tendency is for a slight increase of irrigated cropped areas from year to year. It is believed that the area irrigated in 1929 in the lower San Joaquin Valley probably represents the maximum area irrigated at any time up to that year.

With a limited use of ground water in the lower San Joaquin Valley, there has been no general lowering of ground water levels due to pumping in excess of replenishment as in the upper San Joaquin Valley. The depth to ground water is from 5 to 10 feet over a large part of the area irrigated east of the San Joaquin River. Such lower-

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.

ing as has occurred in recent years has been beneficial. North of the Tuolumne River, the depth to ground water over a considerable portion of the area is from 10 to 50 feet and from 50 to 100 feet near the foothills.

Water Requirements.

The uses of water in the San Joaquin River Basin are many. They include domestic, municipal, irrigation, salinity control, industrial, navigation, power development and recreational uses. Of all these uses, however, that for irrigation predominates at the present time and probably will continue to do so. Recreational and navigation uses result in no actual consumption of water and in most instances do not alter the regimen of the stream. The use for development of hydroelectric energy, while altering in some instances the regimen of the stream, does not consume any water. For domestic service alone, the unit use within small cities is practically the same as for irrigation. For industrial and commercial areas in or near municipalities, the amount of water used may be somewhat larger than for the irrigation requirements for an equivalent area. In this basin, the water requirements for present and future ultimate developments have been based on irrigation use. It is believed that on this basis ample water would be provided for all uses except that for salinity control in the Sacramento-San Joaquin Delta. In the State Water Plan, provision for that requirement is made primarily from the Sacramento River Basin.

Water requirements, for any particular area, vary not only in amount with the use to which the water is put, and in monthly demand, but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area and the opportunity afforded for reuse of water controlled by topographic, geographic and geologic conditions, are factors that have an important bearing on water requirements. For these reasons, variations in treatment of the problems for the different areas necessitated the employment of different terms of use, as follows:

"Irrigation requirement" is the amount of water in addition to rainfall that is required to bring a crop to maturity. This amount varies with the crop to be supplied and the point at which the water is measured. As related to the point of measurement, it is the "gross allowance," "net allowance," or "net use." These terms together with the term "consumptive use" are defined as follows:

> "Gross allowance" designates the amount of water diverted at source of supply.
>
> "Net allowance" designates the amount of water actually delivered to the area served.
>
> "Consumptive use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.
>
> "Net use" designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

In the upper San Joaquin Valley, full development will require importation of water at relatively high costs. It is believed that service under such conditions would be justified only for the better lands. Therefore, in evolving a plan for furnishing a water supply to that region, the area of service has been taken to include only irrigable lands in classes 1 and 2 and a small irrigable area of Class 3 land suitable for citrus development which could be served by diversion from Tule River. The remaining areas of classes 3 and 4 lands classed as irrigable have not been included in the area for service under the State Water Plan for the ultimate development of the upper San Joaquin Valley. This reduces the net irrigable area to be served in the upper San Joaquin Valley from 3,648,000 to 3,135,000 acres on the valley floor and eliminates 41,000 acres of foothill land. In the lower San Joaquin Valley, a region wherein water supplies are adequate if conserved, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin. The net irrigable areas to be served and the water requirements thereof under the ultimate State Water Plan are set forth in the following tabulation. The unit water requirements applied to the irrigable areas to obtain total requirements are based upon data as to present use in the various sections of the basin under the prevailing irrigation methods and conveyance losses. The water requirements for the San Joaquin River Basin (excluding the delta) which would amount to 13,326,000 acre-feet gross allowance if provision were made for the irrigable areas of classes 3 and 4 lands in the upper valley floor and foothills, are reduced to 12,177,000 acre-feet under the adopted plan of service.

SEASONAL WATER REQUIREMENTS OF IRRIGABLE LANDS TO BE SERVED UNDER ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Section	Net irrigable area to be served, in acres	Gross allowance, in acre-feet		Net allowance, in acre-feet		Net use, in acre-feet	
		Average per acre	Total	Average per acre	Total	Average per acre	Total
Upper San Joaquin Valley floor	3,135,000	2.0	6,270,000	2.0	6,270,000	2.0	6,270,000
Lower San Joaquin Valley floor, excluding San Joaquin Delta	1,676,000	3.0	4,968,000	2.2	3,651,000	1.8	3,019,000
Foothill areas	339,000	2.8	939,000	2.0	674,000	1.7	563,000
Totals, excluding San Joaquin Delta	5,150,000	------	12,177,000	------	10,595,000	------	9,852,000
San Joaquin Delta—							
Irrigation and other uses	257,000	[1]	824,000	[1]	824,000	[1]	824,000
Salinity control	------------	------	1,590,000	------	1,590,000	------	1,590,000
Totals, San Joaquin River Basin	5,407,000	------	14,591,000	------	13,009,000	------	12,266,000

[1] Value for net use per unit of area is not given since ultimate total requirements and use are divided among irrigation use, evaporation from delta channels, transpiration from tules and other natural vegetation and evaporation from levees and uncultivated land surfaces.

Major Units of Ultimate State Water Plan in San Joaquin River Basin.

The fundamental objective of the ultimate State Water Plan in the San Joaquin River Basin is to provide and operate works for the conservation, regulation, utilization and distribution of the available water resources so that all areas within the basin, practicable of development, might have adequate water supplies for all purposes and flood protection. A comparison of the available water supplies with the ultimate water requirements of the irrigable areas to be served in the San Joaquin River Basin shows that there is insufficient water to meet the ultimate needs. There would be a large deficiency particularly in the upper San Joaquin Valley where the average seasonal water supply for the 40-year period 1889–1929, exclusive of the San Joaquin River, is but 50 per cent of the ultimate seasonal water requirement. In the lower San Joaquin Valley, excluding the delta, the water supply would be sufficient for ultimate needs. However, in the Sacramento River Basin, studies reveal that there is a surplus of water over its ultimate needs. The logical source of supplemental water supply for the San Joaquin River Basin is the surplus water of the Sacramento River Basin. Therefore, the plans for development in the two basins are interdependent and interrelated and together constitute a unified plan for the entire Great Central Valley. The plan evolved is designed to make the greatest practicable use of the available water supplies in both basins to meet the full requirements for ultimate development in the entire Great Central Valley.

The basic features included in the State Water Plan for the Great Central Valley are storage reservoirs, both surface and underground, and natural and artificial conveyance channels. Surface reservoirs would be constructed on the major streams and operated to equate the erratic run-off in the interest of all uses. Hydroelectric power plants would be installed at those dams where such development would be justified in order to assist in defraying the cost of the capital expenditures. Conveyance channels, both natural and artificial, would transport water supplies from areas having a surplus to areas of deficiency.

Because of the large expense involved in exporting water supplies from the Sacramento River Basin to the San Joaquin Valley, the plan for the San Joaquin River Basin is designed to provide for the fullest practicable utlilization of all local water supplies. In addition to surface storage regulation, this necessitates the maximum practicable utilization of underground reservoirs for the storage and subsequent extraction of water supplies. Provision is made for the conveyance and distribution of surplus Sacramento River Basin water, made available by storage and regulation with the major units of the State Water Plan in the Sacramento River Basin, to provide for that portion of the water requirements of the San Joaquin Valley which can not be met by the fullest practicable utilization of local supplies.

Surface Storage Reservoirs—The surface storage reservoir units in the San Joaquin River Basin are thirteen in number, namely, Nashville on Cosumnes River; Ione on Dry Creek, a tributary of Mokelumne River; Pardee on Mokelumne River; Valley Springs on Calaveras River; Melones on Stanislaus River; Don Pedro on Tuolumne River; Exchequer on Merced River; Buchanan on Chowchilla River; Windy Gap on Fresno River; Friant on San Joaquin River; Pine Flat on Kings River; Pleasant Valley on Tule River; and Isabella on Kern River. Power plants are proposed at Melones, Don Pedro, Friant and Pine Flat reservoirs. The Exchequer and Pardee reservoirs with power plants are included in the plan as already constructed and are assumed to be operated for the purposes for which they were designed. The Valley Springs reservoir would be enlarged from 76,000 acre-feet to 325,000 acre-feet capacity, reserving 165,000 acre-feet of space in the reservoir for flood control purposes. At the Melones and Don Pedro reservoirs it is proposed to construct new dams downstream from existing ones, creating reservoirs of larger capacity, and to reconstruct and enlarge the power plants. Flood control features are included in the Nashville, Ione, Valley Springs, Melones, Don Pedro, Exchequer, Friant, Pine Flat and Isabella reservoirs. The aggregate capacity of the surface storage reservoirs proposed for ultimate development is 5,130,000 acre-feet.

Underground Reservoirs—An essential feature of the State Water Plan in the San Joaquin River Basin is the utilization of underground reservoirs for the storage and subsequent extraction of water supplies by pumping. The underground capacity affords the only means of providing the large amount of cyclic storage required to equate the extremely variable run-off and bring the available supply in consonance with the demand and make the fullest practicable utilization of local supplies. Operated in conjunction with surface regulation and distribution, the utilization of the underground reservoirs is shown to result in the cheapest, most flexible and dependable plan of any that has been suggested or investigated. Underground reservoir utilization is particularly important in the upper San Joaquin Valley where experience has already demonstrated its practicability and value and where wells and pumping plants with an aggregate capacity of over 20,000 second-feet already are in operation.

The usable underground capacity in the upper San Joaquin Valley aggregates over 20,000,000 acre-feet and in the lower San Joaquin Valley about 3,000,000 acre-feet. The plan proposes to make full utilization of this underground capacity, particularly in the upper San Joaquin Valley, with operation thereof coordinated with surface storage regulation. The chief cost involved in the utilization of the underground reservoirs would be for the pumping of water supplies. Costs of two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot are representative of the general average for pumping in the San Joaquin Valley.

Conveyance Units—The proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin are designed primarily to bring necessary water supplies from the Sacramento River Basin to the San Joaquin Valley to supplement the available local water supplies. The adopted plan of conveyance includes a pumping system on the San Joaquin River to transport water from Sacramento-San Joaquin Delta to Mendota. It provides for the exchange of a portion of the pumped water for San Joaquin River water which would be diverted at the Friant Reservoir, 61 miles farther upstream and 308 feet higher in elevation than the point of delivery of imported water at Mendota. It provides conduits leading north and south from Friant Reservoir to convey San Joaquin

River water to the lands on the eastern slope of the upper San Joaquin Valley. An extension of the pumping system southerly from Mendota is provided to serve the lands on the western slope of the upper San Joaquin Valley. The advantages of the plan are many. Both capital and annual costs would be much less than for conveyance by any other method. By means of the proposed exchange at Mendota, a pumping lift of about 300 feet would be saved over a direct pumping plan. Diversion in the Sacramento-San Joaquin Delta would be effected below all the riparian lands in the Sacramento River Basin. The source of the water supply in the Sacramento-San Joaquin Delta is the temporary catch-basin of the run-off and return water from 42,900 square miles of drainage area, which comprises 74 per cent of the entire area of the Sacramento and San Joaquin River basins and contributes 91 per cent of the run-off of the two basins. Water developed in any part of the two basins north of the upper San Joaquin River would naturally find its way to this catch-basin. The flexibility of the plan would be of great advantage. It would lend itself more readily to progressive development with minimum expenditures and it would interfere least with present rights and interests. By this plan, full recharge of ground water storage would be made by gravity diversion from Friant, whereas any other plan not providing for exchange of water at Mendota would require a greatly increased pumping lift for such purpose. These great advantages would not be attained by any scheme that does not utilize the delta as a source of supply, and only in part, if not combined with exchange with San Joaquin River water.

The conveyance channels, natural and constructed, which would be required for the exportation and delivery of water from the Sacramento River Basin to the lands of the San Joaquin River Basin, would extend from the Sacramento River at the head of Snodgrass Slough to the southern extremity of the San Joaquin Valley.

Beginning at the northerly end of the conveyance system a new connecting channel, in conjunction with a suitable diversion structure in the Sacramento River, is proposed to carry from the Sacramento River to the San Joaquin Delta the water required for exportation to the San Joaquin Valley. It also would convey water for use in the San Joaquin Delta and adjacent uplands and the upper San Francisco Bay region. It would consist of an artificial channel dredged from the Sacramento River at a point just below Hood to the head of Snodgrass Slough, from which point this natural channel would be utilized, with improvements, to Dead Horse Island. The North and South forks of the Mokelumne River would be utilized from there to the San Joaquin River at Central Landing. The length of this cross connection, designated as the Sacramento-San Joaquin Delta Cross Channel, by the shortest route would be 24 miles.

From Central Landing to the first unit of the pumping system below Mossdale bridge, it is proposed to utilize three main channels, each about 30 miles in length. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two main channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed, such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity would be adequate to meet the requirements of irrigation in the delta and adjacent areas and that of exportation to the San Joaquin River Basin.

The first unit of the San Joaquin River Pumping System would be located just above the point of bifurcation of the San Joaquin River and Old River. From this point to the mouth of the Merced River the channel of the San Joaquin River would be utilized for a distance of 72 miles. By means of a series of five successive dams and pumping plants water would be conveyed from the delta and raised to an elevation of 62 feet U. S. Geological Survey datum. The dams used for this portion of the conveyance system would be of the collapsible type so that the river channel could be opened to permit free discharge in case of large flows. The maximum capacity of the pumping system would be 8000 second-feet.

From the pond above Plant No. 5 it is proposed to depart from the river with a constructed canal extending southerly along the most favorable topography. By means of three pumping lifts in a distance of seven miles the water would be raised to an elevation of 137 feet at the discharge of Plant No. 8 and would continue a distance of sixteen miles to Plants No. 9 and No. 10, about five miles west of Los Banos. An exchange would be made with existing systems serving lands lying below Plant No. 9. From the discharge of Plant No. 10, at an elevation of 180 feet, the canal would extend southerly about 38 miles to the Mendota weir, delivering water to an elevation of 159 feet. The total distance from Pumping Plant No. 1 to Mendota weir would be 135 miles. The pond above the Mendota weir would be the source of supply for lands now served by diversion at and near this point. A small part of the Columbia area would be served by pumping.

The delivery of imported waters to Mendota to meet the demand of existing rights would make possible the diversion at the Friant Reservoir of the flow of the San Joaquin River for use on the eastern slope of the upper San Joaquin Valley. To effect such diversion it is proposed to construct, in addition to the Friant Reservoir, two main canals, one on each side of the San Joaquin River. The Madera Canal, with a diversion capacity of 1500 second-feet, on the north side of the river would extend for eighteen miles to the channel of the Fresno River. The San Joaquin River-Kern County Canal on the south side of the stream would extend southward along the eastern rim of the valley a distance of 165 miles. With a diversion capacity of 3000 second-feet at the Friant Reservoir, it would cross in turn the channels of the Kings, Kaweah, Tule and Kern rivers, terminating at the Kern Island Canal, with a capacity of 500 second-feet.

In order to utilize Kern River waters released by the importation of new supplies, it would be necessary to construct the Kern River Canal with a diversion point near the mouth of the canyon on the south side of the stream and extending under the Kern Mesa and thence around the south end of the valley to Buena Vista Valley. The maximum diversion capacity of this canal would be 1500 second-feet and the total length 75 miles.

To make water available for the good land lying on the western slope of the upper San Joaquin Valley, the Mendota-West Side Pumping System is provided extending from Mendota Pool to Elk Hills. Water for this area would be imported through the San Joaquin River Pumping System. An essential element of such a system would be a conveyance channel which, for full development, would be 100 miles long and have a capacity varying from 4500 to 500 second-feet. It would terminate at an elevation of 250 feet.

Capital and Annual Costs—Estimates of both the capital and annual costs were made for each surface storage and conveyance unit, based on the costs of labor and materials as of 1929 and 1930 and on the assumption that each unit would be completely constructed in one step. The following tabulation sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Four of the reservoirs include power plants. The capital cost of each of these reservoirs includes power features. The net annual cost consists of the annual cost of the reservoir and the gross annual cost of the power plant less the estimated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

COSTS OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Location	Capital cost	Net annual cost
Storage Units—			
Nashville Reservoir	Cosumnes River	$7,400,000	$441,000
Ione Reservoir	Dry Creek	8,600,000	517,000
Pardee Reservoir	Mokelumne River	Constructed	Constructed
Valley Springs Reservoir	Calaveras River	7,600,000	452,000
Melones Reservoir[1]	Stanislaus River	26,200,000	937,000
Don Pedro Reservoir[1]	Tuolumne River	32,500,000	979,000
Exchequer Reservoir	Merced River	Constructed	Constructed
Buchanan Reservoir	Chowchilla River	2,600,000	155,000
Windy Gap Reservoir	Fresno River	3,300,000	200,000
Friant Reservoir[2]	San Joaquin River	14,500,000	805,000
Pine Flat Reservoir[1]	Kings River	11,600,000	541,000
Pleasant Valley Reservoir	Tule River	2,900,000	171,000
Isabella Reservoir	Kern River	5,700,000	340,000
Subtotals		$122,900,000	$5,538,000
Conveyance Units—			
Sacramento-San Joaquin Delta Cross Channel	Sacramento-San Joaquin Delta	$4,000,000	$300,000
San Joaquin River Pumping System	Lower San Joaquin Valley	28,500,000	[3]6,779,000
Mendota-West Side Pumping System	West side Upper San Joaquin Valley	16,000,000	[4]3,088,000
Madera Canal	East side Upper San Joaquin Valley, north of San Joaquin River	2,500,000	213,000
San Joaquin River-Kern County Canal	East side Upper San Joaquin Valley, south of San Joaquin River	28,000,000	2,281,000
Kern River Canal	East side and south end of Upper San Joaquin Valley, south of Kern River	9,000,000	721,000
Subtotals		$88,000,000	$13,382,000
Totals, all units		$210,900,000	$18,920,000

[1] Includes power plant.
[2] Includes power plant for ultimate development, only.
[3] Includes energy cost of $4,240,000.
[4] Includes energy cost of $1,692,000.

Operation and Accomplishments—Because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the supply required to meet its ultimate requirements, consideration of the operation and accomplishments of the plan in the San Joaquin River Basin must be combined with those in the Sacramento River Basin. The proposed major units for ultimate development in the two basins constitute a unified project for the entire Great Central Valley, and these major units would be operated coordinately to provide the ultimate water requirements and to accomplish the objectives sought for the fullest practicable conservation, regulation, distribution and utilization of the water resources. The proposed major units in the Sacramento River Basin would be operated not only to take care of the requirements for all purposes within that basin itself but also to provide the supplemental supply required in the San Joaquin River Basin, including the San Joaquin Delta and the adjacent delta uplands. Provision would also be made to supply the water requirements of the upper San Francisco Bay region with water furnished chiefly from the Sacramento River Basin. Details as to the operation of the major units in the Sacramento River Basin are set forth in another report.*

In the lower San Joaquin Valley the proposed surface storage reservoirs on the Cosumnes, Calaveras and Mokelumne rivers and Dry Creek, a tributary of the Mokelumne River, would be operated coordinately with storage units on the American River in the Sacramento River Basin so that the combined amount of water obtained from these local sources and from the supplies imported from the American River would meet the ultimate water requirements of the irrigable area to be served by these streams. The surface reservoirs on the Stanislaus, Tuolumne and Merced rivers would be operated to provide an adequate surface irrigation supply for all irrigable lands to be served in their respective service areas. However, a portion of the service area under the Merced River would be supplied in part through ground water storage and pumping and in part from water conveyed through the San Joaquin River Pumping System. For the bulk of the area on the east side of the upper San Joaquin Valley from the Chowchilla River to the southern end, the surface storage reservoirs would be operated in combination with ground water storage and pumping to provide a full supply in all years to the irrigable area to be served under ultimate development. To accomplish the desired results would require the operation of the underground reservoirs in a specific manner similar to that of surface reservoirs. Water would be stored in the underground reservoirs when the available supplies are in excess of the net requirements. The supplies stored underground would be drawn upon for the most part through the medium of privately owned pumping plants. However, in order to maintain a balance in supply and draft over long periods throughout the areas to be supplied in part by ground water, works for the distribution of surplus waters, and pumping equipment in strategic locations, necessarily would be controlled and operated by recognized local public agencies. Friant Reservoir would be operated as a key unit for the entire area on the east side

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

of the upper San Joaquin Valley to provide the necessary supplies to supplement the amounts made available from local sources through surface and underground storage regulation. The supplies from this reservoir would be distributed through the Madera and San Joaquin River-Kern County canals.

The areas to be served on the westerly slope of both the upper and lower San Joaquin Valley would be supplied by water conveyed through the San Joaquin River and Mendota West-Side Pumping systems. The source of water supply would be chiefly surplus Sacramento River Basin water conveyed from the delta channels through these pumping systems to the southerly terminus near Elk Hills. An additional source of supply would be the return flows from irrigated lands in the lower San Joaquin Valley and unregulated surplus water of the San Joaquin River and its east side tributaries, which would be intercepted in that portion of the San Joaquin River Pumping System utilizing the river channel below the mouth of the Merced River. The interception and utilization of these return and surplus waters would reduce the capital and annual costs of the pumping system. However, the amounts intercepted would necessarily be replaced in the delta by Sacramento River Basin water in order to provide for delta requirements and hence the amount of supplemental water supply required from the Sacramento River Basin for the San Joaquin Valley would not be reduced by the interception and utilization of these return and surplus waters.

Based upon a detailed monthly analysis of the proposed plan of operation with the available water supplies during the 40-year period 1889–1929, the water supplies which would be made available to meet the water requirements under the ultimate State Water Plan in the San Joaquin River Basin may be summarized as follows:

1. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of a net area of 1,810,000 acres of irrigable land in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley, after deducting from the full natural run-off of the lower San Joaquin River tributaries, 565,000 acre-feet per season for an adequate and dependable irrigation supply for 205,000 acres of land embracing all of the net irrigable mountain valley and foothill lands situated in the lower San Joaquin Basin at elevations too high to be irrigated by gravity from the major reservoir units.
2. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of classes 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley.
3. A supply of 1,570,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of all of the net irrigable area of 772,000 acres of classes 1 and 2 lands lying on the western slope of the upper San Joaquin Valley and 13,000 acres of classes 1 and 2 lands in the Columbia Canal area.

In addition to the water supplies furnished from the local streams in the San Joaquin River Basin, there would have been required from the Sacramento River Basin an average seasonal supply of about 2,000,000 acre-feet, exclusive of about 1,000,000 acre-feet of return flow and surplus water from the lower San Joaquin Valley intercepted and utilized in the San Joaquin River Pumping System, which would be replaced in the delta by Sacramento River Basin water. The required supplemental supply for the San Joaquin Valley would have been provided by the proposed major units in the Sacramento River Basin, including the Trinity River diversion, in addition to providing the full ultimate requirements in the Sacramento River Basin itself, the full requirements in the Sacramento-San Joaquin Delta including control of salinity and maintenance of fresh water in the delta channels, and the provision of supplemental supplies for the upper San Francisco Bay region.

In addition to the water supplies furnished, an average annual energy output of 728,500,000 kilowatt hours would be generated at the major reservoirs in the San Joaquin River Basin incidental to their primary operation for irrigation; additional flood protection would be effected on several of the major streams; and navigation would be improved on the San Joaquin River above Stockton.

Initial Development of State Water Plan in San Joaquin River Basin.

The initial development of the State Water Plan in the San Joaquin River Basin is proposed as the first progressive step in the consummation of the plan for ultimate development. It is designed primarily to meet the immediate pressing needs of existing developments. Certain areas in the basin, particularly in the upper San Joaquin Valley and in the San Joaquin Delta region, have serious problems of water shortage as previously described in this chapter. The adequate solution of these problems to maintain the productive resources and investments of present developments would require the construction and operation of initial units of the State Water Plan. In addition to providing supplies to meet present deficiencies, additional flood protection and improvement of navigation on the San Joaquin River above Stockton are desirable.

In the developed areas on the east side of the upper San Joaquin Valley, studies of water supply and water requirements during the period 1921–1929 reveal that the average seasonal deficiency in water supply during this period amounted to 387,000 acre-feet. The area involved aggregates about 400,000 acres of fully developed and irrigated lands. Water supplies are obtained largely by pumping from underground and the depletion of the underground reservoirs has resulted in a general lowering of ground water levels causing excessive pumping lifts in some localities. Supplemental water supplies are required to meet not only the deficiencies between supply and demand but also to replenish the underground reservoirs and reduce pumping lifts. It is estimated that an average seasonal importation of supplemental water of from 500,000 to 600,000 acre-feet should be provided as a minimum requirement.

In the San Joaquin Delta a developed irrigated area of 219,000 acres has experienced a deficiency in water supply to meet the net water requirements for irrigation and to keep the water in the delta channels fresh as against invasion of saline water from the bay. Supplemental water supplies are required to meet the deficiency in this area and in the Sacramento River portion of the delta as well, which is estimated to have averaged 451,000 acre-feet annually during the period 1920–1929. In addition there is an immediate need of supplemental water supplies for present industrial and agricultural developments in the upper San Francisco Bay region adjoining the delta.

The plan for initial development to provide supplemental supplies to the upper San Joaquin Valley has been considered in two steps, first, an immediate initial development to provide an average seasonal supplemental supply of 500,000 to 600,000 acre-feet during a similar period of run-off such as 1921–1929, and, second, a complete initial development to furnish a larger supplemental water supply and provide with greater certainty for the complete relief of present developed areas, more substantial ground water replenishment, and for some expansion of irrigated areas on lands adjacent to present developments. The provision of supplemental supplies for the Sacramento-San Joaquin Delta and adjacent areas also would be required under both the immediate and complete initial plans of development. The plan for initial development in the San Joaquin River Basin involves initial units in the Sacramento River Basin which would be required to provide for the immediate requirements of the delta and adjacent areas and for supplemental water supplies required in the upper San Joaquin Valley for complete initial development. The units for initial development in the two basins constitute a unified project for the entire Great Central Valley.

For the relief of the areas of deficient water supply in the upper San Joaquin Valley, it is proposed in the plan for immediate initial development to acquire, by purchase of existing rights, waters of the San Joaquin River now devoted to inferior use on "grass lands" for pasture, served by diversions from this river above the mouth of the Merced River. The water so acquired together with surplus water of the San Joaquin River would be regulated in Friant Reservoir and conveyed to the areas in the upper San Joaquin Valley through the Madera and San Joaquin River-Kern County canals. Based on the period of run-off from 1921 to 1929, sufficient water to meet the present deficiencies could be obtained from this source for the upper San Joaquin Valley at a cost less than that from any other source.

The proposed physical works in the San Joaquin River Basin for immediate initial development comprise the following:

1. Friant Reservoir with a gross capacity of 400,000 acre-feet and a usable capacity of 270,000 acre-feet above elevation 467 feet, diversion elevation of San Joaquin River-Kern County canal.
2. San Joaquin River-Kern County canal to Kern River with a maximum diversion capacity of 3000 second-feet.
3. Madera canal with a maximum capacity of 1500 second-feet.
4. Magunden-Edison pumping system with a capacity of 20 second-feet.

After providing an adequate water supply from the San Joaquin River to meet the demands of crop lands now served from this stream above the mouth of the Merced River in accord with present rights, the average seasonal amounts of water that could have been obtained from regulation of surplus and "grass land" waters in Friant Reservoir and delivered through the conduits diverting therefrom would have been of the following amounts for different periods from 1889–1929.

Period	*Supply for areas served by San Joaquin River-Kern County Canal, average seasonal amount, in acre-feet*	*Supply for Madera area, average seasonal amount, in acre-feet*	*Total average seasonal amount, in acre-feet*
1889–1929	851,000	181,000	1,032,000
1909–1929	688,000	151,000	839,000
1917–1929	495,000	107,000	602,000
1919–1929	485,000	108,000	593,000
1921–1929	493,000	108,000	601,000
1924–1929	410,000	90,000	500,000

The allocation of the supplemental water supplies furnished from Friant Reservoir to the areas requiring immediate relief on the east side of the upper San Joaquin Valley would be based not only upon the average deficiencies in supply but also upon the needs for ground water replenishment in the absorptive areas where ground water supplies are utilized.

If it should prove desirable and necessary to furnish a direct surface supply from imported water from the San Joaquin River to lands lying to the east of Tulare Lake in Kings County, now used chiefly for the growing of annual crops and having a variable water supply, water would be available for this purpose, however, with a reduction of supply to the other counties. It is estimated that 90,000 acre-feet seasonally would be adequate for the irrigation of the lands now cropped.

Studies of the operation of Friant Reservoir under the plan of immediate initial development, with the water supplies obtained therefrom combined with local supplies in the upper San Joaquin Valley and with regulation of local and imported supplies from the San Joaquin River effected by underground storage and pumping, show that during the period 1921–1929 the present water requirements would have been fully met and there would have been 1,361,000 acre-feet more water available in the underground reservoirs at the end of the period than at the beginning.

When water supplies in addition to the amounts made available from the proposed plan of immediate initial development are required in the upper San Joaquin Valley, either for the purpose of more adequately meeting the needs of present developed areas for actual water requirements and ground water replenishment or for expansion of irrigated areas or for both purposes, importation of Sacramento River Basin water will be required. The additional units required for this purpose would comprise the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System with an initial maximum capacity of 3000 second-feet. It is considered that this would be a second step in the initial development and it is believed that the construction of the conveyance units required for importation of Sacramento River Basin water to the San Joaquin Valley could be deferred. However, in view of the possibility of the occurrence of seasons or periods of run-off even more subnormal than during the period 1921–1929 and the resulting possible need of supplemental water supplies from the Sacramento River Basin to adequately meet the present needs of developed areas, provision should be made in the plan of financing for the initial development to meet the cost of these additional units.

Under the plan of complete initial development water supplies made available from the surplus in the Sacramento River Basin would be conveyed from the delta to Mendota sufficient in amount to provide a full supply for the crop lands now served from the San Joaquin River above the mouth of Merced River. Practically the entire flow of the San Joaquin River at Friant would be regulated in Friant Reservoir for utilization on the east side of the upper San Joaquin Valley. Based on the run-off during the 12-year period 1917–1929, the average seasonal supply from Friant Reservoir would have been 1,366,000 acre-feet. This supply combined with the utilizable supplies from the unregulated local streams in the upper San Joaquin Valley, would amount to 3,574,000 acre-feet average per season and would have been sufficient to irrigate about one and one-half times the present irrigated area now supplied from local streams on the east side of the upper San Joaquin Valley.

Economic and Financial Aspects—Consideration of the economic and financial aspects of the initial plan of development in the San Joaquin River Basin must be combined with the initial plan in the Sacramento River Basin because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the water supply required. The units in the two basins comprise a unified project for the entire Great Central Valley. Analyses of cost, anticipated revenues and plans of financing have, therefore, been made for the initial State Water Plan in the entire Great Central Valley. In addition to the units in the San Joaquin River Basin, the initial plan of development in the Great Central Valley would include Kennett Reservoir (capacity 2,940,000 acre-feet) and power plants on the Sacramento River and a conduit to convey water from the delta to the upper San Francisco Bay area.

The capital and gross annual costs of the proposed units of the initial State Water Plan in the Great Central Valley are shown in the following tabulation. Capital costs include interest at 4½ per cent during construction, and annual costs include interest at 4½ per cent, amortization on 4 per cent sinking fund basis in 40 years, depreciation, and operation and maintenance expense.

CAPITAL AND ANNUAL COSTS OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY

Item	Immediate initial development		Complete initial development	
	Capital cost	Gross annual cost	Capital cost	Gross annual cost
Kennett reservoir and power plant	$84,000,000	$5,297,000	$84,000,000	$5,297,000
Sacramento-San Joaquin Delta cross channel	----------	----------	4,000,000	300,000
Contra Costa County conduit	2,500,000	300,000	2,500,000	300,000
San Joaquin River pumping system	----------	----------	15,000,000	2,500,000
Friant reservoir and power plant	15,500,000	1,062,000	14,500,000	885,000
Madera Canal	2,500,000	213,000	2,500,000	213,000
San Joaquin River-Kern County Canal	27,300,000	2,225,000	27,300,000	2,225,000
Magunden-Edison pumping system	100,000	18,000	100,000	18,000
Water rights and general expense	7,000,000	389,000	8,000,000	444,000
Total costs	$138,900,000	$9,504,000	$157,900,000	$12,182,000

Direct revenues would be derived from sale of electric energy and water under the operation of the initial State Water Plan. The anticipated revenues from sale of electric energy and water, based upon the estimated amounts of electric energy and water which would be sold, are set forth in the following tabulation:

AVERAGE ANNUAL REVENUES OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY

Source of revenue	Immediate initial development		Complete initial development	
	Annual output, in kilowatt hours	Revenue	Annual output, in kilowatt hours	Revenue
Electric energy sales—				
Kennett, including Keswick	1,591,800,000	$4,218,000	1,581,100,000	$3,826,000
Friant, river plant	105,000,000	367,000	----------	----------
Friant, Madera Canal plant	----------	----------	23,000,000	80,000
Subtotals	1,696,800,000	$4,585,000	1,604,100,000	$3,906,000
Water sales—	Annual delivery, in acre-feet	Revenue	Annual delivery, in acre-feet	Revenue
Upper San Joaquin Valley	600,000	$1,800,000	1,720,000	$5,160,000
Contra Costa County	43,500	300,000	43,500	300,000
Sacramento-San Joaquin Delta and Sacramento River	420,000	420,000	420,000	420,000
Subtotals	1,063,500	$2,520,000	2,183,500	$5,880,000
Total electric energy and water sales	----------	$7,105,000	----------	$9,786,000

With interest at $4\frac{1}{2}$ per cent and amortization of the capital investment in 40 years, the gross annual cost of the initial State Water Plan in the Great Central Valley exceeds the anticipated revenues from the sale of water and power by over $2,000,000. However, in addition to the direct anticipated revenues, it is believed that the large benefits which would accrue to the many interests, not only local but also national and state-wide, might reasonably justify the anticipation of direct contributions by the Federal and State governments to defray a portion of the cost of the project. It also is possible that the project could be financed at a lower average rate of interest and with repayment extended over a longer period than that assumed in the estimated gross annual costs as previously presented. Such modifications might reduce the gross annual cost, including interest and amortization on capital expenditures to be directly borne by the project, to such an extent that the revenues would be sufficient to meet the annual carrying charges. The analyses of several tentative plans of financing based upon various assumed interest and sinking fund rates, amortization periods and Federal and State contributions are summarized in the following tabulation:

FINANCIAL ANALYSES OF INITIAL STATE WATER PLAN IN GREAT CENTRAL VALLEY WITH VARIOUS ASSUMED BASES OF FINANCING

Annual Direct Revenues from Sale of Water and Electric Energy: Immediate Initial Development, $7,105,000; Complete Initial Development, $9,786,000

Basis of financing	Immediate initial development			Complete initial development		
	Capital cost	Gross annual cost	Net annual cost (—) or return (+)	Capital cost	Gross annual cost	Net annual cost (—) or return (+)
Without direct Federal or State Contributions—						
Plan 1. Interest at 4½ per cent and 40-year amortization on a 4 per cent sinking fund basis	$138,900,000	$9,504,000	—$2,399,000	$157,900,000	$12,182,000	—$2,396,000
Plan 2. Interest at 4½ per cent and 50-year amortization on a 4 per cent sinking fund basis	138,900,000	8,960,000	—1,855,000	157,900,000	11,556,000	—1,770,000
Plan 3. Interest at 4½ per cent and 70-year amortization on a 4 per cent sinking fund basis	138,900,000	8,438,000	—1,333,000	157,900,000	10,956,000	—1,170,000
Plan 4. Interest at 4 per cent and 50-year amortization on a 4 per cent sinking fund basis	137,400,000	8,179,000	—1,074,000	156,200,000	10,649,000	—863,000
Plan 5. Interest at 3½ per cent and 50-year amortization on a 3½ per cent sinking fund basis	136,000,000	7,564,000	—459,000	154,700,000	9,945,000	—159,000
Plan 6. Interest at 3 per cent and 50-year amortization on a 3 per cent sinking fund basis	134,500,000	6,975,000	+130,000	152,900,000	9,253,000	+533,000
Plan 7. No interest and repayment of principal sum in 40 equal annual installments	125,400,000	4,767,000	+2,338,000	142,900,000	6,673,000	+3,113,000
With direct Federal and State contributions—						
Plan 8. Same as Plan 1, with direct Federal contribution of $6,000,000 in the interest of navigation and State contribution of $3,400,000 for the relocation of State highway above Kennett Reservoir	*$129,500,000	$8,980,000	—$1,875,000	*$148,500,000	$11,658,000	—$1,872,000
Plan 9. Same as Plan 2, with Federal and State contributions as in Plan 8	*129,500,000	8,475,000	—1,370,000	*148,500,000	11,071,000	—1,285,000
Plan 10. Same as Plan 3, with Federal and State contributions as in Plan 8	*129,500,000	7,989,000	—884,000	*148,500,000	10,507,000	—721,000
Plan 11. Interest at 4½ per cent and refunding bonds, with same Federal and State contributions as in Plan 8	*129,500,000	7,512,000	—407,000	*148,500,000	10,099,000	—313,000
Plan 12. Same as Plan 5, with Federal and State contributions as in Plan 8	*126,600,000	7,188,000	—83,000	*145,300,000	9,613,000	+173,000
Plan 13. Same as Plan 12, with Federal contribution increased to $20,000,000	*112,600,000	6,591,000	+514,000	*131,300,000	9,016,000	+770,000

*Direct Federal and State contributions not included.

NOTE.—If financed under the provisions of Title II of the National Industrial Recovery Act of 1933, with a direct Federal contribution of 30 per cent of the cost of labor and materials and a Federal loan to finance the balance of the cost with interest at 4 per cent and amortization on a 4 per cent sinking fund basis in 50 years, the gross annual cost of the project for complete initial development would be considerably less than the anticipated revenue from water and power sales.

Flood Control.

Under natural conditions, about one and three-quarters million acres of land in the San Joaquin River Basin is subject to inundation by floods. About half of this flooded area has been protected in varying degree by flood control works, chiefly comprising levees. These works have been constructed almost entirely by local interests. No general plan of flood control has been adopted in the San Joaquin Valley such as that in the Sacramento Valley. More adequate flood protection is needed in many of the areas now partially protected from floods, and flood control works for lands now unprotected will be necessary and desirable.

One of the important objectives of the State Water Plan in the San Joaquin River Basin is the provision of additional flood protection to reduce flood hazards on the areas subject to flooding. It is proposed to reduce flows by surface reservoir regulation, thereby increasing the degree of protection on lands now leveed and reducing the cost of additional levee protection. The reservation of space and its operation for flood control is provided for in most of the major reservoirs. The following tabulation sets forth the streams on which flood control by reservoirs is proposed, the maximum reservoir space required to regulate floods to certain controlled flows, the amounts of these controlled flows and the frequency with which the controlled flows would be exceeded. The operation of these reservoirs for flood control would not materially impair their value for conservation purposes, nor materially decrease the amount or value of electric energy generated by water released from them.

RESERVOIR SPACE REQUIRED FOR CONTROLLING FLOODS TO CERTAIN SPECIFIED FLOWS

Reservoir	Stream	Point of control	Maximum reservoir space employed, in acre-feet	Controlled flow, in second-feet[2]
Nashville	Cosumnes River	Michigan Bar	56,000	15,000
Ione	Dry Creek	Galt	[1]121,000	5,000
Pardee	Mokelumne River	Clements	[1]0	10,000
Valley Springs	Calaveras River	Jenny Lind	165,000	25,000
Melones	Stanislaus River	Knights Ferry	204,000	15,000
Don Pedro	Tuolumne River	La Grange	214,000	15,000
Exchequer	Merced River	Exchequer	59,000	25,000
Friant	San Joaquin River	Friant	75,000	15,000
Pine Flat	Kings River	Piedra	80,000	15,000
Isabella	Kern River	Bakersfield	67,000	7,500

[1] Floods which would cause flows in excess of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reservoir to Dry Creek by the Jackson Creek spillway and the water stored in Ione Reservoir.
[2] Controlled flow would be exceeded once in 100 years on the average.

The operation of the foregoing reservoirs for flood control, employing the reservoir space reserved in each reservoir for the specific purpose of controlling floods to the specified flows, would result in a substantial reduction of flood flows at points of concentration along the areas subject to inundation. The following table sets forth, for various points on the San Joaquin River, the crest flood flow exceeded once in 100 years, with and without reservoir control. The flows without reservoir control are those that would obtain with levees constructed along the San Joaquin River from Herndon to the delta to form a channel of sufficient width to care for these flows and reclaim the remaining land now subject to overflow. The flows with reservoir control are those that would obtain with the same channel, but with the flood flows from the larger streams controlled by means of regulation to those shown in the foregoing tabulation. If reclamation of the valley lands by means of levees were not effected until after the reservoirs with flood control features were completed, a narrower flood channel along the river could be constructed because of the smaller regulated flows. Under this condition, however, the flows might be slightly larger than those shown in the last column of the following tabulation, since the reduction of quantities by storage in the narrower channels might be less and the rate of concentration somewhat greater.

FLOOD FLOWS IN SAN JOAQUIN VALLEY WITH AND WITHOUT RESERVOIR CONTROL

Point of concentration	Crest flood flow in second-feet, exceeded once in 100 years on the average	
	Without reservoir control	With reservoir control
San Joaquin River below confluence with Merced River	70,000	51,000
San Joaquin River below confluence with Tuolumne River	103,000	64,000
San Joaquin River below confluence with Stanislaus River	133,000	82,000
Combined concentrations Sacramento and San Joaquin rivers—opposite Collinsville	780,000	595,000

It is estimated that the reduction in flood flows by reservoir control as proposed under the State Water Plan would effect a probable minimum saving of about $18,000,000 in cost of flood protection works in the San Joaquin Valley.

Navigation.

In the formulation of the State Water Plan for the coordinate development and utilization of the water resources of the Great Central Valley, consideration has been given to the need for water transportation and the feasibility of further improvement of navigation. Within the San Joaquin River Basin, the navigable waterways comprise the main San Joaquin River, the tributary Mokelumne River and many miles of interconnecting natural and artificial channels in the San Joaquin Delta. The Federal Government has recognized these streams as navigable waterways since the seventies and has exercised jurisdiction over them, through the Corps of Engineers of the United States War Department, in the interest of improvement and maintenance of navigation.

In accord with investigations made by the United States War Department, the portion of the San Joaquin River which is worthy of consideration with a view to further improvement in the interest of navigation lies between Stockton and Mendota. This river offers a potential inland waterway through the heart of the San Joaquin Valley which, if adequately improved, would provide a means of cheap water transportation for the large and increasing volume of tonnage moving to and from the San Joaquin Valley. The lower section of the river below Stockton has been improved to provide dependable navigation for commercial craft and is functioning as one of the most important and successful internal waterways in the nation. About one million tons of freight valued at nearly 43 million dollars are moved annually on this waterway. A deep water channel to Stockton, which will accommodate ocean going vessels, is expected to be completed early in 1933, thus adding Stockton as a port in the San Francisco Bay Harbor. On the section of the river above Stockton, commercial craft in former years, starting as early as the fifties, navigated as far up stream as Mendota and occasionally to Herndon. However, navigation has always been seasonal in character because of the greatly reduced stream flow during several months of the year when navigation is not practicable. The lack of dependable navigation depths has discouraged water transportation and there has been no commercial navigation of importance for many years on the San Joaquin River above Stockton.

The plan recommended by the Division Engineer, Pacific Division, United States War Department for the improvement of navigation on the San Joaquin River from Stockton to Mendota provides for the canalization of the waterway by the construction of movable dams equipped with locks to maintain a minimum navigable depth of six feet. The Division Engineer estimates the capital cost at $12,000,000 of which $6,000,000 is for the estimated cost of the locks alone; and the annual cost of maintenance and operation at $110,000. The economic value of improvement, based upon estimates of probable savings in transportation costs which would be effected by the proposed improvement, is estimated by the Division Engineer at nearly $6,000,000 or an amount sufficient to justify about half of the capital expenditure required. It is believed, however, that a more comprehensive analysis of potential savings in transportation cost than that made by the Division Engineer might show an economic value sufficient in amount to justify the entire capital expenditure required for the plan of canalization from Stockton to Mendota.

The plan for conveyance of water from the delta to Mendota provided under the State Water Plan could be effectively coordinated with the plan for navigation improvement of the upper San Joaquin River. The plan as proposed for the San Joaquin River Pumping System would canalize the river from the delta to Salt Slough and would provide slack water navigation if the dams were equipped with locks. Above Salt Slough, this conveyance unit would depart from the river in accord with the most economical location and plan determined from detailed studies of alternate plans and routes. However, if sufficient funds were made available in the interest of navigation to pay for the cost of locks and a portion of the dams for a combined canalization and conveyance project on the San Joaquin River from Stockton to Mendota, it would be desirable and advantageous to adopt an all-river channel route for the San Joaquin River Pumping System and thus combine conveyance of water and navigation improvements in one system of works with resulting economy for both purposes.

Conclusions.

1. The water supply originating in the San Joaquin River Basin, which could be made available and utilized under the fullest practicable development, is insufficient in amount to meet the ultimate water requirements for all uses in the basin.

2. The greatest practicable utilization of the available capacity of underground reservoirs particularly in the upper San Joaquin Valley for storage and subsequent extraction of water is essential for effecting the required maximum conservation and utilization of the available local water supplies and reducing the amount of water required to be imported from outside the basin. The use of underground storage in conjunction with surface storage reservoirs offers the cheapest and most feasible method of water conservation and utilization.

3. The logical source of supplemental water supply for the San Joaquin River Basin is in the Sacramento River Basin, where surplus water in excess of the amount required for all uses in the complete ultimate development of that basin could be provided by a full practicable development of the available water supplies therein with the addition of regulated supplies diverted from the Trinity River.

4. The most feasible and least expensive plan for importing water from the Sacramento River Basin to the upper San Joaquin Valley and the one involving the least interference with existing rights and minimum legal difficulties, is one which would provide for pumping from the Sacramento-San Joaquin Delta channels up the San Joaquin River.

5. The plans for water supply development in the Sacramento and San Joaquin River basins must be combined under a unified project for the entire Great Central Valley, with all units of the project operated coordinately to effect the greatest conservation, regulation and utilization of the available water supplies to meet the needs for all purposes in both basins.

6. The proposed major units of the ultimate State Water Plan in the Great Central Valley combined with underground storage in the San Joaquin Valley, operated coordinately under conditions of stream flow equivalent in amount and distribution to that during the dry period 1917–1929 reduced by ultimate net use requirements in the mountain and foothill areas above the major reservoir units, would furnish adequate and dependable irrigation supplies for all irrigable lands in the Great Central Valley, would reduce flood flows in the major streams, would improve navigation on the Sacramento and San Joaquin rivers, would maintain a flow past Antioch into Suisun Bay sufficient to prevent invasion of saline water in harmful degree into the Sacramento-San Joaquin Delta channels, and would furnish a supply of water to the San Francisco Bay Basin to supplement water supplies in that basin for irrigation and industrial uses.

7. Under present conditions of water supply development and utilization, the available water supply in the San Joaquin River Basin is inadequate to meet the water requirements of fully developed and producing irrigated lands, particularly in the southern San Joaquin Valley where the supply for 400,000 acres of irrigated crops is only half that required, and in the San Joaquin Delta and adjacent uplands where the supply is insufficient to meet the requirements for about 300,000 acres of irrigated crops together with other consumptive demands and to prevent invasion of saline water from the bay into the delta channels.

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8. A minimum supplemental water supply of about one-half million acre-feet average per season would be required to meet the deficiencies in supply in the present developed area of 400,000 acres in the upper San Joaquin Valley and to replenish the diminishing ground water supplies, based upon the water supply available during the period 1921–1929.

9. Based upon the stream flow into the Sacramento-San Joaquin Delta during the period 1920–1929, a supplemental supply averaging 451,000 acre-feet and ranging from a minimum of 150,000 acre-feet to a maximum of 1,128,000 acre-feet per season during that period would be required to meet the present consumptive use requirements in the delta and prevent saline invasion. About two-thirds of this supply would be required in the San Joaquin Delta.

10. The utilization by storage and regulation at Friant Reservoir of the surplus waters in the upper San Joaquin River and waters to be made available through purchase of water rights attached to so-called "grass lands" on the San Joaquin River would furnish an adequate and also the least expensive supply to be secured by an initial step for the relief of the present developed areas of permanent deficiency in water supply in the upper San Joaquin Valley, based upon the stream flow during the period 1921–1929; but the feasibility of this plan would be contingent upon the effective control of salinity and the meeting of consumptive use requirements in the Sacramento-San Joaquin Delta by the development of storage in the Sacramento River Basin to furnish regulated supplemental supplies for this purpose.

11. The units proposed for immediate development of the initial State Water Plan in the Great Central Valley (Kennett and Friant reservoirs, the San Joaquin River-Kern County Canal, the Madera Canal, Magunden-Edison Pumping System and the Contra Costa County Conduit) would furnish adequate water supplies for present needs in the Sacramento Valley, Sacramento-San Joaquin Delta and upper San Francisco Bay region, and upper San Joaquin Valley, would increase the degree of flood protection and improve navigation on the Sacramento River, and incidentally would generate an annual average of 1,696,800,000 kilowatt hours of hydroelectric energy.

12. When water supplies in addition to the amounts made available by regulation in Friant Reservoir of surplus and "grass land" waters of the San Joaquin River are required in the San Joaquin Valley, either for more adequately meeting the requirements of present developed areas and providing more substantial ground water replenishment, or providing for expansion of irrigation areas, or for both, importation of water from the Sacramento River Basin would be required. Such additional supplies could be made available in the Sacramento-San Joaquin Delta channels through the operation of the initial storage unit (Kennett Reservoir on the Sacramento River) of the State Water Plan in the Sacramento River Basin, from surplus water in excess of the present needs of the Sacramento Valley, Sacramento-San Joaquin Delta and adjacent upper San Francisco Bay Basin.

13. The second step in the initial State Water Plan in the Great Central Valley, designated the "complete initial" development, would

require the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System to convey Sacramento River water to the upper San Joaquin Valley. It is believed these units would not be required immediately but provision should be made in any plan of financing for initial development for funds to defray the cost of these units.

14. Improvement of navigation on the San Joaquin River above Stockton could be effected by the incorporation of locks in the dams of that portion of the San Joaquin River Pumping System utilizing the river channel. If sufficient funds were made available in the interest of navigation, it would be desirable and advantageous to combine improvement of navigation and conveyance of water in one system of works extending from the delta to Mendota.

15. The initial State Water Plan in the Great Central Valley could not be financed from direct revenues which could be anticipated from the sale of water and electric energy on a basis of financing at an interest rate of $4\frac{1}{2}$ per cent per annum and amortization of the capital investment in 40 years.

16. Many interests, not only local but also State and National, would be benefited substantially through the consummation of the initial State Water Plan in the Great Central Valley. The furnishing of adequate water supplies for the maintenance of production on the present developed lands in the upper San Joaquin Valley, Sacramento Valley and Sacramento-San Joaquin Delta would prevent a loss of taxable wealth, help to restore agricultural credit, maintain and increase business in communities of the affected areas and between those areas and the large metropolitan centers, and assist in the protection of public utility and banking investments in these areas. Similar benefits would accrue from furnishing of adequate water supplies to the industrial areas in the upper San Francisco Bay region. Industrial and commercial business would be benefited not only within the State but in interstate trade as well. Reduction of floods on the Sacramento and San Joaquin rivers would provide an additional degree of flood protection and decrease potential flood damages. Improvement of navigation on the Sacramento and San Joaquin rivers would effect material savings in transportation costs on commodities moving to and from the Sacramento and San Joaquin valleys. The value of the foregoing benefits would more than offset the portion of the cost not capable of being met by anticipated direct revenues from sale of water and electric energy.

17. With the financial assistance of the Federal Government which would be justified and might be reasonably anticipated, in the form of direct contributions and loans at a low interest rate or without interest, in conformity with established policies and precedents for financial participation in such projects for improvement of navigation, flood control, irrigation and hydroelectric power development, and with contributions from the State Government in accord with its interest therein, the direct revenues anticipated from the sale of water and electric energy under the operation of the initial State Water Plan for the Great Central Valley would be sufficient in amount to meet all annual carrying charges comprising interest, amortization, depreciation, operation and maintenance, and the initial project would be self-supporting and self-liquidating.

CHAPTER II

WATER SUPPLY

The water supply of the San Joaquin River Basin, as set forth in this report and considered available for use, is the run-off from the mountain and foothill areas only. Contributions to surface run-off and ground water from precipitation on the valley floor, although of considerable importance in some localities in the basin, have not been included in the available water supply because of the lack of definite knowledge as to the amounts.

Description of Basin.

The San Joaquin River Basin occupies that portion of the State lying between the Sierra Nevada on the east, the Coast Range on the west, the San Emigdio and Tchachapi mountains on the south and the San Joaquin, Mokelumne and Cosumnes rivers on the north. The basin is approximately 290 miles long and 130 miles wide and embraces an area of 32,000 square miles, 20.6 per cent of the total area of the State. It contains within its exterior boundaries 36.3 per cent of the agricultural land of the State, the largest percentage of the seven basins into which the State has been divided. The water supply, on the other hand, is only 16.8 per cent of the State's total, exceeded in amount by each of the supplies of the North Pacific and Sacramento River basins. The relations of the San Joaquin River Basin to the remainder of the State in area, in extent of agricultural land and in water production are shown on the frontispiece, "Geographical Distribution of Water Resources and Agricultural Lands in California."

The San Joaquin River Basin is drained by the San Joaquin River and its many tributaries. This stream system, for the purpose of this investigation, has been grouped into 35 divisions, of which there are 13 major streams and 22 minor streams and stream groups. The major streams, all of which head in the Sierra Nevada on the east side of the basin, are from north to south—the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, San Joaquin, Kings, Kaweah, Tule and Kern rivers. The minor streams and stream groups named in geographical order from the most northerly on the west side of the valley to the most southerly and thence northerly on the east side of the valley are Orestimba Creek, Panoche Creek, Cantua Creek, Los Gatos Creek, Tejon Creek, Caliente Creek, Poso Creek, Deer Creek, Yokohl Creek, Limekiln Creek, Dry Creek, Cottonwood Creek, Daulton Creek, Dutchman Creek, Mariposa Creek, Owens Creek, Bear Creek, Burns Creek, Wildcat Creek, Littlejohns Creek, Martells Creek and Sutter Creek.

Most of the major streams of the San Joaquin River Basin drain a rugged mountainous area ranging in elevation from a few hundred feet above sea level, in the foothills, to from 10,000 to nearly 15,000 feet above sea level at the crest of the Sierra Nevada. Some of the

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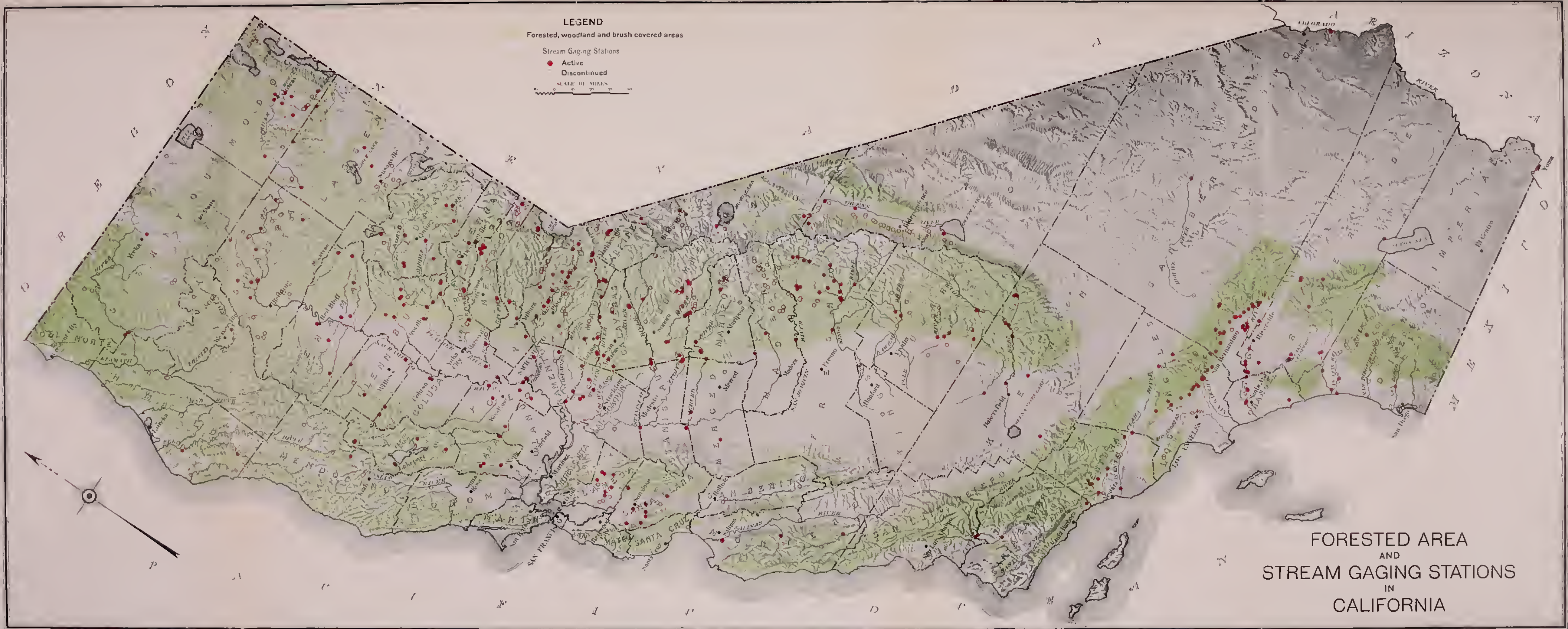

FORESTED AREA
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major streams, however, have drainage areas which do not reach to the crest of the Sierra Nevada. These streams are the Cosumnes, Calaveras, Chowchilla and Fresno rivers.

The drainage areas of the 22 minor streams and stream groups are situated in general at lower elevations than those of the major streams. Although the drainage basins of Tejon, Caliente, Poso and Deer creeks reach comparatively high elevations, the greater part of each area is located in the foothills adjacent to the valley floor. The minor streams in the lower San Joaquin Valley,* with the exception of Dry Creek in the Sutter Creek group, are not considered as contributing waters utilizable under the general plan of conservation, as their run-off is comparatively small and subject to wide seasonal variations. The estimated run-offs from some of the minor streams on the east side of the upper San Joaquin Valley were considered in computing the inflow to ground water units.

The mountain and foothill areas of the basin total 19,000 square miles. Large portions of these areas are covered with a timber growth. These timbered areas are shown on Plate I, "Forested Areas and Stream Gaging Stations in California."

The main San Joaquin River rises on the western slope of the Sierra Nevada at elevations in excess of 10,000 feet, flows southwesterly until it debouches from the foothills onto the valley floor, thence westerly to a point midway on the valley floor, where it turns northwesterly and traverses the main valley to its confluence with Sacramento River at the head of Suisun Bay. The watershed, above the valley floor, which drains a large area on the western slope of the Sierra Nevada in Fresno and Madera counties, is bounded on the north by that of the Merced and Fresno rivers and on the south by that of the Kings River. It extends eastward to the crest of the Sierra at elevations greater than 13,000 feet at Mt. Lyell and Mt. Goddard and reaches the valley floor about fifteen miles northerly from Fresno at an elevation of 300 feet. The watershed is extremely rugged in character and the formation of the higher portion is largely granitic. The upper reaches of the river have several large branches, the two principal ones being the Middle and South forks, each of which has its source in the glacial lakes near the summit of the range. Below their confluence they form the main channel of the San Joaquin, a narrow and deep canyon with steep sides until it begins to emerge from the foothills. The North Fork rises on the southern slope of Iron Mountain and flows in a nearly due south direction to its junction with the main stream. Several smaller tributaries join the main river between the South and North forks, Stevenson, Big Rock, Chiquito and Kaiser creeks being the more important. Much of the basin below the timber line is forest covered. As the elevation of the head waters of the river is over 10,000 feet, it is snow-fed throughout a large part of the summer.

The Cosumnes River, the most northerly of the San Joaquin River tributaries, drains a secondary watershed on the western slope of the Sierra Nevada just south of the American River. The headwaters

* In this report, the terms "upper" and "lower" San Joaquin Valley are used to designate southerly and northerly divisions of the valley lying respectively south and north of the Chowchilla River on the east side and a line extending from Mendota to Oro Loma on the west side.

originate at an altitude of 7700 feet near Alder Hill, a minor peak about fifteen miles west of the main divide, and the stream follows a southwesterly course to its junction with the Mokelumne River in the San Joaquin River delta region about six miles west of Galt. The total length of the watershed is about 70 miles, the lower half of which stretches across the valley plain and contributes very little to the run-off of the stream. The length of the basin within the main mountain drainage area is about 35 miles with an extreme width of about eighteen miles.

The Mokelumne River drains an area on the western slope of the Sierra Nevada in Amador, Alpine and Calaveras counties. The headwaters rise in the numerous glacial lakes near the crest of the main divide at an elevation of about 10,000 feet. Round Top, the highest peak on the eastern boundary, reaches an elevation of 10,430 feet. The drainage basin is long and narrow extending from the crest of the Sierra in a southwesterly direction for a distance of 140 miles to its junction with the San Joaquin River about twenty miles northwest of Stockton. The mountain area is well forested except in the east end of the basin, which is above the timber line and characterized by bare granite peaks. Over much of the basin the precipitation in winter is entirely in the form of snow, but elevations even in the highest part of the catchment area are not sufficient to support perpetual snow fields. The stream flow is well maintained in the early summer, but rapidly falls off during July and August after the snow has gone. The main stream is formed by the junction of its three principal branches—North, Middle and South forks—which unite some five miles above Electra at an elevation of about 1500 feet. The North Fork is the principal tributary. Below this point, the drainage basin is only four or five miles wide and the main stream follows its canyon for about 35 miles until it emerges from the foothills to the valley floor near the town of Clements at an elevation of 100 feet. It then runs westerly across the valley for 30 miles, passing the towns of Lockeford, Lodi and Woodbridge and joining the San Joaquin River near Central Landing. The Cosumnes River and Dry Creek join the Mokelumne River in the San Joaquin delta region before it discharges into the San Joaquin River.

The Calaveras River drains a secondary watershed on the lower western slope of the Sierra Nevada situated between the basin of the Mokelumne River on the north and that of the Stanislaus River on the south. It rises at an elevation of 5100 feet at the extreme eastern boundary of the watershed about 35 miles west of the main divide of the Sierra Nevada. The two main forks, North and South, join about two miles west of the town of San Andreas to form the main river which flows in a southwesterly direction and joins the San Joaquin River a few miles west of Stockton. The original channel passes to the north of Bellota, 15 miles northeast of Stockton, and extends northwesterly for about nine miles, then turns and runs in a southwesterly direction passing to the north of Stockton before entering the San Joaquin River.

Mormon Slough, which branches from the Calaveras River just east of Bellota, is now considered the main channel of the river. The slough stream bed at this point is several feet lower than the old river and only flood waters now enter the original channel. Mormon Slough flows in a southwesterly direction passing through Stockton and joins the San Joaquin River about one and one-half miles south of the mouth of the original channel. In 1908–10, the Stockton diverting canal was constructed by the United States Government, connecting Mormon Slough with the original channel. This canal, four and one-half miles long, was built for the purpose of diverting a portion of the flood waters of Mormon Slough to the east of Stockton back into the Calaveras River.

The extreme length of the Calaveras watershed from the mouth of the river to its eastern boundary is 67 miles, while the greatest width is 20 miles. The lower foothills are covered with a rather sparse growth of oak and brush. At the higher altitudes there is a heavy growth of timber. Most of the precipitation on the watershed occurs in the form of rainfall. The snowfall is generally light and lies on the ground only for short periods. The watershed above Jenny Lind is favorable for high concentration of discharge as demonstrated by the flood of January 31, 1911, which yielded an average run-off for that day of 177 second-feet per square mile. The flow of the Calaveras River is extremely flashy in nature, with floods of short duration, immediately following heavy rainstorms and lasting from one to three days only.

The Stanislaus River drains a narrow basin on the western slope of the Sierra Nevada between the watersheds of the Calaveras and Mokelumne rivers on the north and that of the Tuolumne River on the south. The watershed area has a length of approximately 100 miles and an average width of ten miles in the lower half. It spreads out above the junction of its forks to a width of 24 miles at its eastern border along the Sierra crest. The main stream is formed by the junction of North, Middle and South forks at an elevation of about 950 feet, seven miles north of Sonora, from which point it meanders in a southwesterly direction a distance of 35 miles through the foothills and thence 25 miles across the valley floor to its junction with the San Joaquin River about three miles northeast of Vernalis. The watershed slopes from an elevation of over 10,000 feet at the crest of the Sierra Nevada to an elevation of about 20 feet at the San Joaquin River. The upper reaches of the basin are characterized by bare granite peaks and precipitous canyons. At lower elevations the ridges and valleys are well covered with timber which gradually gives way to scattering oak and brush as the foothill region is reached.

The watershed of the Tuolumne River drains an area on the western slope of the Sierra Nevada lying between the basin of the Stanislaus River on the north and that of the Merced River on the south. The stream has its source in the glacial lakes on the northern slope of Mount Lyell and flows in a southwesterly direction for a distance of about 150 miles to its junction with the San Joaquin River 10 miles west of Modesto. The upper portion of the drainage basin is characterized by plateaus and meadows, but the stream soon drops into a deep canyon cut in the granite formation by glacial action, and follows this gorge for a distance of 80 miles, finally emerging from the foothills onto the San Joaquin Valley floor near the town of La Grange. Elevations of the watershed range from 300 feet at the mouth of the canyon near La Grange to over 13,000 feet along the crest of the Sierra divide which separates the Tuolumne Basin from the Mono Lake and Walker River watersheds to the east. These higher elevations are for the most part granite peaks, but at lower elevations the mountains and valleys are well timbered with several varieties of pine. The foothills are fairly well covered with scrub oak and brush. The principal tributaries of the Tuolumne River enter from the north, and in an upstream order are: Woods Creek, North Fork of Tuolumne River, Clavey River, Cherry, Falls, Rancheria and Return creeks. The South Fork of Tuolumne River with its tributary, the Middle Fork, enters the main stream from the south at about elevation 1800 feet.

The Merced River rises at an elevation of about 11,000 feet in the Cathedral and Ritter ranges west of the head waters of the Tuolumne and San Joaquin rivers in the Sierra Nevada. Elevations in the watershed vary from about 400 feet at the Exchequer Dam to 13,090 feet at the summit of Mt. Lyell. The main river flows for a distance of 135 miles almost in a due westerly direction from its source to its junction with the San Joaquin River, four miles northeast of Newman. After it passes through Yosemite Valley at an elevation of about 4000 feet, it is joined by the South Fork which rises in the vicinity of Merced Peak. The drainage basin, lying wholly within Mariposa and Merced counties, is very rugged at the head waters, but is more regular below Yosemite Valley. It has a length of about 65 miles from the crest of the ridge to the valley floor and an average width of 20 to 25 miles.

The Chowchilla River drains a secondary watershed on the lower western slope of the Sierra Nevada, lying between the basin of the Merced River on the north and that of the Fresno River on the east and south. It rises at an elevation of about 6000 feet, 50 miles westerly from the crest of the Sierra Nevada, and flows in a southwesterly direction to the valley floor. The channel divides after reaching the plains and water enters the San Joaquin River only at high flow stages. The drainage basin is situated in Mariposa and Madera counties. The upper part of the basin is fairly well forested, and the lower part is covered with scattering trees and brush. The stream rises at a point too far from the crest of the Sierra and at too low an elevation to be snow fed in the summer months, resulting in a run-off varying from little or no flow to flashy floods.

The Fresno River, like the Chowchilla, drains a secondary watershed of the lower western slope of the Sierra Nevada lying between the Merced River watershed on the north and the San Joaquin River watershed on the south. The watershed has the same general characteristics as that of the Chowchilla River. The Fresno River rises at an elevation of about 7000 feet, 40 miles westerly from the crest of the Sierra Nevada, and flows in a southwesterly direction to the valley floor, thence westerly to its junction with the San Joaquin River northeasterly from Dos Palos. The upper portion of the watershed consists of several branches which come together to form a single channel at Windy Gap. From this point the stream remains in a well defined rock-bound channel for several miles with no tributaries of importance until its junction with Coarse Gold Creek. On the lower reaches the streambed of Fresno River broadens to a wide sandy channel. The stream rises at a point in the Sierra Nevada at an elevation too low to be snow fed in the summer months and the natural run-off varies from little or no flow in late summer to flashy floods during the rainy season.

The Kings River drains a large area on the western slope of the Sierra Nevada in Fresno and Tulare counties. The watershed is situated between the San Joaquin River Basin on the north and that of the Kaweah and Kern River basins on the south. The main stream is formed well up in the mountains by the confluence of the North, Middle and South forks. These branches head in the numerous glacial lakes spread along the crest of the Sierra Nevada, between Mount Goddard, elevation 13,555 feet, on the north and nearly to Mount Whitney on the south, which rises to an elevation of 14,501 feet above sea level, the highest peak in the United States. Above elevation 10,000 feet the drainage basin is very rugged, consisting mainly of granite left bare by glacial action, but below this elevation the mountains are well timbered. The main canyon of the river extends southwesterly to a point in the foothills about ten miles northeast of Sanger. Here the river emerges from the foothills to the valley floor, where it has built up a large delta. Most of the discharge reaching the lower part of the delta passes northwesterly through Fresno Slough to the San Joaquin River about two miles north of Mendota. In times of high flood, however, a portion of the discharge flows southerly to Tulare Lake. The watershed has characteristics very similar to that of the San Joaquin River. As nearly 400 square miles of the basin are above elevation 10,000 feet, it is snow fed during a large part of the year. The basin, above the valley floor, has a length of about 50 miles and an average width of about 30 miles.

The Kaweah River drains a watershed on the western slope of the Sierra Nevada in Tulare County, adjoining that of the Kings River on the north and the Tule River on the south and extending on the east to a secondary ridge, parallel to the main backbone of the Sierra Nevada, called the Great Western Divide, which separates its basin from that of the upper Kern River. The headwaters rise in glacial lakes along the divide near Triple Divide Peak, elevation 12,651 feet. The main stream is formed about ten miles above the head of its delta, by the confluence of the North, Middle and South forks. Below the foothills it divides into several distributaries, which cross the delta fan and enter Tulare Lake near Corcoran. The basin above the lower edge of the foothills is about 26 miles long with an average width of about 20 miles.

The Tule River drains a small and somewhat rectangular area on the lower western slope of the Sierra Nevada lying south of the Kaweah River Basin, west of the Kern River Basin and north of the Deer Creek Basin. The headwaters rise at an elevation of about 9500 feet near Sheep Mountain. The main stream is formed by the junction of the North and Middle forks about ten miles northeast of its point of emergence from the foothills at Porterville. The South Fork joins the main stream six miles east of this point. Flood waters flow westward through old delta channels to Tulare Lake. The north and south length of the basin is about 25 miles and its average width about fifteen miles.

The Kern River is the most southerly of the large streams rising in the Sierra Nevada and discharging into the San Joaquin Valley. Its watershed is situated in Kern and Tulare counties. The basin extends almost due north and south for 90 miles, with a maximum width of about 30 miles. The northern part of the watershed is divided into two drainage basins by a high rugged central ridge that runs nearly due south from the main divide at Cottonwood Pass and terminates north of South Fork Valley just east of Kernville. The western basin is drained by the North Fork and its main tributary, Little Kern, and the eastern basin by the South Fork. The eastern boundary of the basin runs south from Mt. Whitney and is formed by the main backbone of the Sierra Nevada. The western boundary is formed by the Great Western Divide and by its extension, the Greenhorn Mountains. The northern boundary lies on the Kings-Kern Divide and the southern along the terminal ridges of the Sierra Nevada, where they join the Tehachapi Mountains. The main or North Fork of the Kern River heads in the extreme north end of the basin in the Mt. Whitney region and flows southerly for about 80 miles to its junction with the South Fork. The South Fork, which drains the eastern part of the Kern River Basin, flows southward parallel to the eastern boundary and then turns nearly due west to join the main stream. The two parts of the drainage basin differ greatly in topography. The basin of the North Fork is extremely rugged, while that of the South Fork is rather flat and abounds in meadows situated among irregular chains of hills. The two forks join at Isabella to form the main Kern River, which flows in a southwesterly direction through a deep and rugged canyon for about 31 miles, and then emerges abruptly onto the valley floor about twelve miles east of Bakersfield. From this point its course is westerly to Buena Vista Lake.

The rocks of most of the region are granitic, but the granite formation is most noticeable in the barren and arid ridges of the southern part of the basin, and in the glaciated higher peaks. The southern and eastern parts of the basin are sparsely covered with juniper and chaparral, but above Kernville the growth improves generally and at some points the forest cover is excellent. About 47 per cent of the North Fork drainage area lies above elevation 8000 feet whereas 76 per cent of the South Fork lies below that elevation. The effect of this difference in elevation is reflected in the run-off record, for although it drains approximately one-half the total area, the North Fork yields about 75 per cent of the mean seasonal run-off. Altitudes in the Kern River Basin range from a few hundred feet at the mouth of the river's lower canyon to more than 14,000 feet on the headwaters. More than 50 peaks in the basin exceed 13,000 feet in elevation and many of the lakes which feed the upper stream are at an altitude of 11,000 feet or more.

The watershed areas above the lower edge of the foothills for each of the major streams of the San Joaquin River Basin, between various elevations, are set forth in Table 1.

TABLE 1

DISTRIBUTION OF DRAINAGE AREAS OF THE MAJOR STREAMS OF THE SAN JOAQUIN RIVER BASIN ABOVE THE LOWER EDGE OF THE FOOTHILLS BY ZONES OF ELEVATION

River	Area, in square miles				
	Below 2,500 feet	Between 2,500 and 5,000 feet	Between 5,000 and 10,000 feet	Above 10,000 feet	Totals
Cosumnes, above Michigan Bar	238	212	84	0	534
Mokelumne, above Clements	121	194	317	0	632
Calaveras, above Jenny Lind	301	90	3	0	394
Stanislaus, above Knights Ferry	223	205	541	14	983
Tuolumne, above La Grange	248	375	805	115	1,543
Merced, above Merced Falls	191	317	494	52	1,054
Chowchilla, above Buchanan	161	72	5	0	238
Fresno, above edge of foothills	167	89	14	0	270
San Joaquin, above Friant	182	227	925	297	1,631
Kings, above Piedra	283	201	824	386	1,694
Kaweah, above Three Rivers	61	141	275	37	514
Tule, above Porterville	142	117	131	0	390
Kern, above Bakersfield	102	572	1,470	266	2,410

The San Joaquin Valley floor is a comparatively level area except for an isolated group of hills along its southwestern edge called the Kettleman Hills. The valley is about 270 miles long from the mouth of the San Joaquin River to the edge of the foothills south of Bakersfield and averages 50 miles wide. Elevations range from a few feet below sea level in the San Joaquin River Delta to 1500 feet at the edge of the foothills in the southern end of the valley. The area of the valley floor is about 13,000 square miles including the San Joaquin Valley portion of the delta formed at the confluence of the Sacramento and San Joaquin rivers. The main valley floor contains a gross area of agricultural lands of about 11,300 square miles, and the San Joaquin Valley portion of the delta about 436 square miles. The valley floor, by reason of physiographic characteristics, falls naturally into three divisions, the area south of the upper San Joaquin River, the area between the upper San Joaquin River and the delta and the delta region. The delta division comprises the delta proper or the low marsh and peat lands, which in their natural condition were subject to tidal overflow, and the bordering alluvial rim-lands subject to occasional inundation from flood waters. The area between the delta and upper San Joaquin River is divided on the east side of the main river by the major tributary channels. The west side is fairly smooth, except for occasional minor stream channels or draws. Upstream from the mouth of the Merced River, bordering the main San Joaquin River on the west for a width of several miles, is a strip of territory traversed by the winding courses of scores of slough channels, some of which are as large as the main San Joaquin River channel itself, and in time of floods carry the major portion of the stream flow. Immediately south of the San Joaquin River is a natural ridge or barrier formed by the Kings River Delta on the east side of the valley trough, and to a minor extent by deposit from Panoche Creek on the west. In the depression south of this ridge is Tulare Lake which receives the surplus flow of all streams south of Kings River. Part of the surplus Kings River run-off flows north through Fresno Slough to the San Joaquin River and part south to Tulare Lake. In its natural condition Tulare Lake covered an area varying from a few square miles in dry cycles to about 760 square miles in wet ones. Reclamation by levees now restricts the submerged area to smaller tracts under normal run-off conditions. South of Kern River Delta a similar shallow but smaller lake stores surplus flood waters of Kern River. The area of this lake also has been restricted by levees, which cause excess water to drain north to Tulare Lake through an artificially deepened and leveed channel. A delta also has been built up by the Kaweah River immediately south of the Kings River Delta. It does not extend westward a sufficient distance, however, to form a barrier in the valley trough.

Precipitation.

Data on the precipitation in the San Joaquin River Basin have been collected, compiled and published by the United States Weather Bureau and its predecessor, the Army Signal Corps, for about 150 stations for varying periods. Some of the earlier stations established have been discontinued. The longest record available is at Stockton, which has been kept continuously since 1867. A number of these rainfall records date back to the early 70s and are of great value in estimating the probable water yield of the San Joaquin River Basin during the period prior to the commencement of stream flow measurements by the United States Geological Survey.

During a previous investigation* a careful study and analysis were made of precipitation records of the entire State. Inquiry was made into the geographical distribution, magnitude and variation of occurrence, both seasonal and periodic, of precipitation in all sections of the State. An important part of the study was the relation of precipitation in any one season to normal or mean precipitation. From the results of the study the State was divided into 26 precipitation groups or divisions, having similar precipitation characteristics. These are shown by the blue lines on Plate II, "Geographical Distribution of Precipitation in California," and have been identified by letters of the alphabet. Eight of the divisions (K, L, P, Q, R, S, T and V) lie entirely or partly in the San Joaquin River Basin. A list of the precipitation stations in the San Joaquin River Basin, compiled and published by the United States Weather Bureau, and the period of record at each station are set forth in Table 2. In general, the periods of record are continuous between the dates shown. However, there is an occasional month, in which it is believed there was some precipitation, for which records are missing for certain stations. In calculating the number and fractions of years of available records, no deductions were made for these months. The locations of these stations are also shown on Plate II. The solid red dots indicate stations at which records are now being obtained, and open red circles those which have been discontinued.

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works, 1923.

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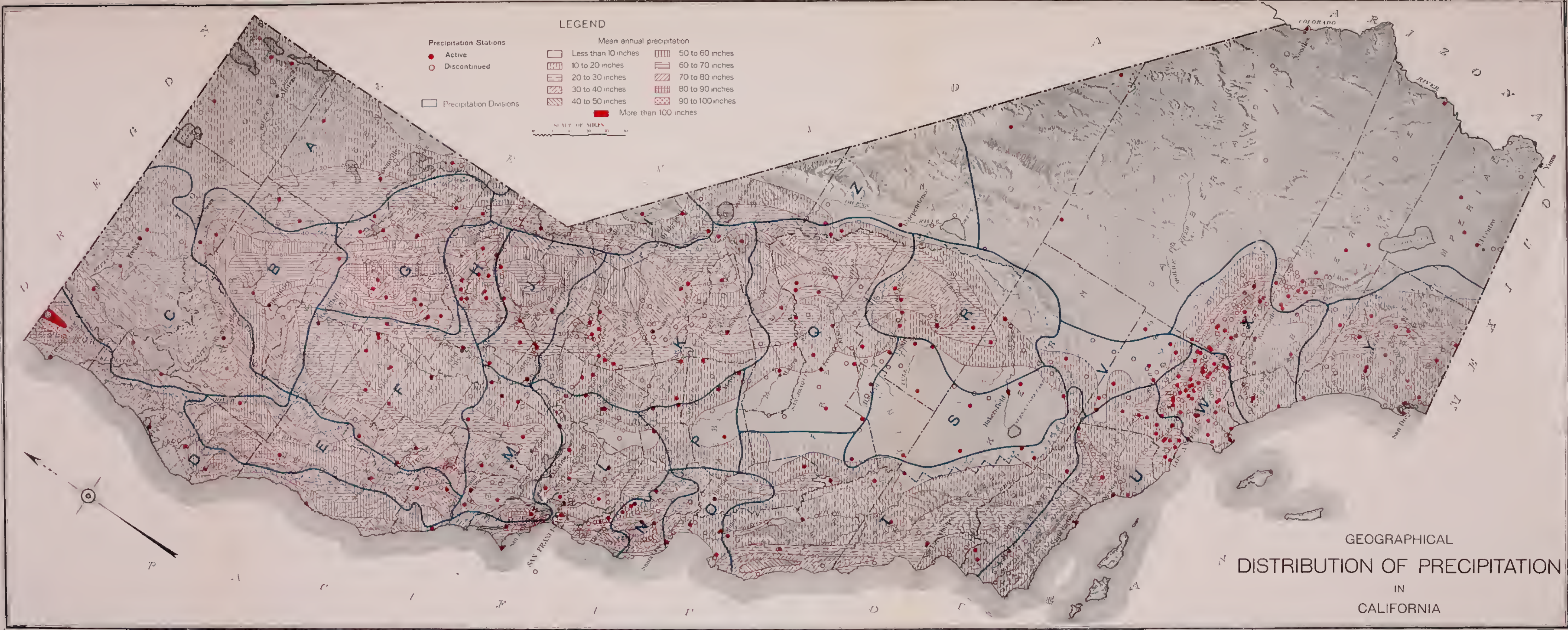
LEGEND
Precipitation Stations
Active
Discontinued
Precipitation Divisions
Mean annual precipitation
Less than 10 inches
10 to 20 inches
20 to 30 inches
30 to 40 inches
40 to 50 inches
50 to 60 inches
60 to 70 inches
70 to 80 inches
80 to 90 inches
90 to 100 inches
More than 100 inches
SCALE OF MILES
GEOGRAPHICAL
DISTRIBUTION OF PRECIPITATION
IN
CALIFORNIA

80997

TABLE 2

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division K—			
Oleta*	Sutter Creek	July, 1891–June, 1902	11
Drytown*	Sutter Creek	Dec., 1891–Sept., 1906	14¾
Ione*	Sutter Creek	Jan., 1878–Dec., 1915	38
Sutter Creek*	Sutter Creek	July, 1887–Jan., 1899	11½
Jackson*	Sutter Creek	Sept., 1877–June, 1886	8¾
Jackson (near)*	Sutter Creek	Nov., 1891–Oct., 1903	12
Kennedy Mine	Sutter Creek	Jan., 1892–June, 1929	37½
Tamarck*	Mokelumne River	Mar., 1900–Aug., 1903 Jan., 1906–June, 1927	25
Bear River*	Mokelumne River	July, 1907–June, 1914	7
Mitchell Mill*	Mokelumne River	Jan., 1915–Sept., 1916	1¾
West Point	Mokelumne River	Jan., 1894–June, 1929	35½
Mill Creek No. 1	Mokelumne River	Jan., 1907–June, 1929	22½
Electra	Mokelumne River	Jan., 1904–June, 1929	25½
Mokelumne Hill*	Mokelumne River	Jan., 1882–June, 1927	45½
Lancha Plana	Mokelumne River	July, 1926–June, 1929	3
Wallace	Bear Creek	July, 1926–June, 1929	3
Valley Springs*	Calaveras River	Jan., 1888–Dec., 1915	28
Jenny Lind	Calaveras River	Jan., 1907–June, 1929	22½
Milton*	Rock Creek	July, 1888–Oct., 1928	40⅓
Calaveras Ranger Station*	Stanislaus River	Jan., 1916–Dec., 1920	5
Angels Camp*	Stanislaus River	Jan., 1908–Nov., 1915	8
Melones*	Stanislaus River	Jan., 1907–June, 1927	20½
American Camp*	Stanislaus River	Jan., 1915–Jan., 1917	2
Penstock Camp*	Stanislaus River	Mar., 1907–Aug., 1910	3½
Long Camp*	Tuolumne River	Jan., 1909–April, 1911	2⅓
Phoenix Dam*	Tuolumne River	Nov., 1908–Dec., 1916	8¼
Sonora	Tuolumne River	Sept., 1887–June, 1929	41¾
Jamestown*	Tuolumne River	Jan., 1903–July, 1915	12½
Jacksonville*	Tuolumne River	Jan., 1907–Dec., 1917	11
Groveland*	Tuolumne River	Jan., 1904–April, 1916	12⅓
La Grange	Tuolumne River	Jan., 1868–June, 1900 Oct., 1908–June, 1929	53¼
Merced Falls	Merced River	Jan., 1907–June, 1929	22½
Dudleys	Merced River	Jan., 1909–June, 1929	20½
Kinsley*	Merced River	Jan., 1915–Nov., 1916	2
Crockers*	Tuolumne River	July, 1896–April, 1910	13¾
Lake Eleanor	Tuolumne River	Nov., 1909–June, 1929	19⅔
Hetch-Hetchy	Tuolumne River	Oct., 1910–June, 1929	18¾
Yosemite	Merced River	Jan., 1904–June, 1929	25½
Glacier Point*	Merced River	Jan., 1920–Oct., 1923	3¾
Summerdale*	Merced River	Jan., 1896–Sept., 1912	16¾
Mariposa	Mariposa Creek	July, 1908–June, 1929	21
Galt*	San Joaquin Valley Floor	Jan., 1878–Dec., 1915	38
Elliot	San Joaquin Valley Floor	July, 1926–June, 1929	3
Clements	San Joaquin Valley Floor	July, 1926–June, 1929	3
Bellota	San Joaquin Valley Floor	Jan., 1911–June, 1929	18½
Farmington*	San Joaquin Valley Floor	Jan., 1877–Dec., 1915	39
Oakdale*	San Joaquin Valley Floor	Oct., 1880–May, 1918	37⅔
Oakdale (near)	San Joaquin Valley Floor	Mar., 1918–June, 1929	11⅓
Denair (Elmwood) (Elmdale)	San Joaquin Valley Floor	Jan., 1899–June, 1929	30½
Precipitation Division L—			
Antioch	San Joaquin Valley Floor	Jan., 1879–June, 1929	50½
Brentwood*	San Joaquin Valley Floor	July, 1890–Dec., 1894 June, 1897–Dec., 1899	7
Byron*	San Joaquin Valley Floor	Feb., 1890–Dec., 1894 June, 1897–Dec., 1905	13½
Tracy*	San Joaquin Valley Floor	Jan., 1879–Dec., 1915	37
Lathrop	San Joaquin Valley Floor	July, 1877–Dec., 1894 June, 1897–Nov., 1899 July, 1909–June, 1929	40
Stockton No. 1	San Joaquin Valley Floor	Jan., 1867–June, 1929	62½
Stockton No. 2	San Joaquin Valley Floor	July, 1926–June, 1929	3
Lodi	San Joaquin Valley Floor	Jan., 1888–Sept., 1912 July, 1926–June, 1929	27¾
Rio Vista	San Joaquin Valley Floor	Jan., 1893–June, 1929	36½
Bensons Ferry	San Joaquin Valley Floor	Jan., 1918–June, 1929	11½
Precipitation Division P—			
Modesto	San Joaquin Valley Floor	Jan., 1871–Dec., 1915 July, 1927–June, 1929	47
Westley*	San Joaquin Valley Floor	Jan., 1889–Dec., 1915	27

* Discontinued in U. S. Weather Bureau publications.

TABLE 2—Continued

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division P—Continued			
Newman	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Turlock	San Joaquin Valley Floor	Jan., 1879–Dec., 1899	30
Livingston*	San Joaquin Valley Floor	Aug., 1920–June, 1929 Nov., 1885–Sept., 1898 Jan., 1921–Nov., 1922	14¾
Merced	San Joaquin Valley Floor	Jan., 1872–June, 1929	57½
Le Grand	San Joaquin Valley Floor	June, 1899–June, 1929	30
Los Banos	San Joaquin Valley Floor	Jan., 1873–Dec., 1915 Jan., 1926–June, 1929	46½
Orestimba*	San Joaquin Valley Floor	Feb., 1899–May, 1899	⅓
Precipitation Division Q—			
Raymond*	Fresno River	Mar., 1899–Oct., 1900	1⅔
Pollasky*	San Joaquin River	June, 1897–Dec., 1903 Jan., 1907–Dec., 1911	11½
Friant	San Joaquin River	Jan., 1897–Dec., 1903 Jan., 1906–June, 1929	30½
North Fork	San Joaquin River	Mar., 1904–June, 1929	25⅓
Crane Valley	San Joaquin River	July, 1903–June, 1929	26
Huntington Lake	San Joaquin River	July, 1915–June, 1929	14
Big Creek (Cascada)	San Joaquin River	July, 1915–June, 1929	14
Stevenson Creek*	San Joaquin River	April, 1916–Dec., 1917	1¾
Auberry	San Joaquin River	July, 1915–June, 1929	14
Balch Camp	Kings River	July, 1926–June, 1929	3
Dinkey Meadow	Kings River	Nov., 1921–June, 1929	7⅔
Helm Creek (Hobbler's Camp)	Kings River	Jan., 1922–June, 1929	7½
Cliff Camp	Kings River	Nov., 1921–June, 1929	7⅔
Dunlap*	Kings River	Jan., 1912–Dec., 1915	4
Hume*	Kings River	Jan., 1914–Dec., 1915	2
Piedra	Kings River	Jan., 1917–June, 1929	12½
Athlone*	San Joaquin Valley Floor	Dec., 1885–May, 1898	13½
Minturn*	San Joaquin Valley Floor	Jan., 1899–Dec., 1899	1
Firebaugh	San Joaquin Valley Floor	Jan., 1873–June, 1886 Jan., 1907–June, 1929	36
Mendota*	San Joaquin Valley Floor	Jan., 1894–Nov., 1908	15
Berenda*	San Joaquin Valley Floor	Mar., 1889–Dec., 1894 June, 1897–Dec., 1899	7½
Madera (Storey)	San Joaquin Valley Floor	June, 1899–June, 1929	30
Borden*	San Joaquin Valley Floor	May, 1875–Dec., 1895	20⅔
Clovis (near)	San Joaquin Valley Floor	Jan., 1917–June, 1929	12½
Helm	San Joaquin Valley Floor	Dec., 1927–June, 1929	1½
McMullin*	San Joaquin Valley Floor	Jan., 1895–Feb., 1898	3¼
Fresno	San Joaquin Valley Floor	July, 1881–June, 1929	48
Sanger*	San Joaquin Valley Floor	Jan., 1889–Dec., 1915	27
Kings River	San Joaquin Valley Floor	Jan., 1929–June, 1929	½
Reedley*	San Joaquin Valley Floor	Aug., 1899–June, 1923	24
Selma*	San Joaquin Valley Floor	Jan., 1886–Dec., 1915	30
Kingsburg (near)	San Joaquin Valley Floor	July 1879–Dec., 1900 Jan., 1928–June, 1929	23
Dinuba	San Joaquin Valley Floor	June, 1897–Dec., 1899 Jan., 1909–June, 1929	23
Huron*	San Joaquin Valley Floor	Oct., 1891–Oct., 1905	14
Lemoore*	San Joaquin Valley Floor	July, 1879–Dec., 1901	22½
Goshen*	San Joaquin Valley Floor	July, 1887–Oct., 1902	15⅓
Traver*	San Joaquin Valley Floor	Dec., 1885–Dec., 1894 Aug., 1897–Dec., 1899	11½
Westhaven	San Joaquin Valley Floor	Jan., 1926–June, 1929	3½
Hanford	San Joaquin Valley Floor	June, 1899–June, 1929	30
Visalia	San Joaquin Valley Floor	July, 1877–June, 1886 Jan., 1888–June, 1929	50½
Precipitation Division R—			
Lemoncove	Kaweah River	Jan., 1899–June, 1929	30½
Lime Kiln*	Kaweah River	June, 1898–Oct., 1898	½
Three Rivers	Kaweah River	July, 1909–June, 1929	20
Ash Mountain	Kaweah River	July, 1926–June, 1929	3
Giant Forest	Kaweah River	July, 1921–June, 1929	8
Milo*	Tule River	April, 1898–May, 1922	24¼
Springville (near)	Tule River	Oct., 1907–June, 1929	21¾
Hot Springs	Deer Creek	Jan., 1907–June, 1929	22½
Glenville (near)	Poso Creek	July, 1909–June, 1929	20
Weldon*	Kern River	Jan., 1904–Dec., 1906	3
Kernville	Kern River	Jan., 1894–June, 1929	35½

* Discontinued in U. S Weather Bureau publications.

TABLE 2—Continued

PRECIPITATION STATIONS IN SAN JOAQUIN RIVER BASIN

Records published by U. S. Weather Bureau

Station	Stream Basin	Period of Record	Record available to June 30, 1929, in years
Precipitation Division R—Continued			
Isabella*	Kern River	Feb., 1896–June, 1910	14½
Mt. Breckenridge*	Kern River	Jan., 1897–Aug., 1897	⅔
Caliente*	Caliente Creek	Jan., 1876–Dec., 1915	40
Delano*	San Joaquin Valley Floor	Jan., 1876–Dec., 1908	33
Precipitation Division S—			
Exeter*	San Joaquin Valley Floor	Mar., 1892–Dec., 1899	7¾
Lindsay	San Joaquin Valley Floor	July, 1914–June, 1929	15
Porterville	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Tulare*	San Joaquin Valley Floor	Mar., 1874–Dec., 1914	40¾
Tulare (near)*	San Joaquin Valley Floor	Jan., 1893–Oct., 1909	16¾
Angiola	San Joaquin Valley Floor	July, 1899–June, 1929	30
Wasco	San Joaquin Valley Floor	July, 1899–June, 1929	30
Famosa*	San Joaquin Valley Floor	Jan., 1897–Aug., 1897	⅔
Bakersfield	San Joaquin Valley Floor	Jan., 1889–June, 1929	40½
Calloway Canal*	San Joaquin Valley Floor	Jan., 1895–Feb., 1899	4¼
Edison (near)	San Joaquin Valley Floor	Jan., 1904–June, 1929	25½
Bear Valley No. 1*	Sycamore Canyon	Jan., 1897–Jan., 1916	19
Precipitation Division T—			
Coalinga	San Joaquin Valley Floor	Jan., 1912–June, 1929	17½
Alcalde*	San Joaquin Valley Floor	Aug., 1888–July, 1893	5
Antelope Valley	San Joaquin Valley Floor	July, 1911–June, 1929	18
Idria	Panoche Creek	Jan., 1918–June, 1929	11½
Dudley	San Joaquin Valley Floor	Jan., 1912–June, 1929	17½
Middlewater	San Joaquin Valley Floor	July, 1911–June, 1929	18
Maricopa	San Joaquin Valley Floor	July, 1911–June, 1929	18
Pattiway	Bitter Creek	Dec., 1915–June, 1929	13½
Fort Tejon*	Grape Vine Creek	Feb., 1895–Dec., 1901	7
Precipitation Division V—			
Keene*	Caliente Creek	July, 1879–June, 1902 Jan., 1906–Dec., 1912	30
Girard*	Caliente Creek	Jan., 1889–Dec., 1894 Jan., 1897–Dec., 1899	9
Tehachapi	Caliente Creek	Dec., 1876–Dec., 1915 July, 1926–June, 1929	42
Tejon Ranch	Tejon Creek	Jan., 1894–May, 1896 July, 1898–Dec., 1906 April, 1909–June, 1929	31¼

*Discontinued in U. S. Weather Bureau publications.

In the previous investigation the precipitation in a particular season at a station was expressed by a number representing the precipitation in per cent of normal and defined as the "index of seasonal wetness." The indices for each division were calculated from precipitation records at stations within the division. For stations with missing records, indices were estimated from records at other stations within the same or adjacent divisions. The index for each season in a particular division was taken as the arithmetical mean of the indices of seasonal wetness of the several stations in that division. Indices were calculated for the 26 precipitation divisions for the period 1871 to 1921.

Precipitation division "K" embraces the western slope of the Sierra Nevada and the eastern portion of the San Joaquin Valley floor adjacent thereto, from the drainage basin of Cosumnes River on the north to that of the Chowchilla River on the south and that portion of the eastern slope of the Sierra draining into Mono Lake. Precipitation division "L" includes that part of the San Francisco Bay drainage basin in Alameda, San Mateo and Contra Costa counties, the drainage basins of the small streams on the west side of the San Joaquin River Basin and the western part of the valley floor in Contra Costa, Alameda, San Joaquin and the northern portion of Stanislaus counties. Precipitation division "P" includes the drainage basins of the small streams on the west side of the valley and the western portion of the valley floor in the southern part of Stanislaus and the northern part of Merced counties. Precipitation division "Q" covers the drainage basins of the streams draining the western slope of the Sierra Nevada from the Daulton Creek Group on the north to the Kings River on the south, the eastern part of the valley floor adjacent thereto and the northern portion of the Owens River drainage basin on the eastern slope of the Sierra Nevada. Precipitation division "R" includes the western slope of the Sierra Nevada from the drainage basin of the Kaweah River on the north to that of Kern River on the south and the southern portion of the Owens River drainage basin on the eastern slope of the Sierra Nevada. Precipitation division "S" contains the southern portion of the San Joaquin Valley floor lying in Kings, Tulare and Kern counties. Precipitation division "T" includes the drainage basins of the minor streams on the western side of the San Joaquin Valley from Panoche Creek on the north to Muddy Creek on the south. Precipitation division "V" covers the northern slope of the Tehachapi Mountains and contains the drainage basins of the minor streams from Caliente Creek on the east to San Emigdio Creek on the west.

In the present investigation, the indices of seasonal wetness for the precipitation divisions of the San Joaquin River Basin were calculated for the seasons 1921–1929, by the same method used in the previous investigation. The normal for the period, 1871–1921, was used for each station in making the extensions. In precipitation division "V" the rainfall records at all stations used in Bulletin No. 5 were discontinued. This made the substitution of additional stations necessary and indices were recomputed for the 50-year period. In division "T" the addition of several new stations within the San Joaquin River Basin made the recomputation of the indices advisable. The indices of seasonal wetness for precipitation divisions in the San Joaquin River Basin for the period 1871–1929 are shown in Table 3. These indices are useful not only in showing the variation of precipitation by seasons during the 58-year period, but also in estimating the run-off from unmeasured streams and measured streams with missing records.

A review of the data on indices of seasonal wetness in Table 3 shows that there is a wide variation in precipitation from season to season at any particular station and also that there are wet and dry periods which have occurred throughout the basin. The period from 1916 to 1929 was one of low precipitation. The precipitation in a majority of the seasons in that period was less than normal. The variation in mean seasonal precipitation throughout the State is delineated on Plate II. On this plate, each type of shading represents areas having a mean seasonal precipitation within the limits set forth in the legend.

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TABLE 3

INDICES OF SEASONAL WETNESS FOR SAN JOAQUIN RIVER BASIN

Season	Index of wetness in division							
	K	L	P	Q	R	S	T*	V*
1871-72	122	130	119	119	120	119	79	79
1872-73	86	79	91	74	75	74	56	56
1873-74	87	86	87	100	101	100	84	84
1874-75	61	69	83	64	64	64	82	96
1875-76	154	131	123	124	125	124	138	124
1876-77	34	43	30	60	53	43	28	36
1877-78	112	129	108	109	140	100	137	155
1878-79	78	79	59	41	25	36	65	42
1879-80	105	99	98	134	137	90	123	139
1880-81	87	107	94	122	96	118	80	93
1881-82	85	69	65	69	83	56	80	78
1882-83	88	87	92	85	88	72	81	92
1883-84	135	125	158	178	181	138	189	184
1884-85	67	66	71	78	71	66	66	78
1885-86	129	115	133	169	123	110	146	110
1886-87	68	70	50	88	86	72	75	77
1887-88	64	78	59	67	60	74	100	85
1888-89	74	98	74	92	78	89	119	97
1889-90	174	192	178	153	119	130	192	122
1890-91	86	86	80	79	87	83	91	105
1891-92	90	91	93	102	107	96	70	123
1892-93	132	139	130	101	94	95	143	109
1893-94	122	111	81	83	88	58	44	105
1894-95	148	147	137	119	139	122	103	132
1895-96	104	106	100	82	91	81	84	103
1896-97	124	112	111	107	125	114	101	118
1897-98	62	57	48	56	54	62	35	71
1898-99	89	91	73	82	73	81	66	58
1899-00	103	104	106	102	82	104	71	84
1900-01	129	121	134	137	119	127	130	94
1901-02	97	91	86	75	97	96	81	101
1902-03	108	99	100	81	97	78	86	101
1903-04	108	105	73	81	71	78	73	79
1904-05	108	124	135	132	118	147	132	130
1905-06	139	120	144	148	169	189	118	159
1906-07	148	144	160	131	123	131	153	135
1907-08	64	72	74	81	90	109	100	98
1908-09	119	124	114	113	165	142	146	117
1909-10	98	93	99	95	102	104	97	80
1910-11	133	121	125	132	103	117	163	86
1911-12	62	64	65	73	76	85	90	89
1912-13	58	52	48	66	67	79	61	96
1913-14	117	128	152	123	135	131	149	134
1914-15	114	126	145	124	111	174	161	148
1915-16	94	120	136	123	153	121	107	89
1916-17	82	78	83	88	98	107	87	90
1917-18	77	53	94	91	62	80	110	84
1918-19	89	105	100	81	88	109	85	90
1919-20	76	66	82	91	99	106	76	73
1920-21	110	98	120	95	92	119	79	80
1921-22	106	103	129	124	102	144	126	109
1922-23	106	102	109	101	98	97	74	64
1923-24	47	47	49	48	48	63	58	91
1924-25	115	117	110	99	119	112	66	99
1925-26	76	87	92	77	76	82	93	71
1926-27	105	104	100	108	111	129	112	98
1927-28	90	87	83	78	77	98	69	76
1928-29	76	67	85	80	87	91	59	76

* Indices for divisions T and V are computed for and apply particularly to those portions of these divisions lying in the San Joaquin River Basin.

From Plate II it may be seen that there is considerable difference in the values of the mean seasonal precipitation in various portions of the San Joaquin River Basin. The mean seasonal precipitation varies from 50 inches in the mountains at the northern end of the basin to less than 10 inches at the southern end of the San Joaquin Valley floor. In general, the precipitation decreases from north to south and increases with the elevation in the Sierra Nevada up to a maximum at an elevation of about 6000 feet and decreases slightly above this elevation to the crest of the mountains. The precipitation on the eastern slope of the Coast Range Mountains draining toward the San Joaquin River Basin is less than at the same elevation of the western slope of the Sierra Nevada.

Precipitation in the San Joaquin River Basin has large monthly variations. With the exception of occasional summer showers in the mountain areas, practically all of the precipitation occurs during the months of September to May, inclusive. About ninety per cent occurs during the months of November to April, inclusive. There is little or no rainfall on the valley floor between May and September, the period of greatest irrigation demand. The entire seasonal precipitation on the valley floor contributes only a fraction of the water supply required for the consumptive use of the average crops produced in the San Joaquin Valley.

Precipitation on the higher mountain areas occurs in the form of snow during the winter months. This snow packs down, does not melt until late spring or early summer months, and produces the same effect in run-off as though the precipitation had been extended beyond the usual rainy season.

Run-off.

The most reliable knowledge of the run-off of the San Joaquin River Basin is derived from stream flow measurements. The first stream flow records were obtained during the period 1878–1884, under the direction of William Ham. Hall, State Engineer. Measurements and estimates were made of the run-off for the following streams in the San Joaquin River Basin: San Joaquin River at Hamptonville, Kern River at Rio Bravo Ranch, Caliente Creek at base of foothills, Poso Creek at base of foothills, White River at base of foothills, Deer Creek at base of foothills, Tule River at Porterville, Kaweah River at Wutchumna Hill, Kings River at Slate Point, Fresno River at base of foothills, Chowchilla River at base of foothills, Mariposa Creek at base of foothills, Bear Creek at base of foothills, Merced River at Merced Falls, Tuolumne River at Modesto, Stanislaus River at Oakdale, Calaveras River at Bellota, Mokelumne River at Lone Star Mill, Dry Creek at base of foothills and Cosumnes River at Live Oak Suspension Bridge. These activities were discontinued after 1884.

Beginning in the nineties, gaging stations were established on the more important streams in the San Joaquin River Basin by the United States Geological Survey. Since 1903 these stations have been maintained by the Geological Survey in cooperation with the State. The oldest station in the basin for which a continuous record of run-off is available to date is that on the Kern River near Bakersfield, established September 29, 1893 and still maintained by the Kern County Land and Water Company. This gives a continuous 36-year record of run-off from October, 1893, to October, 1929. Other stations were progressively established and at the present time are maintained on all the major streams and many of their tributaries. In 1929, stream flow records were available from 89 of the United States Geological Survey stations. During the 1929–1930 seasons five stations were established or reestablished in the San Joaquin River Basin by that agency. In addition to the records from stations maintained by, or others made available through United States Geological Survey, there are a number from stations maintained by power companies and irrigation districts on streams, canals or reservoirs which are of value, particularly in estimating diversions and use from the various streams. The stations of greatest value in estimating the available water supply of the San Joaquin River Basin are those maintained on the major streams at or near the line where the foothills meet the valley floor. These stations at the foothill line furnish data on the run-off of the mountain and foothill areas which may be made available for use in the valley. The United States Geological Survey gaging stations in the San Joaquin River Basin established prior to September 30, 1929, are shown in Table 4. In the table are given for each station, the name of the stream, location of the gaging station, the tributary drainage area, where known, and the period of stream flow record.

TABLE 4

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Kern River	Near Kernville	845	Jan. 1, 1912–Sept. 30, 1929
Kern River and Kern No. 3 Canal	Near Kernville	845	Oct. 1, 1920–Sept. 30, 1929
Kern River	At Kernville		Jan. 1, 1905–Sept. 30, 1912
Kern River	At Isabella	1,220	Oct. 5, 1910–Sept. 30, 1912 Oct. 1, 1925–Sept. 30, 1929
Kern River and Borel Canal	At Isabella		Oct. 1, 1925–Sept. 30, 1929
Kern River	Near Bakersfield	2,410	Sept. 29, 1893–Sept. 30, 1929
Kern River No. 3 Canal	Near Kernville		Mar. 7, 1921–Sept. 30, 1929
Salmon Creek	Near Kernville		Feb. 19, 1922–Sept. 30, 1923
Kern River Power Co.'s Canal	At Kernville		Jan. 1, 1910–Sept. 30. 1914
Borel Canal	At Tilley Creek		Jan. 1, 1910–Sept. 30, 1914 Oct. 1, 1925–Sept. 30, 1929
South Fork of Kern River	Near Onyx		Sept. 12, 1911–Aug. 31, 1914 Jan. 23, 1919–Sept. 30, 1929
South Fork of Kern River	At Isabella		Jan. 1, 1929–Sept. 30, 1929
Erskine Creek	Near Isabella		Feb. 7, 1911–Sept. 30, 1912
Thomas Ditch	Near Onyx		April 11, 1929–Sept. 30, 1929
Lowell Ditch	Near Onyx		April 11, 1929–Sept. 30, 1929
Basin Creek	Near Havilah	36	Feb. 8, 1911–Sept. 30, 1912
Tejon House Creek	At Tejon ranch house	17	Jan. 1, 1895–Nov. 30, 1896
San Emigdio Creek	At San Emigdio ranch house	54	Sept. 1, 1894–Dec. 31, 1895
Poso Creek	Near Bakersfield	247	Mar. 21, 1920–May 26, 1920
White River	Near Hot Springs	33	Jan. 18, 1911–Sept. 30, 1913
Deer Creek	At Hot Springs	11	Oct. 7, 1910–Sept. 30, 1929
Tyler Creek	Near Hot Springs		Jan. 16, 1911–Sept. 30, 1913
North Fork of Middle Fork of Tule River	Near Springville		Jan. 1, 1909–Dec. 31, 1912
Tule River	Near Porterville	264	April 8, 1901–Sept. 30, 1929
S. Fork of Middle Fork of Tule River	Near Springville		Jan. 1, 1909–Dec. 31, 1912
Bear Creek	Near Springville		Jan. 23, 1911–Oct. 25, 1916
South Fork of Tule River	Near Porterville	74	Oct. 10, 1910–Sept. 30, 1929
Kaweah River	Near Three Rivers	514	April 29, 1903–Sept. 30, 1929
Kaweah River	At McKay Pt. near Lemoncove		Oct. 1, 1918–July 7, 1921
North Fork of Kaweah River	At Kaweah		Oct. 12, 1910–Sept. 30, 1929
South Fork of Kaweah River	Near Three Rivers		Sept. 18, 1911–Sept. 30, 1924
Kings River	Near Hume	835	Aug. 28, 1921–Sept. 30, 1929
Kings River	Above North Fork	952	Mar. 16, 1927–Dec. 31, 1928
Kings River	At Piedra (near Sanger)	1,694	Sept. 3, 1895–Sept. 30, 1929
Kings River	At Kingsburg	1,742	May 1, 1896–Dec. 31, 1897
North Fork of Kings River	Below Meadowbrook	35	Oct. 1, 1921–Sept. 30, 1929
North Fork of Kings River	Near Cliff Camp	174	Aug. 25, 1921–Sept. 30, 1929
North Fork of Kings River	Below Rancheria Creek	225	Mar. 8, 1927–Sept. 30, 1929
North Fork of Kings River	Above Dinkey Creek	246	Dec. 26, 1919–Sept. 30, 1929
Helm Creek	At Sand Meadow	34	Oct. 22, 1922–Sept. 30, 1929
Rancheria Creek	Near Smith Meadow	22	Oct. 1, 1924–Sept. 30, 1929
Dinkey Creek	Near Ockenden		Sept. 17, 1910–Sept. 30, 1912
Dinkey Creek	At Dinkey Meadows	51	Oct. 27, 1921–Sept. 30, 1929
Dinkey Creek	At mouth	136	Jan. 7, 1920–Sept. 30, 1929
Deer Creek	Below East Fork	21	Oct. 1, 1923–Sept. 30, 1929
Big Creek	Near Tollhouse		Mar. 21, 1911–Sept. 30, 1913
Tulare Lake	In Kings County		June 6, 1906–Sept. 30, 1920
South Fork of San Joaquin River	Near Florence Lake	171	Dec. 29, 1921–Sept. 30, 1929
South Fork of San Joaquin River	Near Hoffman Meadow	428	Nov. 17, 1921–Sept. 30, 1928
San Joaquin River	Above Big Creek	1,060	Aug. 11, 1912–Sept. 30, 1915 Mar. 25, 1922–Sept. 30, 1929
San Joaquin River	Near North Fork		April 1, 1910–Sept. 30, 1914
San Joaquin River	Near Friant	1,631	Oct. 18, 1907–Sept. 30, 1929
San Joaquin River	At Herndon	1,637	Jan. 1, 1895–Dec. 31, 1901
San Joaquin River	Near Newman		April 29, 1912–Sept. 30, 1929
San Joaquin River	Near Vernalis		July 29, 1922–Sept. 30, 1929
San Joaquin River	At Lathrop		Oct. 1, 1920–July 15, 1922
Florence Lake Tunnel	At intake		April 13, 1925–Sept. 30, 1929
Bear Creek	Near Vermillion Valley	53	Nov. 29, 1921–Sept. 30, 1929
Mono Creek	Near Vermillion Valley	93	Nov. 25, 1921–Sept. 30, 1929
Middle Fork of San Joaquin River	At Miller Bridge	251	Oct. 12, 1921–July 18, 1928
North Fork of San Joaquin River	Below Iron Creek	37	Oct. 1, 1920–July 15, 1928
Iron Creek	At mouth		Oct. 1, 1922–Sept. 30, 1923
West Fork of Granite Creek	Near Timber Knob		Jan. 1, 1922–Sept. 30, 1925
Granite Creek	Near Cattle Mountain	54	Dec. 2, 1921–July 6, 1928
Middle Fork of Granite Creek	Near Cattle Mountain		Feb. 17, 1922–Sept. 30, 1923
East Fork of Granite Creek	Near Cattle Mountain		Jan. 1, 1922–Sept. 30, 1925
Jackass Creek	Near Jackass Meadow	14	Dec. 1, 1921–July 6, 1928

TABLE 4—Continued

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Jackass Creek	Near Fullers Meadow		Mar. 1, 1924–Sept. 30, 1925
West Fork of Jackass Creek	Near Fullers Meadow		Mar. 1, 1924–Sept. 30, 1925
Chiquito Creek	Near Mugler Meadows		Mar. 1, 1924–Sept. 30, 1925
Chiquito Creek	Near Arnold Meadow	60	Sept. 12, 1921–July 7, 1928
Big Creek	Below Huntington Lake	79	Jan. 1, 1910–Sept. 30, 1915 June 18, 1925–Sept. 30, 1929
Big Creek at mouth	Near Big Creek	131	May 10, 1923–Sept. 30, 1928
Pitman Creek	At Big Creek	27	Jan. 1, 1910–Sept. 30, 1915 Jan. 26, 1922–Sept. 30, 1928
Pitman Creek	Below Tamarack Creek		Dec. 1, 1927–Sept. 30, 1929
Stevenson Creek	At Shaver	30	Oct. 1, 1916–Sept. 30, 1920 April 9, 1922–Sept. 30, 1928
Fresno Flume and Lumber Co.'s Upper Flume	At Shaver		Nov. 13, 1915–July 7, 1920
Fresno Flume and Lumber Co.'s Lower Flume	At Shaver		Jan. 6, 1916–June 28, 1919
Southern California Edison Co.'s Flume	At Shaver		Feb. 16, 1922–Sept. 5, 1926
North Fork of San Joaquin River	Near North Fork		April 1, 1910–Dec. 31, 1911
South Fork Creek	Near North Fork	38	April 1, 1910–Sept. 30, 1915
South Fork Ditch	Near North Fork		April 3, 1910–Dec. 31, 1910
Crane Valley Reservoir	Near North Fork	55	April 1, 1910–Sept. 30, 1915
Whiskey Creek	Near North Fork	13	April 1, 1910–Sept. 30, 1915
Cascadel Creek	Near North Fork		April 1, 1910–April 30, 1912
Panoche Creek	Near Panoche		Nov. 15, 1922–May 22, 1923
Silver Creek	Near Panoche		Nov. 21, 1922–May 23, 1923
Fresno River	Near Knowles	134	Sept. 16, 1911–Dec. 31, 1913 Nov. 13, 1915–Sept. 30, 1929
Chowchilla River	Near Buchanan reservoir site	238	Oct. 1, 1921–Sept. 30, 1923
Merced River	Above Illilouette Creek	118	Aug. 21, 1915–Dec. 31, 1915
Merced River	At Happy Isles Bridge near Yosemite	181	Aug. 23, 1915–Sept. 30, 1929
Merced River	At Yosemite	236	July 11, 1904–June 27, 1909 Jan. 4, 1912–Sept. 30, 1916
Merced River	At Pohono Bridge nr. Yosemite	322	Nov. 2, 1916–Sept. 30, 1929
Merced River	At Horseshoe Bend		Nov. 17, 1922–Sept. 30, 1929
Merced River	At Exchequer	1,020	Nov. 28, 1915–Sept. 30, 1929
Merced River	Near Merced Falls	1,054	April 6, 1901–Nov. 30, 1913 April 1, 1923–April 20, 1926
Merced River	Near Livingston		April 29, 1912–Sept. 30, 1912 Mar. 18, 1921–Aug. 31, 1921 Mar. 10, 1922–Sept. 30, 1929
Illilouette Creek	Near Yosemite	62	Aug. 21, 1915–Dec. 31, 1915
Tenaya Creek	Near Yosemite	47	July 11, 1904–June 24, 1909 Jan. 5, 1912–Sept. 30, 1929
Yosemite Creek	At Yosemite	43	July 11, 1904–June 27, 1909 Jan. 4, 1912–Sept. 11, 1926
South Fork of Merced River	Near Wawona		Dec. 15, 1910–June 1, 1922
Lake McClure	At Exchequer		April 20, 1926–Sept. 30, 1929
Tuolumne River	At Hetch Hetchy cabin		Oct. 10, 1910–Sept. 30, 1916
Tuolumne River	At Hetch Hetchy Dam Site	459	May 30, 1901–Sept. 30, 1901 Dec. 1, 1910–Aug. 31, 1915
Tuolumne River	Near Hetch Hetchy		Dec. 20, 1914–Sept. 30, 1929
Hetch Hetchy Reservoir	At Hetch Hetchy	459	May 7, 1923–Sept. 30, 1929
Tuolumne River	Near Buck Meadows		Sept. 2, 1907–Mar. 31, 1909 Sept. 3, 1910–Sept. 30, 1929
Tuolumne River	Near Jacksonville		July 31, 1923–Sept. 30, 1929
Don Pedro Reservoir	Near La Grange	1,536	Oct. 1, 1924–Sept. 30, 1929
Tuolumne River	Above La Grange Dam		Mar. 19, 1915–Sept. 30, 1929
Tuolumne River and canals	Near La Grange	1,543	Aug. 29, 1895–Sept. 30, 1917
Tuolumne River	At Modesto		Jan. 1, 1895–Dec. 31, 1896
Falls Creek	Near Hetch Hetchy	45	Nov. 22, 1915–Sept. 30, 1929
Cherry Creek	At Eleanor Trail Crossing	130	May 26, 1901–Sept. 30, 1901
Cherry Creek	Near Hetch Hetchy	114	April 1, 1910–Sept. 30, 1929
Eleanor Creek	At Eleanor Trail Crossing	81	June 1, 1901–Oct. 15, 1901
Eleanor Creek	Near Hetch Hetchy	79	Nov. 20, 1909–Sept. 30, 1929
Lake Eleanor	Near Hetch Hetchy	79	Oct. 1, 1919–Sept. 30, 1929
South Fork of Tuolumne River	At Italian Flat nr. Sequoia		Oct. 1, 1924–Sept. 30, 1929
South Fork of Tuolumne River	At Harden ranch nr. Sequoia		Jan. 11, 1914–Feb. 23, 1918
South Fork of Tuolumne River	Nr. Oakland Recreation Camp		Mar. 19, 1923–Sept. 30, 1929
South Fork of Tuolumne River	Near Buck Meadows		Oct. 1, 1916–Sept. 30, 1921
Golden Rock Ditch	Near Sequoia		Jan. 1, 1914–June, 30, 1915
Middle Fork of Tuolumne River	Near Mather		Oct. 1, 1924–Sept. 30, 1929

TABLE 4—Continued

UNITED STATES GEOLOGICAL SURVEY STREAM GAGING STATIONS IN SAN JOAQUIN RIVER BASIN

Established prior to September 30, 1929

Stream	Station name	Area of drainage basin, in square miles	Period of stream flow record
Middle Fork of Tuolumne River	Near Buck Meadows		Nov. 23, 1916–Sept. 30, 1929
Woods Creek	Near Jacksonville	103	Oct. 1, 1925–Sept. 30, 1929
Sierra San Francisco Power Co.'s Canal	Near La Grange		Jan. 1, 1908–Jan. 25, 1926
Modesto Canal	Near La Grange		April 26, 1903–Sept. 30, 1929
Turlock Canal	Near La Grange		July 1, 1899–Sept. 30, 1929
Middle Fork of Stanislaus River	At Sand Bar Flat, nr. Avery	329	Sept. 1, 1905–Sept. 30, 1929
Stanislaus River	Near Knights Ferry	973	Dec. 18, 1915–Sept. 30, 1929
Stanislaus River	At Knights Ferry	983	May 19, 1903–April 30, 1916
Stanislaus River	At Oakdale	1,051	June 1, 1895–Feb. 16, 1901
Relief Creek	Near Baker Station		Oct. 1, 1910–Sept. 30, 1918
Relief Reservoir	Near Baker Station	28	Oct. 1, 1910–Sept. 30, 1918
North Fork of Stanislaus River	Near Avery	197	July 14, 1914–Sept. 30, 1922 Nov. 10, 1928–Sept. 30, 1929
Utica Gold Mining Co.'s Canal	Near Avery		May 19, 1915–Sept. 30, 1921
South Fork of Stanislaus River	At Strawberry	54	Oct. 21, 1911–Jan. 31, 1917
Oakdale Canal	Near Knights Ferry		May 3, 1914–Sept. 30, 1929
South San Joaquin Canal	Near Knights Ferry		May 1, 1914–Sept. 30, 1929
Stanislaus and San Joaquin Water Co.'s Canal	At Knight's Ferry		Jan. 1, 1899–Dec. 31, 1899 June 11, 1904–Sept. 30, 1912
Calaveras River	At Jenny Lind	394	Jan. 1, 1907–Sept. 30, 1929
Calaveras River	Near Stockton		Oct. 1, 1925–Sept. 30, 1926
South Channel of Littlejohns Creek	At Farmington	193	Oct. 1, 1925–Sept. 30, 1926
Bear Creek	Near Clements	43	Oct. 1, 1926–Sept. 30, 1927
Bear Creek	Near Lockeford	52	Oct. 1, 1926–Sept. 30, 1929
North Fork of Mokelumne River	Above Moore Creek	160	Sept. 23, 1926–Sept. 30, 1929
North Fork of Mokelumne River	Near West Point	270	April 28, 1917–Sept. 30, 1918 Feb. 1, 1924–Sept. 30, 1929
Mokelumne River	At Electra	537	Jan. 1, 1901–Dec. 31, 1901 May 11, 1903–Dec. 31, 1904
Mokelumne River	Near Mokelumne Hill	539	Nov. 11, 1927–Sept. 30, 1929
Mokelumne River	Near Lancha Plana	584	June 23, 1926–Sept. 30, 1929
Pardee Reservoir	Near Valley Springs	575	Mar. 9, 1929–Sept. 30, 1929
Mokelumne River	Near Clements	632	Jan. 1, 1905–Sept. 30, 1929
Mokelumne River	Near Victor		July 21, 1927–Sept. 30, 1929
Mokelumne River	At Woodbridge	648	May 27, 1924–Sept. 30, 1929
Mokelumne River	Near Thornton	690	July 6, 1926–Sept. 30, 1929
Bear River	At Pardoe Camp	33	July 3, 1927–Sept. 30, 1929
Cold Creek	Near Mokelumne Peak	23	July 23, 1927–Sept. 30, 1929
Middle Fork of Mokelumne River	At West Point	69	Oct. 9, 1911–Sept. 30, 1929
South Fork of Mokelumne River	Near Railroad Flat	41	Oct. 23, 1911–Sept. 30, 1929
Licking Fork of Mokelumne River	Near Railroad Flat		Oct. 23, 1911–Sept. 30, 1912 Mar. 24, 1915–Dec. 17, 1917
Woodbridge Canal	At Woodbridge		April 28, 1926–Sept. 30, 1929
Dry Creek	Near Ione	273	Oct. 7, 1911–June 30, 1912 Dec. 20, 1925–Sept. 30, 1929
Dry Creek	Near Galt	346	Dec. 4, 1926–Sept. 30, 1929
Sutter Creek	Near Volcano		Feb. 12, 1924–Sept. 30, 1927
Sutter Creek	At Sutter Creek	54	Feb. 5, 1922–Sept. 30, 1929
Goose Creek	Near Elliot	8	Jan. 10, 1927–Sept. 30, 1929
North Fork of Cosumnes River	Near Pleasant Valley	158	Feb. 27, 1906–Sept. 1, 1906 Feb. 1, 1924–May 31, 1924
North Fork of Cosumnes River	Near El Dorado	197	Aug. 13, 1911–Sept. 30, 1929
Cosumnes River	At Michigan Bar	534	Oct. 20, 1907–Sept. 30, 1929
Camp Creek	Near Sly Park		Nov. 1, 1923–Nov. 1, 1924
Camp Creek	Near Pleasant Valley		Feb. 1, 1924–May 31, 1924
Sly Park Creek	At Park		Mar. 2, 1906–June 30, 1906

The locations of these stream gaging stations are shown on Plate I, "Forested Area and Stream Gaging Stations in California." On this Plate the solid red dots indicate stations at which records were being taken on September 30, 1929, and the open red circles those stations which had been discontinued.

Data from the United States Geological Survey stations and from stations maintained by other agencies were used in water supply studies for this report.

Full Natural Run-off. The full natural or unimpaired run-off of a stream above any station is the run-off as it would have been if unaltered by diversions, storage development or importation of water from other watersheds. It is the run-off that would have occurred under natural conditions. In these studies the determination of the full natural run-off of each stream was made before attempting any estimates of impaired run-off.

The full natural run-off was calculated for each month from the measured run-off by adding upstream diversions and quantities stored in reservoirs and subtracting importations and reservoir releases. The corrections for storage were made as far as possible from records of actual reservoir operation. Where records were not available and water was known to have been stored, the amounts stored or released were estimated either from records of actual operation in other seasons or from records of operation of other reservoirs on the same watershed, taking into account the difference between the run-off in the season having record and the season being estimated.

The foregoing method of computing the full natural run-off applies only to streams and to periods for which records of measured run-off were available. For streams and periods for which no run-off records were available, one of two methods of estimating the full natural run-off was used. The first involved utilization of the index of wetness (seasonal or monthly), and the development of a relation of run-off to index of wetness for the particular stream. The second consisted in establishing a run-off relation between adjacent streams of parallel record. During periods, for which there were no run-off records on the stream under consideration, the full natural run-off of an adjacent stream was used in estimating the discharge, providing the relation during the period of parallel record showed that more accurate results could be obtained by this method than by the use of the index of wetness.

In using the second method, the full natural monthly run-off of the stream in question was plotted against the corresponding full natural monthly run-off of the adjacent stream having parallel record, and curves were drawn through the mean of the plotted points for each month. By entering these curves with the full natural monthly run-off of the adjacent stream, during periods of missing record on the stream being considered, the required estimate of monthly run-off was obtained.

When it was necessary to use the first, or index of wetness method, in estimating the full natural run-off, either the seasonal full natural run-off computed from available records was plotted against the index of seasonal wetness or the monthly index of wetness was plotted against the monthly full natural run-off computed from the available records

Stream or stream group
Upper San Joaquin Basin—
Panoche Creek
Cantua Creek Group ([a])
Los Gatos Creek
Tejon Creek Group ([b])
Caliente Creek
Kern River
Poso Creek Group ([c])
Deer Creek
Tule River
Yokohl Creek Group ([d])
Kaweah River
Lime Kiln Creek Group ([e])
Kings River
Dry Creek
San Joaquin River
Cottonwood Creek
Fresno River
Daulton Creek Group ([f])
Chowchilla River
Totals, Upper San Joaqu
Lower San Joaquin
Orestimba Creek
Dutchman Creek
Mariposa Creek
Owens Creek Gro
Bear Creek
Burns Creek Gro
Merced River
Tuolumne River
Wildcat Creek G
Stanislaus River
Totals, Lo
Delta Tributaries
Littlejohns Cr
Martells Cree
Calaveras Riv
Mokelumne R
Sutter Creek
Cosumnes Ri
Totals,
Gra

([a]) Cant
Canoas Cree
Creek, Santi
River, Poso (
Creek, Greas
Romero Cree
Creek, Bushy
Creek Group
Martells Cre

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The full natural run-off was calculated for each month from the measured run-off by adding upstream diversions and quantities stored in reservoirs and subtracting importations and reservoir releases. The corrections for storage were made as far as possible from records of actual reservoir operation. Where records were not available and water was known to have been stored, the amounts stored or released were estimated either from records of actual operation in other seasons or from records of operation of other reservoirs on the same watershed, taking into account the difference between the run-off in the season having record and the season being estimated.

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In using the second method, the full natural monthly run-off of the stream in question was plotted against the corresponding full natural monthly run-off of the adjacent stream having parallel record, and curves were drawn through the mean of the plotted points for each month. By entering these curves with the full natural monthly run-off of the adjacent stream, during periods of missing record on the stream being considered, the required estimate of monthly run-off was obtained.

When it was necessary to use the first, or index of wetness method, in estimating the full natural run-off, either the seasonal full natural run-off computed from available records was plotted against the index of seasonal wetness or the monthly index of wetness was plotted against the monthly full natural run-off computed from the available records

TABLE 5

SEASONAL FULL NATURAL RUN-OFFS OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	Run-off, in acre-feet										
		1889–90	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99	1899–00
Upper San Joaquin Basin—												
Panoche Creek	295	105,500	17,300	6,300	56,700	0	25,200	12,600	23,600	0	4,700	6,300
Cantua Creek Group (a)	208	54,400	7,800	2,200	27,700	0	12,200	5,500	11,100	0	2,200	2,200
Los Gatos Creek	119	41,300	5,700	1,900	20,300	0	8,900	4,400	8,300	0	1,900	2,500
Tejon Creek Group (b)	1,341	306,100	82,000	68,100	164,600	35,700	118,800	59,400	102,300	5,500	8,800	26,900
Caliente Creek	471	60,300	55,300	[illegible]0,300	45,200	40,200	70,400	40,200	57,800	12,600	2,500	20,100
Kern River	2,410	925,000	540,000	7[illegible]8,000	617,000	579,800	1,030,200	637,900	896,000	299,500	342,500	330,900
Poso Creek Group (c)	576	66,000	24,600	[illegible]6,100	30,700	26,100	99,800	29,200	75,300	0	12,300	20,000
Deer Creek	110	27,000	12,900	21,200	15,300	13,500	38,200	14,700	30,600	4,100	8,800	11,200
Tule River	390	163,000	97,000	130,000	109,500	127,700	221,500	119,800	177,200	51,700	49,800	44,700
Yokohl Creek Group (d)	98	20,400	7,800	14,600	9,900	7,800	31,300	8,900	23,500	0	3,700	6,300
Kaweah River	514	1,100,000	509,000	648,000	607,000	399,000	733,000	401,500	471,200	224,400	291,500	311,500
Lime Kiln Creek Group (e)	201	83,500	38,500	65,300	48,200	40,700	116,700	43,900	93,200	8,600	24,600	[illegible]4,300
Kings River	1,694	4,250,000	2,222,000	2,740,000	2,593,000	1,770,000	3,042,000	1,853,700	2,086,200	830,600	1,223,700	1,285,300
Dry Creek	48	12,700	[illegible],500	3,800	3,800	2,000	6,400	1,800	4,600	500	1,800	3,800
San Joaquin River	1,631	4,620,000	2,355,000	2,933,000	2,768,000	1,864,000	2,789,900	1,985,700	2,219,700	922,300	1,269,500	1,343,600
Cottonwood Creek	28	7,000	[illegible]	2,000	1,800	900	3,300	800	2,300	200	800	2,000
Fresno River	270	168,500	31,800	63,600	62,000	36,600	95,400	35,000	71,500	11,100	35,000	63,600
Daulton Creek Group (f)	66	15,900	1,400	4,200	4,200	1,800	7,400	1,800	5,100	400	1,800	4,200
Chowchilla River	238	195,100	44,700	49,700	111,800	94,400	142,900	68,300	99,400	19,900	48,500	67,100
Totals, Upper San Joaquin Basin	10,708	12,221,700	6,055,100	7,618,300	7,296,700	5,040,200	8,593,500	5,325,100	6,458,900	2,441,400	3,334,400	3,586,500
Lower San Joaquin Basin—												
Orestimba Creek Group (g)	1,340	450,200	42,900	71,500	207,200	64,300	235,800	100,000	128,600	0	35,700	107,200
Dutchman Creek Group (h)	72	31,500	4,200	5,000	15,700	12,300	21,500	7,700	13,400	800	4,600	7,700
Mariposa Creek	103	48,200	7,100	7,700	23,000	18,600	31,800	12,100	19,700	2,260	7,700	12,100
Owens Creek Group (i)	66	27,900	2,800	3,500	12,400	9,500	17,700	6,000	10,200	700	3,500	5,600
Bear Creek	71	29,700	3,400	4,600	14,100	11,000	19,800	6,900	11,800	1,100	4,200	6,500
Burns Creek Group (j)	171	80,200	13,700	16,400	43,800	36,500	57,400	24,600	38,300	2,700	15,500	23,700
Merced River	1,054	2,745,000	870,000	963,000	1,625,000	1,535,000	2,378,000	804,500	1,300,200	491,600	688,200	815,400
Tuolumne River	1,543	5,009,000	1,543,000	1,650,000	3,036,000	2,624,000	3,795,000	1,588,200	2,437,100	960,400	1,334,600	1,628,300
Wildcat Creek Group (k)	59	32,900	4,700	5,300	16,300	13,100	22,200	8,500	14,100	900	5,300	8,100
Stanislaus River	983	3,230,000	1,107,000	1,227,000	2,075,000	1,967,000	2,682,400	1,391,200	1,419,800	406,300	828,000	944,200
Totals, Lower San Joaquin Basin	5,462	11,774,600	3,598,800	3,954,000	7,068,500	6,291,300	9,261,600	3,949,700	5,393,200	1,866,700	2,927,300	3,558,800
Delta Tributaries—												
Littlejohns Creek	41	28,700	4,800	5,400	14,000	11,400	19,000	7,800	12,100	2,200	5,200	7,600
Martells Creek Group (l)	122	44,900	8,500	9,800	25,400	21,500	32,500	14,300	22,100	2,600	9,800	14,300
Calaveras River	394	448,400	110,000	93,800	301,200	254,200	470,300	194,300	339,100	44,100	218,500	91,600
Mokelumne River	632	2,062,900	520,300	740,000	1,276,800	942,600	1,446,400	628,300	1,038,000	388,100	547,800	678,800
Sutter Creek Group (m)	285	277,000	57,800	65,500	161,300	137,000	204,000	94,400	141,600	19,800	63,900	92,800
Cosumnes River	534	1,150,900	201,500	312,600	659,500	453,200	820,500	248,100	639,500	173,300	217,100	281,700
Totals, Delta tributaries	2,008	4,012,800	902,900	1,227,100	2,438,200	1,819,900	2,992,700	1,187,200	2,192,400	630,100	1,062,300	1,166,800
Grand totals	18,178	28,009,100	10,556,800	12,799,400	16,803,400	13,151,400	20,847,800	10,462,000	14,044,500	4,938,200	7,324,000	8,312,100

Stream or stream group	Run-off, in acre-feet										
	1900–01	1901–02	1902–03	1903–04	1904–05	1905–06	1906–07	1907–08	1908–09	1909–10	1910–11
Upper San Joaquin Basin—											
Panoche Creek	45,600	11,000	14,200	7,900	47,200	37,800	66,100	23,600	58,200	22,000	75,500
Cantua Creek Group (a)	23,300	4,400	5,500	3,300	23,300	17,700	33,300	11,100	30,000	8,900	38,800
Los Gatos Creek	16,500	3,800	4,400	2,500	17,100	13,300	24,100	8,300	21,600	7,600	26,700
Tejon Creek Group (b)	123,400	46,700	56,600	26,900	163,500	178,200	218,500	76,000	183,300	57,800	192,800
Caliente Creek	27,600	30,200	37,700	20,100	65,300	105,500	72,900	35,200	55,300	20,100	25,100
Kern River	883,800	580,500	569,500	481,000	559,700	1,848,800	1,065,200	479,500	1,771,500	751,200	1,013,700
Poso Creek Group (c)	66,000	35,300	35,300	10,700	64,500	158,200	72,200	27,600	149,000	41,500	43,000
Deer Creek	27,000	16,500	16,500	8,200	27,000	58,200	30,000	14,100	55,200	18,800	18,200
Tule River	161,100	149,700	146,800	92,100	97,200	481,500	210,000	107,400	397,800	157,500	149,700
Yokohl Creek Group (d)	20,400	11,500	11,500	3,700	20,400	49,600	22,500	8,400	47,000	13,100	13,600
Kaweah River	731,700	355,100	403,900	345,700	337,700	1,088,400	593,500	252,600	799,900	409,200	546,000
Lime Kiln Creek Group (e)	83,500	52,500	52,500	22,500	83,500	173,500	91,000	42,800	166,000	58,900	61,000
Kings River	3,142,500	1,553,000	1,687,800	1,743,300	1,427,800	3,856,700	2,752,500	1,033,900	2,809,400	1,779,000	2,826,700
Dry Creek	9,400	1,300	1,800	1,800	8,400	11,700	8,400	1,800	5,600	3,000	8,400
San Joaquin River	3,004,500	1,633,000	1,768,800	1,821,900	1,512,600	4,039,700	2,900,900	1,161,200	2,904,300	2,041,500	3,587,600
Cottonwood Creek	5,000	500	800	800	4,600	6,400	4,400	800	2,700	1,500	4,600
Fresno River	131,900	27,000	33,400	33,400	120,800	155,800	117,600	33,400	84,200	52,400	120,800
Daulton Creek Group (f)	11,700	1,100	1,400	1,400	10,300	14,900	10,300	1,400	6,400	3,200	10,300
Chowchilla River	106,900	58,400	74,600	74,600	74,600	124,300	142,900	22,400	90,700	59,600	114,300
Totals, Upper San Joaquin Basin	8,621,800	4,571,500	4,923,000	4,701,800	4,665,500	12,420,200	8,436,300	3,341,500	9,638,100	5,506,800	8,876,800
Lower San Joaquin Basin—											
Orestimba Creek Group (g)	200,100	57,200	92,900	42,900	207,200	235,800	314,500	28,600	142,900	85,800	171,500
Dutchman Creek Group (h)	14,600	6,500	8,800	8,800	8,800	18,000	21,500	1,200	11,500	6,900	16,100
Mariposa Creek	21,900	9,900	13,700	13,700	13,700	26,800	31,800	2,200	18,100	9,900	23,600
Owens Creek Group (i)	11,700	4,600	6,400	6,400	6,400	14,500	17,700	1,100	8,800	4,600	13,100
Bear Creek	13,300	5,300	8,000	8,000	8,000	16,400	19,800	1,100	10,700	5,700	14,500
Burns Creek Group (j)	41,900	20,100	27,300	27,300	27,300	50,100	57,400	3,600	34,600	21,000	45,600
Merced River	1,554,000	826,200	979,700	1,093,400	897,700	2,035,100	2,125,800	517,900	1,475,400	1,065,900	2,114,600
Tuolumne River	2,717,800	1,606,000	1,973,000	2,661,300	1,720,000	3,525,400	3,[illegible]55,700	1,073,600	2,646,900	2,078,100	3,413,400
Wildcat Creek Group (k)	15,700	6,900	9,400	9,400	9,400	19,100	22,200	1,300	12,500	7,200	16,900
Stanislaus River	1,686,400	959,800	1,123,700	2,046,900	975,700	2,414,500	2,834,400	620,000	1,925,900	1,405,800	2,356,900
Totals, Lower San Joaquin Basin	6,277,400	3,502,500	4,242,900	5,918,100	3,874,200	8,355,700	9,200,800	2,250,600	6,287,300	4,690,900	8,186,200
Delta Tributaries—											
Littlejohns Creek	13,200	6,500	8,600	8,600	8,600	16,200	19,000	2,200	11,000	6,700	14,500
Martells Creek Group (l)	24,100	11,700	15,600	15,600	15,600	28,600	32,500	2,600	20,200	12,400	26,000
Calaveras River	234,100	134,800	235,100	377,800	135,700	427,800	707,800	72,700	391,900	194,800	674,700
Mokelumne River	1,120,000	657,300	824,100	1,337,500	660,200	1,370,100	1,692,000	485,700	1,167,500	920,900	1,530,700
Sutter Creek Group (m)	155,300	79,100	103,500	103,500	103,500	175,300	204,000	22,800	129,400	82,200	164,400
Cosumnes River	593,800	255,500	372,700	524,100	279,000	580,600	816,000	150,500	639,000	462,900	876,400
Totals, Delta tributaries	2,140,500	1,144,900	1,559,600	2,367,100	1,202,600	2,598,600	3,471,300	736,500	2,359,000	1,679,900	3,286,700
Grand totals	17,039,700	9,218,900	10,725,500	12,987,000	9,742,300	23,374,500	21,108,400	6,328,600	18,284,400	11,877,600	20,349,700

(a) Cantua Creek Group—Domengine Creek, Martinez Creek, Salt Creek, Cantua Creek, Arroyo Honda, Arroyo Cierva; (b) Tejon Creek Group—Waltham Creek, Jacalitos Creek, Zapato Creek, Canoas Creek, Garza Creek, Avenal Creek, Franciscan Creek, Packwood Creek, Bitterwater Creek, Devilwater Creek, Media Agua, Santos Creek, Chico Martinez, Salt Creek, Buena Vista Creek, Bitter Creek, Santiago Creek, Muddy Creek, San Amigdio Creek, Pleito Creek, Tecuya Creek, Grapevine Creek, Pastoria Creek, Tunis Creek, El Paso Creek, Tejon Creek; (c) Poso Creek Group—White River, Poso Creek, Rag Gulch; (d) Yokohl Creek Group—Horse Creek, Lewis Creek, Yokohl Creek; (e) Limekiln Creek Group—Limekiln Creek, Rattlesnake Creek, Stokes Creek, Sand Creek, Watoke Creek, Greasy Creek; (f) Daulton Creek Group—Daulton Creek, Dry Creek; (g) Orestimba Creek Group—Little Panoche Creek, Laguna Seca, Ortigalita Creek, Los Banos Creek, San Luis Creek, Romero Creek, Quinto Creek, Mustang Creek, Garzos Creek, Crow Creek, Orestimba Creek, Little Salada Creek, Puerto Creek, Ingram Creek, Hospital Creek, Buenos Aires Creek, Mountain House Creek, Bushy Creek, Kellogg Creek, Marsh Creek, Lone Tree Creek, Sand Creek, Dry Creek, Deer Creek, Salada Creek; (h) Dutchman Creek Group—Dutchman Creek, Deadman Creek; (i) Owens Creek Group—Owens Creek, Miles Creek; (j) Burns Creek Group—Burns Creek, Black Rascal Creek, Fahrens Creek; (k) Wildcat Creek Group—Wildcat Creek, Dry Creek; (l) Martells Creek Group—Martells Creek, Bear Creek, Rock Creek, Big Spring Creek, Peachys Creek; (m) Sutter Creek Group—Dry Creek, Wi[illegible]w Creek, Sutter Creek.

TABLE 5—Continued

SEASONAL FULL NATURAL RUN-OFFS OF SAN JOAQUIN RIVER BASIN STREAMS

Stream or stream group	Drainage area, in square miles	Run-off, in acre-feet																		Mean run-off for period, in acre-feet			
		1911-12	1912-13	1913-14	1914-15	1915-16	1916-17	1917-18	1918-19	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25	1925-26	1926-27	1927-28	1928-29	1889-1929	1909-1929	1919-1929	1924-1929
Upper San Joaquin Basin																							
Pastoria Creek	[illegible]	17,[illegible]	[illegible]	[illegible]	74,000	[illegible]	[illegible]	[illegible]	14,200	[illegible]	11,000	[illegible]	[illegible]	[illegible]	4,700	[illegible]	11,500	6,900	[illegible]	26,400	[illegible]	11,000	13,200
Cantua Creek Group (a)	[illegible]	[illegible]	[illegible]	31,800	37,7[illegible]	[illegible]	[illegible]	[illegible]	5,501	[illegible]	4,4[illegible]	21,1[illegible]	[illegible]	1,130	[illegible]	7,8[illegible]	14,100	[illegible]	1,100	12,600	11,300	6,100	5,500
Los Gatos Creek	110	8,[illegible]	[illegible]	22,800	25,4[illegible]	10,200	7,100	[illegible]	[illegible]	[illegible]	3,8[illegible]	15,2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19,800	[illegible]	[illegible]	9,400	8,400	4,800	4,300
Tejon Creek Group (b)	[illegible]	84,[illegible]	[illegible]	[illegible]	257,000	[illegible]	[illegible]	[illegible]	45,600	23,100	[illegible]	111,000	[illegible]	[illegible]	[illegible]	43,800	[illegible]	21,400	[illegible]	88,600	74,700	[illegible]	41,000
Caliente Creek	[illegible]	35,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27,100	[illegible]	25,100	[illegible]	17,600	42,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15,100	[illegible]	[illegible]	28,000	21,900	22,100
Kern River	[illegible]	[illegible]	[illegible]	1,110,000	675,[illegible]	[illegible]	[illegible]	529,000	544,100	611,000	528,600	853,[illegible]	[illegible]	[illegible]	477,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	735,000	691,000	505,000	[illegible]
Poso Creek Group (c)	[illegible]	15,000	[illegible]	[illegible]	51,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61,700	41,500	[illegible]	0	[illegible]	15,400	[illegible]	[illegible]	[illegible]	45,500	[illegible]	32,300	35,300
Deer Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17,600	[illegible]	[illegible]	[illegible]	5,0[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16,500	13,400	12,600
Tule River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61,200	51,[illegible]	[illegible]	[illegible]	[illegible]	135,000	113,000	87,200	77,000
Yokohl Creek Group	[illegible]	[illegible]	[illegible]	[illegible]	16,700	[illegible]	[illegible]	[illegible]	7,800	12,000	8,000	11,100	[illegible]	0	[illegible]	[illegible]	17,700	4,700	[illegible]	[illegible]	12,000	10,000	10,900
Kaweah River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	477,500	[illegible]	[illegible]	[illegible]	[illegible]	401,100	[illegible]	101,700	[illegible]	218,800	[illegible]	[illegible]	[illegible]	[illegible]	355,000	311,000	291,000
Lime Kiln Creek Group (d)	[illegible]	[illegible]	18,200	110,000	71,700	[illegible]	[illegible]	[illegible]	40,700	[illegible]	45,000	[illegible]	[illegible]	0	84,500	[illegible]	71,700	[illegible]	[illegible]	[illegible]	52,000	16,000	19,700
Kings River	[illegible]	[illegible]	341,[illegible]	[illegible]	1,817,100	[illegible]	[illegible]	[illegible]	[illegible]	1,434,700	1,532,400	[illegible]	[illegible]	[illegible]	1,290,200	1,067,200	1,084,200	870,[illegible]	[illegible]	[illegible]	1,580,000	[illegible]	1,226,000
Dry Creek	48	[illegible]	[illegible]	7,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7,100	[illegible]	[illegible]	[illegible]	1,500	[illegible]	1,400	[illegible]	4,100	[illegible]	4,000	2,600
San Joaquin River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,642,500	[illegible]	[illegible]	445,[illegible]	[illegible]	[illegible]	2,000,100	1,157,500	[illegible]	[illegible]	[illegible]	1,405,000	1,333,000
Cottonwood Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,500	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,800	1,100	1,200
Fresno River	[illegible]	[illegible]	[illegible]	[illegible]	74,700	[illegible]	[illegible]	47,100	[illegible]	[illegible]	54,700	[illegible]	[illegible]	14,400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48,000
Daulton Creek Group	[illegible]	[illegible]	700	[illegible]	8,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	3,400	[illegible]	1,400	1,400	[illegible]	[illegible]	[illegible]	2,700
Chowchilla River	[illegible]	19,[illegible]	[illegible]	87,600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31,700	[illegible]	52,000	[illegible]	70,900	56,200	56,100	55,100
Totals, Upper San Joaquin Basin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,428,800	[illegible]	[illegible]	1,352,400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,646,200	[illegible]	[illegible]	3,688,701
Lower San Joaquin Basin																							
Orestimba Creek Group (e)	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	110,000	[illegible]	142,[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	50,000	[illegible]	120,000	[illegible]	87,200	78,600
Dutchman Creek Group (f)	[illegible]	[illegible]	[illegible]	[illegible]	11,400	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9,200	8,100	8,100	0	[illegible]	[illegible]	8,100	5,100	2,700	[illegible]	6,000	5,700	5,300
Mariposa Creek	[illegible]	[illegible]	1,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7,700	4,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,400	[illegible]	7,100	[illegible]	[illegible]	9,100	9,000	9,100
Owens Creek Group (g)	[illegible]	[illegible]	400	[illegible]	8,100	[illegible]	2,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	1,800	[illegible]	[illegible]	[illegible]	6,700	4,500	4,300	4,100
Bear Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,000	[illegible]	8,400	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,100	5,200
Burns Creek Group (h)	[illegible]	[illegible]	2,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18,300	18,800
Merced River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	765,000
Tuolumne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,744,800	2,020,700	2,474,800	[illegible]	[illegible]	[illegible]	1,114,800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,520,000
Wildcat Creek Group (k)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	5,700	[illegible]	[illegible]	[illegible]	6,200	6,500
Stanislaus River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	932,000
Totals, Lower San Joaquin Basin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3,475,000	3,345,500
Delta Tributaries																							
Littlejohn Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,500	[illegible]	[illegible]	[illegible]	8,400	[illegible]	6,000	6,200
Marsh Creek Group (l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19,400	[illegible]	[illegible]	11,100	10,700	11,100
Calaveras River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	85,200	[illegible]	[illegible]	80,100	[illegible]	150,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	141,000	115,000
Mokelumne River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	610,000
Sutter Creek Group	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75,900	70,500
Cosumnes River	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	147,7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	282,000
Totals, Delta Tributaries	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1,102,800
Grand totals	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8,540,900	[illegible]

(a) Cantua Creek Group: [illegible] Creek, Martinez Creek, [illegible] Creek, Cantua Creek, Arroyo [illegible], Arroyo [illegible]. (b) Tejon Creek Group: [illegible] Creek, [illegible] Creek, Zapata Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, Bitterwater Creek, [illegible] Creek, [illegible] Agua, [illegible], [illegible] Creek, Buena Vista Creek, [illegible] Creek, Santiago Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek, [illegible] Creek. (c) Poso Creek Group: [illegible] River, Poso Creek, Rag Gulch. (d) Yokohl Creek Group: [illegible] Creek, Lewis Creek, Yokohl Creek. [illegible] (e) Orestimba Creek Group: [illegible] (f) Dutchman Creek Group: [illegible] (g) Owens Creek Group: Owens Creek, [illegible] (h) Burns Creek Group: [illegible] (k) Wildcat Creek Group: Wildcat Creek, Dry Creek. (l) Marsh Creek Group: Marsh Creek, [illegible] [illegible] and curves were drawn through the means of the plotted points. By entering these curves with the proper value of the index of wetness for seasons or months of missing record of run-off, the required estimate of run-off was obtained. The indices of wetness used were those for the precipitation division in which the drainage basin of the stream in question was situated. When the period, during which it was necessary to estimate the full natural run-off from the index of wetness, was of sufficient duration to warrant the refinement, monthly indices of wetness were computed; otherwise seasonal indices of wetness were used.

For minor streams or stream groups where no run-off records were available, estimates of the full natural seasonal run-off were obtained by entering "Probable Run-off Curves" with the proper index of seasonal wetness for the precipitation division in which the stream or stream group is located. These curves, published in another bulletin,* show the relation between index of seasonal wetness and run-off and are based upon records of flow on streams adjacent to the minor streams or stream groups having similar characteristics of flow.

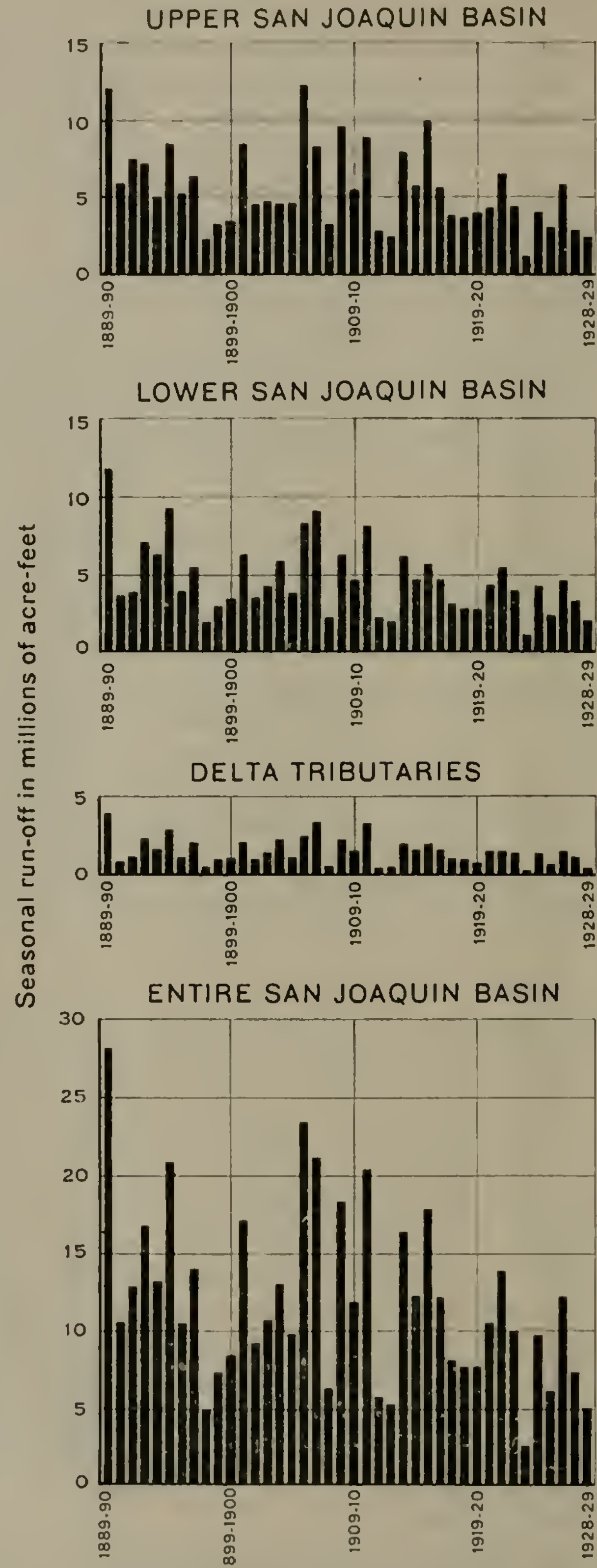
The estimated full natural seasonal run-offs of all streams tributary to the San Joaquin River Basin for the 40-year period, 1889–1929, are shown in Table 5. These estimates show that only about five per cent of the entire run-off from the mountainous area of the San Joaquin River Basin originates in the minor streams or stream groups for which it was necessary to derive run-off estimates entirely by indirect methods. The combined seasonal run-offs of the major streams and minor stream groups tributary to the upper San Joaquin River Basin, lower San Joaquin River Basin and to the delta are shown on Plate III, "Combined Seasonal Run-off of Major Streams and Minor Stream Groups Tributary to San Joaquin River Basin."

Ultimate Net Run-off. The full natural monthly run-off of each major stream at reservoir sites proposed at the edge of the foothills, under the ultimate State water plan, has been adjusted to the run-off anticipated under conditions of ultimate development of the watershed above these points. The ultimate net run-off as used in this report is the natural run-off as modified by diversions and storage development for ultimate irrigation and municipal uses and by present power developments upstream from the main foothill and reservoir sites. Power development and hydraulic mining, while altering the regimen of the stream, do not consume any appreciable amount of water. Therefore, only diversions out of the basin and irrigation use within the basin would materially reduce the full-natural run-off, above the reservoir sites, under conditions of ultimate development. The watersheds of some of the major streams of the San Joaquin River Basin are so mountainous and rugged, however, that no future upstream use for irrigation is considered feasible.

In computing the ultimate net run-off, estimates were made of the total net area to be irrigated by diversion above each of the reservoir sites under conditions of complete development and the amount of water required therefor. Where the natural stream flow was insufficient to furnish adequate irrigation supplies for these areas, it was assumed

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works, 1923.

PLATE III



COMBINED SEASONAL RUN-OFF

OF

MAJOR STREAMS AND MINOR STREAM GROUPS TRIBUTARY TO SAN JOAQUIN RIVER BASIN

ULTI QUIN RIVER BASIN

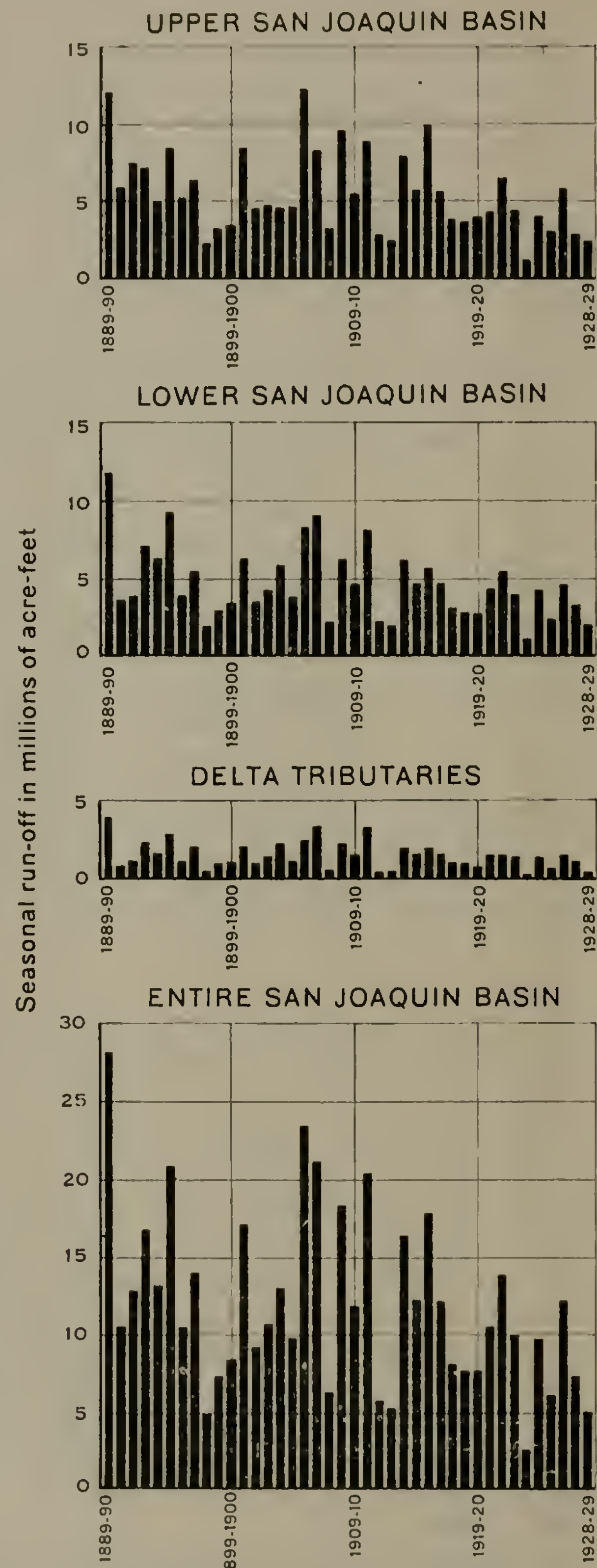
Stream	1889		1900–01	1901–02	1902–03	1900–04
Kern River	91	0	872,100	568,800	557,800	469,300
Tule River[1]	15	0	155,700	145,800	143,400	90,400
Kaweah River	1,10	0	731,700	355,100	403,900	345,700
Kings River	4,25	0	3,142,500	1,553,000	1,687,800	1,743,300
San Joaquin River	4,43	0	2,872,000	1,691,900	1,763,400	1,789,100
Fresno River	15	0	115,800	17,400	26,700	29,700
Chowchilla River	19	0	106,900	58,400	74,600	74,600
Merced River	2,59	0	1,408,400	699,900	834,300	943,700
Tuolumne River	4,03	0	1,899,600	1,352,800	1,443,600	1,737,200
Stanislaus River	3,10	0	1,566,100	855,400	1,016,500	1,929,200
Calaveras River	38	0	175,500	95,300	192,600	334,200
Mokelumne River	2,01	0	1,049,500	647,500	777,900	1,288,200
Cosumnes River	94	0	403,800	151,200	238,600	393,600
Totals	24,26	0	14,499,600	8,192,500	9,161,100	11,168,200

Stream	1904		1915–16	1916–17	1917–18	1918–19
Kern River	54	0	2,462,800	871,800	514,300	532,400
Tule River[1]	9	0	336,400	176,500	51,300	76,300
Kaweah River	33	0	762,200	471,500	229,700	289,200
Kings River	1,42	0	3,041,800	1,892,600	1,363,700	1,203,300
San Joaquin River	1,60	0	2,759,600	1,959,300	1,545,900	1,353,100
Fresno River	10	0	109,100	71,400	40,300	35,300
Chowchilla River	7	0	53,400	39,800	33,600	48,500
Merced River	77	0	1,324,400	991,100	707,500	582,100
Tuolumne River	1,43	0	1,863,400	1,739,000	1,157,200	1,132,600
Stanislaus River	86	0	1,551,900	1,266,000	719,300	668,900
Calaveras River	9	0	304,000	300,300	184,100	69,500
Mokelumne River	6	0	1,004,000	843,700	520,400	568,900
Cosumnes River	16	0	461,800	278,400	134,300	155,600
Totals	8,19	0	16,034,800	10,901,400	7,201,600	6,715,700

Stream		Mean run-off for period, in acre-feet			
		1889–1929	1909–1929	1919–1929	1924–1929
Kern River	0	714,000	679,000	493,000	454,000
Tule River[1]	0	130,000	109,000	84,100	74,500
Kaweah River	0	443,000	355,000	311,000	291,000
Kings River	0	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	0	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	0	55,200	48,200	39,800	34,000
Chowchilla River	0	70,900	56,200	56,900	55,100
Merced River	0	989,000	825,000	705,000	659,000
Tuolumne River	0	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	0	1,239,000	997,000	839,000	820,000
Calaveras River	0	189,000	156,000	96,400	80,100
Mokelumne River	0	820,000	696,000	597,000	581,000
Cosumnes River	0	290,000	235,000	182,000	169,000
Totals	0	10,456,100	8,831,400	7,363,200	6,973,700

[1] Includes South Fork of Tule River,

PLATE III



COMBINED SEASONAL RUN-OFF

OF

MAJOR STREAMS AND MINOR STREAM GROUPS TRIBUTARY TO SAN JOAQUIN RIVER BASIN

TABLE 6

ULTIMATE NET SEASONAL RUN-OFF OF MAJOR STREAMS AT RESERVOIR SITES OF STATE PLAN IN SAN JOAQUIN RIVER BASIN

Stream	Run-off, in acre-feet														
	1889–90	1890–91	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99	1899–00	1900–01	1901–02	1902–03	1900–04
Kern River	913,300	528,300	746,300	605,300	568,100	1,018,500	626,200	884,100	287,800	330,700	319,200	872,100	568,800	557,800	469,300
Tule River[1]	157,800	94,000	125,900	106,100	125,100	212,900	115,900	170,900	50,500	48,500	42,800	155,700	145,800	143,400	90,400
Kaweah River	1,100,000	509,000	648,000	607,000	399,000	733,000	401,500	471,200	224,400	291,500	311,500	731,700	355,100	403,900	345,700
Kings River	4,250,000	2,222,000	2,740,000	2,593,000	1,770,000	3,042,000	1,853,700	2,086,200	880,600	1,223,700	1,285,300	3,142,500	1,553,000	1,687,800	1,743,300
San Joaquin River	4,430,600	2,398,200	2,918,300	2,771,900	1,888,400	2,749,700	2,013,100	2,238,200	1,021,300	1,265,000	1,343,400	2,872,000	1,691,900	1,763,400	1,789,100
Fresno River	151,700	24,400	59,800	53,800	28,900	82,600	27,300	61,100	10,400	33,300	53,000	115,800	17,400	26,700	29,700
Chowchilla River	195,100	44,700	49,700	111,800	94,400	142,900	68,300	99,400	19,900	48,500	67,100	106,900	58,400	74,600	74,600
Merced River	2,593,300	740,600	831,500	1,478,900	1,390,300	2,235,100	672,400	1,183,400	397,200	576,700	709,900	1,408,400	699,900	834,300	943,700
Tuolumne River	4,033,600	1,284,900	1,189,900	2,306,900	2,141,600	3,312,600	1,283,900	1,813,500	931,900	1,065,100	1,461,700	1,899,600	1,352,800	1,443,600	1,737,200
Stanislaus River	3,104,400	999,900	1,114,600	1,960,000	1,854,600	2,559,400	1,292,000	1,302,100	308,100	710,400	834,400	1,566,100	855,400	1,016,500	1,929,200
Calaveras River	380,700	82,000	68,200	241,300	211,300	424,400	160,100	294,300	39,400	160,500	67,100	175,500	95,300	192,600	334,200
Mokelumne River	2,011,600	522,900	691,100	1,223,400	909,900	1,408,300	595,400	1,016,000	423,000	461,700	647,600	1,049,500	647,500	777,900	1,288,200
Cosumnes River	944,200	120,900	183,600	505,000	332,300	693,800	157,400	507,000	112,200	121,800	159,100	403,800	151,200	238,600	393,600
Totals	24,266,300	9,571,800	11,366,900	14,564,400	11,713,900	18,615,200	9,267,200	12,127,400	4,706,700	0,337,400	7,302,100	14,499,600	8,192,500	9,161,100	11,168,200

Stream	Run-off, in acre-feet														
	1904–05	1905–06	1906–07	1907–08	1908–09	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15	1915–16	1916–17	1917–18	1918–19
Kern River	548,000	1,837,100	1,053,600	467,800	1,759,800	739,500	1,002,000	420,900	357,800	1,094,300	663,600	2,462,800	871,800	514,300	532,400
Tule River[1]	92,300	464,400	200,700	104,000	383,300	151,700	145,600	65,000	38,200	163,100	136,700	336,400	176,500	51,300	76,300
Kaweah River	337,700	1,088,400	593,500	252,600	799,900	409,200	546,000	207,400	220,700	486,000	369,500	762,200	471,500	229,700	289,200
Kings River	1,427,800	3,856,700	2,752,500	1,033,900	2,809,400	1,779,000	2,826,700	968,100	941,800	2,548,400	1,817,100	3,041,800	1,892,600	1,363,700	1,203,300
San Joaquin River	1,605,100	3,893,200	2,924,700	1,264,200	2,821,400	2,087,900	3,535,800	1,163,900	888,100	2,770,000	2,006,800	2,759,600	1,959,300	1,545,900	1,353,100
Fresno River	109,300	142,900	104,000	30,500	82,100	38,500	108,600	31,700	19,200	48,600	63,400	109,100	71,400	40,300	35,300
Chowchilla River	74,600	124,300	142,900	22,400	90,700	59,600	114,300	19,900	16,200	87,000	82,000	53,400	39,800	33,600	48,500
Merced River	774,900	1,890,600	1,979,500	390,800	1,340,200	942,200	1,907,500	390,500	298,000	1,281,800	972,000	1,324,400	991,100	707,500	582,100
Tuolumne River	1,438,700	2,709,000	3,273,300	1,039,500	1,715,000	1,070,600	2,856,100	883,700	1,040,100	1,695,400	1,425,400	1,863,400	1,739,000	1,157,200	1,132,600
Stanislaus River	868,600	2,286,200	2,724,600	528,800	1,808,100	1,289,900	2,234,100	507,100	481,800	1,642,600	1,193,400	1,551,900	1,266,000	719,300	668,900
Calaveras River	93,100	383,400	662,200	57,900	334,300	154,500	626,000	51,400	26,600	212,500	218,800	304,000	300,300	184,100	69,500
Mokelumne River	652,100	1,298,900	1,635,200	521,700	1,094,500	914,300	1,468,500	439,300	354,000	1,027,900	804,600	1,004,000	843,700	520,400	568,900
Cosumnes River	169,600	434,300	692,700	97,800	464,000	352,300	714,100	93,900	69,500	358,900	267,000	461,800	278,400	134,300	155,600
Totals	8,191,800	20,469,400	18,739,400	5,811,900	15,502,700	10,589,200	18,145,300	5,242,800	4,752,000	13,416,500	10,020,900	16,034,800	10,901,400	7,201,600	6,715,700

Stream	Run-off, in acre-feet										Mean run-off for period, in acre-feet			
	1919–20	1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28	1928–29	1889–1929	1909–1929	1919–1929	1924–1929
Kern River	589,300	517,200	841,600	522,000	189,900	465,600	340,700	796,000	337,600	328,800	714,000	679,000	493,000	454,000
Tule River[1]	111,800	90,500	139,700	102,000	24,700	89,800	48,900	131,000	48,200	54,800	130,000	109,000	84,100	74,500
Kaweah River	372,100	360,800	461,100	363,500	101,700	325,500	218,800	483,200	203,000	222,800	443,000	355,000	311,000	291,000
Kings River	1,404,700	1,532,300	2,197,600	1,555,900	392,000	1,290,200	1,037,200	1,984,200	970,900	849,300	1,889,000	1,580,000	1,321,000	1,226,000
San Joaquin River	1,310,600	1,559,900	2,279,500	1,683,500	645,000	1,281,300	1,235,200	1,885,700	1,219,700	878,700	1,993,000	1,702,000	1,398,000	1,300,000
Fresno River	37,800	43,000	68,600	63,700	14,400	34,700	25,100	58,800	34,600	17,000	55,200	48,200	39,800	34,000
Chowchilla River	32,300	77,000	107,600	68,400	7,600	85,000	31,700	69,800	52,000	36,800	70,900	56,200	56,900	55,100
Merced River	573,300	891,400	1,295,100	812,800	180,300	785,200	513,600	968,100	638,700	388,900	989,000	825,000	705,000	659,000
Tuolumne River	1,140,400	1,561,600	1,491,200	1,530,700	523,500	1,441,300	961,400	1,536,900	1,256,400	963,900	1,634,000	1,393,000	1,240,000	1,230,000
Stanislaus River	622,700	1,143,700	1,314,600	1,016,400	190,800	1,102,600	512,300	1,234,900	847,200	401,000	1,239,000	997,000	839,000	820,000
Calaveras River	58,600	167,000	172,800	136,400	28,200	99,500	51,300	124,000	89,600	36,300	189,000	156,000	96,400	80,100
Mokelumne River	422,600	830,400	876,900	676,500	260,100	716,800	385,700	807,000	645,800	350,100	820,000	696,000	597,000	581,000
Cosumnes River	100,900	220,400	285,000	332,000	36,600	204,800	95,700	268,500	208,500	68,400	290,000	235,000	182,000	169,000
Totals	6,777,100	8,995,200	11,531,300	8,863,800	2,594,800	7,922,300	5,457,600	10,348,100	6,552,200	4,586,800	10,456,100	8,831,400	7,363,200	6,973,700

[1] Includes South Fork of Tule River, which enters the main Tule below the reservoir site of the State Plan.

that, where available, sufficient upstream storage would be constructed to effect this service. In determining the irrigation requirements, the net use of water and its seasonal distribution were taken from a previous bulletin.* Net uses of 60 and 65 per cent of the gross diversions were assumed for foothill areas north and south of Stanislaus River, with 40 and 35 as the percentages of return flow to the same stream either above or below the reservoir site or to some other stream. Allowances were made for diversions out of the watershed for irrigation purposes on the Cosumnes, Mokelumne, Stanislaus, and Merced rivers. Monthly adjustments for the impounding in and release of stored water from assumed upstream irrigation and present constructed power reservoirs were made as though such reservoirs had been in existence throughout the 40-year period, 1889–1929.

It was assumed that the city of San Francisco would ultimately desire to divert 400,000,000 gallons per day from the Tuolumne River watershed for municipal purposes. The water available for this diversion is limited by the provisions of the Raker Act and was assumed to be regulated by the city's ultimate storage development. It was also assumed that the East Bay Municipal Utility District would ultimately divert 200,000,000 gallons per day from the Mokelumne River for municipal purposes. As this diversion is from the Pardee Reservoir, the foothill reservoir used on the Mokelumne River under the ultimate State Plan, it was not deducted from the total ultimate water supply obtainable from that reservoir. The estimated ultimate net seasonal run-off for each of the major San Joaquin River Basin streams is shown in Table 6.

Net Run-off Under Existing Conditions of Development. The monthly full natural run-off of each of the lower east side tributaries of the San Joaquin River Basin, at the foothill gaging stations, was corrected for the 12-year period, 1917–1929, to that which might be expected under conditions of irrigation development as of the present and municipal diversions estimated as of 1940, both above and below the gaging stations and for storage in and release from present constructed reservoirs at the foothill sites and in the mountains. The foothill reservoirs were assumed to be operated for irrigation purposes with the exception of Pardee Reservoir on the Mokelumne River, which was assumed to be operated for municipal purposes with some incidental power. The present constructed mountain reservoirs were assumed to be operated mainly for power purposes. The diversions for municipal purposes as of 1940 were estimated as 35,000,000 gallons per day or 54 cubic feet per second from the Tuolumne River watershed by the city of San Francisco and 75,000,000 gallons per day or 116 cubic feet per second from the Mokelumne River by the East Bay Municipal Utility District. The net run-off of each of the lower east side tributaries under the existing and assumed conditions of development determines the inflow into the San Joaquin River Delta. The estimated values for the 12-year period 1917–1929, are set forth by seasons in Table 7.

Variation of Run-off. Due to large fluctuations in precipitation in California, there are very wide variations in seasonal, monthly and

* Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, State Department of Public Works, 1923.

TABLE 7

SEASONAL NET RUN-OFF FROM SAN JOAQUIN RIVER BASIN INTO SAN JOAQUIN DELTA FOR THE PERIOD 1917-1929 UNDER CONDITIONS OF IRRIGATION AND STORAGE DEVELOPMENTS AS OF 1929 AND MUNICIPAL DIVERSIONS AS OF 1940

Season	Run-off, in acre-feet							Pumping diversions below gaging stations, in acre-feet	Run-off into San Joaquin Delta, in acre-feet
	San Joaquin River at Newman	Tuolumne River at confluence with San Joaquin River	Stanislaus River at confluence with San Joaquin River	Calaveras River at Jenny Lind	Mokelumne River below Woodbridge	Dry Creek near Ione	Cosumnes River below Michigan Bar		
1917-18	1,336,100	1,002,100	644,100	212,200	439,000	46,200	220,700	89,300	3,811,100
1918-19	1,139,900	840,000	497,400	97,300	484,100	61,100	258,300	89,300	3,288,800
1919-20	683,300	819,000	436,900	83,200	384,400	34,100	168,500	89,300	2,520,100
1920-21	1,40[illegible],200	1,394,600	930,100	221,900	646,300	103,000	404,200	89,300	5,016,000
1921-22	3,190,400	1,908,600	1,148,100	220,500	768,600	86,300	423,200	89,300	7,656,400
1922-23	1,672,000	1,241,800	841,100	181,100	600,800	135,000	435,500	89,300	5,018,000
1923-24	305,700	493,700	147,600	23,700	326,800	3,300	42,200	89,300	1,253,700
1924-25	733,700	1,092,800	884,000	159,100	475,700	83,700	255,900	89,300	3,595,600
1925-26	672,300	729,200	432,200	65,300	416,900	32,200	146,400	89,300	2,405,200
1926-27	1,807,400	1,276,900	1,031,300	181,000	606,400	96,100	449,800	89,300	5,359,600
1927-28	857,500	1,077,300	743,700	130,400	570,600	69,100	313,100	89,300	3,672,400
1928-29	362,200	658,400	248,600	41,000	401,500	22,200	113,400	89,300	1,758,000
Mean for period, 1917-29	1,180,100	1,045,000	665,000	135,000	510,000	64,800	269,000	89,300	3,779,600

daily run-off. It has been shown previously that there is a wide variation in seasonal precipitation over the San Joaquin River Basin. Since run-off is dependent upon precipitation, it will have generally similar variations. Run-off, however, is affected by the intensity and order of occurrence of storms, and its seasonal variation from normal, therefore, may not be exactly the same as the variation of the seasonal precipitation from its normal. The variation in seasonal precipitation over the San Joaquin River Basin is shown by the indices of wetness in Table 3, and the variation in run-off from the watersheds of the major streams of the San Joaquin River Basin is shown by the seasonal run-offs for these streams given in Table 5. The mean seasonal full natural run-offs, and minimum and maximum seasonal run-offs in acre-feet and in per cent of mean seasonals for the 40-year period, 1889–1929, are given in Table 8 for the major streams. These figures show that, for the major streams of the San Joaquin River Basin, the maximum seasonal run-off varies from 225 to 357 per cent and the minimum from 10 to 28 per cent of the mean seasonal for the 40-year period.

The monthly run-off varies more widely than the seasonal run-off. Most of the run-off from the rain which falls on the lower areas finds its way quickly into the stream channels while the snow in the higher mountain regions usually does not melt and appear as run-off until the late spring or early summer. The run-off from melting snow forms the greater part of the stream flows during these seasons. The unequal monthly distribution of the seasonal run-off from the drainage basins of each major stream of the San Joaquin River Basin, except the Chowchilla River, is illustrated in Table 9. Due to the short period of stream flow record on the Chowchilla River, October 1, 1921–September 30, 1923, no attempt was made to estimate the average monthly distribution for the 40-year period, for that stream. The distribution of seasonal run-off during the period of stream flow record in a normal, maximum, and minimum season for the San Joaquin, Kings, and Kern rivers, respectively, is further illustrated graphically on Plate IV, "Distribution of Run-off of San Joaquin, Kings, and Kern Rivers for Typical Seasons." The variation in the daily run-off of any particular stream is greater than either the annual or monthly. The mean daily flows of the larger streams vary from a few second feet in the late summer to thousands of second feet during flood periods. These floods are caused by excessive precipitation in the form of rain during the winter months, by the rapid melting of the snow pack in the mountains during the late spring or early summer months, or by a combination of these causes. To illustrate this variation, the maximum and minimum mean daily flows of each major stream of the San Joaquin River Basin, except the Chowchilla River, are shown in Table 10. The minimum daily stream flows of the San Joaquin, Merced, Tuolumne, Stanislaus and Mokelumne rivers, during recent years, have been affected considerably by storage releases from upstream reservoirs. The proportional variations in daily stream flow of some of the minor streams are greater than for the major streams although records are not available for the determination of maximum variations on the minor streams. Occasionally these streams are torrents due to concentrated rain storms on their watersheds and at other times they are entirely dry.

TABLE 8

VARIATION IN SEASONAL RUN-OFF FOR MAJOR STREAMS IN THE SAN JOAQUIN RIVER BASIN, 1889-1929

Based on full natural run-off for 40-year period 1889-1929

Stream	Point of measurement	Mean seasonal run-off, in acre-feet	Maximum seasonal run-off in 40-year period			Minimum seasonal run-off in 40-year period		
			In acre-feet	In per cent of mean seasonal run-off	Season	In acre-feet	In per cent of mean seasonal run-off	Season
Cosumnes River	At Michigan Bar	407,000	1,151,000	283	1889–1890	40,400	10	1923–1924
Mokelumne River	Near Clements	853,000	2,063,000	242	1889–1890	190,000	22	1923–1924
Calaveras River	At Jenny Lind	227,000	708,000	312	1906–1907	23,700	10	1923–1924
Stanislaus River	Near Knights Ferry	1,350,000	3,230,000	239	1889–1890	261,000	19	1923–1924
Tuolumne River	Near La Grange	2,070,000	5,099,000	246	1889–1890	546,000	26	1923–1924
Merced River	Near Merced Falls and at Exchequer	1,115,000	2,745,000	246	1889–1890	252,000	23	1923–1924
Fresno River	Near Knowles	63,400	168,000	266	1889–1890	14,400	23	1923–1924
Chowchilla River	Near Buchanan Reservoir Site	70,900	195,000	275	1889–1890	7,600	11	1923–1924
San Joaquin River	Near Friant	1,995,000	4,620,000	232	1889–1890	446,000	22	1923–1924
Kings River	At Piedra	1,889,000	4,250,000	225	1889–1890	392,000	21	1923–1924
Kaweah River	Near Three Rivers	443,000	1,100,000	248	1889–1890	102,000	23	1923–1924
Tule River	Near Porterville	135,000	482,000	357	1905–1906	25,600	19	1923–1924
Kern River	Near Bakersfield	725,000	2,474,000	341	1915–1916	202,000	28	1923–1924

TABLE 9

AVERAGE MONTHLY DISTRIBUTION OF SEASONAL RUN-OFF OF MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

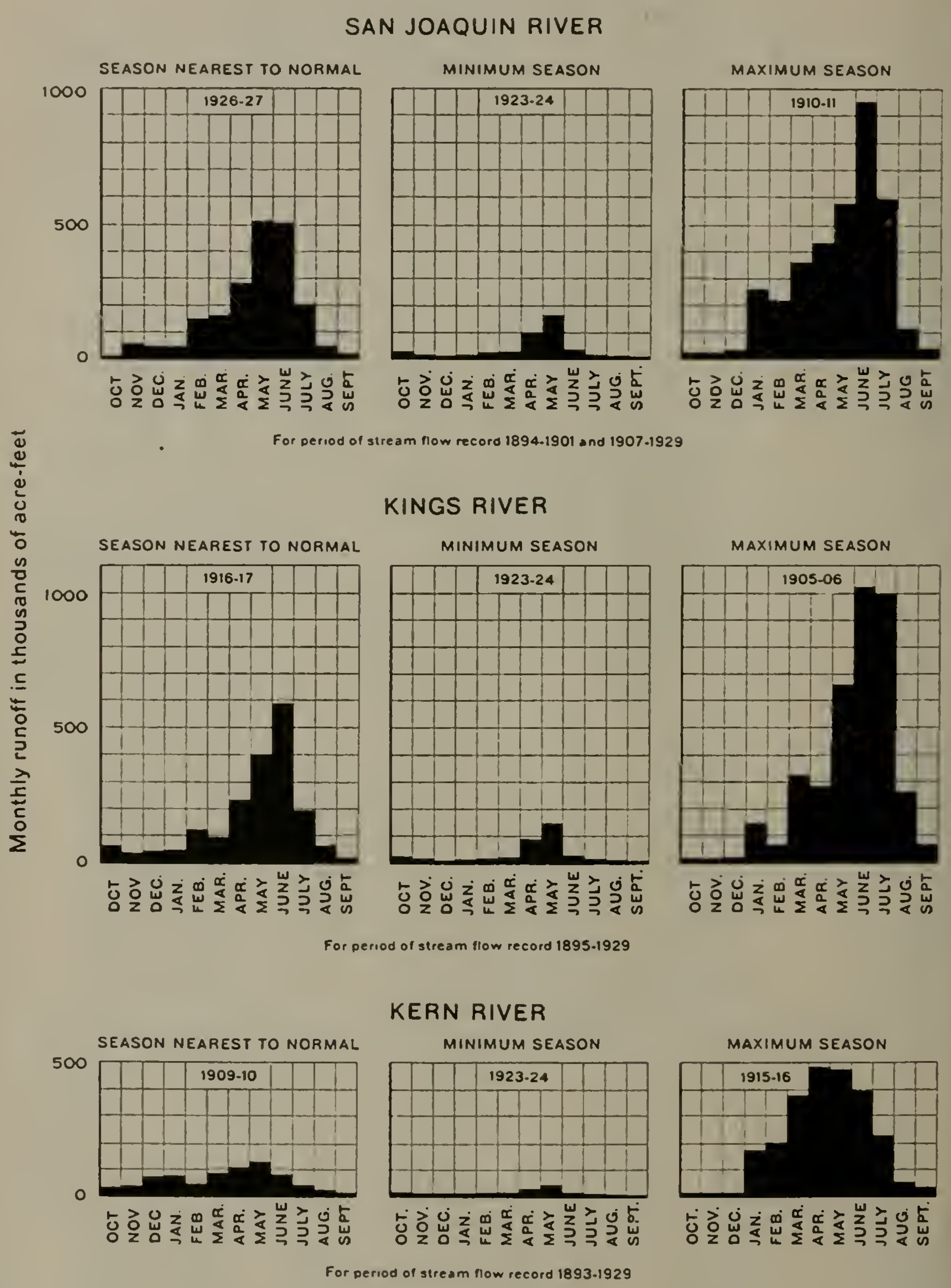
Based on mean full natural run-offs for 40-year period, 1889-1929

Month	Kern River near Bakersfield		Tule River near Porterville		Kaweah River near Three Rivers		Kings River at Piedra	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	18,200	2.5	1,700	1.3	6,200	1.4	27,800	1.5
November	18,900	2.6	3,100	2.3	8,400	1.9	29,400	1.6
December	21,700	3.0	6,800	5.0	11,500	2.6	35,400	1.9
January	35,500	4.9	15,000	11.1	26,500	6.0	78,700	4.2
February	39,200	5.4	15,000	11.1	26,400	6.0	76,500	4.0
March	64,200	8.8	23,800	17.6	45,300	10.2	133,000	7.0
April	102,000	14.1	26,200	19.4	69,500	15.7	240,000	12.7
May	153,000	21.1	24,400	18.1	110,000	24.8	490,000	25.9
June	145,000	20.0	13,100	9.7	93,000	21.0	483,000	25.6
July	77,500	10.7	3,600	2.7	33,200	7.5	208,000	11.0
August	32,600	4.5	1,300	1.0	8,400	1.9	61,500	3.2
September	17,200	2.4	1,000	0.7	4,600	1.0	25,700	1.4
Totals	725,000	100.0	135,000	100.0	443,000	100.0	1,889,000	100.0

Month	San Joaquin River near Friant		Fresno River near Knowles		Merced River at Exchequer		Tuolumne River near La Grange	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	27,700	1.4	500	0.8	13,300	1.2	22,200	1.1
November	31,600	1.6	2,000	3.1	18,000	1.6	37,000	1.8
December	44,000	2.2	3,700	5.8	26,600	2.4	60,700	2.9
January	92,100	4.6	6,900	10.9	68,300	6.1	118,000	5.7
February	94,600	4.7	13,300	21.0	81,900	7.4	149,000	7.2
March	163,000	8.2	14,700	23.2	130,000	11.6	221,000	10.7
April	267,000	13.4	11,400	18.0	171,000	15.3	310,000	15.0
May	494,000	24.8	6,000	9.5	280,000	25.1	498,000	24.0
June	479,000	24.0	3,500	5.5	226,000	20.3	446,000	21.5
July	210,000	10.5	1,200	1.9	75,300	6.8	167,000	8.1
August	64,300	3.2	200	0.3	17,000	1.5	30,600	1.5
September	27,700	1.4	0	0	7,600	0.7	10,500	0.5
Totals	1,995,000	100.0	63,400	100.0	1,115,000	100.0	2,070,000	100.0

Month	Stanislaus River near Knights Ferry		Calaveras River at Jenny Lind		Mokelumne River near Clements		Cosumnes River at Michigan Bar	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	12,100	0.9	1,400	0.6	6,700	0.8	2,000	0.5
November	21,200	1.6	4,400	1.9	17,500	2.0	5,800	1.4
December	35,600	2.6	18,500	8.2	28,000	3.3	26,100	6.4
January	84,100	6.2	50,800	22.4	48,800	5.7	57,600	14.2
February	109,000	8.1	53,300	23.5	66,400	7.8	74,200	18.2
March	176,000	13.1	65,700	29.0	104,000	12.2	90,500	22.2
April	246,000	18.2	21,600	9.5	148,000	17.4	75,400	18.5
May	335,000	24.8	7,600	3.4	216,000	25.3	51,200	12.6
June	232,000	17.2	3,000	1.3	163,000	19.1	20,200	5.0
July	73,900	5.5	500	0.2	46,900	5.5	3,000	0.8
August	16,700	1.2	100	0	5,100	0.6	500	0.1
September	8,400	0.6	100	0	2,600	0.3	500	0.1
Totals	1,350,000	100.0	227,000	100.0	853,000	100.0	407,000	100.0

PLATE IV



DISTRIBUTION OF RUN-OFF
OF
SAN JOAQUIN, KINGS AND KERN RIVERS
FOR TYPICAL SEASONS

TABLE 10

MAXIMUM AND MINIMUM MEAN DAILY STREAM FLOWS IN MAJOR STREAMS OF SAN JOAQUIN RIVER BASIN

Stream	Gaging station	Maximum flow		Minimum flow	
		In second feet	Date	In second feet	Date
Cosumnes River	At Michigan Bar	22,400	Jan. 31, 1911	0	(1)
Mokelumne River	Near Clements	23,400	Mar. 19, 1907	0	July 9, 1924[2]
Calaveras River	At Jenny Lind	69,600	Jan. 31, 1911	0	(3)
Stanislaus River	Near Knights Ferry	57,200	Mar. 19, 1907	0	Dec. 3-5, 1912
Tuolumne River	Near La Grange	52,500	Jan. 30, 1911	1	Nov. 26-Dec. 1, 1922[4]
Merced River	Near Merced Falls and at Exchequer	37,200	Jan. 30, 1911	0	Nov. 21, 1901
Fresno River	Near Knowles	3,770	Feb. 21, 1917	0	(5)
San Joaquin River	Near Friant	38,800	Jan. 31, 1911	54	Monday, Sept. 15, 1924[6]
Kings River	At Piedra	46,300	Jan. 7, 1901	67	Oct. 2, 3, 1924
Kaweah River	Near Three Rivers	10,100	Jan. 17, 1916	10	Aug. 29-Sept. 1, 1924
Tule River	Near Porterville	5,430	Dec. 8, 1909	0	Sept. 27-Oct. 1, 1926
Kern River	Near Bakersfield	16,100	Jan. 18, 1916	82	Sept. 16, 1924

[1] Part of 1908, 1918, 1919, 1924, 1926.
[2] Also August 15 and 20-23, 1924.
[3] Part of 1913, 1914, 1915, 1917, 1918, 1919, 1920, 1921, 1922, 1924, 1925, 1926, 1927, 1928, 1929.
[4] Flow shut off by closure of gates at Don Pedro Dam.
[5] Aug., Sept., 1919; July-Oct., 1924; Aug., Sept., 1926; Aug.-Oct., 1928, and Aug., Sept., 1929.
[6] Due to retention of inflow in power storage over week end. Average for week September 14-21, 182 second-feet.

Return Water.

In the San Joaquin River Basin a substantial potential water supply is that from water which, once used for irrigation, domestic or other purposes, would return to the streams either as direct drainage or as an inflow from the various underground basins. The return irrigation waters would have their sources in the losses from canals or other conduits during conveyance of water from the points of diversion on the streams to points of use, in the surface drainage from the land after irrigation and in seepage to the underground basins. A large portion of the return waters from the mountain and foothill region would be available for storage in the major unit reservoirs of the State Water Plan in which they could be regulated to a supply conforming to the irrigation demand on the valley floor. In the upper San Joaquin Valley most of the waters diverted to the valley floor in excess of consumptive use would be utilized by pumping from underground reservoirs. The efficient utilization of these underground reservoirs would allow only a small portion of this water to reach the valley trough channels. In the lower San Joaquin Valley the waters diverted to the valley floor in excess of consumptive use would enter the streams or artificial drains and finally reach the San Joaquin River or would replenish the underground basins. The return waters reaching the San Joaquin River could be made available for reuse on adjacent lands or exportation to other areas through the major conveyance units of the State Water Plan and would be intermingled with water imported from the Sacramento River Basin.

The suitability of these return waters for reuse is of importance because it would constitute a considerable part of the total available water supply for the San Joaquin River Basin. During 1906 and 1908 at regular intervals throughout each of the respective years, and in

1930 during the low water season, the Water Resources Branch of the United States Geological Survey chemically analyzed water samples taken from many of the principal streams of the State. Among these were analyses of water from the San Joaquin River when nearly the entire flow was return water from irrigation. The locations and the dates of taking these water samples and the results of the analyses are set forth in Appendix E, "The Chemical Character of Some Surface Waters of California, 1930–1932." These analyses, as well as analyses presented in another report,* show that the return water, under present conditions, is entirely satisfactory, chemically, for municipal, irrigation and industrial uses and can be classified as "good."

The amounts and distribution of return waters throughout the season also are important elements in determining the feasibility of utilizing return waters. In order to determine these values as accurately as possible, measurements of diversions and return waters have been made each season since 1924 by the Sacramento-San Joaquin Water Supervisor. Results of these measurements are given in a bulletin of the Division of Water Resources.** From 1924 to 1927, inclusive, three series of measurements were taken, each season, along each major stream of the lower San Joaquin Valley, beginning near the foothills and ending at the mouth. Estimates were made en route, of all diversions between each point of measurement. In 1928, permanent gaging stations were established at the upper and lower point on each stream. For each season since 1927, during the June to October periods, continuous flow records and estimates of diversion have been obtained. The points of stream flow measurement are located at the Yosemite Valley Railroad crossing near Snelling and the bridge of Hills Ferry Road on Merced River; Roberts Ferry Bridge and Tuolumne City on Tuolumne River; Orange Blossom Bridge and Elliott Ranch on Stanislaus River; and at San Luis Ranch, below the mouth of the Merced River near Newman, near Grayson and near Vernalis on San Joaquin River. These stream flow measurements were analyzed in conjunction with records and estimates of diversions to determine the amounts of water which returned to the respective river channels during the period of measurement. As measurements were taken from June to October only, the natural run-off from valley floor lands was eliminated from consideration.

The measurements covered seasons of both large and small total stream flow and the character of the season probably affected the percentage of return water. Greater amounts of water are diverted in seasons of large stream flow than in seasons of smaller yield, and since only a definite amount is consumed by plant growth, the return flows in seasons of large water yield represent a somewhat larger percentage of the total diversions.

Analyses of measurements of surface diversion into, and measurements of outflow from a large fully developed district in the lower San Joaquin Valley, for the 1929 irrigation season, showed a total seasonal return flow of 36 per cent of the gross diversion. From gross diversion

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, State Department of Public Works, 1931.

** Bulletin No. 23, "Report of Sacramento-San Joaquin Water Supervisor," Division of Water Resources, State Department of Public Works, 1930.

and net use analyses presented in Chapter VII, it is estimated that, under conditions of ultimate development, the average proportion of return flow would be about 40 per cent of all of the water diverted from both local and imported supplies for irrigation in the lower San Joaquin Valley, and would be available, in the stream channels, for reuse on adjacent lands or exportation to other areas. During the principal months of the irrigation season practically all of such return flows would be utilized for these purposes.

There is no definite information on the amounts of irrigation water which return slowly to the stream channels during the winter months. An accurate determination of these amounts would be difficult as they are combined with run-offs from rainfall on the valley floor. Estimates, however, have been made of the amounts of return water for the winter season. Studies indicate that during the period, 1924–1929, the return water in the months from July to September, inclusive, in different seasons, varied from 19 to 38 per cent of the diversion for these months. It is estimated that the return flow from general crop irrigation during the principal irrigation months, April to October, inclusive, is about 65 per cent of the total seasonal, and it has been assumed that the remaining 35 per cent returns at about a uniform rate over the other five months. Table 11 sets forth the estimated monthly distribution of return waters in the lower San Joaquin Valley.

TABLE 11

MONTHLY DISTRIBUTION OF RETURN WATERS IN LOWER SAN JOAQUIN VALLEY

Month	Return water in per cent of total seasonal return	Month	Return water in per cent of total seasonal return
October	8	April	7
November	7	May	8
December	7	June	11
January	7	July	12
February	7	August	10
March	7	September	9

CHAPTER III

AGRICULTURAL LANDS

The San Joaquin River Basin, embracing an area of about 32,000 square miles or 20.6 per cent of the State's total, contains within its exterior boundaries, valley, foothill and mountain lands. The uses of water in this area and on these lands include domestic, municipal, irrigation, salinity control, industrial, navigation, power and recreation. Of all the foregoing uses, that for the irrigation of the farm lands in the basin does and probably will continue to predominate. It is believed that the water requirements estimated on the basis of irrigation would be adequate for the future complete development of the basin. Therefore, it was important and necessary in these investigations to determine as nearly as practicable the extent of the agricultural lands in the basin which have been brought under irrigation and of those lands not now irrigated but susceptible of irrigation at some future time. This involved a survey of the basin for the purpose of classifying the lands.

Geology and Soils.

The character of the soils in the San Joaquin Valley is related to its geological history. The following general description of the geology of the valley is quoted from Water Supply Paper 398 of the U. S. Geological Survey:

> "The valley as a whole is a great structural trough and appears to have been such a basin since well back in Tertiary time. Since it assumed its general troughlike form, gradual subsidence, perhaps interrupted by periods of uplift, has continued and has been accompanied by deposition alternating at least along what is now its western border with intervals of erosion. This interrupted but on the whole continuous deposition seems to have been marine during the early and middle Tertiary; but during the later Tertiary and Pleistocene, when presumably the valley had been at least roughly outlined by the growth of the Coast Ranges, fresh water and terrestrial conditions became more and more predominant, until the relations of land and sea, of rivers and lakes, of coast line and interior, of mountain and valley, as they exist now, were gradually evolved. As these conditions developed, the ancestors of the present rivers probably brought to the salt and fresh water bodies that occupied the present site of the valley and its borders, or, in the latest phases of the development, to the land surface itself, the clays, sands, gravels, and alluvium that subsequently consolidated into the shales, sandstones, and conglomerates of the late Tertiary and Pleistocene series, just as the present rivers are supplying the alluvium that is even now accumulating over the valley floor.
>
> "The very latest of these accumulations are the sand and silt and gravel beds penetrated by the driller in his explorations for water throughout the valley. They are like the early folded sandstones, shales and conglomerates exposed along the flanks of the valley, except that they are generally finer, and are not yet consolidated or disturbed. The greater part, perhaps all of them, accumulated as stream wash on the valley surface or in interior lakes like the present Tulare Lake, but a proportion of the older sediment that is greater as we delve farther back into the geologic past accumulated in the sea or in salt bays having free connection with the sea. It is these very latest geologic deposits, saturated below the ground water level by the fresh water supplied chiefly by the Sierran streams, that constitute the reservoirs drawn upon by the wells, whether flowing or pumped, throughout the valley."

All of the five general groups of soils, residual, old valley-filling, recent alluvial, lake-laid and wind-laid, are found within the San Joaquin River Basin. The residual soils occur in the foothill and mountain areas. The portions of these areas in which disintegration has proceeded without erosion form much of the agricultural lands within the foothills and along the edges of some portions of the valley. The old valley-filling soils occur as terraces along streams, remnants of alluvial fans or higher valley areas. The hardpan soils are mainly of this type. The recent alluvial soils represent the recent stream deposits in the valley and along stream channels. The lake-laid soils, mainly of fine texture, have been deposited in lakes of fluctuating volume in flat poorly drained basins in the valley trough and merge gradually with the recent alluvial soils. Wind-laid soils have been deposited as the result of wind action on adjacent light-textured alluvial soils and, in places, closely resemble sand dunes. The old valley-filling and recent alluvial soils represent much the larger part of the agricultural lands.

Land Classification.

Considerable data on land classification in the San Joaquin Valley were available from other sources prior to the undertaking of the investigations on which this report is based. The reports and maps of the U. S. Bureau of Soils were available for the entire valley area. These reports show soil texture and alkali. The maps of the U. S. Geological Survey were available for all but the south end of the valley, on a scale of two inches to the mile with five-foot contour intervals which indicated the roughness of the land. Many local areas had been classified in prior investigations for procedure before the State Engineer relative to irrigation, water storage and water conservation districts. Classifications in such areas were reviewed and utilized as far as practicable.

Standards of classification were established prior to starting a field examination and were maintained throughout the survey. Boundaries between the classes were located on field maps on a scale of two inches per mile. The quadrangle sheets of the U. S. Geological Survey were used where available. Full use also was made of the Reconnaissance Soil Survey maps of the U. S. Bureau of Soils. Field notes were placed directly on the maps. Areas of each classification on each map were measured in the office by means of the planimeter, their totals checked against the total area and then segregated by hydrographic divisions and counties. Land classification is necessarily, to a large extent, a matter of judgment. It was not considered possible to exactly locate the boundaries of areas in each classification and because of limited time and funds refinements were not attempted. However, the areas determined for each classification, as a whole, are believed to be substantially correct.

The total area included within the San Joaquin River Basin consists of valley, foothill and mountain areas. While exact lines of demarcation are difficult to locate, especially between foothill and mountain lands, the total area was divided into three segregations in this investigation, as set forth in Table 12. All of the valley areas were carefully classified in order to determine the portions which would justify development under irrigation. The portions of the foothill areas containing agricultural lands also were classified. The field work on land classification in connection with this report was not extended into the remaining foothills and mountains above the irrigable areas.

TABLE 12

SEGREGATION OF LANDS IN SAN JOAQUIN RIVER BASIN

Segregation	Area	
	In square miles	In per cent of total
Valley lands	13,000	40.6
Classified foothill areas	1,500	4.7
Unclassified foothills and mountains	17,500	54.7
Totals	32,000	100.0

Much of the gross area in these three divisions is nonagricultural in character. All of the mountain and unclassified foothill areas are considered to be nonagricultural. In the valley and classified foothill areas, exclusive of 279,000 acres in the San Joaquin Valley portion of the Sacramento-San Joaquin Delta, about 12,840 square miles have been classified as agricultural, which represents 92 per cent of the gross area of these two divisions and is equal to 8,219,400 acres.

Valley Floor Lands. The methods and standards employed in classifying the valley floor lands are set forth in a rather complete discussion in Appendix A. For that reason only a brief description of the standards of classification used for these lands is given in this chapter.

Class 1 represents those lands where the soil texture, alkali or topography, do not limit the crop yield or the feasibility of irrigation. These are good lands capable of producing high yields at reasonable costs of preparation.

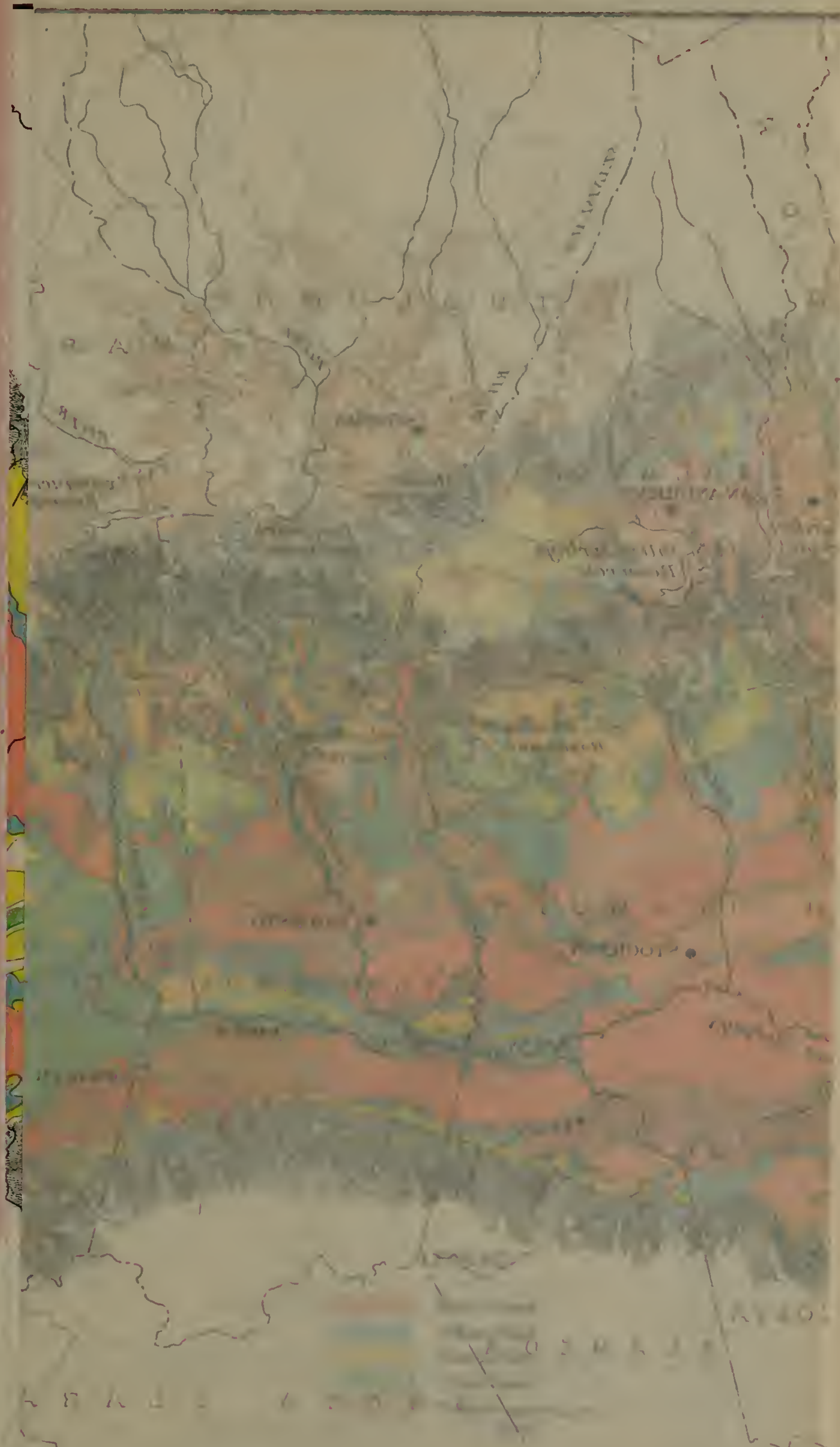
Class 2 represents lands of medium ability to carry costs for water. These are second-grade lands where the difference from Class 1 may be due to hardpan, roughness, alkali or other factors.

Class 3 represents lands which by present standards do not justify irrigation with regulated water supplies, but which may eventually come into Class 2 with improvements in methods of alkali removal or reduction in costs of leveling. These are areas which are not now suitable for irrigation, but where the conditions may not justify a present conclusion of permanent nonsuitability.

Class 4 represents lands suitable only for flooding for pasture and of too poor quality to be suited to the production of usual crops.

Class 5 represents lands which can be considered as permanently nonirrigable by any reasonable or probable future standards. The poor quality of the land may be due to alkali, shallow depths of soil, hardpan, roughness or steepness or a combination of these factors. These lands have been classified as nonagricultural.

Following the completion of the classification of the valley areas, maps showing the results were submitted to the San Joaquin Valley Water Committee and by it referred to the subcommittees for each of the eight counties involved. The classification was reviewed and, with minor exceptions, accepted by the county committees. On Plate V, "Classification of Agricultural Lands in the San Joaquin Valley," are delineated the areas classified under the foregoing standards. This plate shows in general the location of the areas falling within the



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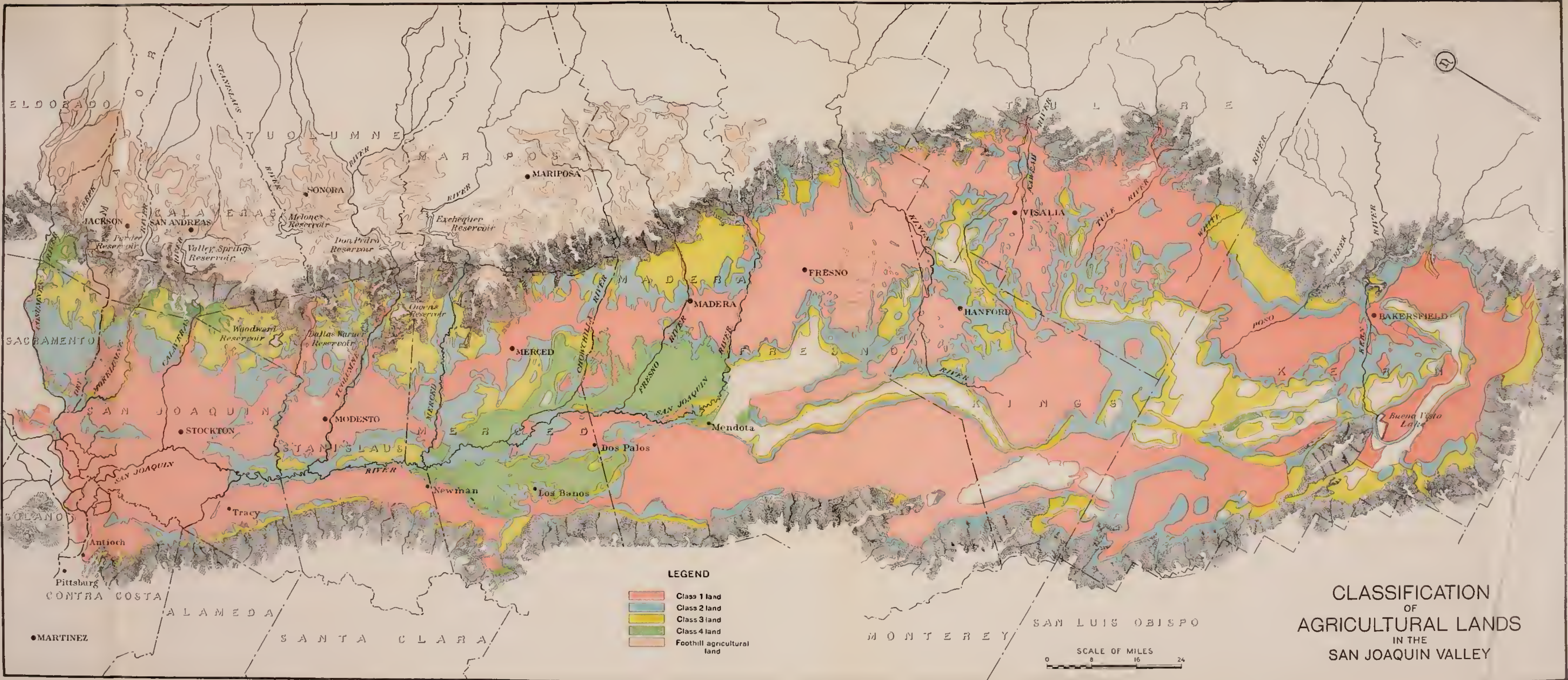

CLASSIFICATION
OF
AGRICULTURAL LANDS
IN THE
SAN JOAQUIN VALLEY
LEGEND
Class 1 land
Class 2 land
Class 3 land
Class 4 land
Foothill agricultural land
SCALE OF MILES
0 8 16 24
ELDORADO
TUOLUMNE
MARIPOSA
CALAVERAS
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
MADERA
FRESNO
KINGS
TULARE
KERN
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
VISALIA
FRESNO
HANFORD
MADERA
MERCED
MODESTO
STOCKTON
BAKERSFIELD
Mendota
Dos Palos
Newman
Los Banos
Tracy
Antioch
Pittsburg
MARTINEZ
Melones Reservoir
Exchequer Reservoir
Don Pedro Reservoir
Valley Springs Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Owens Reservoir
Buena Vista Lake
SAN JOAQUIN RIVER
KINGS RIVER
KAWEAH RIVER
TULE RIVER
WHITE RIVER
KERN RIVER
POSO
FRESNO RIVER
CHOWCHILLA RIVER
MERCED RIVER
TUOLUMNE
STANISLAUS
CALAVERAS
MOKELUMNE
COSUMNES RIVER

various classifications. It should be noted particularly that the boundaries of such areas are not exact as to location and that the basic data for these areas were not obtained with a sufficient degree of accuracy to make this plate usable for the determination of soil characteristics or appraisals of individual tracts or other relatively small areas. Class 5 land is not considered agricultural and is not shown on the plate.

The boundary of the valley floor, south of the San Joaquin River, encompasses a large area of agricultural land out of proportion to the water crop from the adjacent tributaries available for use in its development. With an irrigation development already of such extent that in dry periods the yield of these tributary streams is entirely utilized, the shortage in supply in portions of the area is reflected in continuously receding ground water tables. The northern limit of the areas now under irrigation development where such conditions of disparity between supply and demand obtain is at the Chowchilla River. Northward from this line the available run-off from tributary streams is adequate to support all existing development. Nearly the entire now utilized run-off of the San Joaquin River proper serves an area northward from Mendota. Because of these differences in tributary water supply the San Joaquin Valley has been divided into two parts in this investigation. The portion southward from Mendota and the Chowchilla River has been designated as the upper San Joaquin Valley and that downstream or northerly from the above line of separation, as the lower San Joaquin Valley. The upper San Joaquin Valley extends southward to the southern limit of the Great Central Valley, and the lower San Joaquin Valley northward to Antioch on the west side of the valley and to the Cosumnes River on the east. Table 13 sets forth the areas of each of the five classes of land on the San Joaquin Valley floor. In this table, the area of each class of land in upper San Joaquin Valley; lower San Joaquin Valley, excluding San Joaquin Delta; and San Joaquin Delta is shown separately.

TABLE 13

CLASSIFICATION OF LANDS ON SAN JOAQUIN VALLEY FLOOR

Class	Upper San Joaquin Valley floor		Lower San Joaquin Valley floor, excluding San Joaquin Delta		San Joaquin Delta		Total San Joaquin Valley floor	
	Gross area		Gross area		Gross area		Gross area	
	In acres	In per cent of total	In acres	In per cent of total	In acres	In per cent of total	In acres	In per cent of total
1	2,886,900	52.2	1,063,500	44.3	261,000	93.5	4,211,400	51.3
2	1,051,500	19.0	674,500	28.1	17,000	6.1	1,743,000	21.2
3	772,700	14.0	402,700	16.7	1,000	0.4	1,176,400	14.3
4	170,700	3.1	219,900	9.1	0	0	390,600	4.8
5	647,400	11.7	43,500	1.8	0	0	690,900	8.4
Totals	5,529,200	100.0	2,404,100	100.0	279,000	100.0	8,212,300	100.0

In Tulare County, a land classification survey also was made by the Tulare County Water Committee. The classifications in that county for the two surveys are compared in Table 14.

TABLE 14

COMPARISON OF LAND CLASSIFICATIONS IN TULARE COUNTY

Class	Gross area, in acres	
	State	Tulare County water committee
1	578,900	633,486
2	234,500	190,834
3	90,100	113,726
4	0	0
5	79,200	201,050
Town sites, etc.	---- ------	11,701
Sloughs and channels	----------	7,913
Totals	982,700	1,158,710

The county classification included about 165,000 acres of Class 5 land above the area covered by the State. The division between the valley and the adjacent Class 5 hill-land was in general agreement in the two classifications. The sum of the Class 1 and 2 areas is closely in agreement in the two classifications, although the county classification rates a somewhat larger area as Class 1. A comparison of the results by local areas indicates that the principal differences are due to a more severe rating by the State of the alkali areas extending along the western side of the county. These lands are largely used for pasture with only limited areas of cultivated crops.

Foothill Lands. The foothill areas were classified on somewhat different standards than those used for the valley lands. The base maps available for the foothill areas are on a smaller scale and in much less detail than those available for the valley areas. The better lands occur as separate scattered areas within larger areas containing poorer lands. A detail mapping by individual areas was not practicable within the limits of these investigations. Five grades or classifications were used. Each class represented areas in which the net arable area was estimated to comprise the following percentages of the gross area:

Class 1—80 per cent
Class 2—80 per cent
Class 3—50 per cent and 60 per cent
Class 4—20 per cent and 40 per cent
Class 5— 0

For Classes 3 and 4, the percentage of arable land, for each of the individual areas, was estimated at one of the two values given. Only a small amount of Class 1 land was shown separately as many of the actual areas of Class 1 quality are included in the arable portions of the other classes. It was determined before classifying any of the lands as agricultural that it would be physically possible to develop a water supply for them, without regard, however, to the economic feasibility.

The principal factors affecting the irrigability of foothill lands are roughness and depth of soil. Roughness may consist of general steepness or of general irregularity of topography. In many areas the depth of the soil is insufficient for adequate root development. In general, the depth of soil increases toward the higher elevations where rainfall and frost action are greater. The field work was extended to an elevation of about 4000 feet. The arable lands above this elevation are limited principally to meadow areas along streams which are now largely developed. The stream flow is measured below such higher areas and their use of water is already reflected in the stream flow records. The total area of such lands is not of sufficient magnitude to require separate consideration.

The results of the classification of foothill lands are shown in Table 15. The numbers used to designate the different classes of foothill land do not represent the same basis of classification as for valley lands and the results shown in Table 15 for the foothill lands should not be compared with the results for the same numbered classes of valley lands in Table 13. The Class 5 foothill lands are those areas which do not contain irrigable lands and were not separately measured. Class 5 represents all lands not included in Classes 1 to 4 and is a part of the total area of 17,500 square miles of unclassified foothills and mountains.

TABLE 15

CLASSIFICATION OF AGRICULTURAL LANDS IN FOOTHILLS ADJACENT TO SAN JOAQUIN VALLEY FLOOR

Class	Gross area	
	In acres	In per cent of total
1	3,400	0.3
2	12,000	1.2
3	348,100	35.7
4	613,500	62.8
Totals	977,000	100.0

Classification by Counties. Although the same numbers are used for the classes of land in the foothills as for valley floor lands, it should be kept in mind in combining areas of lands under these classifications that they are on a somewhat different basis. Such a combination was made for Table 16 in which the total area of land in each of the first four classes is shown for that portion of each county in the upper and lower San Joaquin Valley and in the San Joaquin Delta. Since no attempt was made to measure the Class 5 lands in the foothills, this classification was omitted from the table and the total area shown for each county, therefore, is not the gross area of that county.

TABLE 16

CLASSIFICATION OF AGRICULTURAL LANDS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, BY COUNTIES

County	Gross area in acres				
	Class				Totals
	1	2	3	4	
Upper San Joaquin Valley—					
Kern	737,000	330,600	332,500	5,500	1,405,600
Kings	394,600	211,200	106,300	0	712,100
Tulare	578,900	234,500	90,100	0	903,500
Fresno	1,036,300	169,000	146,700	14,800	1,366,800
Madera	140,100	106,200	116,100	238,0C0	600,400
Totals	2,886,900	1,051,500	791,700	258,300	4,988,400
Lower San Joaquin Valley, excluding San Joaquin Delta—					
Fresno	74,800	29,600	7,900	8,600	120,900
Madera	0	0	4,700	8,500	13,200
Merced	235,000	271,300	226,000	240,000	972,300
Mariposa	0	1,400	24,300	122,000	147,700
Stanislaus	287,900	142,600	216,200	15,800	662,500
Tuolumne	0	1,200	20,700	92,500	114,400
Alameda	1,400	1,200	1,400	0	4,000
Contra Costa	25,700	8,300	1,900	100	36,000
San Joaquin	418,500	127,600	83,100	10,000	639,200
Calaveras	700	3,500	49,700	101,500	155,400
Amador	2,900	5,600	16,100	81,100	105,700
El Dorado[1]	300	1,500	34,500	61,600	97,900
Sacramento[2]	19,700	92,700	45,300	4,100	161,800
Totals	1,066,900	686,500	731,800	745,800	3,231,000
San Joaquin Delta—					
Contra Costa	35,000	7,100	200	0	42,300
San Joaquin	186,500	9,500	800	0	196,800
Sacramento[2]	39,500	400	0	0	39,900
Totals	261,000	17,000	1,000	0	279,000
Grand totals	4,214,800	1,755,000	1,524,500	1,004,100	8,498,400

[1] Lands in Cosumnes River Basin only.
[2] Excluding lands in Sacramento Delta and north of Cosumnes River.

Gross Agricultural Areas. Table 17 set forth a summary of the gross areas of agricultural lands in the entire San Joaquin Valley and adjacent foothills, by sections. Class 5 lands are not included in the areas shown in the table since this class is considered as having no portion which will ever be suitable for agriculture.

TABLE 17

GROSS AGRICULTURAL AREAS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, INCLUDING SAN JOAQUIN DELTA

Section	Gross agricultural area	
	In acres	In per cent of total
Upper San Joaquin Valley floor	4,881,800	57.4
Lower San Joaquin Valley floor	2,360,600	27.8
Foothill areas	977,000	11.5
San Joaquin Delta	279,000	3.3
Totals	8,498,400	100.0

Hydrographic Divisions.

For convenience in carrying on the studies of the utilization of local water supplies tributary to the basin, smaller subdivisions of the areas heretofore described have been made. In general, the boundaries of these subdivisions have been so located as to include lands with a common source of surface supply and for that reason they have been called hydrographic divisions. In areas where no such natural boundaries are indicated, arbitrary lines of division, based upon topography or possible sources of future water supply, have been used. These hydrographic divisions have been numbered from south to north as shown on Plate VI, "Hydrographic Divisions and Zones of Water Service in San Joaquin River Basin."

In the upper San Joaquin River Basin south of the San Joaquin River, the valley floor areas extend practically to the limits of agricultural land. In the lower San Joaquin River Basin, the mountain topography does not descend so abruptly to the valley floor and there are considerable areas of agricultural land which may not soon develop but for which a liberal allowance of local water supply must be made. Many of these lands lie above the stream bed elevations of developed or proposed storage sites. These lands together with rim lands situated below the elevations of the major reservoir sites are designated as foothill lands and have been included in hydrographic divisions having the same number, but with a capital letter appended, as that of the valley division having the same source of local water supply.

Division 1 contains all of the southern end of the San Joaquin Valley floor located in Kern County with the exception of the northerly three miles. The sources of local water supply tributary to this division are the Kern River, that part of the Tejon Creek Group from Franciscan Creek to Tejon Creek, Caliente Creek and the Poso Creek Group excluding White River.

Division 2 consists of that part of the San Joaquin Valley floor located in the northerly three miles of Kern County and in those portions of Tulare and Kings counties south of the Kaweah and Kings River areas of service. The sources of local water supply tributary to this division are the Tule River, Deer Creek and White River of the Poso Creek Group on the eastern side of the valley, and Avenal Creek of the Tejon Creek Group on the western.

Division 3 consists of that part of the San Joaquin Valley floor located in those portions of northern Tulare and eastern Kings County within the Kaweah River area of service. The sources of local water supply tributary to this division are the Kaweah River and the Yokohl and Limekiln Creek groups.

Division 4 consists of that part of the San Joaquin Valley floor located in those portions of Fresno, Kings and Tulare counties within the Kings River area of service. The sources of local water supply tributary to this division are Kings River and Dry Creek.

Divisions 5 and 5B consist of those parts of the San Joaquin Valley floor located west of the Kings River area of service, these divisions being the areas below and above the 350-foot contour, respectively. The sources of local water supply tributary to these divisions are those streams of the Tejon Creek Group lying north of Avenal Creek, Los

Gatos Creek, the Cantua Creek Group, Panoche Creek and Little Panoche Creek in the Orestimba Creek Group.

Division 6 consists of that part of the San Joaquin Valley floor located north and east of the San Joaquin River and south of the Chowchilla River. Division 6A is the adjacent eastern foothill area. The sources of local water supply tributary to these divisions are the San Joaquin, Fresno and Chowchilla rivers, Cottonwood Creek and the Daulton Creek Group.

Division 7 consists of that part of the San Joaquin Valley floor located west of the San Joaquin River, from the vicinity of Mendota on the south nearly to Tracy on the north. The sources of local water supply tributary to this division are the San Joaquin River carrying water contributed by lower east side streams and the Orestimba Creek Group from Laguna Seca Creek on the south to Buenos Aires Creek on the north.

Division 8 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River, north of the Chowchilla River and south of the Merced River. Division 8A is the adjacent eastern foothill area and includes all of the irrigable foothill lands between the Chowchilla River and the northern boundary of the Merced River watershed. The sources of local water supply tributary to these divisions are the San Joaquin and Merced rivers, Dutchman Creek Group, Mariposa Creek, the Owen Creek Group, Bear Creek and the Burns Creek Group.

Division 9 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River, on the south by the Merced River and on the north by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and by Dry Creek. Division 9A is the adjacent eastern foothill area within the Tuolumne River watershed, exclusive of lands now receiving a water supply from the Stanislaus River. The sources of local water supply tributary to these divisions are the Tuolumne River and Dry Creek in the Wildcat Creek Group.

Division 10 consists of that part of the San Joaquin Valley floor located south and west of the San Joaquin River Delta and north of Division 7. The sources of local water supply tributary to this division are minor streams in the Orestimba Creek Group north of Buenos Aires Creek. The main water supply for this division is obtained from the delta channels of the Sacramento and San Joaquin rivers.

Division 11 is that part of the San Joaquin Valley floor bounded on the south by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and Dry Creek in the Wildcat Creek Group, on the west by the San Joaquin River and the western boundary of the South San Joaquin Irrigation District, and on the north by Mormon Slough and southern boundary of the Calaveras River watershed. Division 11A is the adjacent eastern foothill area located between the southern boundary of the Calaveras River watershed on the north and Division 9A on the south. The sources of local water supply tributary to these divisions are the Stanislaus River, Wildcat Creek in the Wildcat Creek Group, Littlejohns Creek and Rock, Big Spring and Peachys creeks in the Martells Creek Group.

Gatos Creek, the Cantua Creek Group, Panoche Creek and Little Panoche Creek in the Orestimba Creek Group.

Division 6 consists of that part of the San Joaquin Valley floor located north and east of the San Joaquin River and south of the Chowchilla River. Division 6A is the adjacent eastern foothill area. The sources of local water supply tributary to these divisions are the San Joaquin, Fresno and Chowchilla rivers, Cottonwood Creek and the Daulton Creek Group.

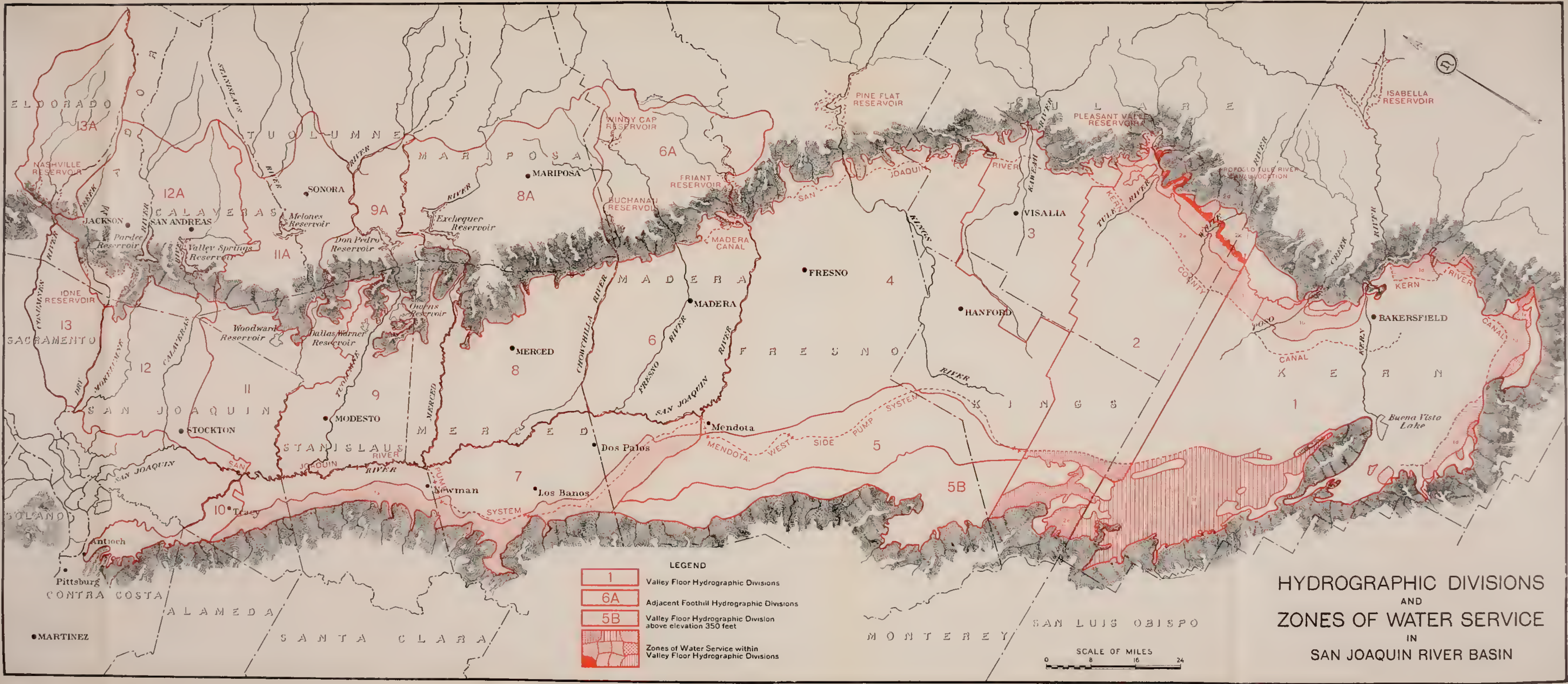
Division 7 consists of that part of the San Joaquin Valley floor located west of the San Joaquin River, from the vicinity of Mendota on the south nearly to Tracy on the north. The sources of local water supply tributary to this division are the San Joaquin River carrying water contributed by lower east side streams and the Orestimba Creek Group from Laguna Seca Creek on the south to Buenos Aires Creek on the north.

Division 8 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River, north of the Chowchilla River and south of the Merced River. Division 8A is the adjacent eastern foothill area and includes all of the irrigable foothill lands between the Chowchilla River and the northern boundary of the Merced River watershed. The sources of local water supply tributary to these divisions are the San Joaquin and Merced rivers, Dutchman Creek Group, Mariposa Creek, the Owen Creek Group, Bear Creek and the Burns Creek Group.

Division 9 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River, on the south by the Merced River and on the north by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and by Dry Creek. Division 9A is the adjacent eastern foothill area within the Tuolumne River watershed, exclusive of lands now receiving a water supply from the Stanislaus River. The sources of local water supply tributary to these divisions are the Tuolumne River and Dry Creek in the Wildcat Creek Group.

Division 10 consists of that part of the San Joaquin Valley floor located south and west of the San Joaquin River Delta and north of Division 7. The sources of local water supply tributary to this division are minor streams in the Orestimba Creek Group north of Buenos Aires Creek. The main water supply for this division is obtained from the delta channels of the Sacramento and San Joaquin rivers.

Division 11 is that part of the San Joaquin Valley floor bounded on the south by the Stanislaus River, the southern boundary of the Oakdale Irrigation District and Dry Creek in the Wildcat Creek Group, on the west by the San Joaquin River and the western boundary of the South San Joaquin Irrigation District, and on the north by Mormon Slough and southern boundary of the Calaveras River watershed. Division 11A is the adjacent eastern foothill area located between the southern boundary of the Calaveras River watershed on the north and Division 9A on the south. The sources of local water supply tributary to these divisions are the Stanislaus River, Wildcat Creek in the Wildcat Creek Group, Littlejohns Creek and Rock, Big Spring and Peachys creeks in the Martells Creek Group.



HYDROGRAPHIC DIVISIONS AND ZONES OF WATER SERVICE IN SAN JOAQUIN RIVER BASIN

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Division 12 is that part of the San Joaquin Valley floor bounded on the west by the San Joaquin River Delta north of Stockton and by the main San Joaquin River south of Stockton, on the south by westerly boundary of the South San Joaquin Irrigation District, Mormon Slough and the southern boundary of the Calaveras River watershed, and on the north by Dry Creek of the Sutter Creek Group. Division 12A is the adjacent eastern foothill area located in the watersheds of the Mokelumne and Calaveras rivers and Dry Creek. The sources of local water supply tributary to these divisions are the Calaveras and Mokelumne rivers, Bear and Martells creeks of the Martells Creek Group and Dry and Sutter creeks of the Sutter Creek group.

Division 13 consists of that part of the San Joaquin Valley floor located east of the San Joaquin River Delta, north of Dry Creek and south of the Cosumnes River. Division 13A is the adjacent eastern foothill area within the watershed of the Cosumnes River. The sources of local water supply tributary to these divisions are the Cosumnes River and Willow Creek of the Sutter Creek Group.

Hydrographic divisions 1, 2 and 7 are further divided into zones of water service which are delineated on Plate VI. Hydrographic divisions 1 to 6, inclusive, comprise the upper San Joaquin Valley; and 7 to 13, inclusive, the lower, exclusive of the San Joaquin Delta. The segregation of the classification of valley floor lands, by hydrographic divisions, are set forth in Table 18. The classification of agricultural lands in eastern foothills adjacent to San Joaquin Valley floor is given by hydrographic divisions in Table 19.

TABLE 18

CLASSIFICATION OF LANDS ON SAN JOAQUIN VALLEY FLOOR BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Gross area, in acres					
	Class					Totals
	1	2	3	4	5	
Upper San Joaquin Valley—						
1	706,100	316,200	310,900	5,600	240,100	1,578,900
2	470,000	231,300	111,800	0	138,000	951,100
3	233,700	102,000	46,000	0	14,500	396,200
4	793,500	237,200	167,500	9,000	164,200	1,371,400
5	304,300	21,000	23,000	0	53,600	401,900
5B	239,200	37,600	8,600	0	25,600	311,000
6	140,100	106,200	104,900	156,100	11,400	518,700
Totals	2,886,900	1,051,500	772,700	170,700	647,400	5,529,200
Lower San Joaquin Valley excluding San Joaquin Delta—						
7	305,700	124,100	63,300	128,900	1,200	623,200
8	114,490	154,100	83,800	85,200	3,400	440,900
9	184,100	134,700	95,700	0	16,900	431,400
10	71,600	10,100	6,200	100	5,300	93,300
11	160,600	106,600	76,800	0	7,400	351,400
12	201,400	50,100	28,400	200	9,300	289,400
13	25,700	94,800	48,500	5,500	0	174,500
Totals	1,063,500	674,500	402,700	219,900	43,500	2,404,100
Totals, San Joaquin Valley floor excluding Delta	3,950,400	1,726,000	1,175,400	390,600	690,900	7,933,300
San Joaquin Delta	261,000	17,000	1,000	0	0	279,000

TABLE 19

CLASSIFICATION OF AGRICULTURAL LANDS IN FOOTHILLS ADJACENT TO SAN JOAQUIN VALLEY FLOOR, BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Gross area, in acres				
	Class				Totals
	1[1]	2[1]	3	4	
6A	0	•0	19,000	[3]58,500 29,100	106,600
8A	0	1,100	[2]7,300 62,500	[3]51,200 105,200	227,300
9A	0	0	[2]22,600 65,000	[3]10,800 35,000	133,400
11A	0	2,400	[2]24,800 49,600	[3]55,500 33,600	165,900
12A	2,700	5,100	62,700	[3]30,700 126,800	228,000
13A	700	3,400	34,600	77,100	115,800
Totals	3,400	12,000	348,100	613,500	977,000

[1] For classes 1 and 2, 80 per cent of gross area is considered irrigable.

[2] Areas for which 50 per cent of gross area is considered irrigable; remainder of Class 3 considered as 60 per cent irrigable.

[3] Areas for which 40 per cent of gross area is considered irrigable; remainder of Class 4 considered as 20 per cent irrigable.

Present Agricultural Development of San Joaquin Valley and Adjacent Foothills.

During the investigations, a survey was made of the present agricultural development of the San Joaquin Valley and adjacent foothills to ascertain the use made of the land and the area under irrigation.

Cropped Areas. A crop survey was made for the purpose of determining the location in which crops of different kinds were grown, the approximate number of acres planted to each of these crops in 1929, and the adaptability of certain areas to the growing of crops of different types. In making this survey, the crops were divided into groups, each of which was designated by a number. The numbers used and the crops represented by them are shown in the following tabulation:

Number Crop or use of land represented by number

1. Citrus orchards.
2. Deciduous orchards, including figs and nuts, and olives.
3. Grape vineyards.
4. Grain.
5. Alfalfa.
6. Field crops—under this classification there were included such crops as sorghum, feterita, sudan grass, field corn, maize, etc.
7. Cotton.
8. Irrigated pasture land.
9. Truck crops—including truck gardening, root and bush vegetables and fruits, such as beans, potatoes, sugar beets, melons, strawberries, etc.
10. Rice.
11. Unclassified irrigated areas—probably annuals on the valley floor and small orchards in the foothills.

The crop survey covered substantially the area of land classification, including the area classified from data obtained from previous surveys. No effort was made to grade the crops but their quality was observed as an aid in classifying the land.

Practically every crop grown in California can be found in some part of the San Joaquin Valley and its adjacent foothills. Citrus fruits are grown chiefly in Tulare County in the region adjacent to the eastern foothills between Orange Cove on the north and Terra Bella on the south, in Fresno County in coves adjacent to the foothills between Orange Cove on the south and Fancher Creek on the north and in Kern County in the vicinity of Edison about seven miles east of Bakersfield.

Deciduous orchards, including those of fig and nut trees, are quite generally distributed throughout the eastern side of the valley from the Cosumnes River on the north to Deer Creek on the south, and on the west side from Orestimba Creek north to Antioch. There are smaller scattered areas on the east side of the valley south of Deer Creek in Tulare County and in Kern County.

Grapes of nearly all varieties are grown on scattering areas throughout most of the valley but the largest single area planted to vines is in Fresno and Tulare counties on the Kings River Delta where there is a vineyard area equal to more than half that of the entire valley. Large vineyard areas also are found in San Joaquin, Stanislaus, Merced, Madera, Kings and Kern counties.

In the early days of agriculture in the San Joaquin Valley, grain was the principal crop. As the valley developed and more land was brought under irrigation, portions of the area devoted to grain farming became more valuable for other crops and the areas of grain plantings were considerably reduced. The area still planted to grain, however, is nearly one-third of the entire cropped area of the San Joaquin Valley and approximates twice that of any other single crop. The largest areas are in San Joaquin, Madera, Fresno, Stanislaus, Merced, Kings and Kern counties, but grain is grown extensively in every San Joaquin Valley county. About one-third of all the area planted to grain receives some irrigation.

Alfalfa is found in general throughout the same areas as deciduous orchards and vineyards, the largest areas being located in Stanislaus and Merced counties in the Modesto, Turlock and Merced Irrigation districts. San Joaquin, Fresno, Tulare, Kern, Kings, Madera and Contra Costa counties follow in the order named in the relative size of areas planted to alfalfa.

Field crops which include sorghum, feterita, sudan grass, field corn, maize, etc., are grown in every San Joaquin Valley county. The largest area is found in Kern County, with San Joaquin County second and Fresno County third.

Cotton is grown extensively in all San Joaquin Valley counties south of Merced River. Tulare, Kern and Fresno counties have the largest areas planted to this crop.

The largest single area devoted to the growing of truck crops is located in San Joaquin and Contra Costa counties in and adjacent to the San Joaquin Delta. Areas planted to truck crops also are found in Stanislaus and Merced counties.

A few tracts have been planted to rice during recent years in the lower San Joaquin Valley, principally on the west side of the San Joaquin River between Mendota and Newman, but rice has not become an important crop in the San Joaquin Valley.

Table 20 sets forth the areas of crops under each of the classifications shown in the foregoing list, for that portion of each county in the San Joaquin Valley and adjacent foothills covered by the land classification and crop survey, with the exception of areas in El Dorado and Sacramento counties, which are included in another report.*

The yields and values of agricultural and live stock products from the San Joaquin River Basin and an inventory value of farms, equipment and live stock in the basin are shown in Table 21, by counties. These data were taken mainly from the Fifteenth Census of the United States and no means are available for determining what portion of the products and their values from counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. To offset the losses on products and values from the portions of these counties lying in the basin, the products and values from portions of Contra Costa and Kern counties which lie outside of the basin are included with those for lands in these counties lying within the basin. It is believed, therefore, that the totals shown for the thirteen counties in Table 21 closely approximate those which would be obtained for the San Joaquin River Basin area only.

For comparison of the agricultural industry in the San Joaquin River Basin with that of the entire State, totals are given in the last column of Table 21 for the yields and values of agricultural and live stock products and the inventory values from farms, equipment and live stock, for the State.

Future Agricultural Development of San Joaquin River Basin.

A study was made to estimate the ultimate water requirements in the San Joaquin River Basin, as explained in Chapter V. In order to estimate these ultimate water requirements, it was necessary to make an estimate of the amounts of land that would be irrigated under the conditions of ultimate development. It was necessary, also, to take into account the marked difference between the upper and lower San Joaquin valleys in the adequacy of local streams to meet the ultimate irrigation demand. The lower San Joaquin Valley is an area in which the local supplies, afforded by the San Joaquin River and its east side tributaries, may be considered plentiful in amount and dependable in occurrence if properly conserved and regulated. It was assumed, therefore, that all of the arable land in this area will be brought ultimately into use and that all lands which are of sufficiently good quality and for which it is physically possible to furnish a water supply will be irrigated. This procedure, also, was followed in estimating the irrigation requirements for lands in the Sacramento River Basin. The upper San Joaquin Valley, on the other hand, is an area in which the tributary run-off is inadequate to meet present requirements and in which ultimate development will be possible only with the importation of waters from distant sources, at relatively high costs. Service under such conditions is only justified for the better lands. In estimating net irrigable areas in each classification the following percentages of gross agricultural areas were used for valley floor lands:

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works, 1931.

S BY COUNTIES, 1929

Area of unirrigated crops, in acres							Total cropped area in acres
2	3	4	5	6	9		
Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Truck crops	Total unirrigated crops	
0	0	37,900	0	0	0	37,900	239,500
0	0	0	0	0	0	0	138,000
0	0	0	0	0	0	0	316,900
0	0	96,100	0	0	0	96,100	597,900
0	0	205,000	0	0	0	205,000	288,300
0	0	47,000	0	0	0	47,000	283,300
0	0	0	0	0	0	0	2,900
700	100	22,200	1,200	2,300	400	26,900	291,700
	0	0	0	0	0	0	3,200
1,000	5,900	165,300	100	5,500	700	178,500	588,800
0	0	1,200	0	0	0	1,200	2,500
0	0	3,900	0	0	0	3,900	71,400
1,700	6,000	578,600	1,300	7,800	1,100	596,500	2,824,400
0	0	0	0	0	0	0	158,000
0	0	0	0	0	0	0	36,300
0	0	0	0	0	0	0	194,300

Table 20 sets forth the areas of crops under each of the classifications shown in the foregoing list, for that portion of each county in the San Joaquin Valley and adjacent foothills covered by the land classification and crop survey, with the exception of areas in El Dorado and Sacramento counties, which are included in another report.*

The yields and values of agricultural and live stock products from the San Joaquin River Basin and an inventory value of farms, equipment and live stock in the basin are shown in Table 21, by counties. These data were taken mainly from the Fifteenth Census of the United States and no means are available for determining what portion of the products and their values from counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. To offset the losses on products and values from the portions of these counties lying in the basin, the products and values from portions of Contra Costa and Kern counties which lie outside of the basin are included with those for lands in these counties lying within the basin. It is believed, therefore, that the totals shown for the thirteen counties in Table 21 closely approximate those which would be obtained for the San Joaquin River Basin area only.

For comparison of the agricultural industry in the San Joaquin River Basin with that of the entire State, totals are given in the last column of Table 21 for the yields and values of agricultural and live stock products and the inventory values from farms, equipment and live stock, for the State.

Future Agricultural Development of San Joaquin River Basin.

A study was made to estimate the ultimate water requirements in the San Joaquin River Basin, as explained in Chapter V. In order to estimate these ultimate water requirements, it was necessary to make an estimate of the amounts of land that would be irrigated under the conditions of ultimate development. It was necessary, also, to take into account the marked difference between the upper and lower San Joaquin valleys in the adequacy of local streams to meet the ultimate irrigation demand. The lower San Joaquin Valley is an area in which the local supplies, afforded by the San Joaquin River and its east side tributaries, may be considered plentiful in amount and dependable in occurrence if properly conserved and regulated. It was assumed, therefore, that all of the arable land in this area will be brought ultimately into use and that all lands which are of sufficiently good quality and for which it is physically possible to furnish a water supply will be irrigated. This procedure, also, was followed in estimating the irrigation requirements for lands in the Sacramento River Basin. The upper San Joaquin Valley, on the other hand, is an area in which the tributary run-off is inadequate to meet present requirements and in which ultimate development will be possible only with the importation of waters from distant sources, at relatively high costs. Service under such conditions is only justified for the better lands. In estimating net irrigable areas in each classification the following percentages of gross agricultural areas were used for valley floor lands:

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works, 1931.

TABLE 20

CLASSIFICATION OF CROPS IN THE SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS BY COUNTIES, 1929

County	Area of irrigated crops, in acres												Area of unirrigated crops, in acres							Total cropped area in acres
	1	2	3	4	5	6	7	8	9	10	11		2	3	4	5	6	9		
	Citrus orchards	Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Cotton	Irrigated pasture land	Truck crops	Rice	Unclassified irrigated areas	Total irrigated crops	Deciduous and olive orchards	Grape vineyards	Grain	Alfalfa	Field crops	Truck crops	Total unirrigated crops	
Kern	1,900	8,800	23,600	900	30,400	66,300	64,300	0	4,400	1,000	0	201,600	0	0	37,900	0	0	0	37,900	239,500
Kings	0	12,900	16,300	53,300	21,200	5,500	22,000	6,800	0	0	0	138,000	0	0	0	0	0	0	0	138,000
Tulare	37,100	41,200	75,500	10,100	54,600	12,200	69,500	16,700	0	0	0	316,900	0	0	0	0	0	0	0	316,900
Fresno	2,600	51,400	209,100	0	54,900	37,500	60,500	38,000	1,500	2,800	43,500	501,800	0	0	96,100	0	0	0	96,100	597,900
Madera	0	8,500	25,400	0	17,100	2,000	28,200	1,500	600	0	0	83,300	0	0	205,000	0	0	0	205,000	288,300
Merced	0	29,000	22,200	26,300	69,100	10,700	28,500	20,600	20,100	9,800	0	236,300	0	0	47,000	0	0	0	47,000	283,300
Tuolumne	...	...	...	...	...	...	...	...	...	...	2,900	2,900	0	0	0	0	0	0	0	2,900
Stanislaus	50	26,800	26,400	61,300	86,250	9,800	3,600	8,600	39,000	3,000	0	264,800	700	100	22,200	1,200	2,300	400	26,900	291,700
Calaveras, Amador	...	...	...	...	...	...	...	...	...	...	3,200	3,200	...	0	0	0	0	0	0	3,200
San Joaquin	0	39,400	64,900	94,600	59,000	34,900	2,300	38,000	77,200	0	0	410,300	1,000	5,900	165,300	100	5,500	700	178,500	588,800
Alameda	0	0	200		1,000	100	0	0	0	0	0	1,300	0	0	1,200	0	0	0	1,200	2,500
Contra Costa	150	13,600	2,100	15,100	8,350	9,500	0	5,000	13,700	0	0	67,500	0	0	3,900	0	0	0	3,900	71,400
Totals	41,800	231,600	465,700	261,600	401,900	188,500	278,900	135,200	156,500	16,600	49,600	2,227,900	1,700	6,000	578,600	1,300	7,800	1,100	596,500	2,824,400
San Joaquin Delta,[1] included in county totals—																				
San Joaquin	0	1,500	0	53,000	15,600	25,500	0	6,300	56,100	0	0	158,000	0	0	0	0	0	0	0	158,000
Contra Costa	0	0	0	13,100	500	8,500	0	4,500	9,700	0	0	36,300	0	0	0	0	0	0	0	36,300
Totals	0	1,500	0	66,100	16,100	34,000	0	10,800	65,800	0	0	194,300	0	0	0	0	0	0	0	194,300

[1] The San Joaquin Delta also includes 24,500 acres of crops irrigated in 1929 in Sacramento County.

TABLE 21

AGRICULTURAL STATISTICS OF SAN JOAQUIN RIVER BASIN BY COUNTIES

Item	Unit	Kern	Kings	Tulare	Fresno	Madera	Merced	Mariposa	Tuolumne	Stanislaus	Calaveras	Amador	San Joaquin	Contra Costa	Total for 13 counties	Total for State
Yield of agricultural products in 1929—																
Citrus[1]	Boxes	88,700	0	5,608,000	73,000	300	1,500	600	0	7,000	300	300	300	100	5,780,100	53,803,000
Olives	Tons	215	250	7,519	1,934	224	186	0	0	160	35	3	267	5	10,798	20,800
Orchard fruits[2]	Tons	7,230	26,700	63,730	85,740	9,940	32,370	60	1,200	68,880	370	740	11,940	12,120	321,020	1,139,000
Nuts	Tons	30	20	485	158	27	514	1	4	753	30	9	967	1,110	4,108	42,500
Grapes (fresh basis)	Tons	70,600	49,600	269,000	693,000	51,100	64,800	10	170	65,000	490	1,100	152,000	9,540	1,426,410	1,691,000
Grain[3]	Bushels	370,000	2,322,000	991,000	1,328,000	1,038,000	1,460,000	8,000	13,000	1,892,000	19,000	58,000	4,012,000	780,000	14,341,000	42,367,000
Alfalfa	Tons	92,500	82,000	212,600	195,900	55,800	210,900	100	500	278,700	1,000	2,300	187,600	24,500	1,344,400	2,793,800
Hay and forage crops[4]	Tons	17,000	11,600	45,300	32,100	10,200	27,630	3,400	4,100	40,600	8,200	4,800	66,800	46,100	317,800	1,494,300
Field crop[5]	Bushels	110,300	152,600	147,600	41,400	24,800	85,600	200	500	62,200	1,200	4,100	950,000	216,800	1,797,300	3,171,400
Seed[6]	Bushels	410	270	380	130	0	2,580	0	0	3,940	0	70	63,820	27,400	9,000	226,000
Beans and peas (dry)	Bushels	5,770	1,700	1,200	10,700	300	109,500	0	0	462,900	60	920	503,500	10,450	1,107,000	5,589,200
Cotton	Bales	60,300	22,830	61,260	43,730	20,830	16,260	0	0	1,690	0	0	520	0	227,420	253,900
Cotton seed	Tons	28,670	11,270	30,510	21,460	10,030	8,020	0	0	840	0	0	260	0	111,060	124,000
Small fruits[7]	Quarts	99,800	47,100	246,500	391,700	18,500	431,400	8,500	50,300	240,400	8,500	3,600	304,000	16,000	1,866,300	21,736,000
Sugar beets	Tons	0	0	0	0	0	0	0	0	0	0	0	94,820	30,420	125,240	452,800
Potatoes	Bushels	339,600	380	48,860	12,750	5,950	6,100	1,320	2,750	28,230	4,930	3,780	3,817,000	286,300	4,557,950	6,489,000
Cantaloupes and muskmelons	Value in dollars	31,500	1,000	90,700	58,200	3,200	106,700	0	100	648,400	200	200	41,000	11,500	992,700	9,364,000
Tomatoes	Value in dollars	17,500	4,600	35,600	31,200	8,400	173,200	100	1,300	39,400	1,500	900	202,800	543,000	1,059,500	5,481,000
Asparagus	Value in dollars	5,300	200	3,600	71,600	400	9,500	0	0	4,900	0	0	1,195,200	281,600	1,572,300	7,786,000
Celery	Value in dollars	100	0	0	4,000	800	3,500	0	0	43,000	100	0	444,800	1,200	497,500	5,753,000
Dry onions	Value in dollars	57,800	100	17,300	6,700	2,700	14,500	0	600	7,500	300	200	438,600	22,400	568,700	1,831,000
Rice	Bushels	27,700	0	0	141,200	0	389,100	0	0	143,200	0	0	0	24,500	725,700	4,968,000
Yield of live stock products in 1929																
Milk produced	Gallons	6,161,000	14,308,000	28,507,000	18,348,000	6,137,000	31,275,000	172,000	557,000	33,080,000	490,000	759,000	23,428,000	5,360,000	168,582,000	445,530,000
Wool shorn (unwashed)	Pounds	633,000	364,000	202,000	878,000	157,000	397,000	35,000	38,000	431,000	180,000	124,000	327,000	300,000	4,066,000	18,747,000
Honey	Pounds	67,000	73,000	98,000	197,000	42,000	144,000	0	8,100	231,000	1,300	3,900	218,000	39,000	1,122,300	5,476,000
Chicken eggs produced	Dozens	912,000	638,000	3,405,000	2,071,000	509,000	2,259,000	72,000	183,000	4,632,000	67,000	93,000	3,215,000	1,063,000	19,119,000	159,422,000
Chickens sold	Number	101,000	44,000	233,000	169,000	36,000	159,000	4,000	13,000	317,000	12,000	9,000	220,000	82,000	1,399,000	13,861,000
Value of crops and live stock products in 1929—																
Fruits and nuts	In dollars	$2,779,000	$2,482,000	$31,316,000	$22,686,000	$1,770,000	$4,229,000	$8,000	$97,000	$6,194,000	$54,000	$81,000	$6,579,000	$1,532,000	$79,807,000	$296,242,000
Cereals	In dollars	540,000	2,345,000	1,171,000	1,326,000	916,000	1,552,000	6,000	13,000	1,656,000	17,000	54,000	4,102,000	864,000	14,562,000	43,040,000
Other grains and seeds	In dollars	25,000	10,000	9,000	43,000	1,000	438,000	0	0	2,089,000	0	4,000	2,427,000	149,000	5,195,000	28,779,000
Hay and forage	In dollars	1,695,000	1,442,000	3,740,000	3,416,000	985,000	3,523,000	47,000	64,000	4,684,000	124,000	116,000	3,694,000	1,054,000	24,584,000	66,863,000
All other field crops	In dollars	6,284,000	2,384,000	6,364,000	4,555,000	2,089,000	1,700,000	0	0	182,000	0	0	754,000	213,000	24,525,000	30,629,000
Vegetables	In dollars	763,000	46,000	386,000	402,000	78,000	873,000	12,000	32,000	1,399,000	42,000	18,000	7,810,000	1,504,000	13,365,000	71,926,000
Dairy products	In dollars	1,293,000	3,097,000	6,064,000	3,791,000	1,383,000	7,337,000	20,000	98,000	7,683,000	77,000	144,000	5,381,000	1,159,000	37,527,000	96,357,000
Wool shorn	In dollars	171,000	98,000	55,000	237,000	42,000	107,000	10,000	11,000	116,000	50,000	35,000	88,000	84,000	1,104,000	5,192,000
Chicken eggs produced	In dollars	403,000	271,000	1,021,000	978,000	153,000	678,000	24,000	60,000	1,390,000	41,000	51,000	964,000	428,000	6,462,000	51,519,000
Chickens sold	In dollars	101,000	44,000	233,000	169,000	36,000	159,000	4,000	13,000	317,000	12,000	9,000	220,000	86,000	1,403,000	14,699,000
Honey	In dollars	7,000	7,000	7,000	15,000	3,000	11,000	0	1,000	17,000	0	0	16,000	4,000	88,000	523,000
Cattle sold	In dollars	2,027,000	1,024,000	2,494,000	1,782,000	980,000	1,960,000	325,000	303,000	2,049,000	530,000	414,000	1,359,000	682,000	15,929,000	43,808,000
Sheep and lambs sold	In dollars	854,000	370,000	285,000	1,253,000	290,000	484,000	34,000	40,000	456,000	199,000	103,000	740,000	313,000	5,421,000	19,646,000
Hogs sold	In dollars	294,000	238,000	653,000	442,000	189,000	316,000	123,000	66,000	245,000	49,000	76,000	346,000	211,000	3,248,000	14,475,000
Total value	In dollars	$17,236,000	$13,858,000	$53,798,000	$41,095,000	$8,915,000	$23,367,000	$613,000	$798,000	$28,477,000	$1,195,000	$1,105,000	$34,480,000	$8,283,000	$233,220,000	$783,698,000
Inventory value of farms, implements and machinery, and live stock in 1930—																
Land and buildings		$74,497,000	$38,951,000	$151,033,000	$142,982,000	$27,932,000	$68,013,000	$3,265,000	$3,531,000	$97,700,000	$6,316,000	$6,259,000	$138,489,000	$49,590,000	$808,558,000	$3,419,471,000
Implements and machinery		3,101,000	2,248,000	7,484,000	7,275,000	1,518,000	3,492,000	155,000	211,000	5,007,000	265,000	214,000	6,281,000	2,392,000	39,643,000	135,741,000
Domestic animals, chickens and bees		7,007,000	4,251,000	9,727,000	8,974,000	3,569,000	7,967,000	1,018,000	974,000	8,613,000	1,817,000	1,411,000	6,346,000	3,042,000	64,716,000	200,288,000
Total value		$84,605,000	$45,450,000	$168,244,000	$159,231,000	$33,019,000	$79,472,000	$4,438,000	$4,716,000	$111,320,000	$8,398,000	$7,884,000	$151,116,000	$55,024,000	$912,917,000	$3,755,500,000

NOTE. Data compiled from Fifteenth Census of the United States, 1930, except value of cattle, sheep and hogs sold. The value of live stock sold was computed from the live stock inventory and estimate of value of live stock production by California Cooperative Crop Reporting Service.

[1] Grapefruit, lemons, oranges and limes.

[2] Apples, apricots, cherries, figs, nectarines, peaches, pears, plums and prunes, and quinces

[3] Wheat, oats, barley, rye and mixed grains not separated in harvesting.

[4] Corn silage, timothy, clovers, tame and wild grasses, small grains for hay, legumes for hay and sorghum fodder.

[5] Corn and sorghums harvested for grain.

[6] Grass seeds, clover, alfalfa, sunflower, vetch, flower and vegetable seeds.

[7] Blackberries, loganberries, blueberries, gooseberries, strawberries, raspberries, currants and other fruits.

Class 1 80 per cent
Class 2 80 per cent
Class 3 60 per cent
Class 4 20 per cent

The percentages used for foothill areas have been set forth in Table 19. A higher percentage was used for lands in the delta.

The ultimate net irrigable areas for all classes of land are presented in Table 22 by the same sections as were used in showing the gross agricultural areas in the San Joaquin River Basin, in Table 17. A more detailed tabulation of ultimate net irrigable areas for various classes of land by hydrographic divisions and also an estimate of the net irrigable areas to be served under ultimate development are given in Chapter V.

TABLE 22

ULTIMATE NET IRRIGABLE AREAS IN SAN JOAQUIN VALLEY AND ADJACENT FOOTHILLS, INCLUDING SAN JOAQUIN DELTA

Section	Net irrigable area	
	In acres	In per cent of total
Upper San Joaquin Valley floor	3,648,000	61.2
Lower San Joaquin Valley floor	1,676,000	28.1
Foothill areas	380,000	6.4
San Joaquin Delta	257,000	4.3
Totals	5,961,000	100.0

CHAPTER IV

IRRIGATION DEVELOPMENT AND WATER SUPPLY UTILIZATION

Favorable soil and climatic conditions, with the one exception of adequacy of rainfall, have made the San Joaquin Valley a pioneer section in irrigation in California. The development has been rapid and extensive. More than one-third of the total irrigated land of the State lies in the San Joaquin Valley. The irrigated area in the San Joaquin River Basin was over two and one-quarter million acres in 1929. This is about two-fifths of the entire net acreage susceptible of irrigation in that basin.

History of Irrigation Development.

Irrigation development in the San Joaquin Valley began in the decade following 1850 when diversions were made to lands lying adjacent to the streams, although areas of naturally overflowed land had been used for pasturage prior to that time. The lands adjacent to streams had, in many instances, passed into private title as Spanish or Mexican land grants. In later years, additional areas were acquired under various swamp and overflow land acts. The early irrigation developments were largely individual enterprises, some of which have continued in this form to the present time.

Construction of the railroad through the valley during the period 1869 to 1875 resulted in an increase in population and a demand for suitable land for more intensive cultivation. Areas under some of the earlier canals were then subdivided and sold. Additional systems were also built to serve dry sections and bring more land under irrigation. Various forms of organization were used for these enterprises. In some cases, water was sold without participation by the land owner in the ownership of the canal system. This method usually resulted in the canal company becoming a public utility, later subject to regulation in its rates and service. Many of the canals, particularly those of small to medium size, were built through the joint effort of the land owners to be served, under mutual water company forms of organization. While many of these earlier private and mutual water companies still remain in operation, organized developments in recent years have taken the form of irrigation, reclamation and water storage districts. Such districts have, in several instances, absorbed the former public utility systems.

The first California irrigation district law was passed in 1872. It was entitled ''An Act to Promote Irrigation'' and provided for the formation of irrigation districts by owners of lands susceptible of one mode of irrigation or drainage. All of such owners were required to sign the petition to the county supervisors which initiated the organization, rather than a majority, as provided in later acts. The irrigation district, in the form generally used in the United States, had its origin, however, in the Wright Irrigation District Act, passed by the Legislature of California in 1887.

The early enterprises made use of the natural stream flow only. Due to the rapid reduction in stream flow following the melting of snow on the higher drainage areas, usually in June or early July, the lands which could be given full service without storage were limited. Many areas received only a partial service and either adjusted the crops to those of early maturity, or by excessive use of flood waters, while available, raised the ground water to provide at least partial subirrigation during the remainder of the season. Water logging was often caused by such excessive applications, and continued high ground water resulted in soil injury through alkali accumulations in many areas. Drainage was undertaken in some sections to afford relief.

In the southern or upper valley the first irrigation developments were made by direct surface diversion to lands, principally on the delta fans. For areas distant from streams, where surface supplies were not obtainable, ground water was found to be available and pumping began to be practiced in the early part of the present century. In many localities, where artesian wells first were secured, increased draft has resulted in a lowering of the water table and pumping is now required. Early pumping plants of the steam and gas engine type have been replaced by electrically driven equipment or by modern gas engines. Pumping from wells has been developed to a very large extent in this section of the valley, where stream flow is small in relation to the demand. On the Kings and Kaweah river deltas, pumping from wells, within the irrigated areas, is extensively used to supplement direct surface diversion. For areas further south, practice includes all variations from entire dependence on stream diversion to full pumping or combinations of these two practices.

In the northern or lower valley, direct surface diversions were used until the developments had become sufficiently extensive to enable storage to be financed. These storage developments were made, to a large extent, economically feasible by the development and sale of hydroelectric energy in conjunction with the storage and release of irrigation water. Such storage is now in use on the Merced, Tuolumne and Stanislaus rivers. Pumping from wells is limited to drainage. However, drainage water, in most instances, is re-used for irrigation. On the San Joaquin River, some storage for power is now available as a partial aid to irrigation. Supplies from the lower portions of the San Joaquin River have been obtained by pumping rather than by gravity diversion. This method is used for all west side areas, under irrigation, north of Patterson.

Agencies Furnishing Irrigation Service.

Various forms of organization are used to furnish irrigation service to California lands. They comprise irrigation districts, public utilites, mutual water companes, contract companies, individuals, partnerships, associations, private companies, United States Bureau of Reclamation, United States Indian Service, county water districts, municipal improvement districts, water conservation districts, water storage districts and reclamation districts. Those furnishing service in the San Joaquin River Basin include irrigation districts, public utilities, mutual water companies, water storage districts, a reclamation district, water conservation districts, a county water district, private companies and individuals.

Irrigation Districts—The irrigation district is probably the most important form of organization furnishing irrigation service in California. Districts are formed under the "California Irrigation District Act." The districts have power to issue bonds to pay for their works and to levy and collect taxes, assessments and water tolls to amortize

TABLE 23

IRRIGATION DISTRICTS IN SAN JOAQUIN RIVER BASIN

Active Districts

District	Source of supply	County	Year organized	Area within district boundary, in acres	Area irrigated in 1929, in acres
Alpaugh	Groundwater	Tulare	1915	8,175	5,620
Alta	Kings River	Tulare, Fresno, Kings	1888	129,300	68,450
Banta Carbona	San Joaquin River	San Joaquin	1921	14,379	12,677
Byron-Bethany	Old River	Contra Costa, San Joaquin, Alameda	1919	17,200	10,000
Consolidated	Kings River	Fresno, Tulare, Kings	1921	149,047	129,000
Corcoran	Kings and Kaweah rivers	Kings	1919	51,606	31,820
East Contra Costa	Old River	Contra Costa	1926	20,200	14,939
El Nido	Merced River	Merced	1929	9,450	4,000
Foothill	Groundwater	Fresno, Tulare	1920	50,687	11,000
Fresno	Kings River	Fresno	1920	241,300	192,800
Island No. 3	Kings River	Kings	1921	4,620	3,720
James	Kings River	Fresno	1920	26,266	11,640
Laguna	Kings River	Fresno, Kings	1920	34,858	22,500
Lakeland	Kings and Kaweah rivers	Kings	1923	23,283	4,480
Lemoore	Kings River	Kings	1920	53,100	14,574
Linden	Calaveras River	San Joaquin	1929	13,700	6,000
Lindsay-Strathmore	Kaweah River	Tulare	1915	15,250	7,800
Lucerne	Kings River	Kings	1925	33,407	19,556
Madera	San Joaquin River	Madera	1920	182,000	81,000
Merced	Merced River	Merced	1919	189,682	134,379
Modesto	Tuolumne River	Stanislaus	1887	81,183	66,370
Naglee-Burk	Old River	San Joaquin	1920	2,871	2,057
Oakdale	Stanislaus River	Stanislaus, San Joaquin	1909	74,240	23,321
Riverdale	Kings River	Fresno	1920	15,830	8,640
South San Joaquin	Stanislaus River	San Joaquin	1909	71,112	54,340
Stinson	Kings River	Fresno	1921	11,750	5,984
Terra Bella	Deer Creek	Tulare	1915	12,285	3,933
Tracy Clover	Old River	San Joaquin	1922	1,084	900
Tranquillity	Kings River	Fresno	1918	10,750	6,700
Tulare	Kaweah River	Tulare	1889	34,000	22,350
Turlock	Tuolumne River	Stanislaus, Merced	1887	181,498	133,750
Vandalia	Tule River	Tulare	1923	1,276	1,100
Waterford	Tuolumne River	Stanislaus	1913	14,110	5,079
West Side	Old River	San Joaquin	1915	11,828	11,322
West Stanislaus	San Joaquin River	Stanislaus, Merced	1920	21,400	5,855
Woodbridge	Mokelumne River	San Joaquin	1924	13,851	6,184
Totals				1,826,578	1,143,840

Inactive Districts

District	County	Year organized
El Solyo	Stanislaus	1921
Kasson	San Joaquin	1921
Medano	Madera	1921
Mendota	Fresno	1921
Plainsburg	Merced	1919
Stratford	Kings	1916
Webster	Madera	1916

the cost of, and to operate and maintain their water systems. California irrigation districts are political subdivisions of the State and are organized under the jurisdiction of the county or counties in which they are located. Although it is possible to organize an irrigation district and issue bonds without the approval of the State Engineer, or of the board of supervisors of the county in which the district is located, the bonds are not legal security for public funds and savings banks unless they are certified by the California Districts Securities Commission. The affairs of the district are managed by an elective board of directors, assessor, tax collector and treasurer. A secretary is appointed by the board of directors. The plans for the district must be prepared by a competent irrigation engineer.

There are now 36 active irrigation districts in the San Joaquin River Basin and seven inactive ones. Their histories and statistics are given in detail in other publications.* Of the active districts, only four, the Alta, Modesto, Turlock and Tulare, were in existence prior to 1890. No additional districts were organized until 1909. The period of greatest activity in the formation of these districts was from 1915 to 1925. In 1920, fourteen districts were organized in the State nine of which are in the San Joaquin River Basin. Information on the active districts is given in Table 23.

Public Utilities—A public utility water company is usually a private corporation operating a water system and subject to the provisions of the public utilities act of California and the jurisdiction, control and regulation of the State Railroad Commission. The term also applies to any person, firm or private corporation, their lessees, trustees, receivers or trustees appointed by any court, owning, controlling, operating or managing any water system within the State which sells, leases, rents, or delivers water for compensation to any person, firm, private corporation, municipality, or any other political subdivision of the State. An exception is made in the case of a private corporation or association organized for the purpose, solely, of delivering water to its stockholders or members at cost. Such organization is not a public utility and is not subject to the jurisdiction, control and regulation of the State Railroad Commission. However, a contract water company that sells water to non-contract holders and mutual water companies, delivering water for compensation to others than members or stockholders, becomes a public utility and subject to the jurisdiction of the State Railroad Commission.

The Railroad Commission has power not only to fix rates but also to regulate substantially the entire activities of all public utilities. A public utility water company has no power to levy taxes or assessments against the area it serves, must stand ready to give service if called upon, and may not make any charge unless water service is ordered.

A list of the principal public utility water companies for which data are available in the San Joaquin River Basin, their sources of water supply, the county or counties in which they furnish service and the approximate areas irrigated are given in Table 24.

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* Bulletins No. 21, 21-A, and 21-B, "Irrigation Districts in California," Division of Engineering and Irrigation, and Division of Water Resources, State Department of Public Works.

TABLE 24

PUBLIC UTILITY WATER COMPANIES IN SAN JOAQUIN RIVER BASIN, 1929

Name of company	Source of supply	County in which water is served	Approximate area irrigated, in acres
Buena Vista Canal, Incorporated	Kern River	Kern	3,968
Central Canal Company	Kern River	Kern	632
East Side Canal Company	Kern River	Kern	6,053
East Side Canal and Irrigation Company	San Joaquin River	Merced	6,500
Farmers Canal Company	Kern River	Kern	2,890
Foothill Ditch Company	Kaweah River	Tulare	1,800
Kern Island Canal Company	Kern River	Kern	40,610
Kern River Canal and Irrigating Company	Kern River	Kern	2,276
Kings County Canal Company	Tule River	Tulare, Kings	1,203
Lone Oak Canal Company	Last Chance Ditch (Kings River)	Kings	2,000
Madera Canal and Irrigation Company	Fresno River	Madera	6,322
Pacific Gas and Electric Company	Stanislaus River	Tuolumne	1,050
Pioneer Canal, Incorporated	Kern River	Kern	1,908
San Joaquin and Kings River Canal and Irrigation Company, Incorporated	San Joaquin River	Fresno, Merced, Stanislaus	99,419
Stine Canal, Incorporated	Kern River	Kern	6,521
Utica Mining Company	Stanislaus River	Calaveras	466

Mutual Water Companies—A mutual water company, sometimes called "cooperative water company," is any private corporation or association organized for the purpose, solely, of delivering water to its stockholders or members at cost. The stock usually represents physical works and water rights entirely owned by those to be served. Mutual water companies are incorporated under the California statutes regulating the organization of private companies. Many of the mutual companies have been organized as land settlement enterprises. Usually the promoters of the enterprises build the irrigation systems, either wholly or in part, in advance of settlement, organize the mutual companies and issue shares of stock to settlers when the land is sold. In most cases, the settlers obtain control of the mutual company after 50 per cent of the stock has been issued. Some mutual companies have been organized by the landowners directly, working together for the development of a water supply and the construction of an irrigation system. Funds are raised by subscriptions to capital, by direct assessments of capital stock, by bonds and by small loans. In some companies, the stock is appurtenant to the land and may not be separated therefrom. In others, it may be transferred from one owner to another, independent of land ownership. Under this arrangement an irrigator may invest in as many shares as he needs, depending on the crops grown.

The affairs of mutual companies are controlled by a board of directors elected annually by the stockholders. The president is elected by the directors from one of their own number. As a rule the secretary keeps the books and records and computes and collects water charges. A superintendent usually is placed in charge of water delivery, operation and maintenance. A list of the principal organizations for which data are available, considered to be mutual water companies in the San Joaquin River Basin, their sources of supply, the approximate areas irrigated and the county or counties wherein the service areas lie are set forth in Table 25. These data have been obtained from public files, reports, and other available sources and are believed to be fairly reliable.

TABLE 25

MUTUAL WATER COMPANIES IN SAN JOAQUIN RIVER BASIN, 1929

Name of company	Source of supply	County in which water is served	Approximate area irrigated, in acres
Campbell and Moreland Ditch Company	Tule River	Tulare	675
Columbia Canal Company	San Joaquin River	Madera	16,000
Consolidated Peoples Ditch Company	Kaweah River	Tulare	15,500
Crescent Canal Company	Kings River	Fresno and Kings	2,894
Elk Bayou Ditch Company	Kaweah River	Tulare	5,637
Emigrant Ditch Company	Kings River	Fresno	4,500
Empire Water Company	Kings River	Kings	16,000
Evans Ditch Company	Kaweah River	Tulare	2,500
Farmers Ditch Company	Kaweah River	Tulare	8,000
Firebaugh Canal Company	San Joaquin River	Fresno	24,000
First Edison Well Company	Groundwater	Kern	412
Fleming Ditch Company	Kaweah River	Tulare	1,014
Freemont Irrigation Association	San Joaquin River	San Joaquin	649
Goshen Ditch Company	Kaweah River	Tulare	1,867
Hubbs and Mirer Ditch Company	Tule River	Tulare	1,059
Jacob Rancho Water Company	Lemoore Canal (Kings River)	Kings	11,013
Jennings Ditch Company	Kaweah River	Tulare	800
Lakeside Ditch Company	Kaweah River	Kings	19,750
Last Chance Water Ditch Company	Kings River	Kings	19,556
Lemon Cove Ditch Company	Kaweah River	Tulare	1,100
Lemoore Canal and Irrigation Company	Kings River	Kings	14,574
Liberty Canal Company	Kings River	Fresno	1,000
Liberty Mill Race Company	Kings River	Fresno	3,870
Lower Tule Water Users Association	Tule River	Tulare	4,259
Mathews Ditch Company	Kaweah River	Tulare	1,150
Melga Canal Company	Kings River	Kings	7,993
Merryman Ditch Company	Kaweah River	Tulare	1,680
Modoc Ditch Company	Kaweah River	Tulare	4,000
Oakes Ditch Company	Kaweah River	Tulare	1,000
Packwood Canal Company	Kaweah River	Tulare	3,000
Patterson Water Company	San Joaquin River	Stanislaus	14,000
Peoples Ditch Company	Kings River	Kings	23,400
Persian Ditch Company	Kaweah River	Tulare	3,500
Pioneer Water Company	Tule River	Tulare	3,012
Poplar Irrigation Company	Tule River	Tulare	3,192
Porter Slough Ditch Company	Tule River	Tulare	1,405
Poso Canal Company	San Joaquin River	Fresno and Merced	20,114
Reed Ditch Company	Kings River	Fresno	3,000
Rhodes and Fine Ditch Company	Tule River	Tulare	437
San Luis Canal Company	San Joaquin River	Merced	40,500
Settlers Ditch Company	Peoples Ditch (Kings River)	Kings	5,300
Second Edison Well Company	Groundwater	Kern	300
Stinson Canal and Irrigation Company	Kings River	Fresno	5,984
Tulare Irrigation Company	Kaweah River	Tulare	3,284
Uphill Ditch Company	Kaweah River	Tulare	1,900
Watson Ditch Company	Kaweah River	Tulare	2,900
Woods Central Irrigating Ditch Company	Tule River	Tulare	1,307
Wutchumna Water Company	Kaweah	Tulare	*7,446

* Exclusive of area in Lindsay-Strathmore Irrigation District.

Water Storage Districts—In general, the purposes of these districts are to store water for irrigation and to distribute water among the owners of lands within their boundaries, in accordance with such priorities in right to water, between the different consumers, as may legally exist. Water storage districts are formed by petition to the State Engineer, rather than to county supervisors, as is the case with irrigation districts. For purposes of carrying out the water storage district act, the Governor is authorized to name two executive directors to assist the State Engineer. A petition for formation must be signed by a majority in number of the holders of title or evidence of title to lands already irrigated, or susceptible of irrigation from a common source and by the same system of storage and irrigation works, and representing a majority in value of said lands; or the petition may be signed by not less than 500 holders of title or evidence of title to lands therein, representing not less than 10 per cent in value of all the lands within the proposed district. The State Engineer determines the practicability, feasibility and utility of the proposed project set forth in such petition. After a hearing by the State Engineer, the matter of organization is submitted by him to an election for majority approval, at which only the holders of title or evidence of title to lands within the district are entitled to vote. The construction of works by a water storage district and the management of the district are under the direction of a board of directors, who have the powers necessary to carry out the purposes of the water storage district act, and may submit propositions relating to the project to the qualified electors at any general or special election. During the construction of works, reports must be filed with the State Engineer.

Four water storage districts have been formed in California, all in the San Joaquin River Basin: San Joaquin River Water Storage District, Kern River Water Storage District, Buena Vista Water Storage District and Tulare Lake Basin Water Storage District. In the case of the San Joaquin and Kern River districts, the objective in organizing was to equitably adjust water rights on San Joaquin and Kern rivers, and to bring about more economic utilization of run-off through the construction and operation of storage reservoirs. The plans of these districts were not consummated. Both were dissolved by due legal process in 1929.

Tulare Lake Basin Water Storage District includes a gross area of 192,730 acres of which 11,520 acres are set aside for reservoir purposes, leaving a net assessable area of 181,210 acres. About 162,000 acres are classed as irrigable, although portions of this area are subject to overflow during years of excessive run-off. The water supply is received from surplus flows of Kings, Kaweah, Tule and Kern rivers. The district includes about twenty reclamation districts and also the Lakeland Irrigation District. With the exception of a small area which projects into Tulare County, north of Alpaugh, the entire district is located in Kings County.

Buena Vista Water Storage District embraces land receiving water from Kern River at the, so-called, "Second Point of Measurement," which is below diversions of the various canals that supply the main portion of Kern River Delta, in the vicinity of Bakersfield. The district boundaries encompass Buena Vista Lake, containing 25,459 acres. This lake, partly used as a storage reservoir and partly farmed, is owned by Buena Vista Reservoir Association, in which Miller and Lux, Inc., hold an 84 per cent interest. The irrigable area in the district, over which assessments have been spread, is 50,405 acres.

Reclamation Districts—Although reclamation districts in California have been formed primarily for the purpose of constructing works to reclaim swamp and overflow lands, some of these districts also have constructed irrigation works. The reclamation district law authorizes the trustees to include in their plans of development such works as may be necessary for irrigation, and gives them the power to adopt rules and regulations for the distribution of water and the establishment and collection of water tolls. In most cases, irrigation within reclamation districts is carried on by individual land owners. However, in some instances the areas are served by mutual water companies.

In other instances, lands in the reclamation district receive irrigation service from irrigation districts. These lands may or may not lie within the irrigation district boundaries. There are many small reclamation districts within the Tulare Lake Water Storage District and on the lower Kings River in Fresno and Kings counties, which are served by that district and organized irrigation districts with flood waters from the Kings, Kaweah and Tule rivers. In the Sacramento-San Joaquin Delta, many of the reclamation districts operate irrigation works. District 2075 (McMullen), organized in 1927 and containing a gross area of 5930 acres, is the only reclamation district in the San Joaquin Valley, above the San Joaquin Delta, operating irrigation works as a district. Water is diverted from the Stanislaus and San Joaquin rivers by means of two main pumping plants, one on each stream.

Water Conservation Districts—There are two laws or statutes in California relating to the organization of water conservation districts. The first of these, known as the "California Water Conservation District Act," was approved in 1923 and amended in 1925 and 1927. This act was drafted primarily to organize the various groups which obtain water from Kings River, for the purpose of storing water on Kings River at the Pine Flat reservoir site, and incidentally for accomplishing an adjustment of the complicated water right situation on that stream. The second act, known as the "Water Conservation Act of 1927," was drafted in the interest of various irrigation companies and irrigators obtaining water from Santa Clara River, in Ventura County, and relates largely to the conservation of water by spreading.

A petition proposing the formation of the Kings River Water Conservation District was filed with the State Engineer June 12, 1924, and an order establishing the sufficiency of that petition was issued July 16, 1924. The principal activity of this district, to date, has been in connection with the establishment of the Kings River water right agreement and monthly diversion schedule. This schedule covers direct-flow rights to Kings River water and its distribution. A second schedule, covering storage rights, is part of the proposed program. The interested irrigation districts and other organized agencies, acting largely through the Kings River Water Association, have made studies pertaining to storage development at Pine Flat.

The Kaweah Delta Water Conservation District was formed for the purpose of conservation and preservation of the underground waters of the Kaweah Delta, together with their sources of supply. The district was organized in 1927 and embraces an area of 259,360 acres in Tulare County and 83,000 acres in Kings County. It is made up of several smaller protective associations, two of which, the St. Johns River Association and the Kaweah River Association, include the Tulare Irrigation District.

County Water Districts—These districts are formed under an act approved June 30, 1913, to which amendments have been made by succeeding legislatures. A large number of such districts have been formed in the State, but mainly for securing domestic water supplies. They are not subject to State supervision and are formed by petition to the county supervisors. Bonds may be issued, when authorized by more than a two-thirds vote of the resident electors, as qualified under the general election laws of the State.

The Stevinson County Water District, located in Merced County at the confluence of the Merced and San Joaquin rivers, was organized in 1930, for the purpose of distributing irrigation water from the San Joaquin River and Deadman, Duck, Owens and Bear creeks and Merced River water to be diverted through the works of the Merced Irrigation District. It includes a small portion of the land now served by the East Side Canal and Irrigation Company, a public utility, and adjacent areas bordering on the San Joaquin and Merced rivers. The total area included in the district is about 7500 acres. Negotiations are now pending for the acquisition of the East Side Canal by the district, together with all right, title and interest of the East Side Canal and Irrigation Company to divert waters of the San Joaquin River and its tributaries, and the waters of several creeks and spillways discharging water from the Merced Irrigation District into the East Side Canal.

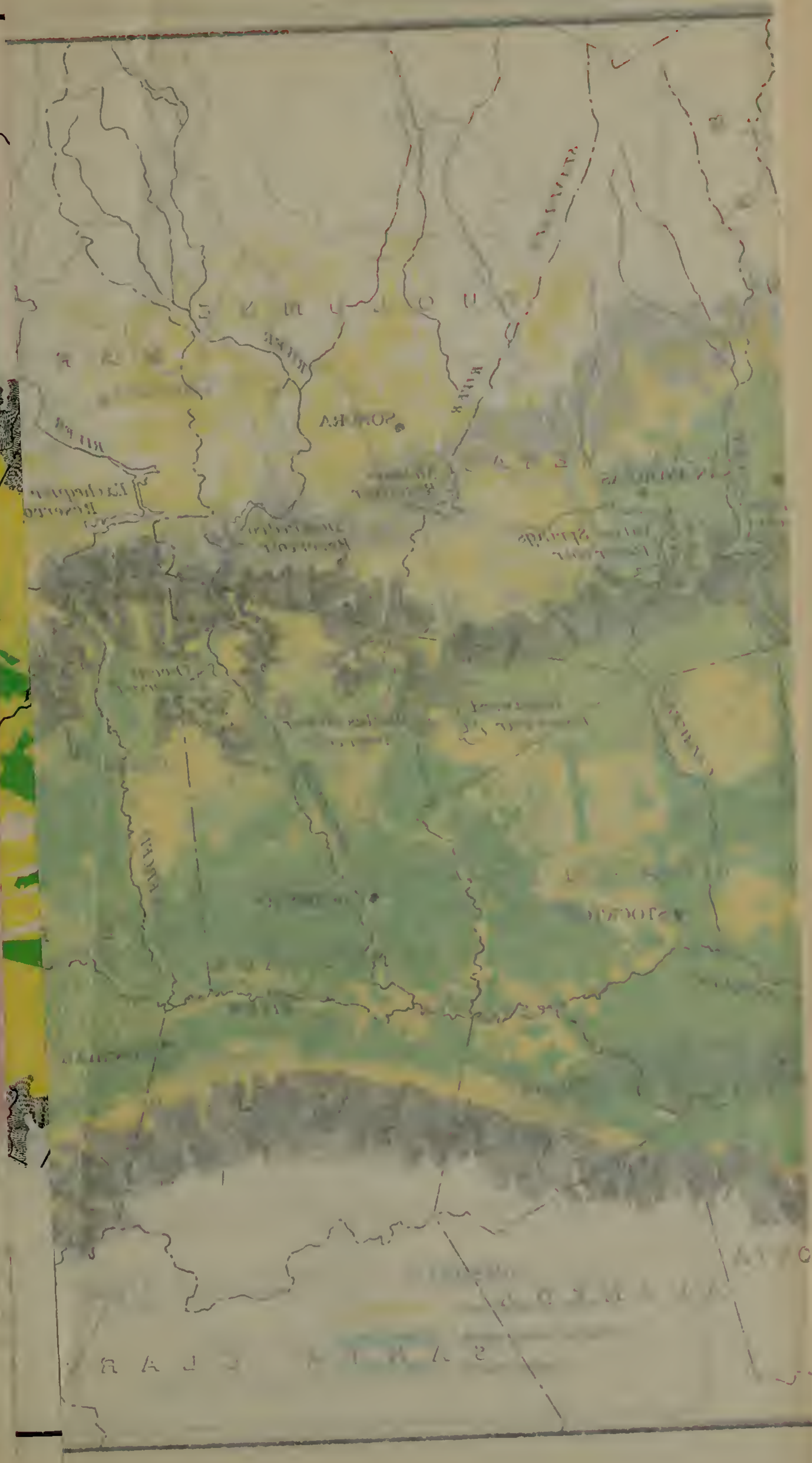
Individual and Private Companies—In many cases, individuals, or companies who farm land outside of an organized area, or who have an adequate water supply independent of organized agencies, divert irrigation water from streams by gravity or by pumping, or pump ground water for the irrigation of their own lands.

General Location and Extent of Irrigation Development.

On Plate VII, "Agricultural Lands and Areas Under Irrigation in the San Joaquin Valley and Adjacent Foothills," the total area of agricultural land is shown in yellow and the portion under irrigation development in green. In addition to the areas shown as being under irrigation development, certain lands are used for dry farming. In the San Joaquin Valley, with a small normal rainfall, such farming is confined chiefly to grain.

An inspection of Table 20, in Chapter III, discloses that, of the total area of 2,824,400 acres cropped in 1929, 596,500 acres or 21 per cent were dry farmed. Of the total 2,227,900 acres of irrigated crop lands shown in the table, 1,026,100 acres lie in the lower San Joaquin Valley and adjacent foothills, including delta lands in Contra Costa and San Joaquin counties, but excluding areas in El Dorado and Sacramento counties. The water tributary to this portion of the basin is adequate to support the existing development. The main streams are regulated by storage reservoirs and the lands are adequately served. With these conditions of plentiful water supply, the tendency in the lower San Joaquin Valley is for the irrigated crop areas to increase slightly, year by year. Therefore, it is believed that the figure given for the irrigated lands in the lower San Joaquin is probably the maximum that has been irrigated at any time.

In the upper San Joaquin Valley, the irrigated area, in 1929, was 1,201,800 acres. This total is made up of lands served by surface diversion only, those served by pumping plants only and lands served by both these classes of supply. Due to the low run-off of the 1928–29 season, the irrigated areas for the upper San Joaquin Valley are somewhat below the average. None of the streams, tributary to this portion of the basin, are regulated by surface irrigation storage and the limit of utilization of their surface run-off, under existing diversion



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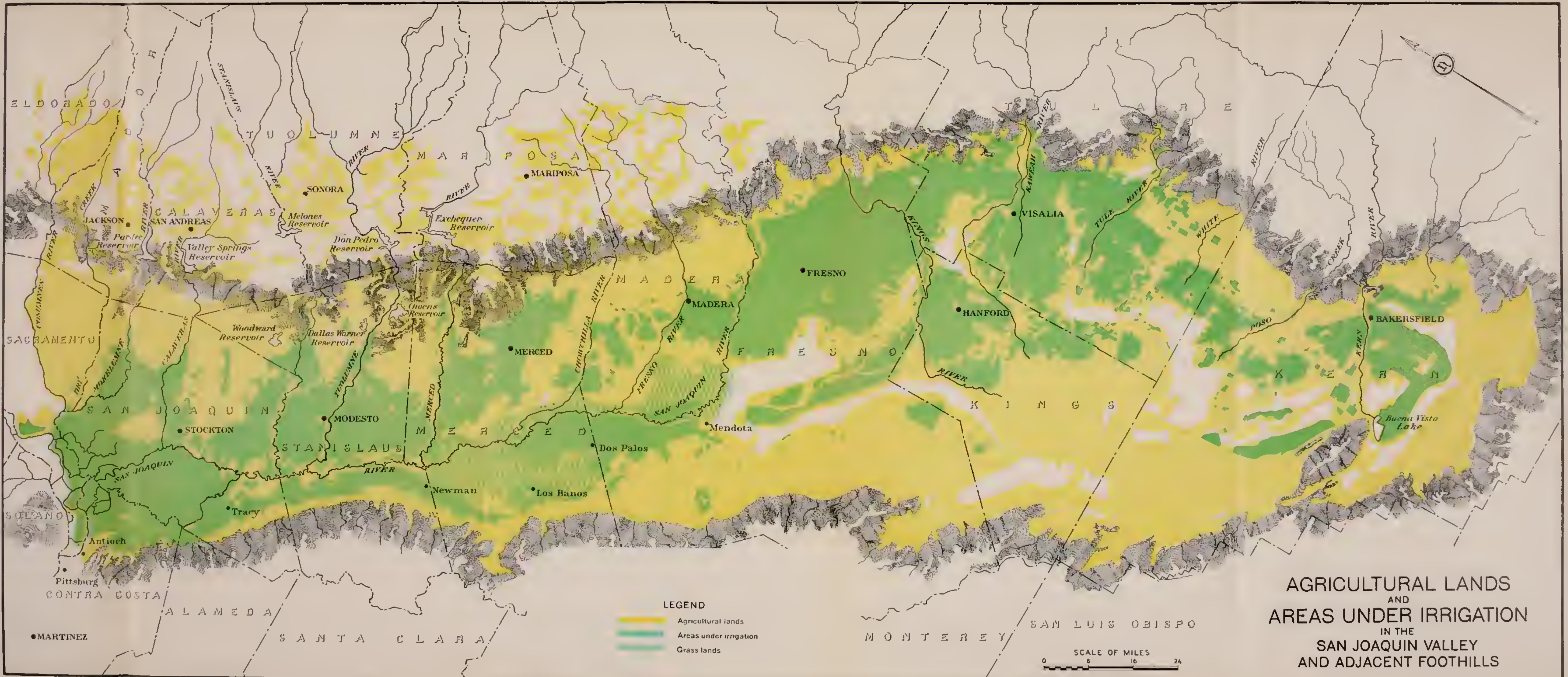

AGRICULTURAL LANDS
AND
AREAS UNDER IRRIGATION
IN THE
SAN JOAQUIN VALLEY
AND ADJACENT FOOTHILLS
LEGEND
Agricultural lands
Areas under irrigation
Grass lands
SCALE OF MILES
0 8 16 24
ELDORADO
AMADOR
TUOLUMNE
MARIPOSA
CALAVERAS
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
MADERA
FRESNO
TULARE
KINGS
KERN
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
SONORA
MARIPOSA
JACKSON
SAN ANDREAS
Melones Reservoir
Exchequer Reservoir
Don Pedro Reservoir
Pardee Reservoir
Valley Springs Reservoir
Woodward Reservoir
Dallas Warner Reservoir
Owens Reservoir
MERCED
MADERA
FRESNO
HANFORD
VISALIA
BAKERSFIELD
Buena Vista Lake
STOCKTON
MODESTO
Mendota
Dos Palos
Los Banos
Newman
Tracy
Antioch
Pittsburg
MARTINEZ
SAN JOAQUIN RIVER
KINGS RIVER
KAWEAH RIVER
TULE RIVER
WHITE RIVER
POSO CREEK
KERN RIVER
FRESNO RIVER
CHOWCHILLA RIVER
MERCED RIVER
TUOLUMNE RIVER
STANISLAUS RIVER
CALAVERAS RIVER
MOKELUMNE RIVER
DRY CREEK
COSUMNES RIVER

rights, has long since been reached. The cropped land, irrigated solely from surface diversion, varies through wet and dry periods. This is particularly true where lands are in large holdings, as has been the case in Division 1 of this area. On the other hand, the extent of irrigated areas, entirely dependent upon a supply pumped from ground water, has been increasing rapidly even though the water levels underlying these areas have been steadily receding. It is estimated that the acreage so served in 1929 is the maximum of record.

The difference in conditions of present irrigation development, in the upper and lower parts of the San Joaquin Valley, makes a separate discussion of each section essential. In the remainder of this chapter the discussion and maps have been separated into two parts. The first of these deals with the upper San Joaquin Valley, using the same area as that used in Chapter III in discussing agricultural lands. This extends from Chowchilla River on the east side and Mendota on the west side south to the upper limit of the valley. The area from this division northward to the delta and Sacramento Valley areas is discussed under the heading of the lower San Joaquin Valley.

UPPER SAN JOAQUIN VALLEY

Location of Present Irrigation Development.

Practically all present irrigation development is on the east side of the valley and within the valley floor. Water supplies from west side tributaries are inadequate to serve any large area, and ground water is limited in amount and uncertain in quality. Some water from east side tributaries is diverted across the valley trough to lower west side areas along Kern and Kings rivers.

The southern portions of the Sierra Nevada do not contain the same character and extent of foothill lands as occur in the portions adjacent to the lower San Joaquin and Sacramento valleys. The topography is more rough and the soils generally of less depth. There are few mountain valleys of sufficient extent to require consideration in studies of water supplies. The South Fork Valley on Kern River is an exception to this general statement. There are areas of older geologic valley formation, extending from Kern River northward to the vicinity of Porterville, between the valley floor and main mountainous areas, which contain some agricultural lands. These areas, however, have practically no locally tributary water supplies and extend to elevations too great to be considered for service from canals in the valley area. Other cultivated areas, within the foothills, are limited to generally narrow bottom lands along the streams. Broad ridges of tillable land, such as are found in the foothill fruit producing areas further north, do not occur in this general area.

Present Storage.

There are no existing surface reservoirs for irrigation on the streams of the upper San Joaquin Valley, except the relatively unimportant storage in the valley trough on Kern and Kings rivers. Buena Vista Lake stores surplus flood waters of Kern River, for use on lower lands served from that stream. This reservoir is below the main irrigated area on Kern River. Tulare Lake is the depression south of the ridge built across the valley by Kings River, upon which its flow divides, part running north through Fresno Slough to the San Joaquin River and part south to Tulare Lake. Partial reclamation by levees in Tulare Lake restricts the area of overflow, under normal inflow, to smaller areas than those naturally subject to inundation. Water stored in Tulare Lake is used only on adjacent lands below the main areas served from Kings River.

Aside from a relatively small amount on Kaweah River, the existing power storage in the upper San Joaquin Valley is entirely on the San Joaquin River. Much of the water released from this power storage is available for irrigation in the lower San Joaquin Valley. This storage system consists of the reservoirs of the Southern California Edison Company on Big Creek and South Fork, and those of the San Joaquin Light and Power Corporation on the North Fork, comprising a total present constructed capacity of 334,000 acre-feet.

Growth of Irrigated Area.

The growth of irrigation in this area, as a whole, is indicated by the census returns which have been reported by counties, although the county lines do not correspond exactly with the area of the upper valley. The returns for Kern, Tulare, Kings, Fresno and Madera counties represent approximately the area of the upper valley, except that the figures for Fresno and Madera counties include relatively small acreages in the lower San Joaquin Valley. The available data are shown in Table 26. Due to the low seasonal run-off in 1928–29, the figures for irrigated areas tabulated for 1929 are somewhat below the average, as extensive areas normally flooded for pasturage and annuals received no water. The tabular figures indicate the general progress of development. For individual years the acreage is influenced by the volume of run-off, which controls largely the extent of area flooded for pasturage, grain and other annuals.

For the special census of 1902 and the regular censuses of 1919 and 1929, data on irrigated areas have been segregated by stream sources and are shown in Table 27.

TABLE 26

GROWTH OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY BY COUNTIES

County	Area irrigated, in acres				
	From U. S. census of				State crop survey
	1899	1909	1919	1929	1929
Kern	112,533	190,034	223,593	180,106	201,600
Tulare	86,854	265,404	398,662	410,683	316,900
Kings	92,794	190,949	187,868	269,994	138,000
Fresno	283,737	402,318	547,587	533,992	501,800
Madera	23,152	38,705	100,220	140,637	83,300
Totals	599,070	1,087,410	1,457,930	1,535,412	1,241,600

TABLE 27

GROWTH OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY BY STREAM BASINS

Data from U. S. Census reports

Stream	Area irrigated in acres		
	1902	1919	1929
Kern River	116,189	200,641	163,241
Tulare Lake	(1)	70,134	39,804
Tule River	(1)	61,223	74,069
Kaweah River	(1)	149,932	222,363
Kings River	596,091	552,601	742,282
Fresno River	10,729	12,414	17,640
Totals	723,009	1,046,945	1,259,399

[1] Not reported separately; included with Kings River.

Information on the use of underground water in the upper San Joaquin Valley is also available from the census returns. Data are available for the years 1919 and 1929 on the capacities of flowing and pumped wells and are set forth in Table 28. These data clearly indicate the rapid growth of pumping in that region and the decrease in capacities of artesian wells through expansion in the use of underground water.

TABLE 28

CAPACITY OF WELLS IN UPPER SAN JOAQUIN VALLEY, FOR 1919 AND 1929, BY STREAM BASINS

Data from U. S. Census reports

Stream	Flowing wells, capacity in gallons per minute		Pumped wells, capacity in gallons per minute	
	1919	1929	1919	1929
Kern River	13,850	1,475	219,674	893,789
Tulare Lake	8,253	0	434,565	48,735
Tule River	251	0	493,272	565,316
Kaweah River	17	0	842,085	1,884,312
Kings River	10,000	950	1,183,710	5,698,807
Fresno River	200	0	79,255	162,675
Totals	32,571	2,425	3,252,561	9,253,634

The aggregate capacity of the flowing and pumped wells in 1919, for the whole area, was about 7300 second-feet or 440,000 acre-feet per month, if operated continuously. The corresponding values for 1929 were 20,600 second-feet and 1,240,000 acre-feet, respectively. The capacity figure, of 440,000 acre-feet per month for 1919, is about equal to the average total stream flow in June for the major streams south of San Joaquin River for the 10-year period, 1919–1929, and the capacity figure 1,240,000 acre-feet per month for 1929 is about three times that stream flow. The capacity figure for 1919 is about four times and that for 1929 about twelve times the average stream flow for July and August for the same period. These figures indicate the dependence of the upper San Joaquin Valley on ground water for its present development.

Present Irrigated Crops.

A comprehensive survey of the extent and character of crops irrigated in this area was made in 1929 as a part of the investigations on which this report is based. The results for local areas are presented with the description of the details of each local area. For the entire area of the upper San Joaquin Valley, the results of this survey of irrigated crops are summarized in Table 29. Due to the low run-off of the season 1928–29, the irrigated acreages given in the tabulation are somewhat below the average.

TABLE 29

IRRIGATED CROPS IN UPPER SAN JOAQUIN VALLEY, 1929

Crop	Area irrigated in 1929, in acres
Citrus	41,600
Deciduous and olives	122,600
Grapes	349,700
Grain	64,300
Alfalfa	174,200
Field	123,000
Cotton	212,500
Irrigated pasture	62,900
Truck	6,500
Rice	1,000
Unclassified	43,500
Totals	1,201,800

The data in the foregoing table illustrate the wide variety of crops which are produced in the upper San Joaquin Valley. Agricultural practice varies from the highest types of citrus culture to the crude overflow pasture area. Practice has been adjusted to the varying climatic, soil and water supply conditions of the different parts of the area. Citrus fruits are grown along the eastern edge of the valley on areas high enough to be relatively free from frost. Such areas extend southerly from the Kings River area, but the development is not continuous. The necessary favorable conditions of soil, temperature and water supply are not present in all parts of the area. The largest citrus developments occur adjacent to the eastern foothills, from the Kings River south to Deer Creek. Grape vineyards are prevalent throughout the area. They are devoted to the culture of raisin, wine, and table varieties. A large percentage of the raisins produced in the United States is grown in this area. Deciduous fruits comprise nearly all of the commercial varieties, including peaches, apricots, prunes and figs. Alfalfa is grown both for local use, largely in dairying, and for shipment. The long growing season results in large yields, where an adequate water supply is available. A wide variety of annual crops is produced. In 1929, cotton was the irrigated annual crop of largest acreage. The area in cotton varies with price conditions and has declined since 1929. Truck crops are grown more extensively in the southern portion of the area which is nearer to the Los Angeles market. Grain is irrigated in areas of uncertain water supply, when water is available, as it is better adapted to such conditions of irregular service than other crops. It is extensively grown in Tulare Lake Basin. In addition to the area of irrigated grain shown in Table 30, there were

319,000 acres of dry farmed grain in the upper San Joaquin Valley in 1929.

Ground Water Conditions.

While little surface storage for irrigation has been constructed in this area, extensive use has been made of ground water storage. For the conditions existing in many parts of the area this has been an economical type of development.

Prior to the settlement of the valley, all of the tributary water supply either ran off through existing channels or overflowed on adjacent lands. Drainage to the lower valley was retarded by the barrier built by Kings River, and run-off from streams south of the Kings could reach the San Joaquin River only after filling Tulare Lake. Run-off was dissipated by evaporation from Tulare Lake or other water areas, by transpiration of the tule and grass growths on overflowed lands and, in years of extremely large run-off, by overflow to the north into the San Joaquin River. Kern River built a smaller ridge at the southern end of the valley with two depressions on its south side, Kern and Buena Vista lakes, which functioned for Kern River similarly to Tulare Lake for Kings River. The only ground water records for this period are general in character. Lands near streams and overflow areas had generally high ground water. Areas back from streams generally had depths to ground water greater than the limits of plant use. Illustrations of this are the depths of 50 to 60 feet to ground water near Fresno and similar depths at Rosedale and other areas north of Kern River. Absorption from higher overflow areas or stream channels reached lower areas under confining strata and resulted in artesian pressures in the valley trough. Such artesian areas extended into the lower portions of the stream deltas.

Following the construction of canal systems into areas away from stream channels, artificial sources of ground water were made available. Seepage from canals and percolation from lands resulted in raising the ground water until, in many areas, it came within reach of the crop roots and close enough to the ground surface to result in water logging and alkali concentrations. Such injured lands generally reverted to pasture use.

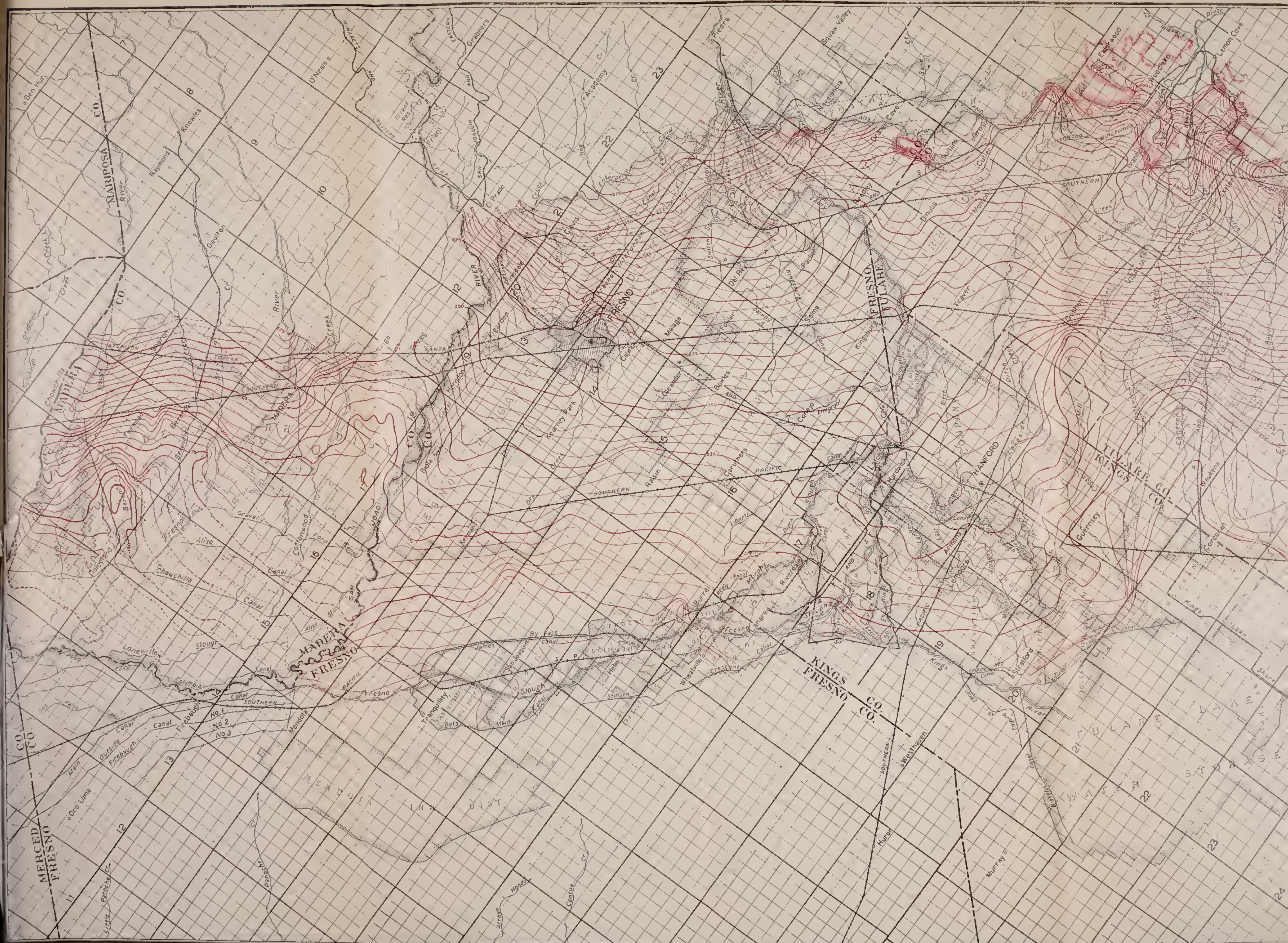
When surface diversions had utilized the available stream flow, ground water developments were begun. Among the earlier developments were attempts to use artesian flow near Semitropic, in Kern County, and pumping for citrus orchards near Lindsay. The loss of artesian pressure and difficulties with soils resulted in a general decline of pumping near Semitropic. The limited local replenishment, in the area near Lindsay, resulted in lowering and change in quality of the ground water, so that it became necessary to seek an outside water supply. The demand for land, in the period from 1900 to 1910, resulted in the undertaking of pumping from wells in many parts of the area. Such developments waited until land values had increased to a point where pumping costs could be supported. Electric power became available for pumping and the growth of ground water use has been continuous to date. Pumping plants have been installed in areas having no surface supply and in canal-served areas for supplemental use.

The extension of pumping in recent years has altered ground water conditions in many irrigated areas. Instead of losses from canal use causing an injuriously high ground water table, pumping drafts have exceeded replenishments and recessions have occurred. Recessions in some areas have been of benefit in supplying needed drainage. In areas of inadequate surface supplies, the draft has exceeded the replenishment and progressive recession is taking place. Such recession increases the pumping lift and costs. The subnormal run-off of recent years has aggravated this condition. In areas dependent entirely on pumping and without active local sources of ground water supply, the success obtained from the operation of the earlier plants has resulted in stimulating additional development until overdraft has occurred. The resulting recession has proceeded in some areas to a point where the cost of the increased pumping lifts exceeds the value of the use on some crops.

The conditions vary so widely in the different local areas that generalizations or averages are of limited assistance only in studying the problems of the upper San Joaquin Valley. A study of ground water conditions in each local area is necessary for a determination of present needs. It is also necessary for the formulation of any plans for the relief of present overdrafts, as ground water storage is an essential part of the plans for such relief. For the purpose of making this study, the area under consideration has been subdivided into smaller areas, designated as ground water units. The boundaries of these units were determined by local conditions of influence upon ground water. The analyses and conclusions regarding amounts of deficiencies are given in Chapter VIII. In the following discussion the records and results regarding past experience in the use of ground water are described, because they are more conveniently discussed with the descriptions of the canal systems in the different local areas. Some features regarding ground water conditions of the valley can be shown for the area as a whole. This has been done on general plates. Other features, applicable to local areas only, are shown on plates described with the discussions of such local areas or units.

Plate VIII, "Lines of Equal Elevation of Ground Water Table in Upper San Joaquin Valley, Fall of 1929," is based on measurements on about 1700 wells distributed throughout the area. Lines of equal elevation shown in red are referred to U. S. G. S. datum. This plate indicates the direction and rate of ground water slope for the area as a whole. The general ground water slope is from the east side of the valley toward the valley trough. Ground water cones are built up under the deltas formed by some of the streams. The effect of excessive ground water draft in some local areas is shown in the resulting ground water depressions.

Sufficient data were not available to plot lines of equal elevation for the Tulare Lake area, which is here used to include the total area of the Corcoran and Lakeland districts and the Tulare Lake Water Storage District, served by water diverted from the Kings, Kaweah and Tule rivers, mainly at high stages. Ground water supplies in this area are obtained mainly from the deeper strata and artesian wells formerly were obtainable. The formation is considered relatively nonabsorptive and a definite natural barrier along the eastern rim seems



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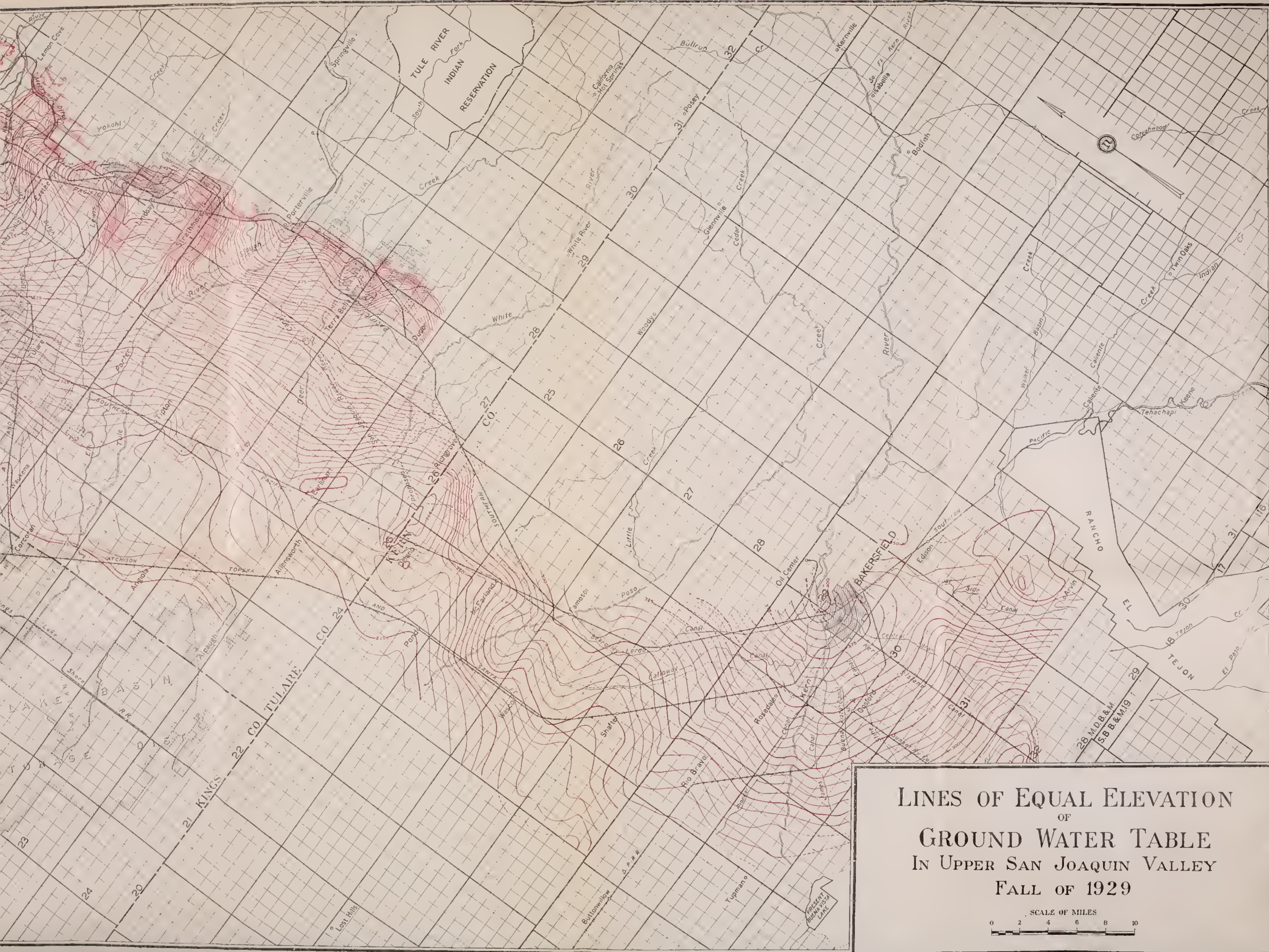
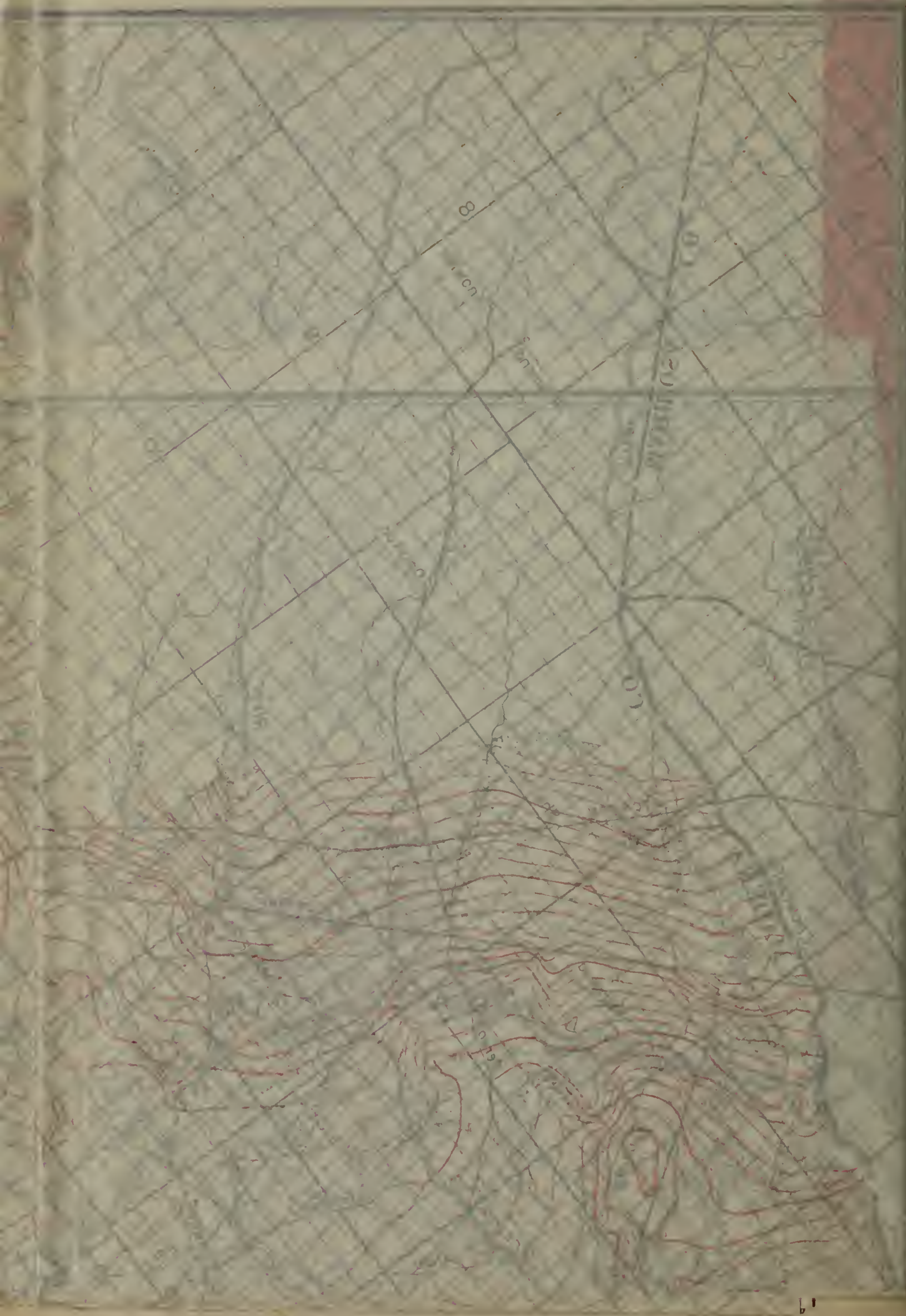
Kearney Park
Malaga
Oleander
Bowles
Caruthers
Raisin
Kerman
Burrel
Riverdale
Laton
Hardwick
Lemoore
Armona
Kingsburg
Selma
Del Rey
Parlier
Sanger
Reedley
Dinuba
Traver
Orosi
Cutler
Sultana
Squaw Valley
Lemon Cove
Woodlake
Elderwood
Goshen
Guernsey
Corcoran
Waukena
Stratford
Tranquillity
Firebaugh
Mendota
Oro Loma
Dos Palos
Huron
Westhaven
Murray
Dairyland
Berenda
Chowchilla
San Joaquin
Kings River
Fresno Slough
SOUTHERN PACIFIC
SANTA FE
Canal
Slough


LINES OF EQUAL ELEVATION
OF
GROUND WATER TABLE
IN UPPER SAN JOAQUIN VALLEY
FALL OF 1929
SCALE OF MILES
0 2 4 6 8 10
TULE RIVER
INDIAN
RESERVATION
BAKERSFIELD
RANCHO
EL
TEJON
TULARE CO.
KINGS CO.
KERN CO.
28 M.D.B.&M.
S.B.B.&M. 19
Lemon Cove
Springville
California Hot Springs
Posey
Kernville
Isabella
Bodfish
Glennville
White River
Porterville
Strathmore
Terra Bella
Ducor
Tipton
Corcoran
Angiola
Allensworth
Richgrove
Delano
McFarland
Famoso
Wasco
Shafter
Rosedale
Oil Center
Edison
Arvin
Caliente
Keene
Tehachapi
Twin Oaks
Rio Bravo
Buttonwillow
Tupman
Lost Hills
PRESENT BUENA VISTA LAKE



to resist ground water movement into the area from the east. The depth to ground water in a few scattered wells measured in 1929 was about 100 feet, as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta.

Among the areas in which the result of excessive ground water draft is shown on Plate VIII are the Edison and Arvin areas, the marked cone of depression near Delano, the smaller cone at Earlimart, the extensive cone surrounding Lindsay and small local depressions in the Madera area. Other areas, in which the draft has resulted in ground water lowering, without having as yet resulted in a closed cone of depression, are in the vicinity of Shafter, Wasco and McFarland in Kern County, west of Tulare and Goshen, within the city of Fresno and in parts of the Madera Unit.

The effect of stream flow in building up the adjacent ground water is illustrated by the ground water contours near Kern River and in the upper portions of Tule and Kaweah deltas. Ground water slopes toward Kings River where it is in a depressed channel through Centerville Bottoms. Below Kingsburg the river is on a slight ground water ridge. The San Joaquin River where it enters the valley flows in a relatively deep channel. On the south side of the river, irrigation in the Fresno Irrigation District with surface supplies from the Kings River has resulted in a ground water table sloping toward the river. On the north side, pumping without canal service in the Madera area has resulted in a slope away from the river.

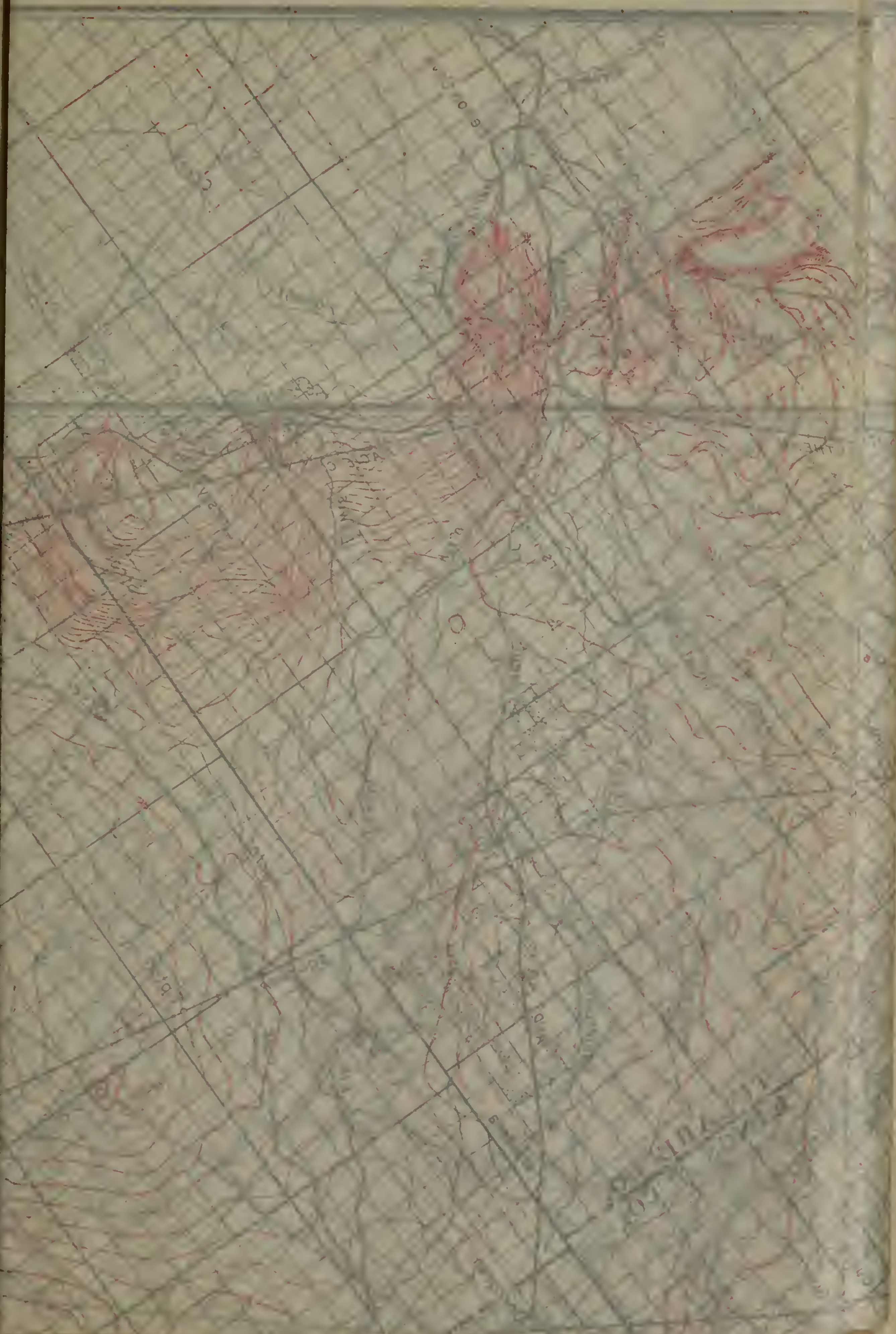
Plate IX, "Lines of Equal Depth to Ground Water Table in Upper San Joaquin Valley, Fall of 1929," shows the difference in elevation between the ground water contours delineated on Plate VIII and the ground surface. These lines are shown in red. The depth to ground water as shown on the plate plus the drawdown while pumping would represent the total pumping lift to ground surface at a particular location. The drawdown during pumping depends on the tightness of the water bearing materials and the rate of pumping draft. For the usual rates of pumping, drawdowns in the more open materials vary generally from ten to 25 feet and for the finer materials drawdowns of from 25 to 50 feet may occur. Plate IX also brings out the effect of excessive pumping on the depth to ground water. Like Plate VIII it is based on measurements of about 1700 wells. While the depth increases from the valley trough toward the eastern side of the valley, local increases in depth are shown in areas of heavy pumping draft away from direct sources of water supply. The rapid increase in depth to ground water in the Arvin area is due to the rise in ground elevation over a relatively flat ground water slope. The same conditions occur in the higher valley areas north of Kern River and in southern Tulare County. The effect of canal service in maintaining a relatively high ground water table is shown in the main canal served areas on Kern and Kings rivers where depths of from five to ten feet occur over large areas, with additional areas having depths of from ten to 20 feet. These relatively shallow depths, shown on Plate IX for 1929, obtain immediately following a series of years of less than normal run-off. Similar lines for 1921 would show much larger areas having ground water within ten feet of the ground surface. The effect of heavy pumping draft in increasing the pumping lift is shown clearly for areas in the vicinities of Delano, Lindsay, Tulare, Goshen and south of Madera and west of Chowchilla. The depth to ground water in these areas is greater than that in similar adjacent areas of smaller pumping draft.

Plate X, "Lines of Equal Total Lowering of Ground Water Table in Upper San Joaquin Valley, 1921–1929," shows the total lowering of ground water that has occurred in the eight-year period for those parts of the area for which records are available. These lines of equal total lowering, shown in red and based on measurements on wells varying in number from about 900 in 1921 to about 1700 in 1929, were interpolated from differences in elevation of ground water estimated for each section corner from the 1921 and 1929 ground water elevations. This plate brings out, even more forcibly than Plates VIII and IX, the large variation in lowering in different areas. The amount of lowering is generally proportional to the distance from direct sources of ground water supply and the extent of pumping draft. Maximum lowering of 85 feet is shown for the Lindsay area which is distant from sources of supply and with large areas irrigated by pumping. Lowering of 70 feet is shown at Delano. The lowering for other areas of heavy pumping draft varies generally from 25 to 50 feet where no direct sources of water supply are available. In other areas of extensive pumping which have direct sources of water supply, such as the areas under the upper Kings River canals, parts of the Kaweah Delta and the main canal served areas on Kern River, lowering of from five to ten feet has occurred. Although the stream flow for the period, 1921–1929, has been below normal, there are some areas in which no lowering has occurred. These are relatively small in extent, however, and occur along stream channels.

On Plate XI, "Zones of Variation in Depth to Ground Water, San Joaquin Valley, Fall of 1929," are shown by zones, the depth to ground water, between given limits, in both the upper and lower San Joaquin valleys. Areas having depths of less than ten feet are generally adjacent to streams or in canal served areas where little pumping for irrigation is practiced. Depths to ground water are generally less in the lower San Joaquin Valley than in the upper. Much of the canal served area in the upper San Joaquin Valley has depths of from ten to 25 feet. Outside of the canal served areas, depths are generally from 50 to over 200 feet.

Ground water profiles and hydrographs of the records of fluctuation of typical wells have been prepared. The locations of these profiles and wells are shown on Plate XII, "Key Map Showing Boundaries of Ground Water Units and Locations of Profiles and Typical Record Wells, Upper San Joaquin Valley."

Plate XIII, "Profiles of Water Levels in Ground Water Units of Upper San Joaquin Valley Along Line X-X, 1921 and 1929," shows the general ground surface and ground water levels through all ground water units from Chowchilla River to the vicinity of Arvin. This plate also illustrates the varying effect of factors of draft and supply. In general, the ground water is close to the ground surface near the main stream channels and has shown little lowering in their vicinity during the eight-year period. This is well illustrated in the Madera

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TULARE CO.
KINGS CO.
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VISALIA
Ben Hur
O'Neals
Academy
Knowles
Raymond
Daulton
Sharon
Trigo
Gregg
Grabners
Friant
El Prado
Clovis
Piedra
Squaw Valley
Navelencia
Orange Cove
Sultana
Reedley
Dinuba
Cutler
Monson
Elderwood
Woodlake
Lemon Cove
Yokohl
Seville
Del Rey
Sanger
Malaga
Oleander
Bowles
Kearney Park
Kingsburg
Selma
Caruthers
Raisin
Kerman
Biola
Herndon
Madera
Chowchilla
Fairmead
Berenda
Dairyland
Cottonwood
Tranquility
Helm
Stinson
Wheatville
Riverdale
Lanare
Grangeville
Armona
Lemoore
Stratford
Goshen
Traver
Elbow
Guernsey
Corcoran
Waukena
Westhaven
Huron
Murray
Mendota
Firebaugh
Oro Loma
Kings
Tulare
Lake
Deep
Creek
River
Canal
Slough
SOUTHERN
PACIFIC
ATCHISON
SANTA FE
By-Pass
James
San Joaquin
Fresno
Crescent
Chowchilla
Lonewillow
Columbia
Outside
Main
No. 1
No. 2
No. 3
Dos Palos
Panoche Cr.
Little Panoche Cr.
Arroyo Hondo
Cantua Cr.
Alta
Enterprise
Gould
Fresno
Interurban
Mill
Elk
Bayou
Cameron
Packwood
St. Johns
Farmersville
Levis
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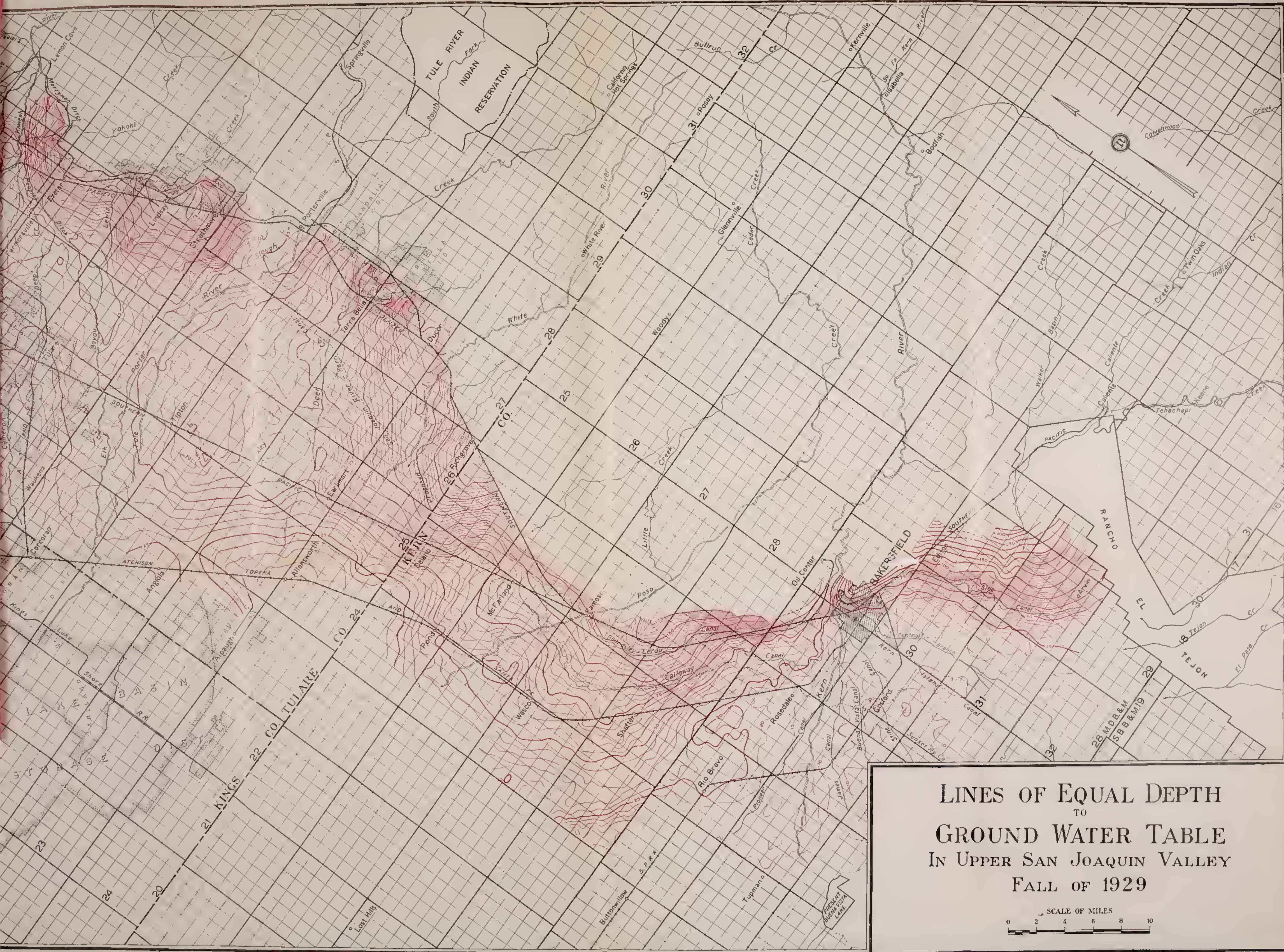

Lines of Equal Depth to Ground Water Table in Upper San Joaquin Valley Fall of 1929

SCALE OF MILES 0 2 4 6 8 10

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TULARE CO.
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Piedra
Squaw Valley
Elderwood
Lemon Cove
Woodlake
Reedley
Dinuba
Orange Cove
Sultana
Cutler
Monson
Traver
Kingsburg
Selma
Fowler
Del Rey
Parlier
Sanger
Clovis
Malaga
Calwa
Oleander
Bowles
Conejo
Caruthers
Raisin
Kearney Park
Herndon
Biola
Kerman
Tranquillity
Helm
Burrel
Riverdale
Laton
Lemoore
Armona
Grangeville
Guernsey
Corcoran
Goshen
Stratford
Westhaven
Huron
Murray
Mendota
Firebaugh
Oro Loma
Dos Palos
Chowchilla
Berenda
Dairyland
Daulton
Sharon
Trigo
Gregg
Mill
El Prado
Friant
Cameron
Waukena
Ivanhoe
Tulare Lake
SOUTHERN PACIFIC
SANTA FE
San Joaquin
Kings River
Fresno Slough
Chowchilla Canal
Lonewillow Slough
Columbia Canal
Outside Canal
Main Canal
James Canal
By Pass
Stinson
Fresno Irrigation District
Laguna de Tache
Tulare Lake Basin
Panoche Cr.
Little Panoche Cr.
Cantua Cr.
Arroyo Hondo

80997

Lines of Equal Total Lowering of Ground Water Table in Upper San Joaquin Valley 1921 - 1929

SCALE OF MILES

0 2 4 6 8 10

Unit, where greater depth and lowering are shown in the areas away from stream channels. The relatively deep channel of the San Joaquin River is shown clearly. This causes the slope of the ground water in the northern portion of the Fresno Irrigation District to be toward the San Joaquin River. Shallow depth, with relatively small lowering, is shown generally in the main Kings River area, crossed by the profile. The profile crosses the Kaweah Delta in its outer portion where the stream is divided among several channels. Cross Creek is the only one of these channels under which the conditions in adjacent areas have supported a relatively high ground water table. Cross Creek is approximately the dividing line between the deltas of Kings and Kaweah rivers. Flows in the portions of Mill, Packwood and Cameron creeks crossed by the profile are not sufficient in amount or in regularity of occurrence to maintain high ground water under present conditions of draft. Tule River and Deer Creek do not show any effect on the adjacent ground water. Profile X-X crosses both of these channels below the point to which regular flow extends. There are no streams of importance, tributary to the area crossed by the profile, from Tule River to Kern River. There are, however, relatively large areas dependent on ground water pumping. The result is clearly shown by the differences in elevation between the ground water profiles for 1921 and 1929. In the Rosedale area near Kern River the depth to ground water is less and, due to the stream flow and canal use, little lowering has occurred. South of Bakersfield Profile X-X crosses the higher ground on the point of the Kern River Bluffs. This causes increased elevation of the ground surface profile. Such increase in ground surface elevation is not reflected, however, in the ground water profiles. These show a relatively flat slope in 1921 with a steepening in 1929, due to the ground water lowering that has occurred in the northern portion of the Edison-Arvin Unit.

In addition to the general plates just described, plates for each local ground water unit showing typical profiles of the ground water for 1921 and 1929, and continuous records of the fluctuations of representative wells for the period, 1921 to 1929, have been prepared. These are described with the discussion of each local unit.

Analyses of Ground Water Records.

Similar methods of presenting and analyzing the material relating to the use of ground water and the resulting effect on the ground water table have been used for nearly all local areas. To avoid repetition in the description of each unit, a general explanation applicable to all areas is here presented. The ground water records used in the analyses begin as early as 1917, for some of the areas, and are fairly complete for most of the upper San Joaquin Valley from 1921 to date. Many of these records have been secured by local organizations. A number of investigations also have been made by the state engineer in cooperation with local interests. The results of some of these studies have been published in other bulletins.* Additional investiga-

* Bulletin No. 9, "Water Resources of Kern River and Adjacent Streams and their Utilization," State Department of Engineering, 1920.

Bulletin No. 3, "Water Resources of Tulare County and their Utilization," State Department of Public Works, Division of Engineering and Irrigation, 1922.

Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," State Department of Public Works, Division of Engineering and Irrigation, 1927.

tions have been made in connection with procedure relating to the various irrigation, water storage and water conservation districts. All of these data have been utilized in the preparation of this chapter.

Terms and Methods Used—In the analyses of canal and ground water records, presented in this chapter, certain terms and methods are used which it is advisable to define.

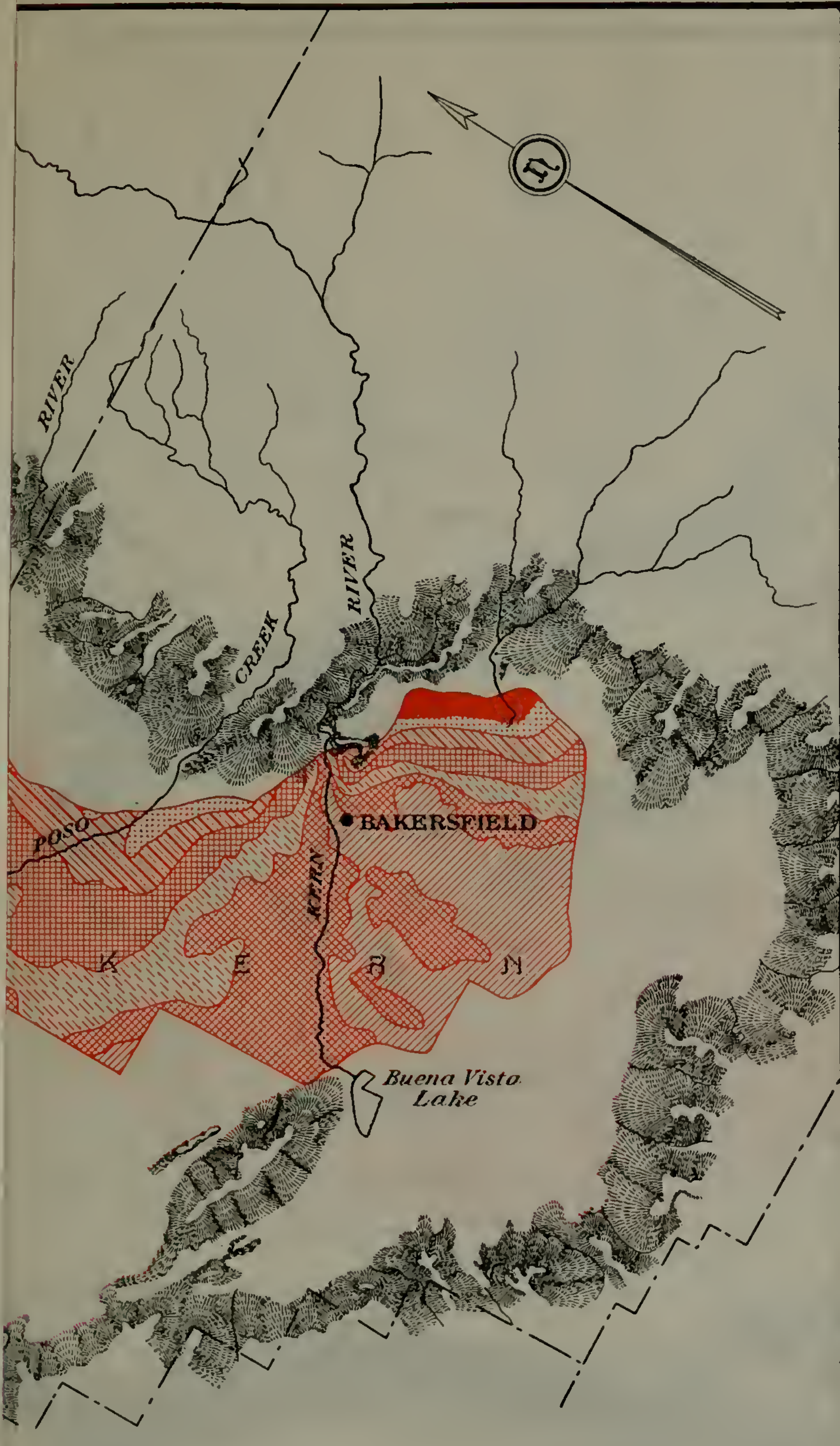
> "Consumptive Use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.
> "Net Use" designates the sum of consumptive use from artificial supplies and irrecoverable losses.

For any particular ground water unit or basin, the portion of the net use termed irrecoverable losses comprises ground water outflow from the unit if any occurs, water consumed by natural vegetation in uncultivated or noncropped areas, and all other water lost or consumed other than that consumed directly in connection with the application of water for crop irrigation. An absorptive area receiving an average water suppy equal to its net use would maintain its ground water without progressive rise or fall. In a particular ground water unit, the rate of gross pumping may, and often does, exceed the rate of net use per unit area of irrigated crops. Such amounts of gross draft in excess of the net use percolate back to the ground water and become available for reuse by subsequent pumping. Net use, as the term has been defined, is limited to moisture received from sources other than direct rainfall on the area. The rainfall in the upper San Joaquin Valley, while helpful in meeting the moisture requirements of crops during the winter months, is insufficient to be a material ground water factor, by direct penetration of moisture to the water table or in meeting crop needs during the summer months, by retention in the surface soil. The precipitation in these areas serves to reduce the irrigation need during the winter months.

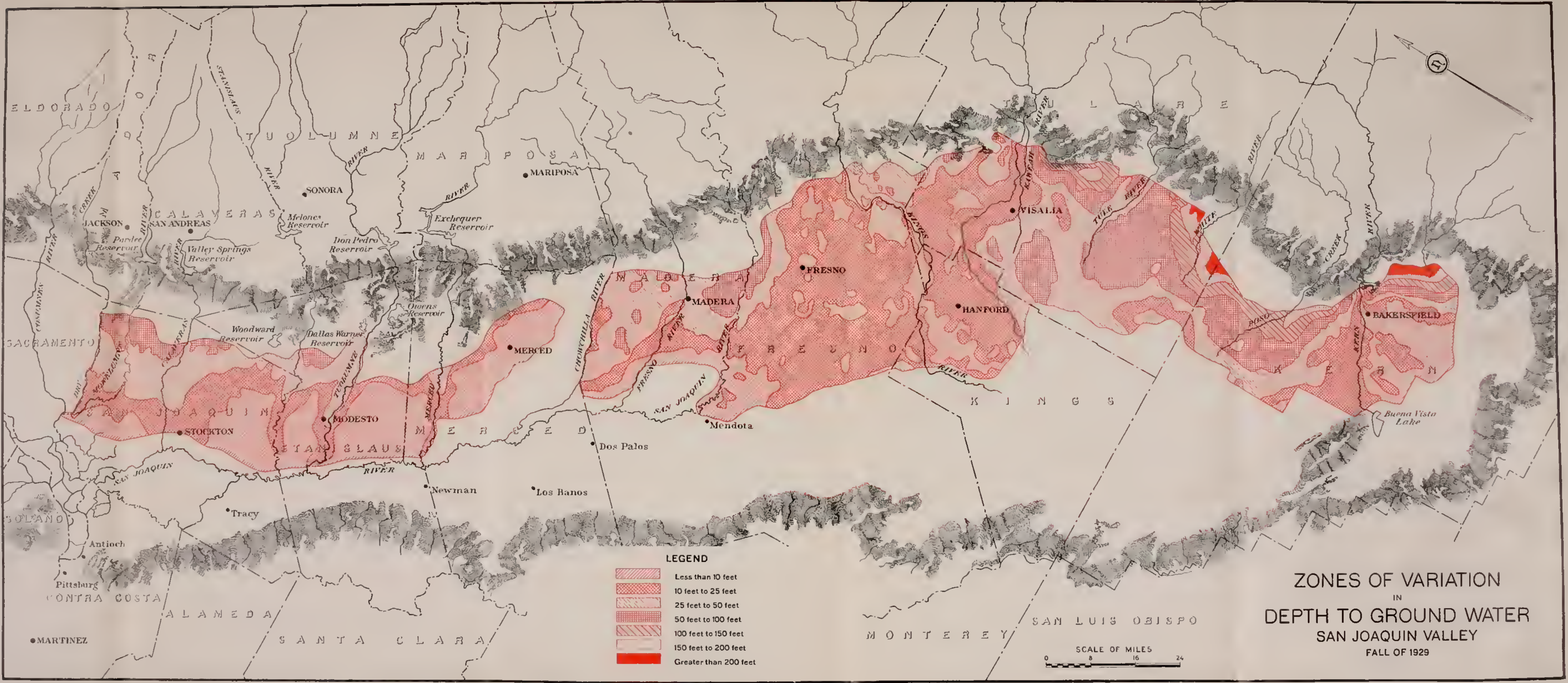
The volume of water represented by ground water fluctuations depends on the total extent of the fluctuations and the proportion of the soil volume filled or drained by the rise or lowering. While from 25 to 30 per cent of the total soil volume may represent the water drained from saturated coarse materials, the average per cent for the mixed materials, usually encountered in the alluvial fills of the San Joaquin Valley, is considerably less than 25 per cent. All moisture will not drain from any soil due to its capillary capacity.

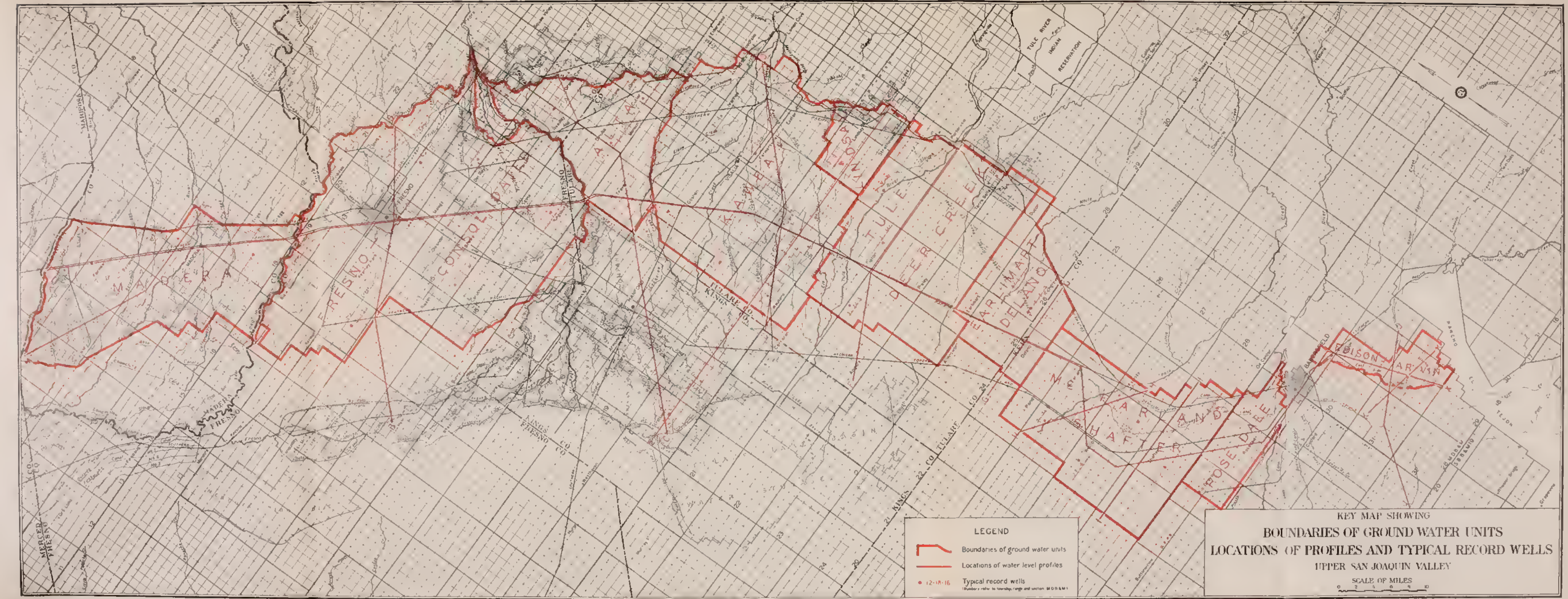
"Drainage Factor" designates the per cent of the total soil volume represented by the water obtained by drainage. The percentage obtained by drainage for any material will be numerically the same as that required for its resaturation when a ground water rise occurs. While over 25 per cent may be drained from coarser materials, the materials within the zone of ground water fluctuation usually include some impervious materials so that the average drainage factor is generally less than that for the coarser materials alone.

The records of areas irrigated, used in this chapter in studies of net use, were secured from the irrigation organizations where available, and by field canvass where not otherwise obtainable. In most sections, these data represent essentially the net service areas, and in fully

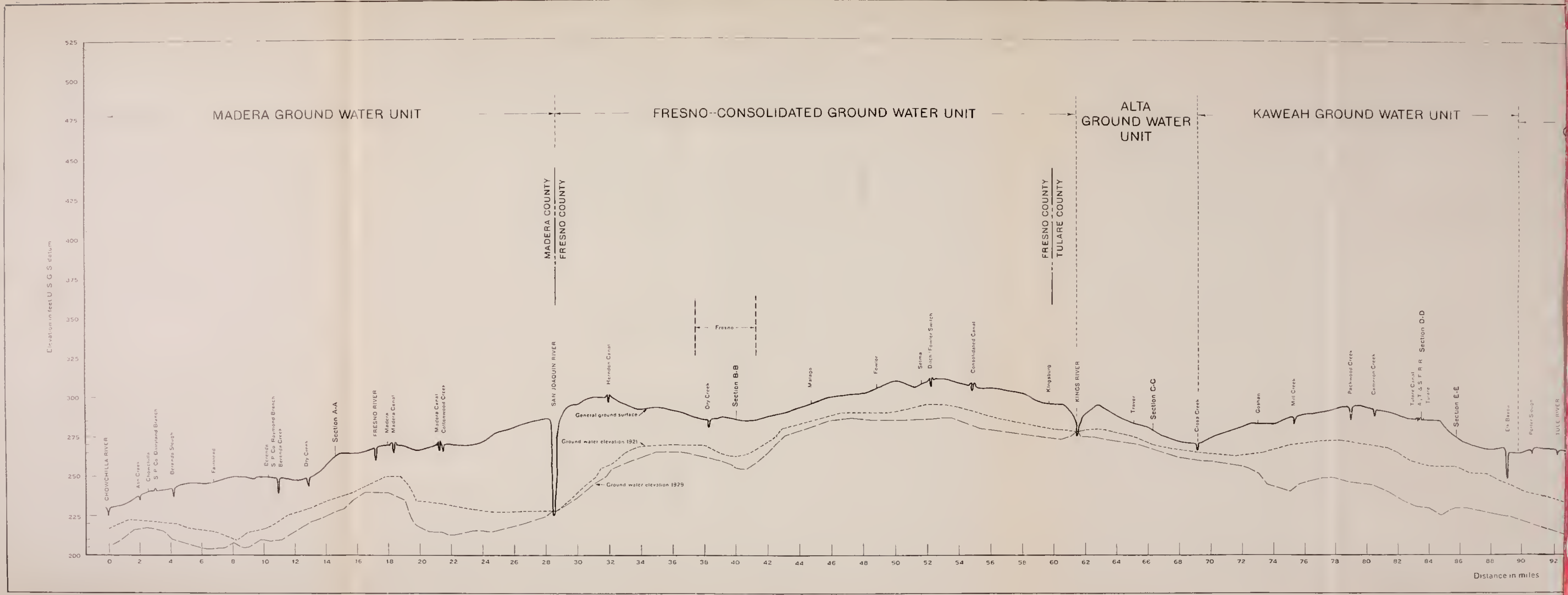


ZONES OF VARIATION
IN
DEPTH TO GROUND WATER
SAN JOAQUIN VALLEY
FALL OF 1929


ZONES OF VARIATION
IN
DEPTH TO GROUND WATER
SAN JOAQUIN VALLEY
FALL OF 1929
LEGEND
Less than 10 feet
10 feet to 25 feet
25 feet to 50 feet
50 feet to 100 feet
100 feet to 150 feet
150 feet to 200 feet
Greater than 200 feet
SCALE OF MILES
0 8 16 24
ELDORADO
AMADOR
TUOLUMNE
MARIPOSA
CALAVERAS
SACRAMENTO
SAN JOAQUIN
STANISLAUS
MERCED
MADERA
FRESNO
KINGS
TULARE
KERN
SOLANO
CONTRA COSTA
ALAMEDA
SANTA CLARA
MONTEREY
SAN LUIS OBISPO
JACKSON
SAN ANDREAS
SONORA
MARIPOSA
MERCED
MADERA
FRESNO
VISALIA
HANFORD
BAKERSFIELD
STOCKTON
MODESTO
MARTINEZ
Antioch
Pittsburg
Tracy
Newman
Los Banos
Dos Palos
Mendota
Buena Vista Lake
Pardee Reservoir
Valley Springs Reservoir
Melones Reservoir
Don Pedro Reservoir
Exchequer Reservoir
Owens Reservoir
Woodward Reservoir
Dallas Warner Reservoir
SAN JOAQUIN RIVER
KINGS RIVER
TULE RIVER
KERN
POSO
CHOWCHILLA RIVER
FRESNO RIVER
TUOLUMNE
MERCED
CALAVERAS
COSUMNES RIVER
MOKELUMNE
STANISLAUS
KAWEAH
WHITE
DRY

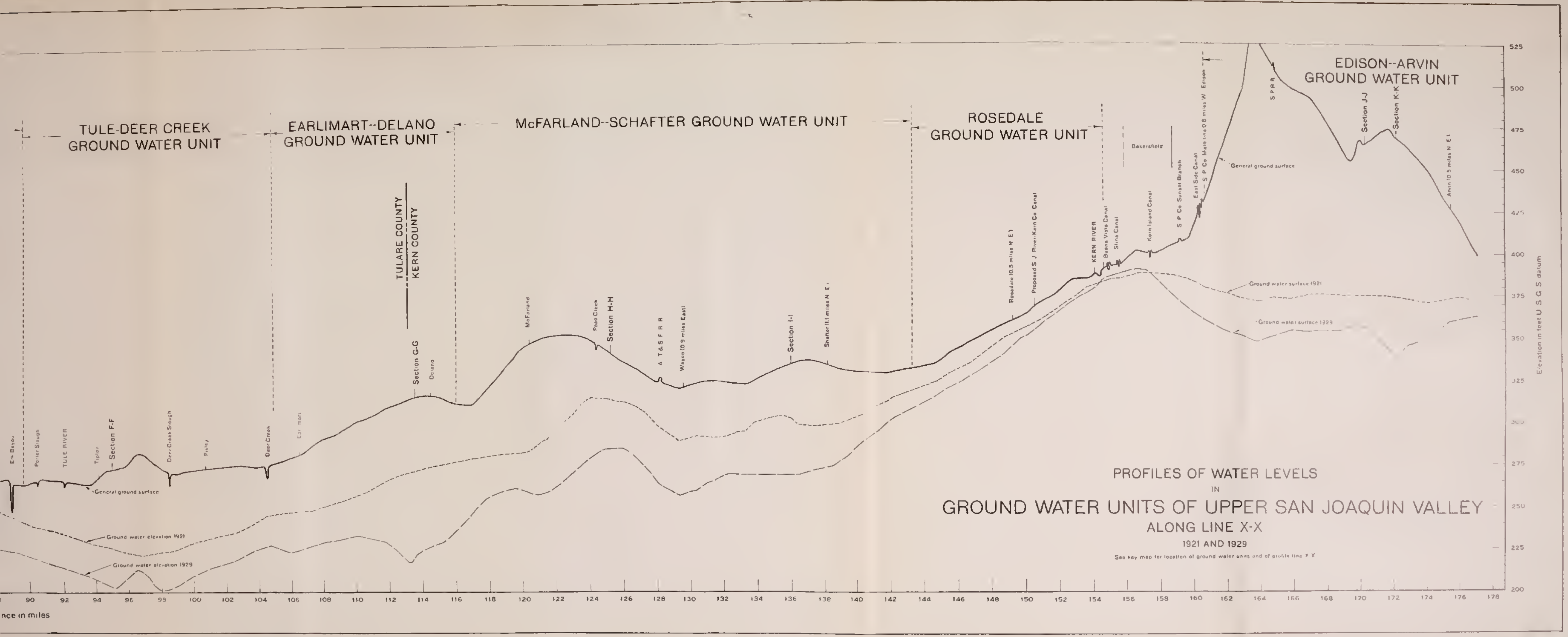

KEY MAP SHOWING
BOUNDARIES OF GROUND WATER UNITS
LOCATIONS OF PROFILES AND TYPICAL RECORD WELLS
UPPER SAN JOAQUIN VALLEY
SCALE OF MILES
LEGEND
Boundaries of ground water units
Locations of water level profiles
Typical record wells
MADERA
FRESNO
CONSOLIDATED
ALTA
KAWEAH
TULE
DEER CREEK
DELANO
MCFARLAND
SHAFTER
POSO
EDISON
ARVIN
TULE RIVER INDIAN RESERVATION
BAKERSFIELD
TULARE CO.
KINGS CO.
MERCED
MARIPOSA
TEJON

80997



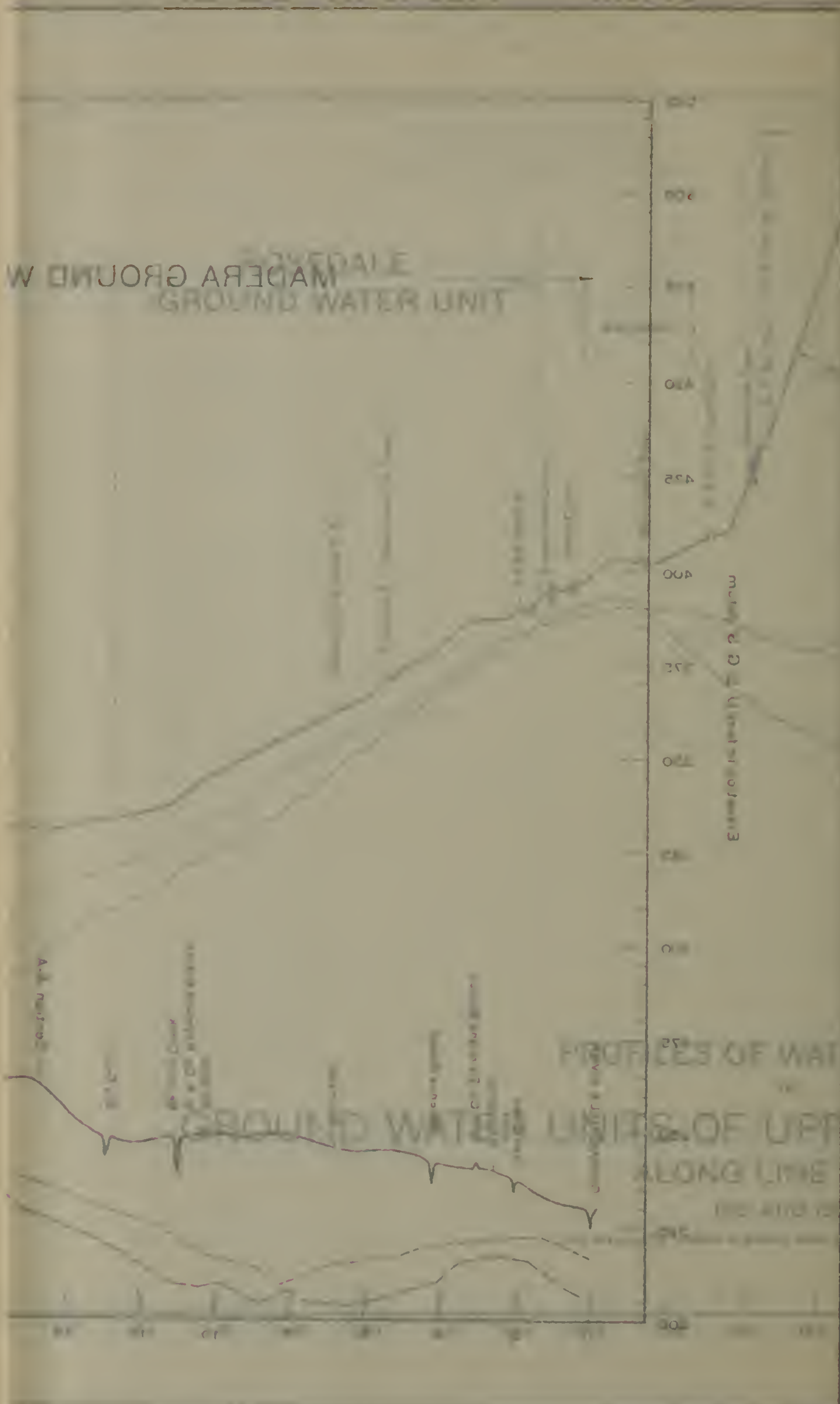
MADERA GROUND WATER UNIT
FRESNO--CONSOLIDATED GROUND WATER UNIT
ALTA GROUND WATER UNIT
KAWEAH GROUND WATER UNIT
MADERA COUNTY
FRESNO COUNTY
FRESNO COUNTY
TULARE COUNTY
Elevation in feet U S G S datum
Distance in miles
General ground surface
Ground water elevation 1921
Ground water elevation 1929
CHOWCHILLA RIVER
FRESNO RIVER
SAN JOAQUIN RIVER
KINGS RIVER
TULE RIVER
Section A-A
Section B-B
Section C-C
Section D-D
Section E-E
Fresno
Madera
Madera Canal
Cottonwood Creek
Herndon Canal
Dry Creek
Malaga
Fowler
Selma
Consolidated Canal
Kingsburg
Traver
Cross Creek
Goshen
Mill Creek
Packwood Creek
Cameron Creek
Elk Bayou

80997



PROFILES OF WATER LEVELS
IN
GROUND WATER UNITS OF UPPER SAN JOAQUIN VALLEY
ALONG LINE X-X
1921 AND 1929

See key map for location of ground water units and of profile line X X


ROSEDALE
GROUND WATER UNIT
PROFILES OF WAT
GROUND WATER UNITS OF UPP
ALONG LINE

developed sections would average about 80 per cent of the gross area of irrigable lands. Lands which are nonirrigable, due to roughness or other factors, have been excluded from the irrigable areas in the land classification.

Determination of the Water Supply Required to Meet Net Use Requirements—In areas where losses by seepage and percolation from canals and irrigated lands are recovered by pumping and re-used, it is necessary to bring to such areas sufficient water only to meet the net use. Several areas in the upper San Joaquin Valley are now developed on the basis of re-use of the percolation to the ground water. Consequently in plans for meeting the water requirements of such areas it is necessary to estimate the amount of net use. The best basis for such an estimate is the actual experience in the areas now under this type of development. If more water is delivered to any area than is consumed by transpiration, evaporation and irrecoverable losses, the excess will percolate to the ground water and cause it to rise. If less is delivered than the net use and the shortage in supply made up by pumping, a lowering of the water table will occur. The records of supply, areas irrigated and ground water fluctuations in many areas enable estimates to be made of the rate of supply required for the mean net use without progressive rise or fall of the water table. A graphical method of making such estimates was used for several areas in the upper San Joaquin Valley, in analyses presented in Bulletin No. 11, previously referred to. A similar method has been used in this report, generally applied, however, to larger units of area. The method consists in plotting the water supply for each season, in terms of acre-feet of measurable net inflow per acre irrigated, against the change in ground water elevation, expressed in feet for the same season. Such plotting for different years indicates the relationship between supply and changes in ground water level. A mean line expressing such relationship is drawn. The intersection of this line with the zero line of the scale of fluctuation indicates, on the scale for inflow, the acre-feet per irrigated acre needed to meet the net use, including the difference between unmeasurable inflow and outflow, without progressive ground water change. The supply used in such comparisons is the sum of all measurable sources of inflow less all similar measurable items of outflow. The product of the unit net use so determined and the average area irrigated during the period of record, shows the mean seasonal net supply which would have been necessary to meet the crop requirements and irrecoverable losses without progressive rise or fall of the ground water. The difference between the seasonal inflow, thus derived, and the mean actual inflow for the period indicates the average shortage of supply for areas where lowering has occurred. This method of analysis assumes that the requirements for net use are met in all years without shortage. This condition is generally met for lands served from wells, but is not always met in years of deficient canal supply for crops dependent on such canal service alone. The method includes, in the determination of net use, the net difference between the ground water inflow and outflow. Neither of these items are directly measurable. The net use determined by this method also includes water used by natural vegetation and uncultivated areas. These inclusions result in variations in net use per unit of area of irrigated crops in different ground water units.

The data available indicate that, in most parts of the upper San Joaquin Valley, general ground water movements from one area to another involving much distance are relatively slow and the quantities involved are generally small and have relatively little effect upon the net use within the areas. The method also is based on the assumption that, on the average, an equal amount of water is released per foot of lowering or that the average drainage factor is constant throughout the full depth of fluctuation. Within usual ranges of fluctuation this assumption is probably closely correct.

Ground water depletion estimates for the units, in which the ground water fluctuations vary consistently with the seasonal inflow, have been based upon the assumption that the average annual depletion is equal to the average annual shortage of net use requirements. An assumed drainage factor is not used in this method of analysis. The actual value of this factor is indicated by the ratio of the average annual depletion, in acre-feet, to the average annual volume of soil drained, expressed in acre-feet. For example, in Table 44, the gross area of the Fresno-Consolidated Ground Water Unit is given as 700 square miles or 448,000 acres. The average area irrigated for the 8-year period 1921–1929 is 319,900 acres and the average seasonal water supply diverted into the unit is 537,000 acre-feet. The average seasonal fall of ground water level is 0.81 foot. On Plate XX it is demonstrated graphically that a supply of 1.90 acre-feet per acre of cropped area would meet crop needs and maintain a constant ground water level. The average seasonal water requirement for this area equals 319,900 acres times 1.9 acre-feet per acre or 607,800 acre-feet. The average annual depletion equals 607,800 acre-feet minus 537,000 acre-feet or 70,800 acre-feet. The depletion per foot of lowering equals 70,800 acre-feet divided by 0.81 foot or 87,400 acre-feet. The soil volume drained per foot of lowering equals 448,000 acre-feet. Therefore, the drainage factor equals 87,400 acre-feet divided by 448,000 acre-feet or 19.5 per cent. While no method of ground water analysis can be exact, due to the many variable factors involved, the generally consistent variations of the annual fluctuations with the water supply, for the several areas, and number of years for which records are now available, indicate that the method is generally applicable to the conditions existing in these areas. The analyses of net use in the various ground water units have been made for the 8-year period 1921–1929, for which records of inflow, irrigated areas and ground water fluctuations are available.

Kern River Areas.

The Kern River areas as the term is here used cover the same area as Hydrographic Division No. 1 on Plate VI. It includes those portions of the upper San Joaquin Valley for which Kern River is the main source of water supply, although many parts of the area are not reached by the present systems diverting from Kern River. It includes all of the portions of Kern County in the San Joaquin Valley except the northern three miles.

The water of Kern River is divided between two groups of canal interests in accordance with the Miller-Haggin agreement. The flow of the river is measured at "First Point of Measurement" which is above all diversions in the valley. From March 1 to September 1, one-third of the flow at First Point in excess of 300 second-feet is delivered at "Second Point of Measurement," located on Kern River about five miles above its point of discharge into Buena Vista Slough, for use on lower lands. The remainder of the flow is diverted by the different canals between First Point and Second Point, to the extent of their capacities. These canals have varying priorities which result in differences in the character of service received by different parts of the canal served areas. At present there is no storage on Kern River above Second Point. Buena Vista Lake acts as a reservoir for part of the "Second Point" water.

Investigations relative to the utilization of the water supply of Kern River were made, during 1920, by the State Engineer in cooperation with Kern County and local interests. In 1923 the Kern River Water Storage District, comprising about 250,000 acres, was formed. Its area corresponded generally with that recommended in the report of the 1920 investigations for service above "Second Point." Extensive investigations were conducted by the storage district and a plan prepared which included the utilization of ground water storage and pumping for areas on the south side of the river in order that water now diverted from the river for use in this area, in excess of net use, might be used for higher lands on the north side of the river. Although such a plan would have resulted in a much more complete and economical use of the available water supply, the various local interests involved were unable to agree regarding its accomplishment and the district was dissolved in 1929.

Most of the important canals using "First Point" water operate as public utilities. These utilities recognize certain lands as having rights to service under the different canals. A number of questions regarding the definition of service, areas and rates have been involved in proceedings before the California Railroad Commission. The areas irrigated in each year vary with the run-off. An area of about 165,000 acres is served usually, under all ditches, with additional areas in years of above normal supply. The records of the canal companies show an average annual diversion of 413.000 acre-feet for the period 1893 to 1925, inclusive. The adequacy and distribution of the supply through the season vary with the different canals, those of early priority having a generally well distributed service.

For purposes of discussion, the area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Edison-Arvin Unit, canal served areas south of Kern River, Rosedale Unit, Pioneer Canal area, Buttonwillow and Semitropic Ridges, Buena Vista Water Storage District and McFarland Shafter Unit. In making the crop survey of 1929 for all units in Kern County, from which the area irrigated in each unit has been determined, all highways, railroads, county and private roads, incorporated and unincorporated towns, main canals, main laterals, sublaterals, and building and uncropped areas of more than one acre were excluded. Private ditches and building areas and yards of less than one acre, situated within the cropped areas, were included.

Edison-Arvin Unit—This unit includes the pump irrigated areas lying above the East Side Canal on the south side of Kern River. Its northern limit is that of the developed area between Bakersfield and Edison, from which it extends southward, a distance of fourteen miles, to the south line of Township 31 South. The eastern limit is that of the intensive development around Arvin and on the cone of Caliente Creek. A small intensive citrus development is located near Edison and an area devoted to both citrus and deciduous fruits extends from Edison westward past Magunden toward Bakersfield on both sides of the Southern Pacific Railroad. Although the principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek, the cone of depression, that has developed during the past five years under this area of heavy pumping draft, has lowered the water table to elevations below that under the East Side Canal three miles to the west. The total irrigation development under pumping service for the portion of this area on the Caliente Creek fan is 17,400 acres. The gross area of the unit is 51 square miles and the area irrigated in 1929 was 31 square miles, or 20,000 acres.

Profile J-J on Plate XIV, "Edison-Arvin Ground Water Unit," extends in a northeasterly direction from a point on the Rim Ditch, ten miles east of Buena Vista Lake, to a point about five miles southeast of Edison. It shows the slope condition in the canal served area south of Kern River as well as that in the Edison-Arvin Unit. Profile K-K, shown on same plate, extends about ten miles, in an easterly direction parallel to the Southern Pacific Railroad, from a point about eight miles south of Bakersfield. Both of these profiles, for the 1929 ground water elevations, show ground water depressions through the East Side Canal and the higher part of the Caliente cone. This has been caused by the excess of draft over supply for the period, 1921 to 1929, as the ground water slope was formerly continuous from the east toward the west. For Well 31–29–16, about eight miles south of Edison near the East Side Canal, the pumping draft and winter recovery are large for each season and amount to more than 30 feet in some years. There has, however, been a general lowering from 1924 to 1929. The characteristics of Well 31–29–23, about ten miles south of Edison and two miles east of the East Side Canal, are somewhat similar to those for Well 31–29–16. Well 29–28–36a, located about three miles westerly from Edison and near the East Side Canal, shows smaller lowering than the other two wells referred to, but is somewhat similar in its general characteristics with regard to winter recovery and general lowering.

The available records of water supply, area irrigated and ground water fluctuation are shown in Table 30. The ground water fluctuations shown in Table 30 do not vary consistently with the estimated run-off for the different years. Caliente Creek does not have a surface run-off in its stream channel that is accessible for measurement, as the flow is largely absorbed and moves slowly to the lower areas. The inconsistencies between the estimated annual run-offs and the resulting ground water fluctuations are due probably to some increasing influence of East Side Canal seepages and the time lag between surface run-off and delivery to the ground water in the area, and prevent the determination of a definite relationship between inflow and changes in

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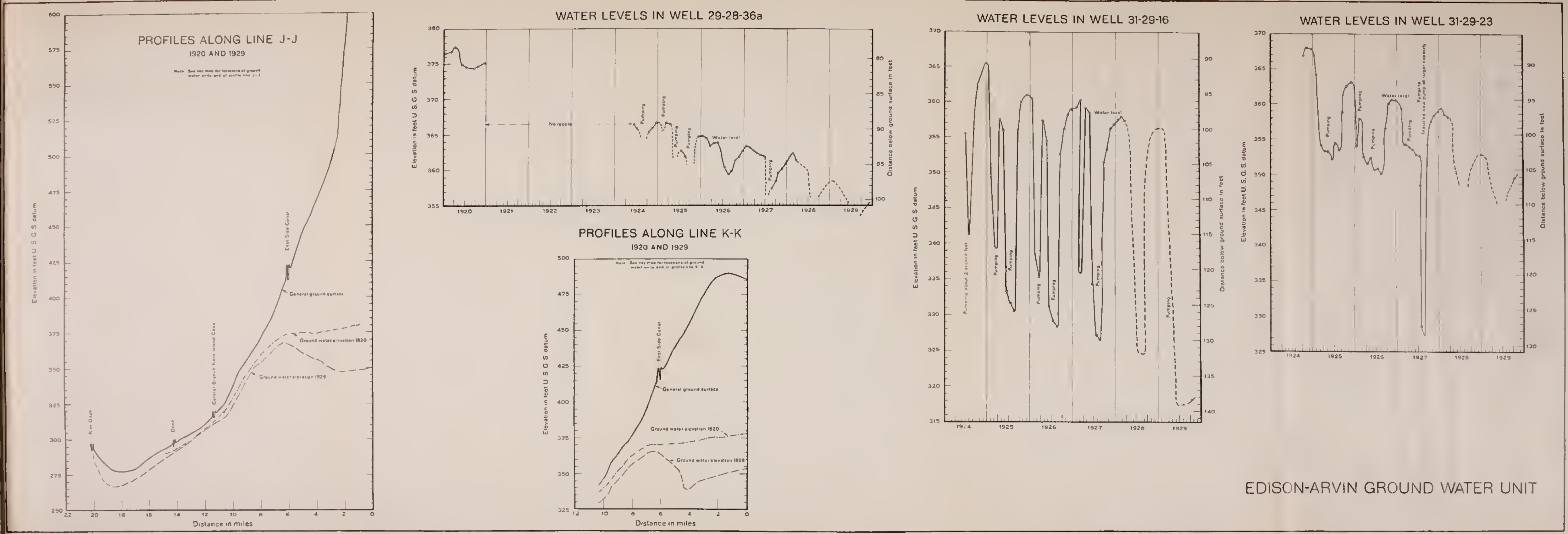


EDISON-ARVIN GROUND WATER UNIT

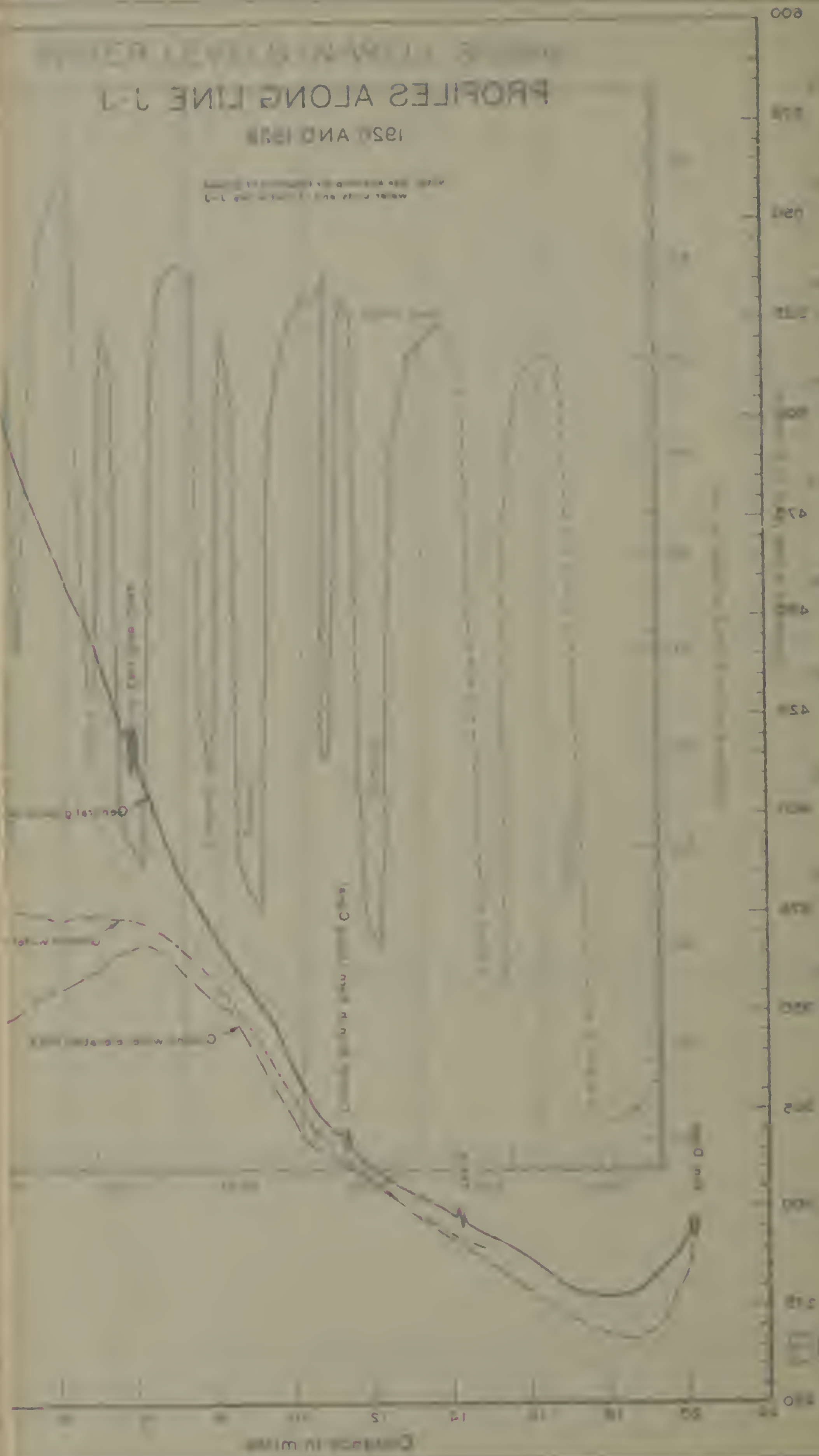

PROFILES ALONG LINE J-J
1920 AND 1958

TABLE 30

EDISON-ARVIN UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area 51 square miles

Season or period	Water supply. Run-off of Caliente Creek, in acre-feet	Area irrigated, in acres	Change of ground water level, in feet[3]
1921-24	77,800	[1]	[2]—9.57
1924-25	35,200	17,437	—0.89
1925-26	12,600	[1]	—2.34
1926-27	32,700	[1]	—3.44
1927-28	15,100	[1]	—1.28
1928-29	15,100	20,000	—3.99
Averages, 1921-29	23,600	18,600	—2.69

[1] Data not available.
[2] Interpolated for period 1921-1924, from 1920 and 1924 records.
[3] (—) indicates lowering of ground water level.

ground water level. The estimated run-off of Caliente Creek is also subject to considerable error as it is based on comparison with adjacent streams due to the lack of stream flow measurements. An average annual depletion of about 13,000 acre-feet has been estimated by subtracting the mean annual run-off of Caliente Creek from an estimated net use of two acre-feet per acre. This would indicate an average drainage factor of 15 per cent for this unit.

Canal-served Areas South of Kern River—The larger part of the "First Point" water is diverted to the area south of Kern River. This area is served by several different canals which are mainly under the control of the Kern County Canal and Water Company. The quantity of water available varies with the different canals and with the character of run-off of the individual seasons. The canal served area south of Kern River is compact, as a whole, except for the area served by the East Side Canal. The ground water is within six feet of the ground surface for about two-thirds of the total area of 90,000 acres, exclusive of the East Side Canal area. This area is one of the few remaining areas in the San Joaquin Valley having injuriously high ground water where no steps to remedy the condition have been taken. For much of this land, drainage is a greater need than additional water. There is comparatively little ground water development in this area although the recent dry years have caused the development of a number of wells for supplemental use. The adequacy of the canal supply has resulted in limited local interest in pumping. Wells of good yield are obtainable in the portions of the area near Kern River where coarser materials are encountered. Toward the south, from Kern Lake to Buena Vista Lake, artesian wells are obtainable. The water-bearing sands are fine, and wells of the gravel envelope type are most effective in securing large yields. The largest present draft on the ground water is that for municipal supply for the city of Bakersfield. The total present ground water draft is a very small proportion of the canal diversions into the area. A large portion of the area shows no lowering of ground water, and the maximum in any part is about five feet.

The area under the East Side Canal is separated from the main South Side Canal area by an intervening strip of alkali land in the topographic trough of the former course of Kern River. About 6000 acres of the gross area of 15,000 acres under the East Side Canal receive canal service. The average total annual diversions into the canal are about 25,000 acre-feet. About 60 per cent of the canal served area also secures a supplemental supply by pumping and an additional area of about 6000 acres is irrigated entirely from wells. Deeper wells within this area are seldom perforated in the upper strata, and are not immediately influenced by the flow of water in the canal or its use on overlying lands. Such supply as may be available in the deeper wells is considered to be received from the general ground water movement from higher areas tributary to Caliente Creek. These waters may now be intercepted, at least partly, by pumping in the areas nearer to Caliente Creek. From 1921 to 1929, the ground water in this area has lowered generally from ten to twenty feet at the north end to five to fifteen feet at the south end. Present depths to water vary from twenty-five to sixty feet.

Rosedale Unit—The Rosedale unit lies immediately south of the Seventh Standard Parallel and extends southward for a distance of five and one-half miles. Its eastern limit is along the Kern River near Bakersfield, and the western boundary is near Rio Bravo. It is served by the Calloway, Beardsley, McCaffrey and Emery canals. The areas irrigated from these canals vary with the run-off of the different years. Table 31 sets forth the available data on water supply, areas irrigated and ground water changes in this unit.

TABLE 31

ROSEDALE UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area 79 square miles

Season	Water supply to unit, in acre-feet	Area irrigated, in acres			Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
		By canal service	By pumping	Total		
1919–1920	77,850	15,250	2,600	17,850	4.36	----------
1920–1921	56,500	11,600	3,200	14,800	3.82	—0.98
1921–1922	98,750	15,550	2,600	18,150	5.44	+1.08
1922–1923	68,800	12,650	3,000	15,650	4.40	—1.04
1923–1924	0	0	6,000	6,000	0	—3.45
1924–1925	35,850	7,800	4,000	11,800	3.04	—2.01
1925–1926	28,400	6,100	4,000	10,100	2.81	—1.35
1926–1927	104,500	13,450	4,000	17,450	5.99	+1.37
1927–1928	25,000	6,000	4,000	10,000	2.50	—1.23
1928–1929	12,100	2,900	4,000	6,900	1.75	—3.64
Averages, 1921–1929	46,700	8,050	3,950	12,000	3.89	—1.28

[1] (+) indicates a rise and (—) a fall in ground water level.

The relationship between the supply per acre of irrigated area and the resulting ground water fluctuation is fairly consistent. However, the indicated rate of gross delivery required to maintain the ground water is about 4.6 acre-feet per acre. This figure is far in excess of consumptive use and is probably the result of the ground water outflow through the coarse materials in this area, due to its proximity to the channel of Kern River. Some of this outflow is used in other areas. Based upon the difference between the actual inflow and an average requirement of 4.6 acre-feet per acre, the indicated mean annual depletion of ground water for the period 1921–1929 is approximately 9000 acre-feet, and indicates a drainage factor of about 14 per cent. Prior to canal irrigation, the ground water was about 50 feet lower than at present. The additions to the ground water from irrigation have changed the ground water slopes so that outward movement now occurs. In the earlier years shown in Table 31 the ground water was sufficiently high to result in loss by soil moisture evaporation from larger areas than the cropped areas given. If a rate of net use, similar to that indicated for other areas, is applied to this area for each year, the resulting unaccounted for water varies widely in different years. During the period 1921–1929 the average seasonal supply exceeded the probable use within the area by about 20,000 acre-feet. In years of larger supply the unaccounted for water is a larger amount. The outflow from this area appears to be responsive to the extent of the supply in each year. The total lowering, from 1921 to 1929, amounting to 10.27 feet, appears to have reduced but not to have eliminated ground water outflow losses in this area.

Pioneer Canal Area—This area covers the lower area north of Kern River, served mainly by the Pioneer Canal. The area irrigated varies with the extent of stream flow in different years and may exceed 12,000 acres in years of large run-off. The canal diversions average about 27,000 acre-feet per year. There is only a limited amount of present use of ground water in this area, although the ground water supply and conditions for pumping are generally favorable. The records of ground water fluctuations are not complete. Those available indicate that some outflow of ground water occurs and that there is probably some ground water inflow from the Rosedale area. Only limited lowering has occurred since 1920.

Buttonwillow and Semitropic Ridges—This area covers the lands along Goose Lake Slough and the adjacent Buttonwillow and Semitropic ridges. There is some irrigation along Goose Lake Slough from wells, largely artesian. As discussed in Chapter III, these lands are generally of poor quality and there is little irrigation development. Toward the northern end a number of wells supply water for duck club use. The records of ground water fluctuations in this area are incomplete. Some wells which formerly flowed now require pumping. Wells pumped during the summer may recover their pressure head and resume flow during the winter season of smaller draft. While there are no surface sources of inflow into this area, ground water movement may occur from adjacent areas at the east and south.

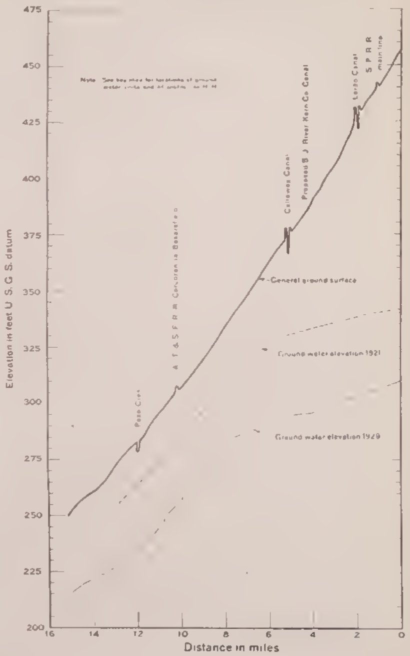
Buena Vista Water Storage District—The "Second Point" water on Kern River is now handled by the Buena Vista Water Storage District. This district contains 78,825 acres including the area of Buena Vista Lake and the valley trough lands extending north to Wasco Road. When organized, about 90 per cent of the land was owned by Miller and Lux, Inc. A portion of the district has since been colonized. Formerly the area irrigated varied with the available run-off, Buena Vista Lake being used for storage. This lake is one of the natural depressions in which excess stream flow collected. The area of submergence is now limited by levees. The depth of flooding is shallow and evaporation losses represent a large part of the water stored. Ground water is fairly close to the surface in much of the area irrigated. The water-bearing materials consist of fine sand which require wells adapted to such conditions, if good yields are to be secured. There has been considerable recent pumping development in the southern part of the main area of the district which has made available a more complete and dependable water supply.

McFarland-Shafter Unit—This unit extends southward from a line three miles south of the Tulare County line, a distance of 21 miles, to the Seventh Standard Parallel. The eastern boundary is about two miles east of the Southern Pacific Railroad and the State highway, and the western limit is the west line of Range 24 East. Part of the eastern portion receives canal service from the Lerdo and Calloway canals. As these canals have flood water rights only, the water supply available varies widely in different years. Poso Creek also supplies some stream flow to the northern part of the area. The gross area is 310 square miles. Table 32 summarizes the available data on water supply, irrigated area and ground water fluctuation for the period 1919–1929, inclusive. The average lowering for the full area has been three feet per year. The lowering has varied in the different parts of the area as shown on Plate X. A total lowering of as much as 40 to 45 feet has occurred in some of the more heavily pumped areas. In the southwest part of the area near Goose Lake Slough, where the ground water draft is slight, little lowering has occurred. The lowering is generally less in the poorer lands along the west side and beyond the areas now developed.

The average ground water fluctuation is plotted against the average water supply per acre for each of the nine years of record on Plate XV, ''McFarland-Shafter Ground Water Unit.'' The points for the different years are scattered somewhat but indicate generally that an inflow of two acre-feet per acre will meet the crop requirements and maintain the ground water at its present level with such unmeasurable ground water outflow or inflow as may now occur. Part of the variations in individual years are due probably to the difference in use on canal-served areas which may receive only partial service. Some ground water outflow to the west also may occur. Such outflow probably would be somewhat larger under the higher ground water conditions of 1922 than at present. Prior to irrigation in this area, the ground water was about 50 feet lower than in 1920. About one-half of the subsequent rise had been lost by 1929. The ground water level, prior to irrigation, was that maintained by the balance of natural inflow and outflow. The natural inflow is represented by the absorption from Poso Creek. The actual pump draft in this area was found by canvass of all plants in 1920 to exceed two acre-feet per acre. Pumped water in excess of net use will return to the ground water as deep percolation and is only a temporary draft on the supply. With full recovery of ground water, a delivered supply into this area of two acre-feet per acre of cropped area should meet the crop requirements and such outflow as may occur, with present ground water elevations, and prevent further ground water lowering. The 1921–1929 average annual ground water depletion is assumed to equal the difference

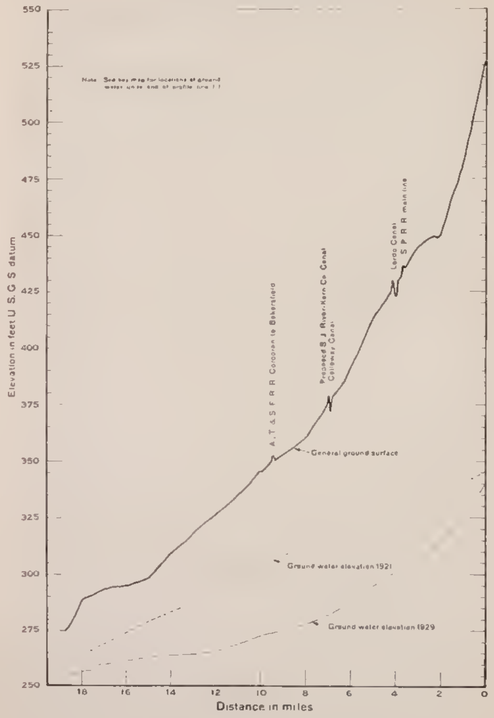
PROFILES ALONG LINE H-H

1921 AND 1929

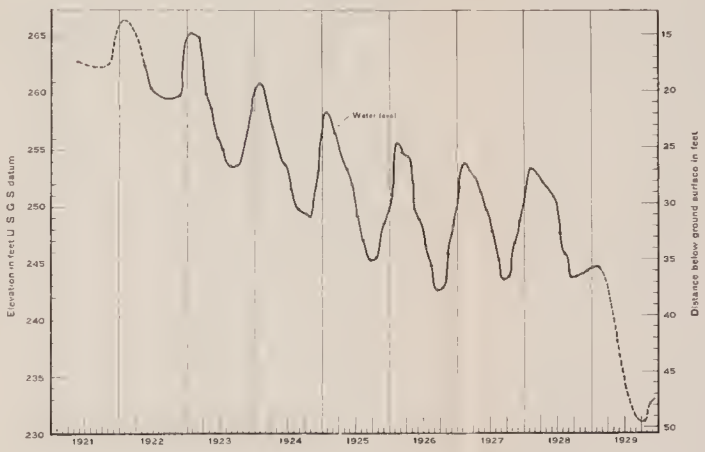


PROFILES ALONG LINE I-I

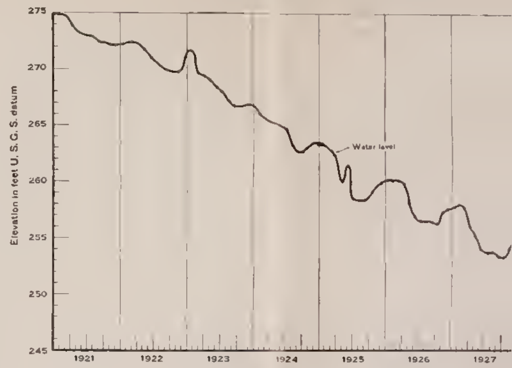
1921 AND 1929



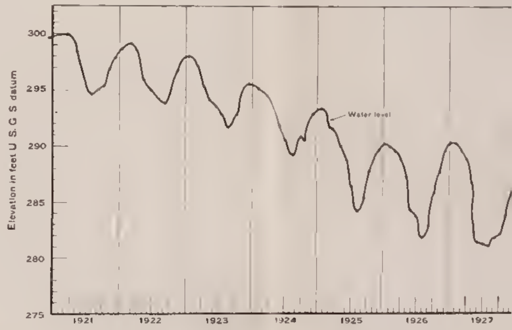
WATER LEVELS IN WELL 26-24-11



WATER LEVELS IN WELL 27-24-10



WATER LEVELS IN WELL 28-25-21



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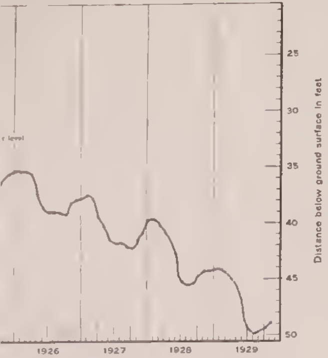
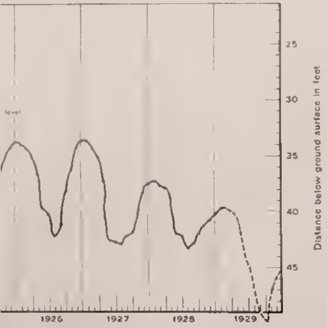
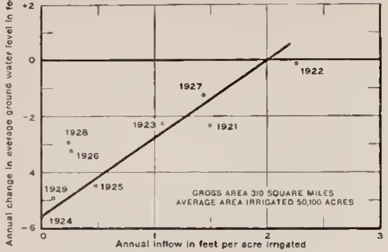
WELL 27-24-10



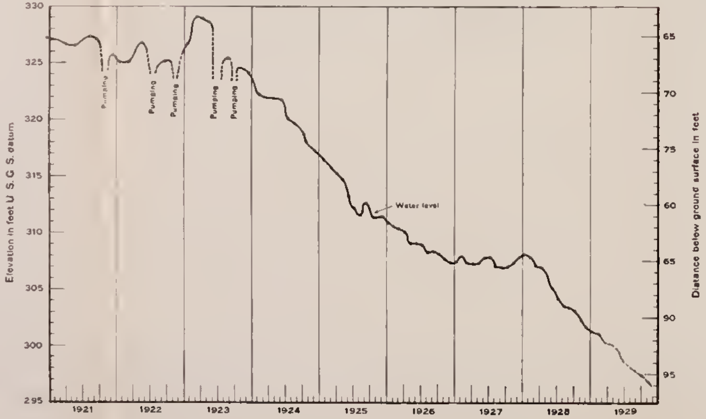
WELL 28-25-21



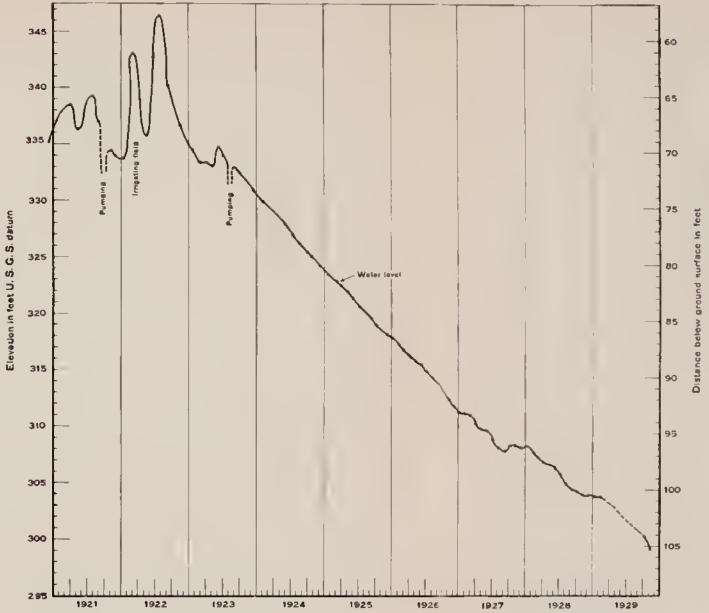
RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER



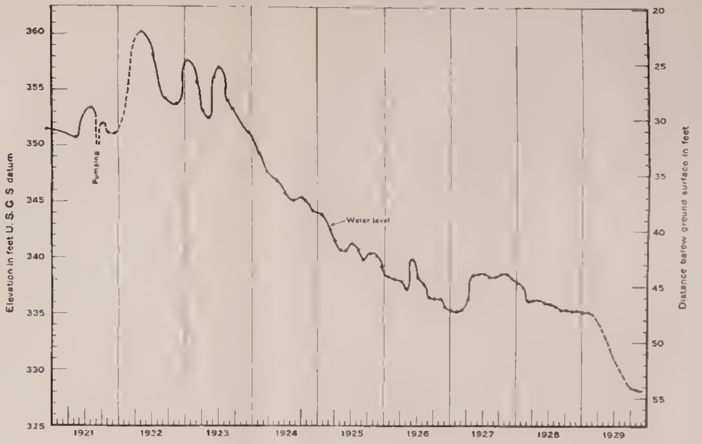
WATER LEVELS IN WELL 27-25-26



WATER LEVELS IN WELL 27-25-1



WATER LEVELS IN WELL 28-26-26a



McFARLAND-SHAFTER GROUND WATER UNIT

TABLE 32

McFARLAND-SHAFTER UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area—310 square miles

Season	Water supply to unit, in acre-feet				Area irrigated, in acres			Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Lerdo Canal	Calloway Canal	Poso Creek[1]	Total net inflow	By pumping from ground water[2]	From canals	Total		
1919-1920	8,050	48,100	7,250	63,400	30,800	14,100	44,900	1.41	----------
1920-1921	11,100	43,900	2,500	57,500	34,100	4,300	38,400	1.50	—2.35
1921-1922	19,600	97,700	5,800	123,100	37,200	17,200	54,400	2.26	—0.18
1922-1923	12,600	31,800	8,050	52,450	39,700	9,800	49,500	1.06	—2.26
1923-1924	0	0	0	0	42,000	0	42,000	0.0	—5.58
1924-1925	4,100	13,700	5,600	23,400	43,800	4,600	48,400	.48	—4.49
1925-1926	4,400	6,200	3,000	13,600	45,400	5,500	50,900	.27	—3.23
1926-1927	12,750	63,300	6,000	82,050	46,800	9,400	56,200	1.46	—1.21
1927-1928	4,600	4,200	3,000	11,800	48,000	1,600	49,600	.24	—2.98
1928-1929	1,750	1,050	2,000	4,800	49,160	640	49,800	.10	—4.91
Averages, 1921-1929	7,480	27,240	4,180	38,900	44,010	6,090	50,100	.77	—3.10

[1] Measured run-off reduced by 2,000 acre-feet for estimated use above this area.
[2] Irrigated area records for 1921, 1924 and 1929; other years interpolated.
[3] (—) indicates lowering of ground water level.

between the required seasonal net use of approximately 100,000 acre-feet for the area under irrigation, and the estimated mean seasonal inflow of about 39,000 acre-feet, or 61,000 acre-feet. This would indicate an average drainage factor of about 10 per cent for this unit.

Profile H-H on Plate XV extends generally parallel to Poso Creek from Famoso to beyond Elmo. The areas under the Lerdo and Calloway canals receive irregular canal service. Pumping is practiced near the lower end of the area crossed by the profile. There has been very little canal service in this area in recent years and larger lowering has occurred in the canal areas than in the pumping areas.

Profile I-I extends east and west near Shafter. Little lowering has occurred at the upper end above the canals. A lowering of about 30 feet is shown in the pumping area near Shafter. At the west, where there is little development, only limited lowering occurred.

Well No. 26–24–11, Plate XV, is located west of Elmo in the edge of the pumping area. Lowering occurs during the summer pumping season with a winter recovery. The winter peaks show an average annual lowering of about two feet each below the peak of the previous year until 1929, except for the winters following the larger supplies of 1922 and 1927, which caused relatively greater winter recoveries. Winter recovery was very small in the winter of 1928–29 and larger lowering occurred in the summer of 1929.

Well No. 27–24–10 is west of the pumping area near Wasco. It shows a continuous lowering of about three feet per year with a small winter recovery from the summer draft.

Well No. 27–25–26 is east of Shafter under the Lerdo Canal. It maintained its level with some gain to 1923 and has dropped steadily since, with the exception of holding even in 1927. Lowering has averaged between four and five feet per year since 1923. The years of lowering are ones of small flow in the Lerdo Canal.

Well No. 27–25–1 is at the side of Poso Creek near Famoso. It shows a marked response of about ten feet to adjacent irrigations in 1922, dropping back quickly after the irrigation. Since 1923 it has lowered steadily at an average rate of about five feet per year. The larger supply in 1927 only reduced the rate of lowering in that year to three feet.

Well No. 28–26–26a is near the Calloway Canal at the southern side of this area. It shows response to adjacent canal use, holding its level in 1922 and 1923, lowering through 1926, gaining enough in 1927 to balance the lowering in 1928, and lowering seven feet in 1929.

Wells in the eastern part of this area do not show a winter recovery. The winter recovery at the west is probably, or at least partly, a pressure recovery similar to the pressure recovery that causes some wells farther west to resume flow during the winter. The winter recovery indicates that some movement occurs, the lowering in the upper areas being reflected by the rise in the lower areas.

Earlimart-Delano Unit.

This unit includes the pump developed areas around those two towns. It is bounded on the north by the division between the areas affected by White River and Deer Creek, and extends southward for eleven miles to an east and west line three miles south of the north line of Kern County. The eastern limit is along the Southern Pacific branch line between Richgrove and Ducor and the western limit is the west line of Range 25 East. This area has only very limited tributary run-off. White River is the only stream draining higher foothill areas. There are additional minor lower drainage areas such as Rag Gulch. All irrigated areas are served entirely by pumping from wells. The generally high quality of the lands in this area has resulted in a relatively large area of pumping. The available records on water supply, areas irrigated and ground water fluctuation are assembled in Table 33. The areas irrigated are based on direct canvass in 1921, 1924, 1925 and 1929 with interpolations for intervening years. A continual increase is shown with a total increase of about 160 per cent in nine years.

In making the crop survey of 1929 for all units in Tulare County, from which the areas irrigated in each unit has been determined, all highways, railroads, incorporated and unincorporated towns, main canals, main laterals, sublaterals and building and uncropped areas of more than one acre were excluded. County and private roads, private ditches and building areas and yards of less than one acre situated within the cropped area were included.

Table 33 shows the average ground water fluctuation in the Earlimart-Delano Unit for each year. Plate X shows the total lowering for the eight-year period, from 1921 to 1929. The lowering has been largest eastward from Delano in the area of heaviest development. A maximum lowering of 70 feet with lowering in excess of 50 feet over a relatively large area is shown. The ground water contours on Plate VIII show that the lowering has resulted in a ground water depression in the area of heaviest pumping, with the ground water sloping into this area from all sides.

TABLE 33

EARLIMART-DELANO UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 150 square miles

Season	Water supply. Estimated run-off of White River, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1920-1921	2,200	11,600	0.19	----------------
1921-1922	3,700	13,000	0.29	—1.93
1922-1923	4,800	14,500	0.33	—3.24
1923-1924	0	15,950	0.0	—3.77
1924-1925	3,600	20,000	0.18	—4.42
1925-1926	1,400	22,500	0.06	—4.97
1926-1927	4,700	25,000	0.19	—4.88
1927-1928	2,300	28,000	0.08	—2.36
1928-1929	1,900	30,550	0.06	—7.78
Averages, 1921-1929	2,800	21,200	0.13	—4.17

[1] Records for 1921, 1924, 1925 and 1929; other years interpolated.
[2] (—) indicates lowering of ground water level.

The total water supply tributary to this area is too small in relation to the draft to enable the fluctuations and supply to be plotted in a form that would indicate the inflow value required for zero fluctuation. Table 33 shows a continual lowering which tends to increase with the increase in irrigated area. For the last four years shown.

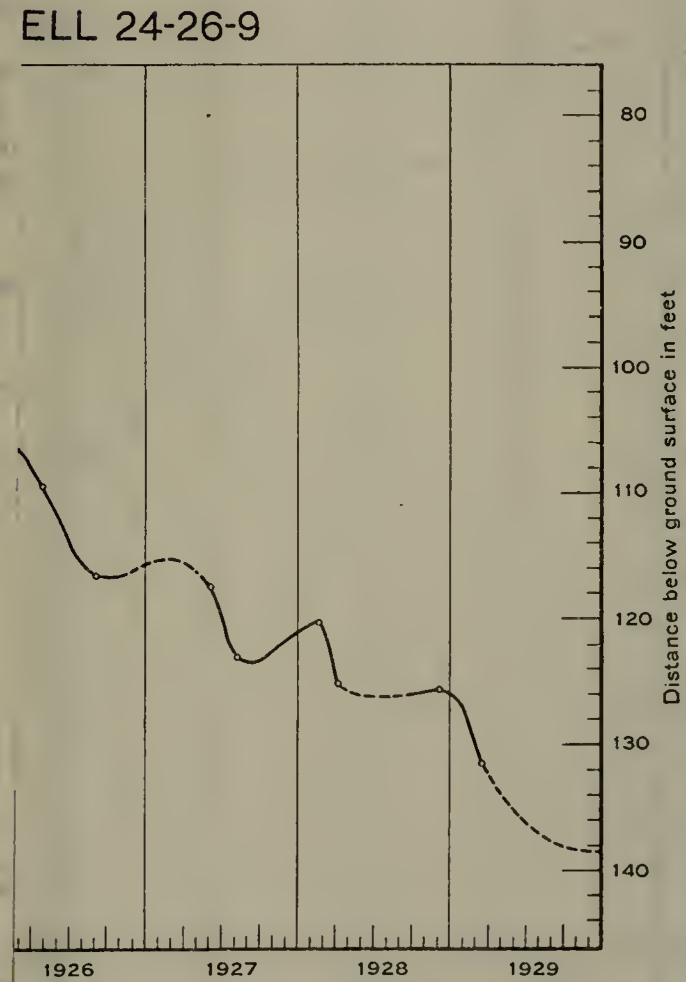
with an average irrigated area of about one-fourth of the gross area, an average lowering of about five feet per year has occurred. A larger lowering occurred in 1927 than in the very dry year of 1924, indicating that the area irrigated is the main factor causing lowering and that differences in the very limited tributary supply in individual years do not materially affect the results. An average annual depletion of about 50,000 acre-feet for the period, 1921–1929, has been estimated for the Earlimart-Delano Unit upon the basis of an assumed drainage factor of 12½ per cent applied to the total drained soil volume. The sum of the annual depletion and the average estimated annual run-off of White River indicates a use of 2.5 acre-feet per irrigated acre average for the eight-year period, and 1.7 acre-feet per acre irrigated in 1929.

On Plate XVI, "Earlimart-Delano Ground Water Unit," is shown a profile extending east and west through Delano. This crosses the area of heavy pumping east of Delano. The relatively flat slope of the ground water in 1921, in comparison with the land slopes, illustrates the rapid increase of pumping lift to the east as well as the light slope of the ground water needed to discharge the naturally tributary supply. The profile for 1929 shows, clearly, the effect of pumping in this area. The lowering has produced a ground water depression which has reversed the ground water slope underlying the western portion of the unit. The plate also shows the hydrographs of two wells whose fluctuations are typical for this area. Well No. 24–26–29 and 24–26–30a, jointly, show the progress of lowering in the almost solidly developed area near Delano. The readings on these wells were not continuous, but sufficient were obtained to show that the steady decline is unaffected by the variations in stream flow in different years. These wells are remote from any stream channels. Well 24–26–9 is on the lower course of White River. A more rapid lowering occurred in the later years shown than at the beginning of the period. This is probably due to the larger area irrigated in later years. The record of water levels in this well does not show the effect which might be expected due to its proximity to the channel of White River. It lowered about as much in 1927 as in 1928 or 1929. The draft in this area is so large in relation to the supply that variations in the annual supply cause little if any change in the rate of lowering.

Tule-Deer Creek Unit.

This unit is bounded on the north by the Kaweah and Lindsay units, along the line of the Fifth Standard Parallel. It extends southward about sixteen miles to a line two miles north of Earlimart. The eastern limit is near Porterville and the western limit is four miles east of Angiola. Tule River and Deer Creek are the principal local tributary streams. The total area is 239,000 acres.

The available data on water supply, areas irrigated and ground water fluctuations are shown in Table 34. A total lowering in eight years of 22.6 feet has occurred. The conditions of water supply and irrigation vary in the different parts of this area. Canals diverting from Tule River serve lands near Porterville. The main portion of the run-off, particularly in years of less than normal run-off, is used in the upper portion of the Tule River Delta. Surplus water is



O GROUND WATER UNIT

with an average irrigated area of about one-fourth of the gross area, an average lowering of about five feet per year has occurred. A larger lowering occurred in 1927 than in the very dry year of 1924, indicating that the area irrigated is the main factor causing lowering and that differences in the very limited tributary supply in individual years do not materially affect the results. An average annual depletion of about 50,000 acre-feet for the period, 1921–1929, has been estimated for the Earlimart-Delano Unit upon the basis of an assumed drainage factor of 12½ per cent applied to the total drained soil volume. The sum of the annual depletion and the average estimated annual run-off of White River indicates a use of 2.5 acre-feet per irrigated acre average for the eight-year period, and 1.7 acre-feet per acre irrigated in 1929.

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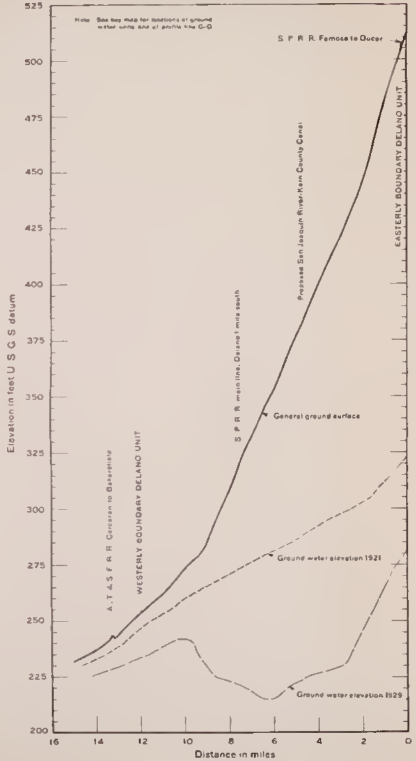
Tule-Deer Creek Unit.

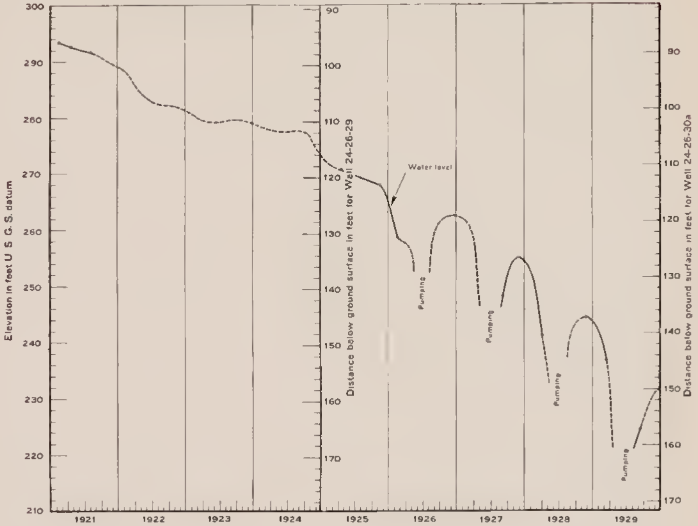
This unit is bounded on the north by the Kaweah and Lindsay units, along the line of the Fifth Standard Parallel. It extends southward about sixteen miles to a line two miles north of Earlimart. The eastern limit is near Porterville and the western limit is four miles east of Angiola. Tule River and Deer Creek are the principal local tributary streams. The total area is 239,000 acres.

The available data on water supply, areas irrigated and ground water fluctuations are shown in Table 34. A total lowering in eight years of 22.6 feet has occurred. The conditions of water supply and irrigation vary in the different parts of this area. Canals diverting from Tule River serve lands near Porterville. The main portion of the run-off, particularly in years of less than normal run-off, is used in the upper portion of the Tule River Delta. Surplus water is

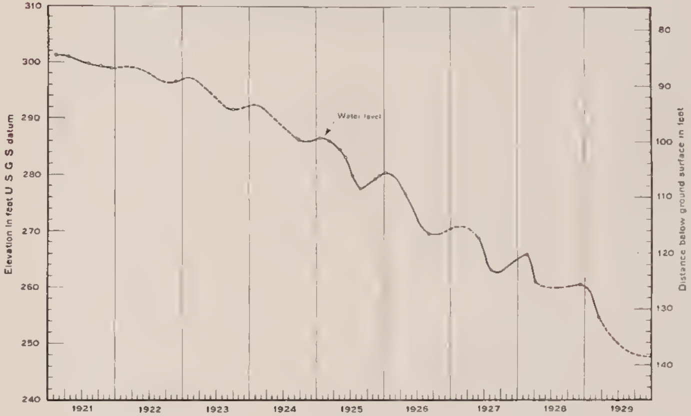
PROFILES ALONG LINE G-G
1921 AND 1929



WATER LEVELS IN
WELL 24-26-29 WELL 24-26-30a



WATER LEVELS IN WELL 24-26-9



EARLIMART-DELANO GROUND WATER UNIT

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largely diverted to lower lands on the delta and larger flows result in some waste to Tulare Lake. There has been no surface outflow from Tule River from 1921 to 1929. Deer Creek has a small run-off. Pumping is carried on along its course by individual land owners and from a group of wells used to serve the Terra Bella Irrigation District, which also exercises a surface diversion right through the Deer Creek Ditch. For the remainder of this general area, there is no direct stream flow or canal use and any ground water replenishment is dependent on the slow outward movement of ground water from adjacent areas. The areas irrigated in 1921 and 1929 were determined from crop surveys, but for other years a uniform rate of increase in the irrigated area has been assumed.

An estimated average annual depletion of 56,000 acre-feet for the Tule-Deer Creek Unit is based upon the difference between the run-off and an indicated net use requirement for zero fluctuation of 2.2 acre-feet per acre for an average irrigated area of 67,400 acres. This gives an indicated average drainage factor of about eight per cent for the entire unit.

TABLE 34

TULE-DEER CREEK UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 373 square miles

Season	Water supply, in acre-feet			Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
	Tule River	Deer Creek	Total			
1920-1921	90,500	12,500	103,000	63,700	1.62	----------
1921-1922	139,700	16,900	156,600	64,500	2.43	—0.89
1922-1923	102,000	14,400	116,400	65,300	1.78	—1.27
1923-1924	24,700	4,950	29,650	66,100	0.45	—5.20
1924-1925	89,800	17,600	107,400	67,000	1.60	—1.87
1925-1926	48,900	7,550	56,450	67,800	0.83	—3.47
1926-1927	131,000	15,600	146,600	68,600	2.14	—1.60
1927-1928	48,200	8,900	57,100	69,400	0.82	—3.64
1928-1929	54,800	13,350	68,150	70,200	0.97	—4.70
Averages, 1921-1929	79,900	12,400	92,300	67,400	1.37	—2.83

[1] Data are available for 1921 and 1929 only. Values for other years interpolated.
[2] (—) indicates lowering of ground water.

In order to compare annual ground water fluctuations with water supply, the portions of this unit more directly dependent on Tule River and on Deer Creek have been separated. The relationship is not as direct as in other areas for which similar comparisons are made. The water supply is not distributed over much of the area which is dependent on these streams for such ground water replenishment as it may receive. The results are presented in Tables 35 and 36.

Table 35 gives the records for the area below Porterville which is more directly dependent on Tule River. The records of run-off of Tule River are reduced by the amount of the estimated use between the gaging stations and Porterville.

TABLE 35

TULE RIVER AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 155 square miles

Season	Water supply, run-off of Tule River at Porterville, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921–1922	129,100	36,000	3.59	—0.02
1922–1923	91,400	37,000	2.47	—1.24
1923–1924	16,700	38,000	0.44	—4.57
1924–1925	79,800	39,000	2.05	—1.27
1925–1926	40,700	40,000	1.02	—4.69
1926–1927	120,400	41,000	2.94	—1.30
1927–1928	40,000	41,000	0.98	—5.19
1928–1929	46,600	41,000	1.14	—4.77
Averages, 1921–1929	70,600	39,100	1.80	—2.88

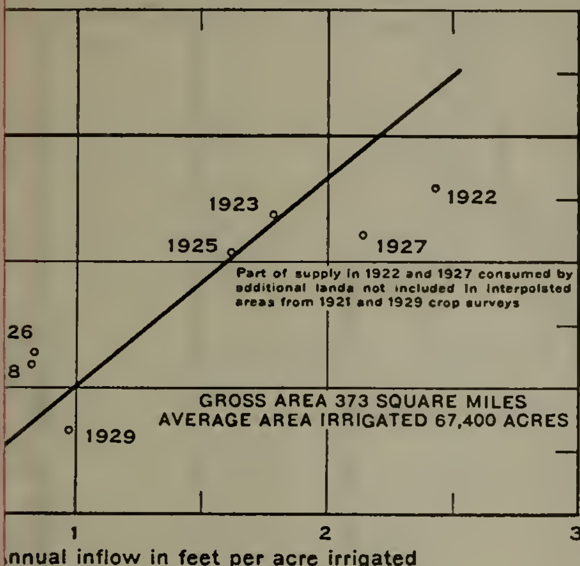
[1] Area irrigated based upon crop surveys for 1921 and 1929 and estimates contained in Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," for 1924 and 1925.
[2] (—) indicates lowering of ground water.

The ground water fluctuations do not indicate the same relationship between supply and use as that found for other areas. The apparent rates of supply needed to maintain the ground water are larger than those found elsewhere. However, there are several elements involved which are considered to account for this difference. The crop area represents regularly cropped and cultivated lands. Larger winter flows may partially serve additional lands not included in the crop survey. Similar conditions occur in years of larger run-off in March and April, during which periods, stream flow is delivered to lower canals under the terms of a court decree governing such use. The crop area does not include the channel areas supporting natural vegetation which also consumes moisture. On the outer portions of the area, there may be a sufficient time lag between the occurrence of run-off and the resulting effect on the ground water so that the fluctuations of a given season may be partially the result of run-off of the preceding season. Therefore, it is believed that the indicated larger net use in this area is to be expected from consideration of these factors affecting its amount.

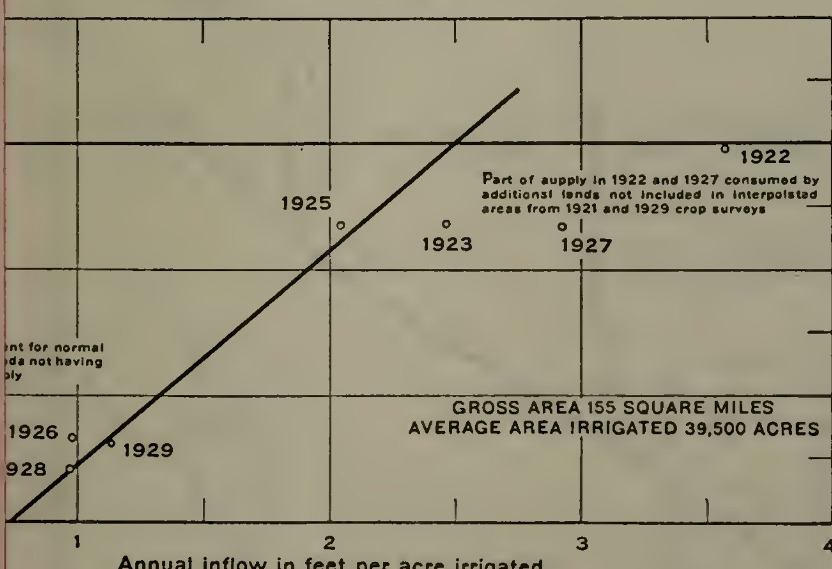
Table 36 gives the records of water supply, area irrigated and ground water changes for the Deer Creek area, below Terra Bella. These show a general relationship between supply and fluctuation. In no year has the supply been sufficient to maintain the ground water. The relation of inflow to change in level of ground water for Deer Creek area, as shown on Plate XVII, "Tule-Deer Creek Ground Water Unit," indicates that a supply of about two acre-feet per acre would meet the net use.

Plate X shows the total lowering that has occurred in the Tule-Deer Creek Unit from 1921 to 1929. Along Tule River the lowering varies from zero in a small area near Porterville to twenty-five feet in the western part of the irrigated area decreasing to ten feet in the lower river where there is only limited development. Along Deer Creek, west of Terra Bella, in the vicinity of the valley wells of the Terra Bella Irrigation District, the largest lowering, of about forty

-ATION OF INFLOW TO
-EVEL OF GROUND WATER FOR
CREEK GROUND WATER UNIT



RELATION OF INFLOW TO
GE IN LEVEL OF GROUND WATER FOR
TULE RIVER AREA



TULE-DEER CREEK
GROUND WATER UNIT

TABLE 35

TULE RIVER AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 155 square miles

Season	Water supply, run-off of Tule River at Porterville, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921-1922	129,100	36,000	3.59	−0.02
1922-1923	91,400	37,000	2.47	−1.24
1923-1924	16,700	38,000	0.44	−4.57
1924-1925	79,800	39,000	2.05	−1.27
1925-1926	40,700	40,000	1.02	−4.69
1926-1927	120,400	41,000	2.94	−1.30
1927-1928	40,000	41,000	0.98	−5.19
1928-1929	46,600	41,000	1.14	−4.77
Averages, 1921-1929	70,600	39,100	1.80	−2.88

[1] Area irrigated based upon crop surveys for 1921 and 1929 and estimates contained in Bulletin No. 11, "Ground Water Resources of the Southern San Joaquin Valley," for 1924 and 1925.
[2] (—) indicates lowering of ground water.

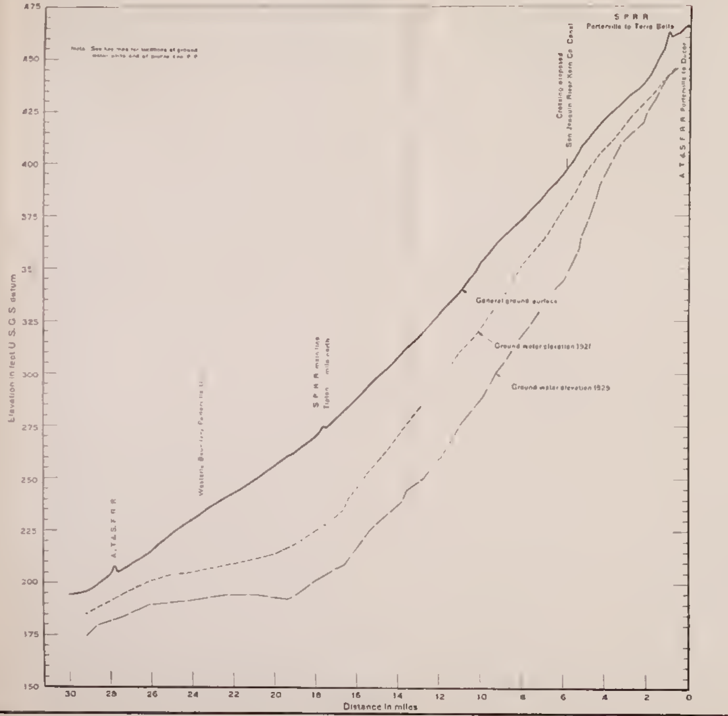
The ground water fluctuations do not indicate the same relationship between supply and use as that found for other areas. The apparent rates of supply needed to maintain the ground water are larger than those found elsewhere. However, there are several elements involved which are considered to account for this difference. The crop area represents regularly cropped and cultivated lands. Larger winter flows may partially serve additional lands not included in the crop survey. Similar conditions occur in years of larger run-off in March and April, during which periods, stream flow is delivered to lower canals under the terms of a court decree governing such use. The crop area does not include the channel areas supporting natural vegetation which also consumes moisture. On the outer portions of the area, there may be a sufficient time lag between the occurrence of run-off and the resulting effect on the ground water so that the fluctuations of a given season may be partially the result of run-off of the preceding season. Therefore, it is believed that the indicated larger net use in this area is to be expected from consideration of these factors affecting it amount.

Table 36 gives the records of water supply, area irrigated and ground water changes for the Deer Creek area, below Terra Bella. These show a general relationship between supply and fluctuation. In no year has the supply been sufficient to maintain the ground water. The relation of inflow to change in level of ground water for Deer Creek area, as shown on Plate XVII, "Tule-Deer Creek Ground Water Unit," indicates that a supply of about two acre-feet per acre would meet the net use.

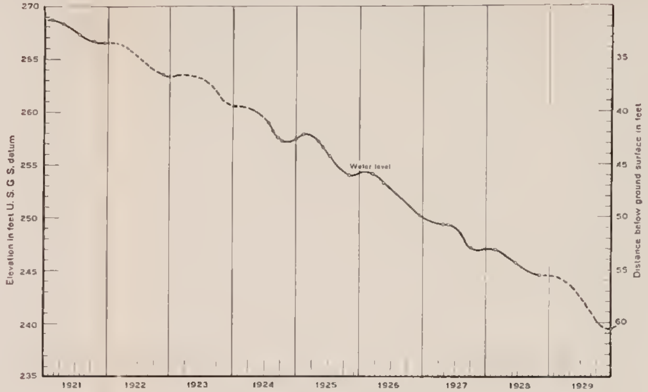
Plate X shows the total lowering that has occurred in the Tule-Deer Creek Unit from 1921 to 1929. Along Tule River the lowering varies from zero in a small area near Porterville to twenty-five feet in the western part of the irrigated area decreasing to ten feet in the lower river where there is only limited development. Along Deer Creek, west of Terra Bella, in the vicinity of the valley wells of the Terra Bella Irrigation District, the largest lowering, of about for

PROFILES ALONG LINE F-F

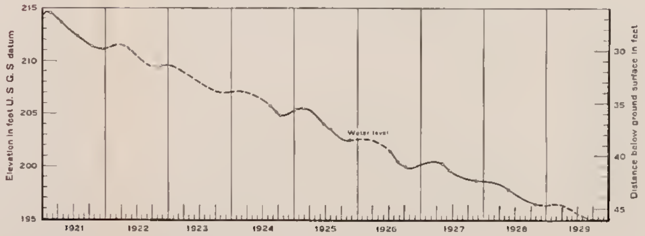
1921 AND 1929



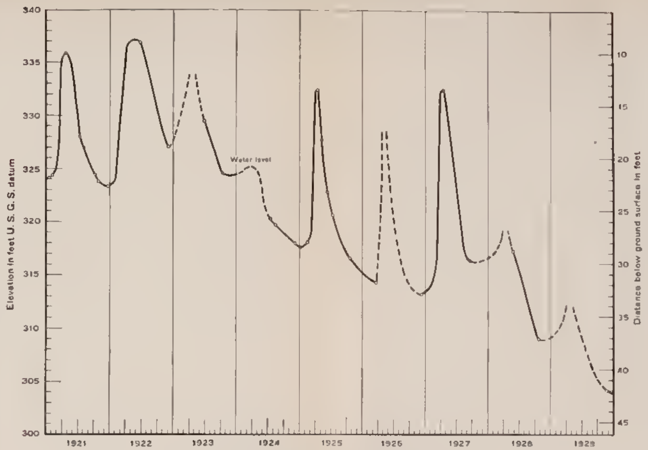
WATER LEVELS IN WELL 21-25-34b



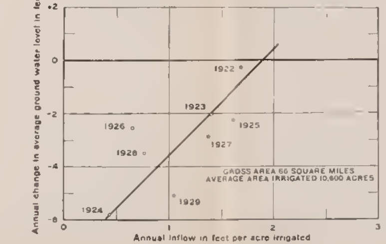
WATER LEVELS IN WELL 22-24-5



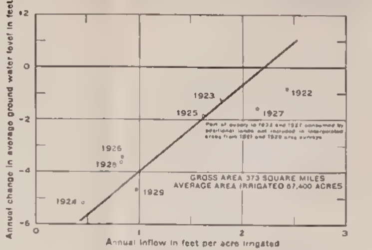
WATER LEVELS IN WELL 21-26-9a



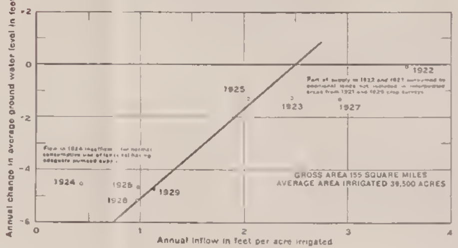
RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR DEER CREEK AREA



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR TULE-DEER CREEK GROUND WATER UNIT



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR TULE RIVER AREA



TULE-DEER CREEK GROUND WATER UNIT

59997

TABLE 36

DEER CREEK AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 66 square miles

Season	Water supply, run-off of Deer Creek at Terra Bella, in acre-feet	Area irrigated, in acres[1]	Seasonal inflow in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
1921-1922	16,500	9,800	1.68	—0.38
1922-1923	14,200	10,100	1.40	—2.03
1923-1924	4,600	10,400	0.44	—5.80
1924-1925	17,200	10,700	1.61	—2.23
1925-1926	7,100	11,000	0.65	—2.55
1926-1927	15,100	11,000	1.37	—2.87
1927-1928	8,400	10,900	0.77	—3.51
1928-1929	11,300	10,800	1.05	—5.10
Averages, 1921-1929	11,800	10,600	1.11	—3.06

[1] Includes irrigated area to the east of the ground water unit assumed, for which ground water changes are available. Acreage based upon crop surveys for 1921 and 1929, and upon Terra Bella Irrigation District reports.
[2] (—) Indicates loweering of ground water level.

feet, has occurred. In the general area, between Tule River and Deer Creek, the lowering has varied from five to twenty-five feet near the east side to twenty to thirty-five feet for the remainder of the area east of Tipton and Pixley, with smaller amounts to the west.

A profile extending across Tule River area from Porterville to Tipton and thence southwest is shown on Plate XVII, "Tule-Deer Creek Ground Water Unit." Lowering from 1921 to 1929 has occurred throughout the length shown. The land on the eastern portion receives canal service but supplemental pumping is also generally practiced. Less lowering has occurred than in the lower portion near Tipton where there is no canal service and irrigation depends entirely on pumping. Pumping just west of Tipton has caused sufficient lowering to have reached the point of reversing the direction of ground water slope. There is less development at the western end of the profile.

On Plate XVII are included the hydrographs of three typical wells extending across the Tule River Delta. Well 21–26–9a is adjacent to Tule River in an area of mixed canal and pumping service. A sharp response to flow in Tule River is shown with a marked lowering after adjacent stream flow ceases. Rises occurred in 1922 and 1927, the only two years, in the period shown, in which the run-off was normal. While a total lowering of about 20 feet is shown for the eight years, it is probable that, in a series of years of normal run-off, ground water at this well would maintain itself. Well 21–25–34b is about three miles east of Tipton in an area of pumping development. It is about three miles south of the nearest channel of Tule River. It shows no response to stream flow but has followed a fairly steady rate of lowering of over three feet per year. Lowering in 1924 was similar to that in 1927. Under existing conditions, only continual lowering can be expected in this area. Well 22–24–5 is located four miles west of Tipton at the outer edge of pumping development and of the Tule River Delta. A steady lowering, unaffected by annual variations in run-off, is shown. An average annual rate of lowering of about two feet has occurred.

Kaweah Unit.

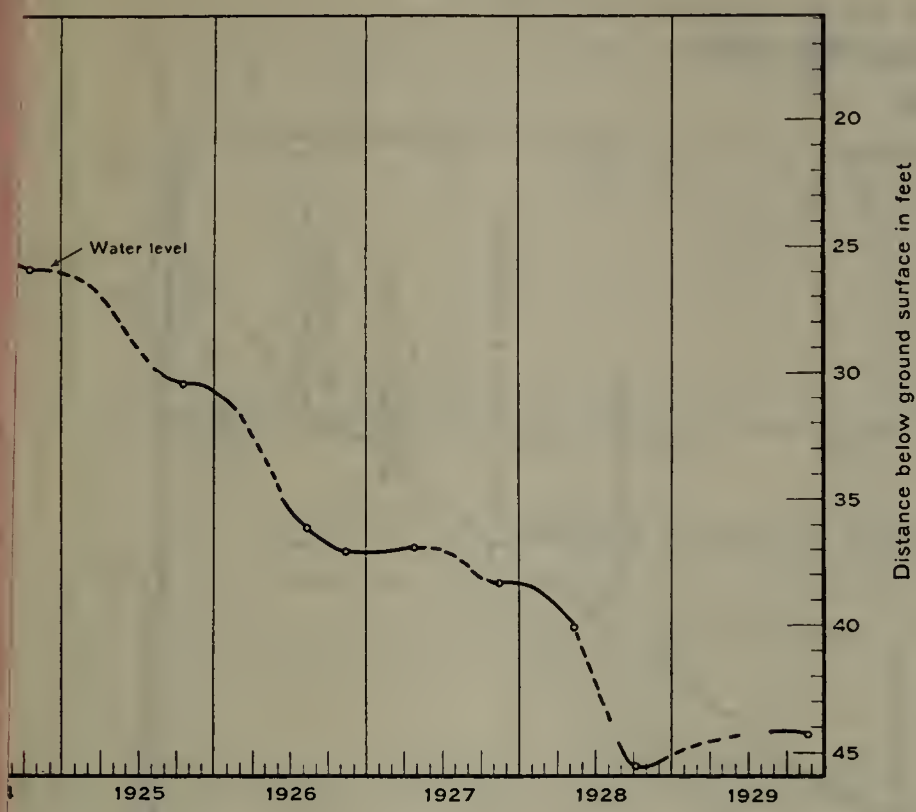
This unit includes that portion of the Kaweah River Delta served by surface waters from that stream. Its northern limit is at Cottonwood Creek and the southern limit two miles south of the Fifth Standard Parallel near Waukena. The eastern limit is about two miles east of Exeter and the western limit one mile east of the east line of Range 22 East at Waukena. The gross area is 468 square miles and the average area irrigated is 209 square miles, or 133,700 acres. While there are a few diversions between Three Rivers and McKay Point, the main use of Kaweah River occurs below McKay Point. Here the river divides into the St. Johns and Kaweah channels. The diversions by the individual canals are governed by their relative rights and priorities have been established through litigation. The larger and more dependable part of the stream flow is used mainly by the higher canals. As the low water flow of Kaweah River is much less than the demands of the total area irrigated, supplemental pumping is usual. Formerly much land secured its supplemental supply by subirrigation from high ground water. Lowering in recent years has necessitated pumping. The individual canals on Kaweah River serve generally small areas which are somewhat intermingled. Nearly all systems are organized as mutual water companies, an exception being the Tulare Irrigation District. The small size and overlapping of the different systems make it impractical to segregate the use and ground water fluctuations, by individual areas.

Plate X shows the changes in ground water from 1921 to 1929. Lowering has occurred throughout the Kaweah Delta except for a spot on the river near the hills and a spot on the north edge where there is practically no use of water. In the main canal served areas the general lowering has varied from five to fifteen feet. Away from canal service, lowering has varied with the extent of pumping draft. General lowering of about twenty feet around Ivanhoe, twenty to fifty feet near Exeter, thirty feet near Goshen, and twenty-five to thirty-five feet near Tulare illustrate results in areas of extensive pumping. Lowering of ten to twenty-five feet has occurred around the edges of the area.

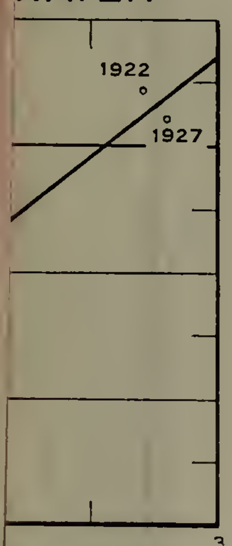
The data on water supply, areas irrigated and ground water changes for the entire area of the Kaweah Unit are given in Table 37. These show an average lowering over the whole area for the eight year period of 2.24 feet per year with an average supply of 1.88 acre-feet per acre irrigated. This area includes some lands adjacent to the Kaweah River but not supplied by it. Some additional areas toward which the ground water slopes from the Kaweah Delta are included in other areas. Accompanying graphs, a typical profile and hydrographs from records of typical wells are shown on Plate XVIII, "Kaweah Ground Water Unit."

An apparent average net use requirement of 2.56 acre-feet per acre for the average irrigated area of 133,700 acres in the Kaweah Unit is indicated, and the estimated average annual depletion of 92,000 acre-feet is based upon the difference between the indicated net use requirement and the mean net inflow of 250,800 acre-feet for the 1921–1929 period. This results in an indicated average drainage factor of about 14 per cent for this unit. This large apparent net use is due to several factors, some of which are: (1) the use of water (not deducted from the inflow) by lands to the east of the ground water unit which are

EVELS IN WELL 19-23-21b



CHANGE
WATER



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KAWEAH

GROUND WATER UNIT

Kaweah Unit.

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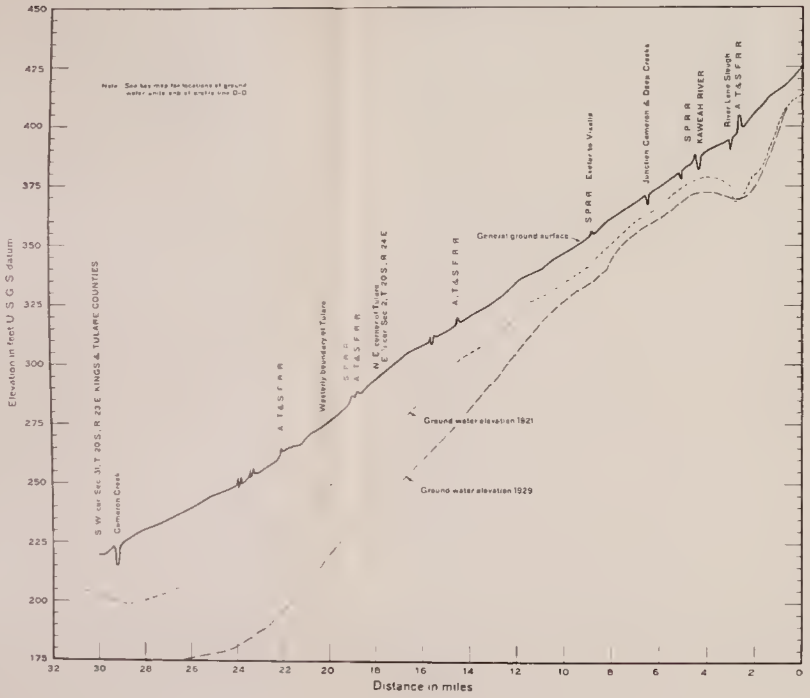
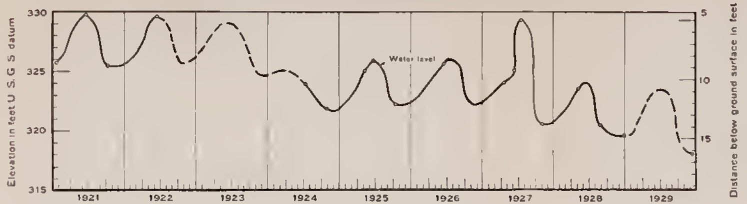
PROFILES ALONG LINE D-D

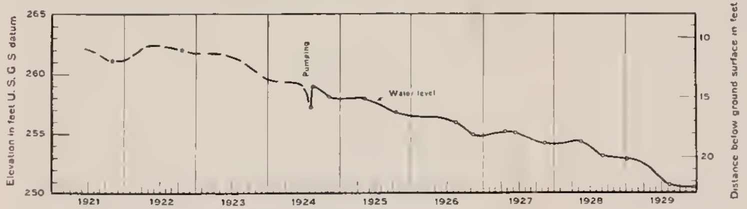
1921 AND 1929



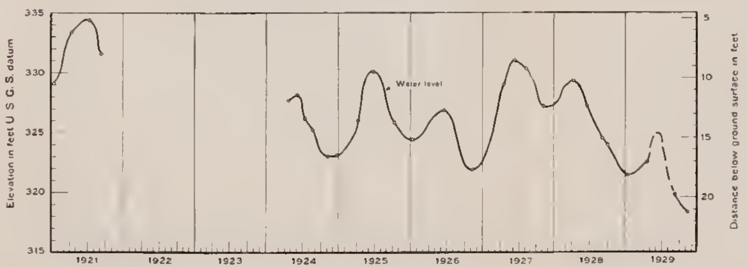
WATER LEVELS IN WELL 18-25-4a



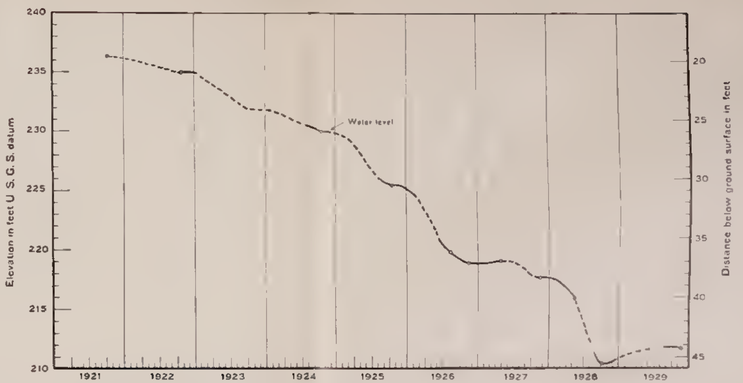
WATER LEVELS IN WELL 18-23-11



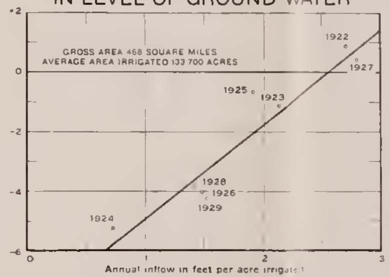
WATER LEVELS IN WELL 18-25-34a



WATER LEVELS IN WELL 19-23-21b



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER



KAWEAH GROUND WATER UNIT


WATER
RELATION OF INFLOW T
IN LEVEL OF GROUND

iot included in the irrigated areas, (2) the subirrigation and flooding n years of large flow of lands not included in the irrigated areas, (3) he underground outflow to lands in the west part of the Lindsay Jnit, (4) possible underground outflow to areas to the west of the elected ground water unit, (5) consumption of water by natural vegeation.

TABLE 37

:AWEAH UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 468 square miles

Season	Water supply			Area irrigated, in acres[2]	Seasonal net supply, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Run-off of Kaweah River at Three Rivers, in acre-feet	Outflow not used on Kaweah Delta, in acre-feet[1]	Net supply for Kaweah Delta, in acre-feet			
921–1922	461,100	83,800	377,300	140,000	2.70	+0.88
922–1923	363,500	63,800	299,700	141,000	2.12	—1.19
923–1924	101,700	13,700	88,000	120,000	0.73	—5.21
924–1925	325,500	51,300	274,200	143,000	1.92	—0.68
925–1926	218,800	33,800	185,000	124,000	1.49	—4.05
926–1927	483,200	78,000	405,200	145,000	2.79	+0.41
927–1928	203,000	20,900	182,100	128,000	1.42	—3.86
928–1929	222,800	28,000	194,800	128,500	1.52	—4.26
Averages, 1921–1929	297,500	46,700	250,800	133,700	1.88	—2.25

[1] Outflow from Lindsay-Strathmore Irrigation District well field on Rancho de Kaweah and 1929 exportation of /atchumna Ditch water, Lakeside Ditch water and estimated outflow through Cross Creek.
[2] Field surveys of irrigated lands were made in 1920 and 1929. Areas for intermediate seasons were estimated by terpolation for areas having adequate facilities for ground water utilization, and in accordance with available surface pplies and consideration of existing water right schedules for other areas.
[3] (+) indicates a rise, and (—) a fall in ground water level.

In order to compare the inflow and fluctuations more directly, the rea below McKay Point dependent on Kaweah River was used. This grees approximately with the area shown as the Kaweah Unit on Plate XII, but excludes lands above McKay Point and includes part f the Lindsay Unit. The results for this area are shown in Table 38.

TABLE 38

WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES FOR KAWEAH DELTA BELOW McKAY POINT

Gross area, 453 square miles

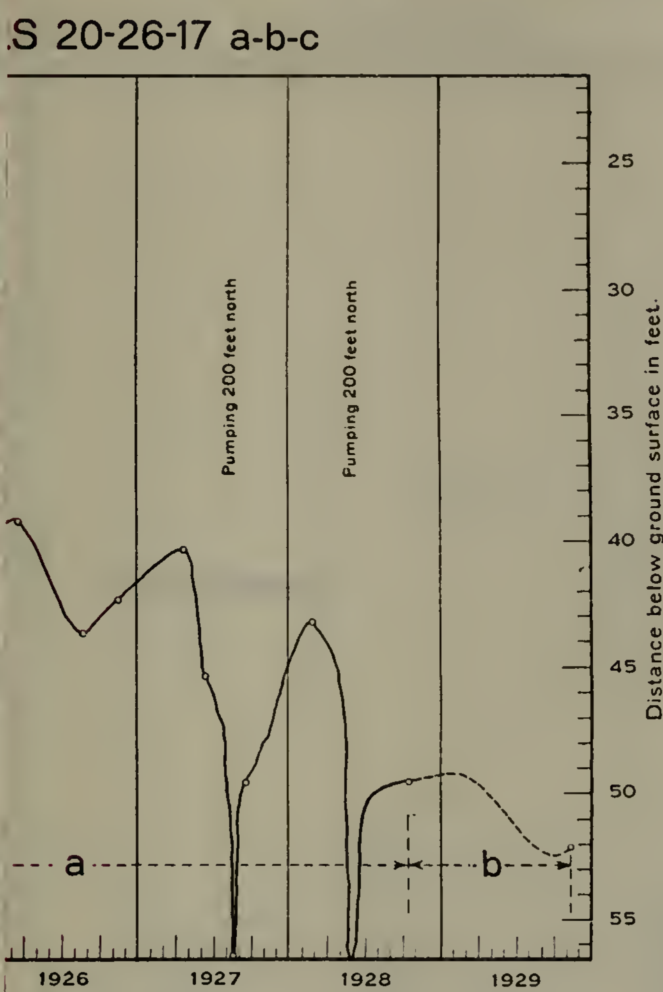
Season	Water supply. Inflow at McKay Point less outflow given in Table 37, in acre-feet	Area irrigated, in acres	Seasonal net inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[2]
920–1921	258,800	131,700	1.97	[1]—1.05
921–1922	364,000	134,100	2.71	+0.50
922–1923	274,000	133,700	2.05	—0.77
923–1924	69,600	108,300	0.64	—5.05
924–1925	268,400	135,500	1.98	—1.20
925–1926	175,800	113,900	1.54	—4.25
926–1927	362,800	137,200	2.64	+0.17
927–1928	160,400	114,800	1.40	—3.82
928–1929	180,200	117,800	1.53	—4.76
Averages, 1921–1929	231,900	124,400	1.86	—2.40

[1] Approximate—records incomplete; not included in mean.
[2] (+) indicates a rise and (—) a fall in ground water level.

The irrigated areas in Table 38 represent only the cropped areas. In addition, there are areas along the channels supporting trees and pasture which also consume water, and in years of larger run-off additional lands receive partial service for pasturage. Definite data regarding the extent of these areas are not available. They are sufficient to be a factor in such years as 1922 and 1927. The average net water supply is plotted against the ground water changes on Plate XIX, "Kaweah and Lindsay Ground Water Units." The normal relationship between supply and change is considered to be represented by the line shown. This line is based on the years 1921, 1923, 1925, 1926, 1928 and 1929. For 1922 and 1927 the additional lands flooded would reduce the supply per acre if the amount of such land were known and added to the cropped area and bring the points for these years, shown on the graph, into closer agreement with the results for other years. In 1924 the stream flow was insufficient to supply the full needs of the cropped areas not equipped for pumping and the smaller indicated net use is due to this shortage. For years in which cropped lands receive a normal supply, an inflow of 2.17 acre-feet per acre of cropped area appears to be needed to meet net use requirements and maintain the ground water. This includes actual moisture use on cropped lands and on the normal areas of channel lands not included in the cropped areas, and takes account of any lack of balance between unmeasured inflow and outflow. The result is somewhat larger than that obtained for areas in the Fresno Consolidated and Alta districts on Kings River. This difference is consistent with the conditions, as these district areas do not include extensive channel lands and the proportion of the areas planted to alfalfa is smaller than that on the Kaweah River Delta. If channel lands are held to their present area and additional lands are not partially supplied in years of larger run-off, the analyses indicate that an acre of irrigated crop can be supplied for each 2.17 acre-feet retained on this area. If the excess, in years of normal or larger run-off, is used on additional areas the number of acres of permanent crops which can be supported will be reduced in proportion to such additional use.

Profile D-D, on Plate XVIII, extends southwesterly across the Kaweah Delta. The upper portion follows the river in an area of heavy pumping, the effect of which shows on the profile. Below this area, the profile crosses the main canal served lands. While development here is extensive, the more direct canal supply has maintained the ground water with only limited lowering, even during the period of less than normal run-off. In the lower portion of the profile, there is little canal service although there are extensive areas depending on pumping. The greater distance from sources of direct supply and heavy draft has resulted in a lowering of over 30 feet during the eight-year period.

Profile E-E on Plate XIX extends east and west through the area between the deltas of Kaweah and Tule rivers, near Lindsay, and across the outer Kaweah Delta into the lower part of the South Kings area. The reversed ground water slopes caused by the heavy draft in the inter-delta area at the east are clearly illustrated by this profile. Near Elk Bayou the more direct canal supply has maintained the ground water with limited lowering even in recent dry years. The western



KAWEAH AND LINDSAY
GROUND WATER UNITS

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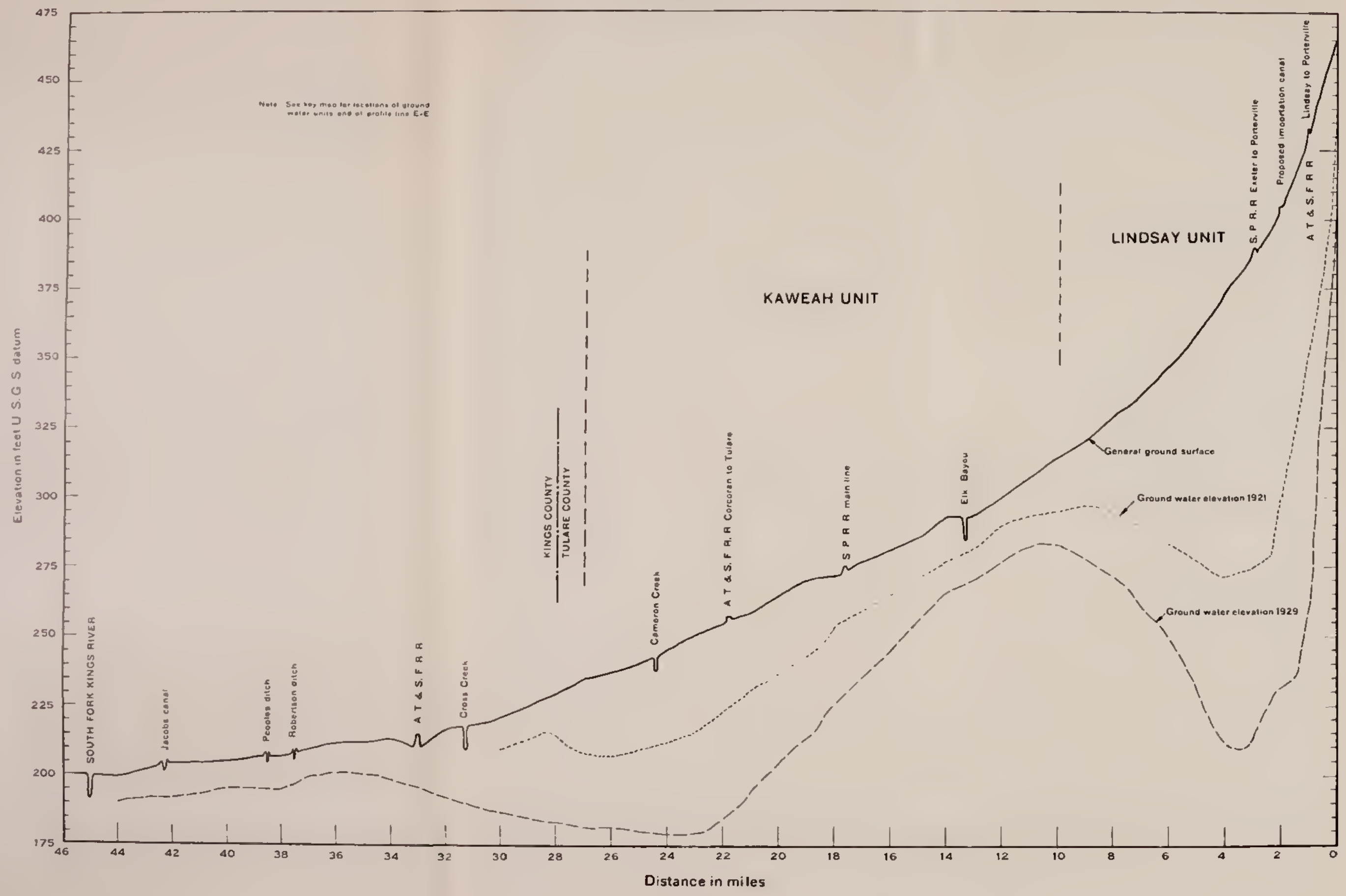
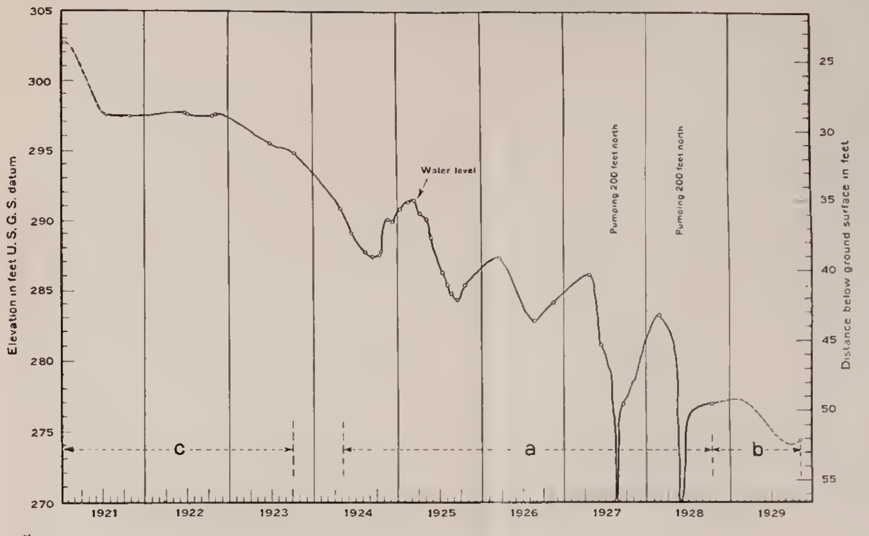
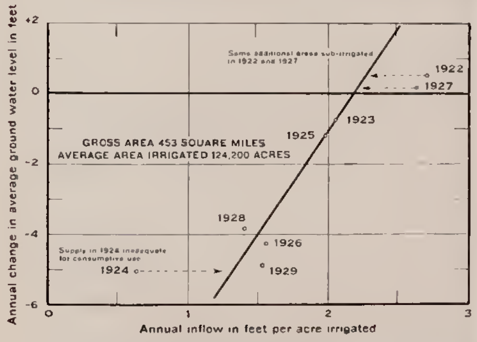
PROFILES ALONG LINE E-E

1921 AND 1929



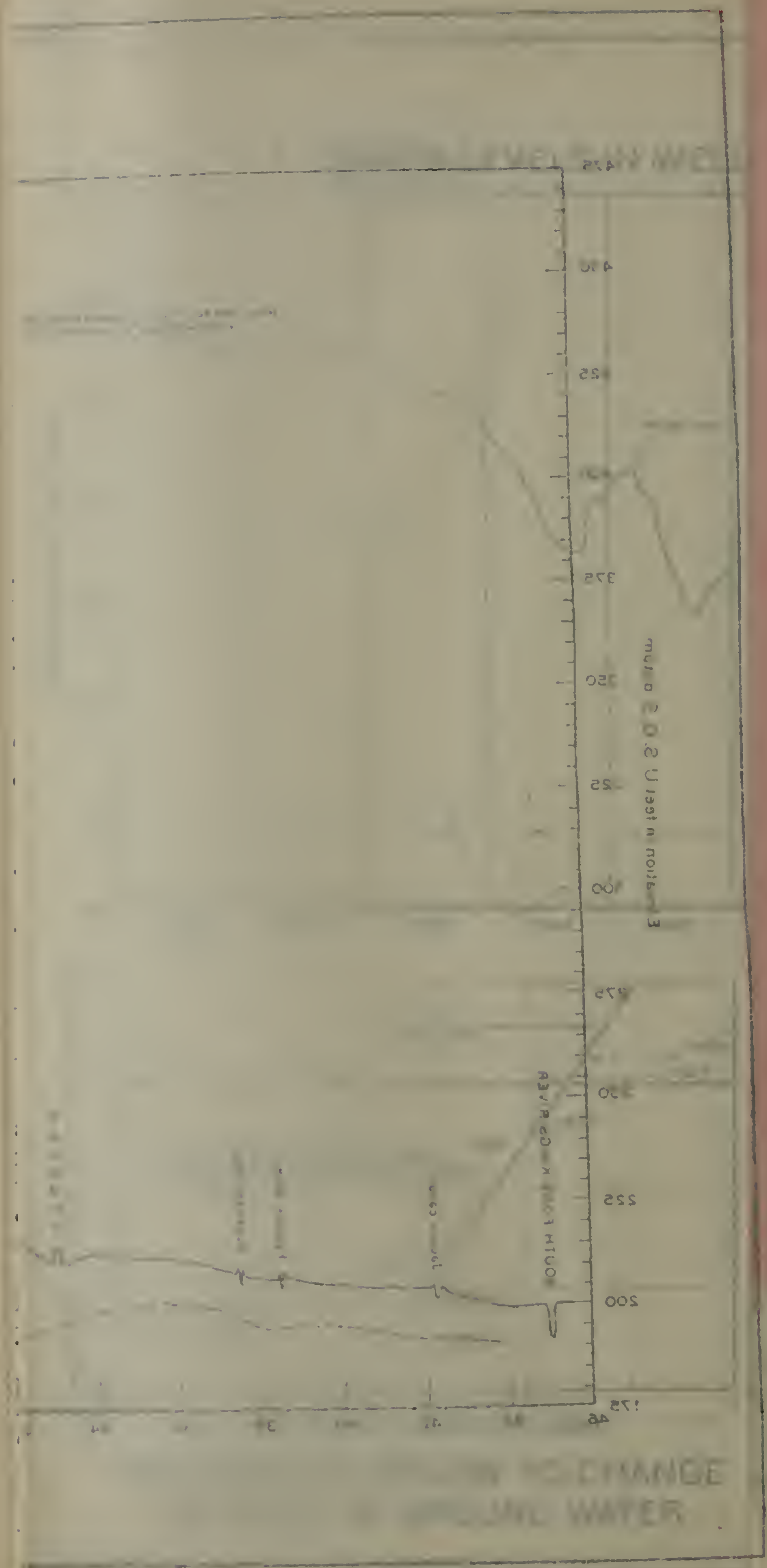
WATER LEVELS IN WELLS 20-26-17 a-b-c





RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER

KAWEAH AND LINDSAY GROUND WATER UNITS



and lower part of the Kaweah Delta shows similar heavy lowering to that shown on Profile D-D on Plate XVIII. On this plate are shown the hydrographs of four wells whose fluctuations illustrate the effect of supply and draft on the ground water. Well No. 18–25–4a is located in the northern part of the Kaweah Delta in an area of scattered canal and pumping service. A quite regular cycle of fluctuation is shown with a rise during the early summer and a decline during the period of low stream flow in the late summer. A total lowering of about seven feet for the eight-year period is shown. Well No. 18–25–34a is near Visalia within the area of canal service. In 1921 water rose in this well to within six feet of the ground surface. It did not fail to remain at more than 10 feet below the ground surface until the latter part of 1928. In 1929 lowering to more than 20 feet below the ground surface occurred. Well No. 18–23–11 is in the outer part of the Kaweah Delta, near Goshen, in an area receiving mainly flood water service and having little pumping development. A continuous and steady lowering, with little response to periods of larger river or canal flow, is shown. The rate of lowering shows little change either in greater than normal years like 1922 and 1927 or in dry years like 1924 or 1929. The lowering is probably the slowly accumulative effect of the general lack of balance between inflow and draft. Well No. 19–23–21b is also in the outer Kaweah Delta in an area of little pump or canal service. The record is incomplete, but indicates a total lowering of about 25 feet in the eight years.

Lindsay Unit.

This includes the area at the eastern rim of the San Joaquin Valley between the deltas of Kaweah and Tule rivers. It includes a large portion of the Lindsay-Strathmore Irrigation District and all of Township 20 South, Range 26 East. The gross area is 64 square miles and the irrigated area 22,000 acres. It is devoted largely to citrus culture. Pumping in this area was among the earliest uses of ground water for irrigation in the San Joaquin Valley. Such pumping resulted in rapid ground water lowering. The increase in salt content with lowering of the ground water, in some areas, rendered the wells unsuited to use. These conditions resulted in the organization of the Lindsay-Strathmore Irrigation District for the purpose of securing outside water of suitable quantity and quality. This district has a gross area of 15,250 acres of which 7800 acres, largely in citrus, were irrigated in 1929. The area here described, of which the Lindsay-Strathmore Irrigation District is a part, has a gross area of 41,216 acres and extends to the west of the Lindsay-Strathmore District. Approximately 22,000 acres of this combined area were irrigated in 1929. This area occupies the higher valley lands against the adjacent foothill slopes in a locality where there are no locally tributary streams of more than nominal run-off. It is relatively distant from the Kaweah and Tule rivers and out of the direction of the main ground water movement of their respective units. This lack of active sources of ground water replenishment is shown by the rapid rate of lowering that has occurred.

The available data on water supply and ground water fluctuations are shown in Table 39.

TABLE 39

LINDSAY UNIT—WATER SUPPLY AND GROUND WATER CHANGES

(22,000 acres irrigated in 1929)
Gross area, 64 square miles

Season	Water supply, inflow from Kaweah unit, in acre-feet	Seasonal average change of ground water level, in feet[1]
1921–1922	13,400	— 1.62
1922–1923	14,100	— 4.33
1923–1924	13,700	—10.01
1924–1925	12,700	— 2.50
1925–1926	14,100	— 9.01
1926–1927	13,300	— 3.17
1927–1928	14,300	— 5.17
1928–1929	15,500	—18.97
Averages, 1921–1929	13,900	— 6.85

[1] (—) indicates lowering of ground water.

The ground water fluctuations do not vary directly with the supply from Kaweah River. The locally tributary run-off, principally from Lewis Creek, is small and widely variable in different years. Supplemental pumping is used and the ground water fluctuations probably reflect the amount of such pumping more directly than variations in local run-off. The inadequacy of local ground water supplies for local areas was demonstrated prior to the construction of systems based on the use of outside sources. The total supply is too small in relation to the draft and the depth to ground water too great to permit the application of the general graphical method of determining the value of net use per acre. An estimated average annual depletion of 19,000 acre-feet for the 1921–1929 period is based upon an assumed drainage factor of about 7 per cent.

Wells 20–26–17a, b and c, Plate XIX, are located at the west side of the Lindsay area about three miles from Elk Bayou. Adjacent irrigation is dependent entirely on pumping as there is no canal service in the vicinity of this well. A continuous general lowering is shown. A rise occurs during the winter, which was as large in 1924 as in 1925 or 1926. Such rise represents general recovery during the period of minimum pumping draft. The ground water movement into this area, under the slope produced by the local lowering, does not appear to have increased so as to be sufficient to maintain present draft.

Ground water profile E-E through this area is shown on Plate XIX. The marked ground water depression illustrates the result of pumping in areas remote from sources of direct replenishment. The total lowering from 1921 to 1929 as shown on Plate XI varies generally from 25 to 75 feet and averages 45 feet. The greatest lowering has occurred in the areas of heaviest development.

Kings River Areas.

Kings River is the source of water supply for a large area served by several different canal systems. The relative priority of diversion right of the different canals varies, so that there are wide differences in the character and amount of supply received. Use varies from a fairly complete service, both in amount and distribution during the season, to flood water practice utilizing water at the occasional times at which it may be available. No storage has as yet been constructed on the Kings River. A site is available at Pine Flat and preliminary steps toward organization for its construction have been taken. Some storage occurs at times in Tulare Lake. Kings River flow divides on the crest of its delta, part flowing north through Fresno Slough to the San Joaquin River and part to the south into Tulare Lake. Tulare Lake is formed by the ridge which Kings River has built across the valley. As the low water flow of Kings River is insufficient to meet the demands during the late summer months, of the lands now developed, extensive pumping from the ground water is practiced in several of the areas served. Such pumping is more general in the upper areas.

Diversions from Kings River since 1918 have been measured by a water master representing the State or the Kings River Water Association. During the later portion of the period such diversions have been under the general control of the water master operating under a schedule of diversions agreed upon by the larger part of the water right interests. This schedule specifies the amount of diversion to which each canal is entitled at river stages extending to river flows of 9450 cubic feet per second in the months of maximum demand. Rights are claimed at higher stages but are not scheduled. The work of the water master makes available an unusually complete record of practically all diversions from Kings River since 1918. The diversion schedule varies in the different months. In June, the month of maximum schedule rights, the entitlements total 9000 second-feet. The schedule shows the diversion which each canal may make for variations in mean daily stream flow of 100 second-feet. The amounts of these diversions for a few stages of the river in June are shown in Table 40. The difference between the river stage and the total schedule

TABLE 40

SUMMARY OF KINGS RIVER SCHEDULE FOR JUNE

Schedule of 1928

Diversion	Schedule for each diversion River stage, mean daily flow, in second-feet				
	1000	2000	5000	7000	9000
Laguna	15	15	300	400	425
Fresno	650	1,300	1,450	1,450	1,475
Lemoore	91	155	275	375	450
Peoples	183	310	450	500	525
Last Chance	46	155	225	325	325
Consolidated		50	1,100	1,400	1,500
Alta			1,000	1,100	1,200
Murphy Slough	15	15	200	325	375
Liberty				100	100
Crescent				175	175
Stinson				175	200
Burrel				75	150
James				150	150
Beta Main				125	125
Heinlen				70	170
Lakelands					450
Total schedule diversions	1,000	2,000	5,000	6,745	7,795

diversions for the higher stages represents diversions not included in the schedule.

Table 41 shows the records of diversion and run-off for each of the years from 1922 to 1929, inclusive. In 1927 the run-off was about normal. In 1924, 1928 and 1929 it was much below normal. The effect of deficient run-off on the diversions of these canals is shown clearly.

TABLE 41

DIVERSIONS BY KINGS RIVER CANALS, 1922 TO 1929

From Reports of Kings River Water Master; Flow of Kings River at Piedra, below Empire Weir No. 2, and at Burrel

District or area	Canals	Acre-feet per year									Area of class 1 and class 2 lands, in acres	Area irrigated in 1929, in acres
		1922	1923	1924	1925	1926	1927	1928	1929	8 year mean		
Alta	Alta	168,682	163,472	14,961	158,854	128,015	255,198	98,095	85,448	134,091	102,308	68,450
Consolidated	Consolidated[1]	260,825	228,476	28,397	216,091	167,273	330,144	135,074	125,594	186,484	146,940	129,000
	Emigrant[2]	9,461	6,843	0	1,048	1,731	3,566	0	0	2,831		
Fresno	Fresno and Gould[3]	367,181	377,297	176,592	423,462	326,952	459,215	324,134	324,633	347,433	230,216	192,800
Peoples	Peoples[4]	173,075	149,073	83,021	170,403	128,791	217,131	119,067	100,527	142,636	51,198	23,400
Lucerne	Last Chance	56,896	63,716	18,238	63,625	52,402	97,125	46,262	36,456	54,340	31,279	19,556
Lemoore	Lemoore	142,052	.125,137	48,333	94,891	81,527	119,498	70,305	59,643	92,673	47,071	14,574
Island No. 3	Island No. 3 (from Fresno)[5]	5,500	2,943	0	4,499	3,021	6,903	2,484	2,409	3,470	4,620	3,720
Liberty	Liberty	14,973	11,174	60	3,097	4,585	14,338	2,261	2,271	6,595	4,000	*1,000
Murphy Slough area[6]	Big and Little Mill Race	26,011	18,633	3,231	11,078	[7]13,113	29,075	10,273	[8]8,127	14,942	10,700	6,780
	Reed	6,643	6,606	1,795	4,983	5,492	9,357	3,516	3,032	5,178		
	Turner-Riverdale	26,612	29,069	5,243	18,410	19,884	38,401	12,109	10,571	20,038	15,198	8,640
Burrell	Cuthbert-Burrel	[8]5,000	[8]2,700	0	1,867	1,440	0	0	0	1,376	9,542	3,740
Laguna	A, Grant, Island, and Summit Lake	65,313	67,621	10,810	48,156	51,597	74,734	30,803	26,586	46,952	28,666	22,500
Crescent	Crescent and Calamity	[9]17,000	21,124	0	9,879	8,661	21,179	4,786	3,870	10,812	8,545	2,894
Stinson	Stinson	11,947	16,712	0	7,185	10,142	13,544	1,194	986	7,714	11,750	5,984
Stratford	Empire No. 1 and No. 2	10,570	10,914	0	1,521	5,496	[7]11,000	0	0	4,938		
Tulare Lake vicinity	Blakeley (Empire No. 3)	36,997	11,440	0	2,299	827	38,972	0	0	11,317		
Corcoran (Lakeland)	Lakeland[11]	32,922	13,446	0	2,944	8,303	20,075	0	0	9,711	*125,000	[10]75,000
Lakeland	Tulare Lake (Empire No. 4[11])	[7]25,945	13,400	0	[7]0	[7]0	25,591	0	0	8,117		
James	James and ⅓ of Beta Main	16,658	18,624	0	2,531	6,510	28,359	0	0	9,085	23,795	11,640
Tranquillity	⅔ of Beta Main	14,738	12,085	0	2,075	3,786	10,826	0	0	5,439	10,210	6,700
Subtotals		1,495,001	1,370,499	390,681	1,248,898	1,029,548	1,824,231	860,363	790,153	1,126,172	861,038	596,378
Flow at Burrel, less diversions of Beta Main and James canals		513,037	138,558	0	7,640	16,549	125,191	0	0	100,122		
Flow toward Tulare Lake, below Empire Weir No. 2		196,711	28,692	0	0	0	6,869	0	0	29,034		
Consumptive use on 10,000 to 15,000 acres, absorption, inflow[12]		16,951	—37,449	8,819	26,462	52,903	27,109	34,037	47,047	21,860	20,000	*12,000
Total flow at Piedra		2,220,700	1,500,300	399,500	1,283,000	1,099,000	1,983,400	894,400	837,200	1,277,188	881,038	608,378

[1] Water master's measurements revised by adding inflow of Lone Tree Canal and deducting outflow to China Slough and Island No. 3 canals in accord with estimates obtained from Consolidated Irrigation District records.

[2] 68.75 per cent of Emigrant Canal stock is owned by Consolidated District.

[3] Water master's measurements revised by deducting flow of Lone Tree Canal.

[4] Peoples Ditch Company records show that the Settler's Ditch owns 16 1/12 shares; the Corcoran District, 4 1/80 shares in addition to 17.4 per cent of the Settler's Ditch stock, and the Lakeland District, 2 67/120 shares out of a total of 63 13/48 shares of outstanding stock. (No revision made.)

[5] From Consolidated Irrigation District estimates.

[6] The Murphy Slough Canal flows were not separately measured except for portions of each year. The unsegregated remainder has been divided as follows: one-half to Turner-Riverdale Canal, ⅛ to Big and Little Mill Race canals, and ⅙ to Reed Canal. The Murphy Slough Record for 1922 was incomplete—the missing period was assumed equal to the average for the five years 1923, 1925–1928.

[7] Flow records missing or incomplete, values estimated.

[8] Estimated on basis of 2 acre-feet per acre for irrigated pasture and 1 acre-foot per acre for irrigated grain.

[9] Flow for Calamity Canal in 1922 estimated.

[10] Two-thirds grain.

[11] Lakeland Canal jointly owned (50 per cent each) by Corcoran and Lakeland Irrigation districts. Kaweah River water also is received.

[12] Centerville Bottoms with a gross area of 14,623 acres of class 1 and class 2 lands, and various diversion rights for riparian lands, among which are Schultz, Brenner and Clarkes Fork, received water from Kings River for the irrigation of between 10,000 and 20,000 acres of land. Return water, seepage and other inflow are included in the amounts shown, and in 1923 exceeded the consumptive use of these lands.

*Approximately.

For purposes of discussion, the Kings River area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Fresno-Consolidated Unit, areas northeast of Fresno Irrigation District, Laguna and Riverdale irrigation districts, areas along north side channels of Kings River, Alta Unit, Foothill Irrigation District and areas served by Kings County canals.

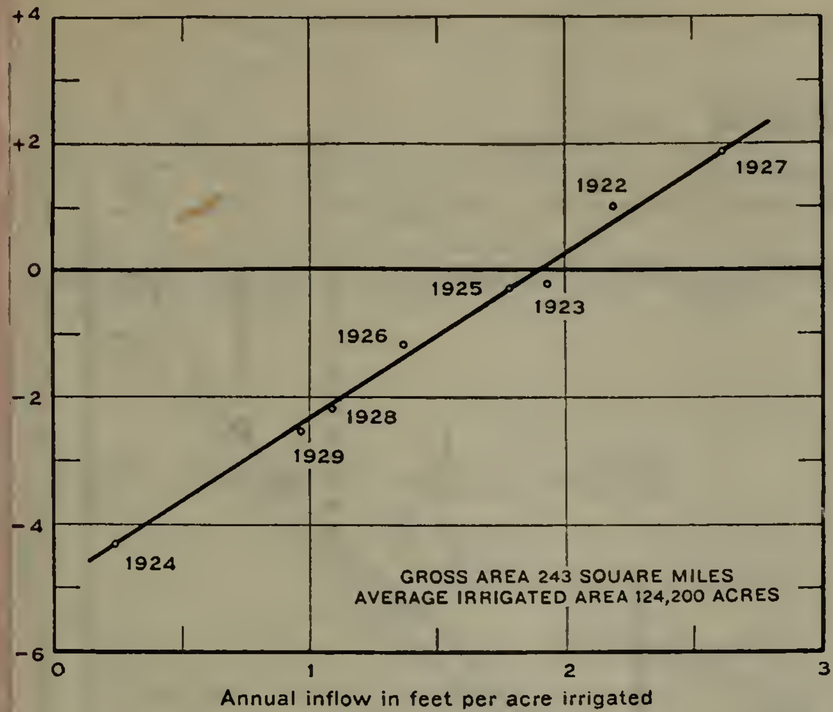
Fresno-Consolidated Unit. This unit includes the total combined area of the two irrigation districts from which its name is derived and a small additional area under pumping development just west of these districts. It extends from the San Joaquin River to the Kings River and has a gross area of 700 square miles, of which 503 square miles, or 321,800 acres, were irrigated in 1929.

The crop surveys in the unit, from which the areas irrigated in each district have been determined, are based on water service areas from which highways, railroads, incorporated and unincorporated towns and main canals have been excluded. The sum of the irrigated areas so determined equals about 80 per cent of the gross irrigable area of this unit.

The Fresno Irrigation District has a gross area of 241,300 acres, of which 192,800 acres were irrigated in 1929. The district has extensive rights of relatively early priority on Kings River and receives a more dependable water supply both in amount and in distribution through the season than other large areas on Kings River. It is generally highly developed, trees and vines constituting the principal plantings. The city of Fresno secures its water supply from ground water within the city area. As a result of irrigation in this area, the ground water has risen from 30 to 60 feet above its elevation prior to the construction of canals.[1] This rise resulted in waterlogging with resulting injury from alkali on much of the lower land in the district. With the increased use of pumping for irrigation in recent years sufficient ground water lowering has occurred so that drainage has been accomplished. In addition to over 30,000 acres which use pumped water exclusively, the larger part of the canal served area also is furnished supplemental service by pumping.

Table 42 shows the records on water supply, irrigation and ground water changes. These show a direct relationship between the water supply per acre and the resulting ground water fluctuation. For the eight-year period, three years show a rise, one year no change and four years a lowering. Plate X shows the lowering from 1921 to 1929 to have varied from zero to ten feet in different parts of the district. Over much of the area the water table has lowered from five to ten feet, with an average of about 5.75 feet. Profile B-B on Plate XX, "Fresno-Consolidated Ground Water Unit," extends southwesterly through Fresno and the wells of the James Irrigation District on McMullin Grade Road to Fresno Slough. Lowering has not been great, except near Fresno. The pumping draft for municipal use in Fresno has resulted in a flattening of the ground water slope immediately beneath the city with a consequent steepening to the eastward. The larger value of diversion per acre irrigated, available to the Fresno

[1] U. S. G. S. Water Supply Paper No. 18, "Irrigation near Fresno, California," 1898.



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR CONSOLIDATED IRRIGATION DISTRICT

FRESNO-CONSOLIDATED GROUND WATER UNIT

For purposes of discussion, the Kings River area as a whole has been divided into smaller local areas and ground water units having similar conditions. These divisions, in the order presented, consist of the Fresno-Consolidated Unit, areas northeast of Fresno Irrigation District, Laguna and Riverdale irrigation districts, areas along north side channels of Kings River, Alta Unit, Foothill Irrigation District and areas served by Kings County canals.

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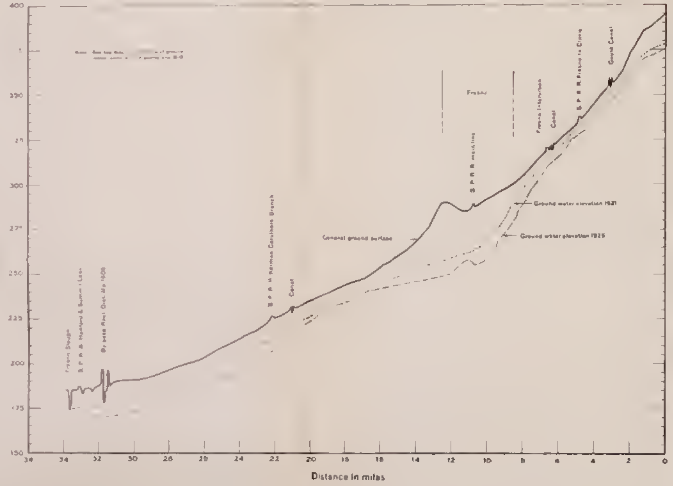
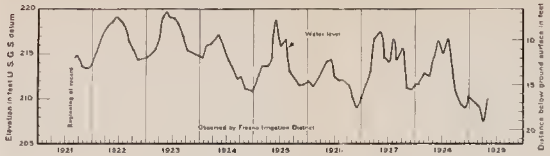
[1] U. S. G. S. Water Supply Paper No. 18, "Irrigation near Fresno, California," 1898.

PROFILES ALONG LINE B-B

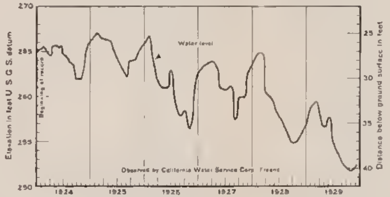
1921 AND 1929



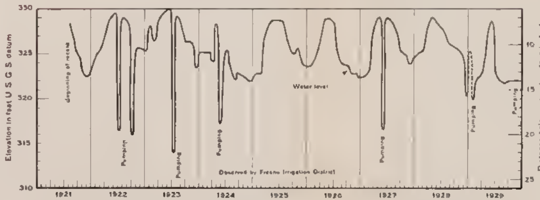
WATER LEVELS IN WELL 14-18-28



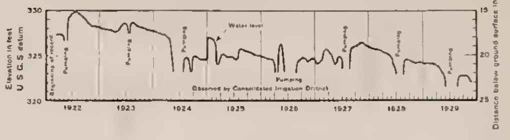
WATER LEVELS IN WELL 14-20-10b



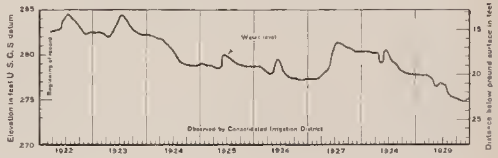
WATER LEVELS IN WELL 14-21-2a



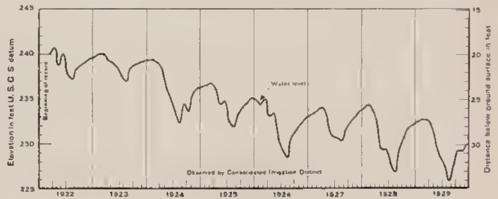
WATER LEVELS IN WELL 14-22-33

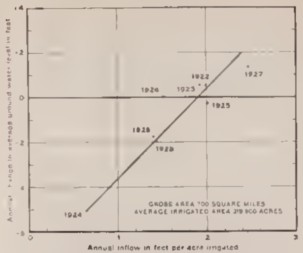


WATER LEVELS IN WELL 16-22-21

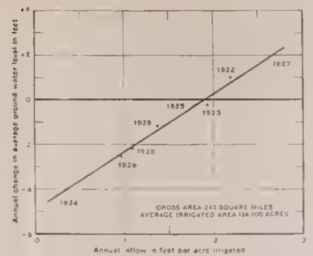


WATER LEVELS IN WELL 15-20-32

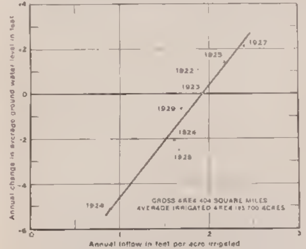




RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR FRESNO-CONSOLIDATED GROUND WATER UNIT



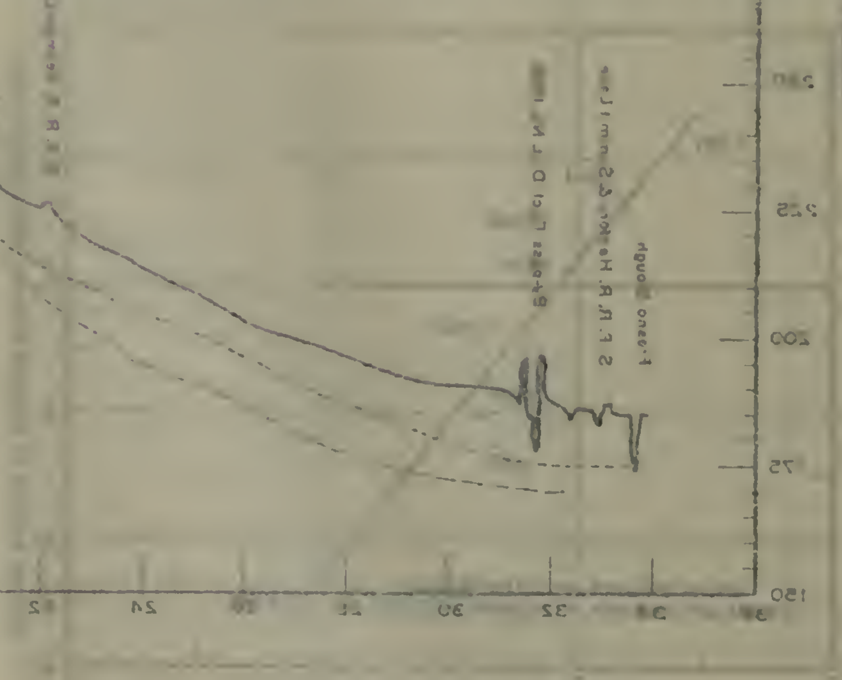
RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR CONSOLIDATED IRRIGATION DISTRICT



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER FOR FRESNO IRRIGATION DISTRICT

FRESNO-CONSOLIDATED GROUND WATER UNIT

RELATION OF INFLOW TO CHANGE IN
LEVEL OF GROUND WATER FOR
DATED GROUND WATER UNIT



RELATION OF INFLOW TO CHANGE IN
LEVEL OF GROUND WATER FOR
FRESNO IRRIGATION DISTRICT

Irrigation District, is reflected in the smaller relative lowering than that in areas of large development with less adequate canal supplies.

TABLE 42

FRESNO IRRIGATION DISTRICT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Season	Water supply. Diversions into area by canals, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
1921–1922	368,000	197,000	1.87	+1.06
1922–1923	378,000	197,000	1.92	0.00
1923–1924	176,000	197,000	.89	−5.12
1924–1925	428,000	197,000	2.17	+1.40
1925–1926	317,000	196,700	1.61	−2.04
1926–1927	466,000	195,000	2.39	+2.14
1927–1928	324,000	193,500	1.67	−2.54
1928–1929	325,000	192,800	1.69	−0.63
Averages, 1921–1929	347,800	195,700	1.78	−0.72

[1] (+) indicates a rise and (—) a fall in ground water level.

On Plate XX the average fluctuations of the ground water are plotted against the canal supplies in acre-feet per acre. A consistent relationship is shown. The line drawn to show the general relationship indicates that a supply of 1.95 acre-feet per acre of cropped area will meet crop needs, supply any excess of ground water outflow over inflow and maintain a stable ground water level. There is some unmeasured but generally small locally tributary run-off from low hill areas above the area, and also probably some ground water outflow to the surrounding lower areas. The cropped area in this district is largely in trees and vines for which the consumptive use is less than that indicated for areas of forage crops.

Well No. 14–18–28 is in the western part of the district southeast of Kerman. The ground water responds to the main irrigation period in the early summer and lowers in the late summer. The total lowering over the whole period has been about five feet. Well No. 14–20–10b is within the City of Fresno. A winter recovery due to lessened municipal draft is shown, the cycle of this well being reversed in time of peak and low point from that in areas having surface irrigation. Lowering since 1925 is shown. Well No. 14–21–2a is east of Fresno near one of the main canals. Quick response to canal flow or pumping is shown with no marked lowering during the period of record.

The Consolidated Irrigation District has a gross area of 149,047 acres of which 129,000 acres were reported as irrigated in 1929. The water rights of the Consolidated District furnish only a limited supply at the medium to low stages of the river but yield a large flow during the short period of high water. Consequently the canal service, while it may be adequate in total amount in years of normal run-off, is not distributed through the season in accordance with crop demands. As a result, practically all canal served lands use supplemental pumping. High ground water has not been as extensive a problem in this district as in some others. There are scattered low areas or pot holes in which water has stood but these represent only a very small percentage of the gross area. With the larger draft on the ground water, during the recent years of subnormal surface supply, practically all of such pot hole areas have become dry. Although the ground water may rise in years of above normal supply, no material problems of drainage are to be anticipated. The lowering from 1921 to 1929 as shown on Plate X varies generally from five to ten feet with small areas of fifteen feet near the Kings River. Table 43 shows the records on water supply, irrigation and ground water fluctuation. A direct relationship between the water supply per acre and the resulting ground water fluctuation is shown. For the eight-year period, a lowering is shown in six years and a rise in two years.

TABLE 43

CONSOLIDATED IRRIGATION DISTRICT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Season	Water supply. Diversions into area by canals, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level in feet[1]
1921-1922	269,000	122,700	2.19	+1.0
1922-1923	235,500	121,500	1.94	—0.2
1923-1924	28,000	120,600	0.23	—4.3
1924-1925	218,000	122,000	1.79	—0.3
1925-1926	169,000	123,700	1.37	—1.2
1926-1927	330,000	126,000	2.62	+1.9
1927-1928	138,500	127,600	1.08	—2.2
1928-1929	125,500	129,000	0.97	—2.5
Averages, 1921-1929	189,200	124,200	1.52	—1.0

[1] (+) indicates a rise and (—) a fall in ground water level.

On Plate XX the average fluctuation of the ground water is plotted against the canal supply in acre-feet per acre. The results for the different years fall consistently on a line which indicates that a supply of 1.90 acre-feet per acre of cropped area will meet crop needs, and maintain the ground water without progressive change under existing conditions of ground water inflow and outflow. The cropped area is planted mainly to trees and vines.

Well No. 15–20–32 on Plate XX is located in the west part of the district, north of Caruthers. Lowering occurs during the pumping season with recovery during the winter. This recovery is probably due partly at least to slow movement from higher ground water areas to the east. A general lowering of about ten feet in eight years is shown. Well No. 16–22–21 is located west of Kingsburg. Less marked seasonal fluctuations are shown than for Well No. 15–20–32. A rise occurred in 1927. Some lowering has occurred in other years since 1923. Well No. 14–22–33 is in the upper portion of the district near Sanger. A slow lowering has occurred in the years of smaller canal supply.

The available records on water supply, areas irrigated and ground water fluctuations for the combined area of the Fresno and Consolidated Irrigation Districts are shown in Table 44. The estimated average annual ground water depletion of 71,000 acre-feet for the Fresno-Consolidated Unit for the period 1921–1929 is based upon the difference between the mean net diversions into the area and the product of the average irrigated acreage of 319,900 and a net use of 1.9 acre-feet per acre. The estimated depletion corresponds to a drainage factor of about 20 per cent.

TABLE 44

FRESNO-CONSOLIDATED UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 700 square miles

Season	Water supply. Diversions by canals into area, in acre-feet			Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
	Fresno Irrigation District	Consolidated Irrigation District	Total			
1920-1921	377,000	258,500	635,500	319,100	1.99	
1921-1922	368,000	269,000	637,000	319,700	1.99	+0.52
1922-1923	378,000	235,500	613,500	318,500	1.92	+0.55
1923-1924	176,000	28,000	204,000	317,600	0.64	—5.05
1924-1925	428,000	218,000	646,000	319,000	2.02	—0.26
1925-1926	317,000	169,000	486,000	320,400	1.52	+0.03
1926-1927	466,000	330,000	796,000	321,000	2.48	+1.39
1927-1928	324,000	138,500	462,500	321,100	1.44	—1.94
1928-1929	325,000	125,500	450,500	321,800	1.40	—1.73
Averages, 1921-1929	347,800	189,200	537,000	319,900	1.68	—0.81

[1] (+) indicates a rise and (—) a fall in ground water level.

Areas Northeast of Fresno Irrigation District—Northeast of the Fresno Irrigation District are small pump irrigated areas. They are irregularly situated within a strip of territory from one to two miles in width, parallel and adjacent to the Enterprise Canal for a distance of about 20 miles. There are 3300 acres in this area which have no water rights in the Enterprise Canal. These irrigated areas consist of 180 acres of trees of the citrus variety, 40 acres of alfalfa, 1250 acres of vines, 1750 acres of figs and 80 acres of assorted trees of the deciduous variety. The average depth to ground water at the end of 1931 was 38 feet, with extremes of from 12 to 20 feet near the main creek channels and 70 to 80 feet in certain isolated small zones of heavy draft. The water supply for these areas is received from creeks draining the lower foothills of the Sierra Nevada between the Kings and San Joaquin rivers. The principal streams are Dry, Dog and Fancher creeks and Sales Creek, a tributary of Dog Creek. The source of replenishment of ground water supply for the 180-acre citrus development near Round Mountain is Fancher Creek, having a drainage area of 21 square miles, the estimated mean seasonal run-off of which is 1300 acre-feet for the 12-year period, 1917-1929. The sources of replenishment of ground water supplies for the areas of vines, figs, alfalfa and deciduous fruits, totaling 3120 acres, are Dry, Dog and Sales creeks, having a drainage area of 104 square miles, the estimated mean seasonal run-off of which is 6300 acre-feet for the 12-year period.

Laguna and Riverdale Irrigation Districts—These two districts cover lands on the north side of Kings River between the river and Murphy Slough. The total area in the Laguna District is 34,858 acres of which 22,500 acres were irrigated in 1929. In the Riverdale District the gross area is 15,830 acres with 8640 acres irrigated in 1929. Pumping from wells in these districts has been increased in recent years. Such pumping was not practiced extensively as early in their development as in the adjacent larger districts. The rights of these districts include some low water flow with the larger part of the supply secured at higher stages. Ground water has been relatively high under much of the area but appears to be under control with the present amount of pumping.

Areas Along North Side Channels of Kings River—There are several separate irrigation systems located along the channels of Kings River leading to the north toward the San Joaquin River. They are listed in Table 45, together with their gross areas and areas irrigated in 1929.

TABLE 45

IRRIGATION SYSTEMS ALONG NORTH SIDE OF LOWER KINGS RIVER

Name of system	Gross area, in acres	Area irrigated in 1929, in acres
Cuthbert Burrel	11,518	3,740
Stinson Irrigation District	11,750	5,984
Crescent Irrigation District	13,150	2,894
James Irrigation District	26,266	11,640
Tranquillity Irrigation District	10,750	6,700
Residual Murphy Slough Group	10,700	6,780
Totals	84,134	37,738

These systems divert directly from Kings River when water is available. The rights to Kings River flow are mainly applicable at the higher stages and yield a variable supply. Supplemental pumping is used at times when river water is not available. Some wells operated by individual landowners are used, but generally such supplemental pumping is by means of batteries of plants pumping from wells into the canal systems. The James and Tranquillity Districts have some rights to pump San Joaquin River water from Fresno Slough. The James District operates both deeper wells within the district and shallow wells in the general area of undeveloped land between Fresno Slough and the Fresno Irrigation District. The estimated pumping draft from these shallow wells is 24,000 acre-feet for 1929 and an average annual of 17,000 acre-feet during the period 1921–29. There is an area of about 180,000 acres of generally poor land between the Fresno and Consolidated Irrigation Districts on the east, and the better lower lands along the lower channels. There is little local development in this area. Ground water was formerly close to the surface and now although lowered about eight feet in the past eight years is still at less depth than in many developed areas.

Alta Unit. This unit consists principally of lands in the Alta Irrigation District on the south side of Kings River and contains 122,000 acres, of which 68,450 acres were irrigated in 1929. It covers the upper canal served area on the south side of Kings River. Its rights in Kings River furnish the larger part of the water supply within a rather short period during high water. While only a small area depends entirely on pumping, nearly all the irrigated land secures supplemental irrigation from wells. High ground water has damaged some of the lower portions of the district. Such lands are used mainly for pasture. The general ground water lowering during recent years of less than average water supply has removed any problems of drainage in the cropped areas. Ground water lowering from 1921 to 1929 is shown on Plate X. This has varied in the different parts of the district depending on relative supply and draft. Lowering of 25 to 35 feet has occurred along the upper portion of the district away from Kings River. In the southern part of the district, used mainly for pasturage with little canal service or pumping, the lowering has varied from nothing to five feet. Lowering in the central portion has varied from five to fifteen feet.

Table 46 shows the records of water supply, area irrigated and ground water fluctuations for the area in the Alta Unit. The area irrigated represents the cropped area, exclusive of the pasture lands in the southern part of the district, to which some water for stock purposes and some flooding is delivered. In making the crop survey of 1929 from which the irrigated area for this unit has been determined, all highways, railroads, incorporated and unincorporated towns, main canals, main laterals and sublaterals and building and uncropped areas of more than one acre were excluded. County and private roads, private ditches and building areas and yards of less than one acre situated within the cropped areas were included.

TABLE 46

ALTA UNIT—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 191 square miles

Season	Water supply. Canal diversions, in acre-feet	Area irrigated, in acres	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[1]
1921-1922	167,000	80,200	2.08	+0.48
1922-1923	145,000	81,600	1.78	+1.28
1923-1924	33,000	83,300	0.40	—8.44
1924-1925	156,000	81,600	1.91	+1.44
1925-1926	122,000	80,000	1.53	—2.95
1926-1927	244,000	81,600	2.99	+6.14
1927-1928	119,000	75,000	1.59	—4.29
1928-1929	85,500	68,450	1.25	—4.88
Averages, 1921-1929	133,900	79,000	1.69	—1.40

[1] (+) indicates a rise and (—) a fall in ground water level.

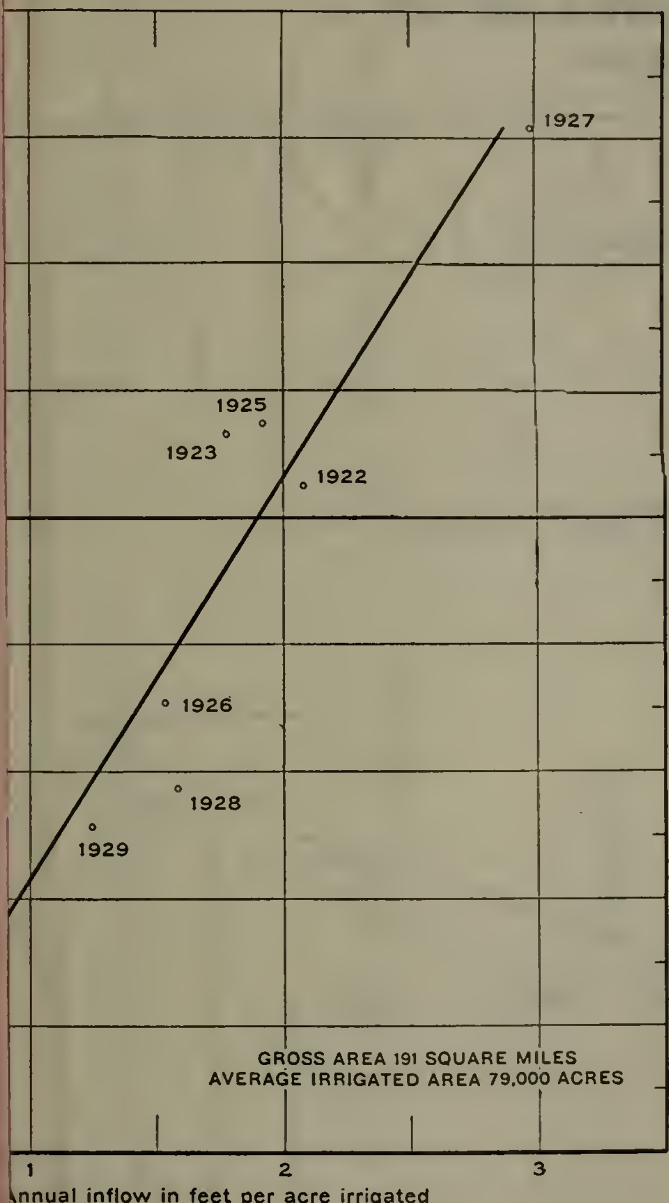
Table 46 shows that, for four years of the period of record, the supply has exceeded the use and the ground water has risen. In the other four years the supply was less than the net use and ground water storage was drawn upon with a consequent lowering. In 1924 with practically no canal supply, an average lowering of over eight feet occurred. In 1927 with a supply of about three acre-feet per acre irrigated there was an average rise of six feet.

The average annual ground water fluctuations and inflow per acre are plotted for each of the eight years of record on Plate XXI, "Alta Ground Water Unit." A fairly consistent relationship is shown. The line drawn to represent the relationship of supply and fluctuations indicates that a supply of about 1.90 acre-feet per acre will meet crop use and maintain present ground water elevations. This rate of supply would also meet any excess of ground water outflow over inflow and includes a supply for use that may occur on pasture areas not included in the crop areas. This rate of use is smaller than that indicated for some other areas. This difference is considered to be due to the fact that crops in the Alta area are very largely deciduous fruits and grapes having a smaller consumptive use than forage crops. The estimated average annual depletion of 20,000 acre-feet for the Alta Unit, for the period 1921–1929, is approximately the difference between the mean canal diversions and the indicated net supply required for the average area of 79,000 acres. The indicated average drainage factor for this unit is about 12 per cent.

Profile CC on Plate XXI shows the slope of the water table and the lowering that has occurred. This profile extends southwesterly from the Alta Canal across the central portion of the Alta District to the southwestern corner of the district. It further extends to the southwest across the central portion of the South Kings area. The profile illustrates the more rapid lowering that has occurred in the upper part of the Alta District where the pumping draft is heavy. There is less cropped area in the lower part of the district so that the lowering has been small due to the lighter pumping draft. In the South Kings area, records are available since 1925 only. The ground water is fairly close to the ground surface and has shown little change.

Hydrographs of four typical wells in the Alta District also are shown on Plate XXI. Well No. 15–23–13C is in the upper portion of the district about three miles from Kings River. This well shows a rapid rise, in response to the flow of water in the Alta canal system, in the early summer with a similar rapid lowering after canal service ends. While the lowering for the very dry year of 1924 was largely recovered in 1927, the total lowering over the eight years shown has exceeded 25 feet. Well No. 17–23–15 is located in the lower portion of the district where the land is used mainly for pasture. The canal service and pumping in this area are limited. In years of larger canal supply, delivery into this area is also larger. These conditions are reflected in the fluctuations of this well. Little total lowering has occurred in the eight year period. In 1924 the ground water dropped to about ten feet below the ground surface to the probable limit of use by vegetation through subirrigation, but did not continue to lower materially in 1925 or 1926. The larger supply in 1927 caused a rise to within four feet of the ground surface. In 1929 it dropped back again to the capillary limit of subirrigation. Wells No. 16–24–30a, b, and c are located two miles southwest of Dinuba in the lower portion of the cropped area of the district and about five miles from Kings River. They show a less marked response to canal supply than wells in the upper part of the district. Their fluctuations are intermediate between those of wells 17–23–15 and 15–23–13c. Well No. 16–25–30a is in the cropped area southeast of Dinuba. Water rose to within about five feet of the ground surface in 1922, but remained over ten feet below since 1924. The recovery in 1927 was lost in 1928 and 1929 and the ground water shows a total lowering of about 20 feet for the full period.

ON OF INFLOW TO CHANGE
EVEL OF GROUND WATER



ALTA GROUND WATER UNIT

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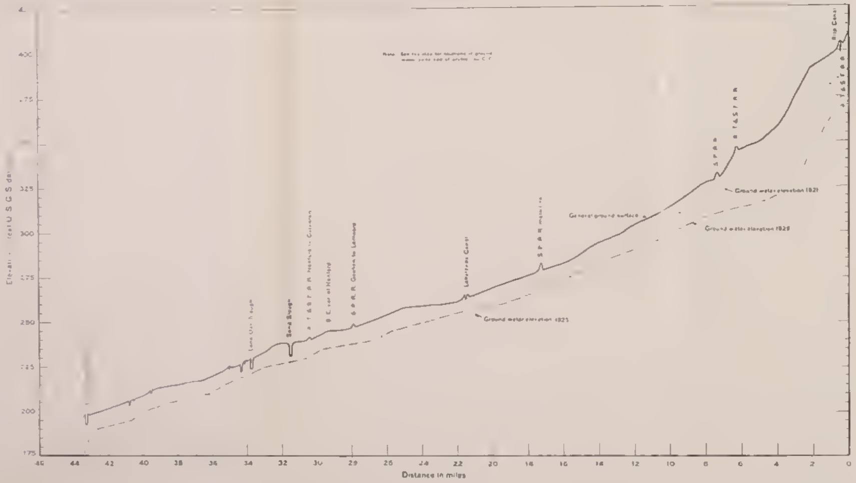
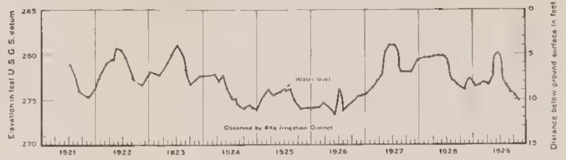
PROFILES ALONG LINE C-C

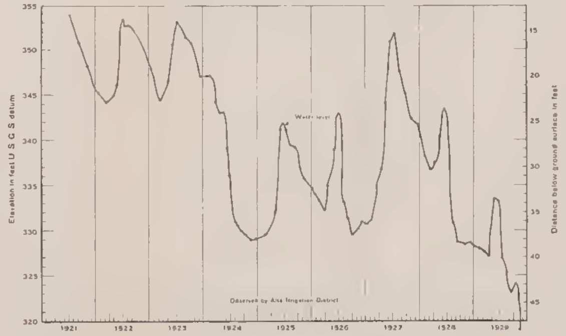
1921 AND 1929



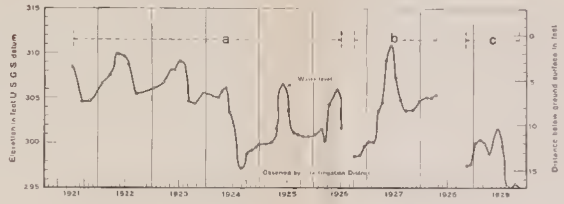
WATER LEVELS IN WELL 17-23-15



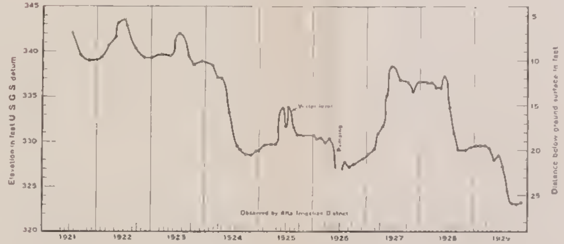
WATER LEVELS IN WELL 15-23-13c



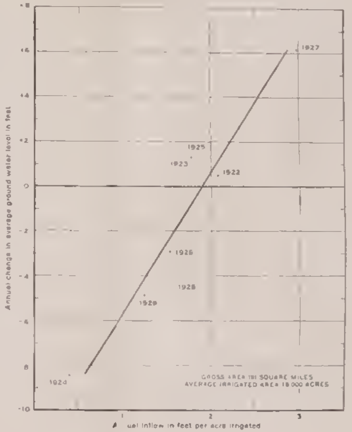
WATER LEVELS IN WELLS 16-24-30 a-b-c



WATER LEVELS IN WELL 16-25-30a



RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER



ALTA GROUND WATER UNIT

40997

Foothill Irrigation District. This district extends along the foothills south from Kings River and above the Alta Irrigation District. It has no present canal system or supply. The gross area is 50,687 acres of which a net area of 11,000 acres was irrigated by pumping in 1929. The area is adapted to citrus culture and present crops are largely of this character. The ground water records are very meager for this area. Material lowering has occurred. It is generally recognized that this area is one of practically zero ground water replenishment. The depth to the underlying granite is less than in the valley areas and the available ground water accumulation is correspondingly small. The Foothill District was organized as a means of endeavoring to secure additional water supplies but to date has not succeeded.

Areas Served by Kings County Canals—The area considered herein embraces lands served by the systems of the Peoples, Last Chance and Lemoore canals which serve adjacent areas on the south side of Kings River in Kings County. The development is a relatively old one. The water supply obtained from Kings River has been sufficient to cause high ground water under much of the area. Such lands are used largely for pasture. In recent years some supplemental pumping has been installed but the extent of the use of the ground water is much less than in the upper Kings River area. Drainage would be beneficial to much of this land under the ground water conditions of years of normal run-off. The gross area, area of Classes 1 and 2 lands and the net area irrigated in 1929 for each of these systems is set forth in Table 47.

TABLE 47

CANAL SYSTEMS IN KINGS COUNTY

Name of system	Gross area, in acres	Area of classes 1 and 2 land in acres	Irrigated area in 1929, in acres
Peoples	72,152	51,198	23,400
Last Chance	33,407	31,279	19,556
Lemoore	53,100	47,071	14,574
Totals	158,659	129,548	57,530

The Lakeside Ditch supplied from the Kaweah River serves lands in the eastern part of this area and has generally similar conditions.

Tulare Lake Area.

This area, as the term is here used, covers the general area of the Tulare Lake Basin Water Storage District and the adjacent Corcoran and Lakeland irrigation districts. These districts have water rights on Kings River, mainly at higher stages of flow. Tulare Lake formerly occupied much of this area in years of excessive run-off. Greater use of water for irrigation coupled with a series of years of sub-normal run-off have resulted in only limited inflow reaching the lake in recent years. The larger part of the bed of Tulare Lake has been reclaimed by levees limiting the overflow area. Due to the uncertainty of water supply and menace of overflow, the crops grown in the lake bed are limited largely to grain. However, there is more diversity of crops on the higher lands. Ground water conditions vary in this area. Artesian wells formerly were obtainable. Water is obtained mainly from deeper strata and many wells are 1500 to 2000 feet deep. The water bearing materials are generally fine. The formation is considered relatively nonabsorptive and a definite natural barrier along the eastern rim seems to resist ground water movement into the area from the east. The depth to ground water in wells in June of 1929 was about 100 feet as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta. Data on a few scattered wells indicate an average lowering of ground water levels of about 40 feet between 1926 and 1929. In some areas irrigation has resulted in building up an artificial, shallow ground water supply which is used to some extent with the deeper water.

Hydrographic Divisions 5 and 5B.

These divisions cover the west side lands from Mendota south. There are no canal systems as there are no available local surface water supplies. The lower, canal served lands along the Kings River channels, are included in the Kings River areas. Some pumping from local ground water has been developed. Deep wells are required. The upper ground water is generally of unsatisfactory quality and wells are perforated only in the lower strata. The total area irrigated in 1929 was about 50,000 acres, practically all of which was within the lower portion of Division 5.

Madera Unit.

This unit has been included in the upper San Joaquin Valley because it is an area in which present use of ground water supplies exceeds the replenishment from local sources, and the natural and most practicable source of supplemental supply required to meet the deficiency between average use and availability of ground water supplies is the San Joaquin River which is also the proposed source of supplemental supply for the remaining easterly portion of the upper San Joaquin Valley. Bounded on the north by the Chowchilla River, on the south by the San Joaquin River and on the east by the line of the Santa Fe Railroad, it extends westward an average distance of fifteen miles to the area served by the present east side canals diverting from San Joaquin River.

The Madera area has had a lengthy history in its efforts to secure canal irrigation. The present Madera Irrigation District was organized with an area of 352,000 acres in 1920. Efforts to work out an adjustment of rights on San Joaquin River resulted in the organization of the San Joaquin River Water Storage District in 1923. That district had a total area of about 550,000 acres including about 184,000 acres in the Madera District as well as the other crop lands served from the San Joaquin River. As efforts to reach a basis on which the storage district could proceed were not successful, it was dissolved in 1929 and the Madera District resumed its efforts to secure a separate supply. The area in the district was reduced by the exclusion of poorer lands to a present area of about 182,000 acres. The district plans include storage on the San Joaquin River at Friant and canals extending as far north as Chowchilla River. Although the area has not as yet succeeded in securing a supply from the San Joaquin River, irrigation has proceeded through the use of Fresno River water and wells. Both Fresno and Chowchilla rivers cross this area and contribute to its ground water. The Madera Canal and Irrigation Company serves a variable area averaging about 10,000 acres near Madera by diversion of direct flow from Fresno River. Both of these streams drain lower portions of the Sierra Nevada and have less regular and dependable run-offs than streams draining higher areas.

Ground water is extensively used, a total of 81,000 acres being wholly or partially irrigated, in 1929, from this source. The principal areas now developed are located from Madera south to the San Joaquin River and in the vicinity of Chowchilla. Ground water contours are shown on Plate VIII. These indicate the effect of replenishment from Fresno and Chowchilla rivers and of the concentration of pumping south of Madera and southwest of Chowchilla. Plate X shows the lowering that has occurred from 1921 to 1929. This has been generally five to ten feet near Fresno River and fifteen to twenty feet south of Madera. Lowering up to 25 feet has occurred in the main pumping areas near Chowchilla. General lowering of ten to twenty feet has occurred in the area between Madera and Chowchilla. Present depths to water as shown on Plate IX vary from fifty to seventy feet in the southeastern part of the area to five to twenty feet in the lower west side areas. Near Chowchilla general depths are thirty to fifty feet. Plates VIII and X do not indicate any material effect on the ground water of this area due to such percolation as may occur from San Joaquin River. The river has a net gain in the section bordering the Madera Unit. Any percolation from the channel affects only a narrow strip adjacent thereto.

Table 48 shows the available data on water supply, areas irrigated and ground water fluctuations for the period, 1921 to 1929. Wells in

TABLE 48

MADERA AREA—WATER SUPPLY, AREA IRRIGATED AND GROUND WATER CHANGES

Gross area, 343 square miles

Season	Water supply				Area irrigated, in acres[2]	Seasonal inflow, in acre-feet per acre irrigated	Seasonal average change of ground water level, in feet[3]
	Run-off of Fresno River near Knowles, in acre-feet	Fresno Lumber Company flume contribution, in acre-feet	Run-off of Chowchilla River at Buchanan, in acre-feet[1]	Total inflow, in acre-feet			
1921–1922	93,000	4,100	108,000	205,100	60,000	3.42	+0.55
1922–1923	82,300	4,100	68,400	154,800	62,100	2.49	—0.17
1923–1924	13,200	3,200	7,600	24,000	64,300	0.37	—2.74
1924–1925	45,600	4,000	85,000	134,600	66,400	2.03	—1.83
1925–1926	31,000	4,000	31,700	66,700	68,500	0.97	—1.82
1926–1927	69,800	4,000	69,800	143,600	72,700	1.98	—0.55
1927–1928	44,200	4,100	52,000	100,300	77,000	1.30	—1.34
1928–1929	21,200	4,100	36,800	62,100	81,000	0.77	—3.37
Averages, 1921–1929	50,040	3,950	57,410	111,400	69,000	1.61	—1.41

[1] Stream flow records for seasons 1921–1922 and 1922–1923, other seasons estimated from indices of seasonal wetness, Division K.
[2] Area for 1929 from crop survey; other years estimated.
[3] (+) indicates a rise and (—) a fall in ground water.

this area have been read only in the spring and fall. The figure for the area irrigated in 1929 is based on an actual survey. Those for preceding years are estimated from the best data available as there are no actual records for earlier years. In making the 1929 crop survey, highways, railroads, incorporated and unincorporated towns and building and minor uncropped areas of more than five acres were excluded. County and private roads, canals, ditches and buildings and uncropped areas of less than five acres, situated within the cropped areas, were included.

The records for this area do not permit of a direct comparison of supply and use, as part of the tributary run-off passes across the area without diversion or absorption. The results shown in the table indicate that an inflow of about 2.5 acre-feet per acre irrigated is needed to furnish a sufficient supply to this area for crop use and outflow. The proportion of the run-off retained within the area varies with the character of its occurrence as well as with its amount. The estimated average annual depletion of 61,000 acre-feet is based upon the difference between an indicated average net use requirement of 2.5 acre-feet per acre for 69,000 acres and the mean seasonal inflow of 111,400 acre-feet. The indicated average drainage factor for this unit is about 20 per cent.

Profile A-A on Plate XXII, "Madera Ground Water Unit," extends west from a point near the crossing of the Santa Fe Railroad and the Fresno River to a point two miles north and eight miles west of Madera and thence in a direction somewhat north of west to Chowchilla River. A lowering of about twenty feet is shown on this line in the westerly part of the unit.

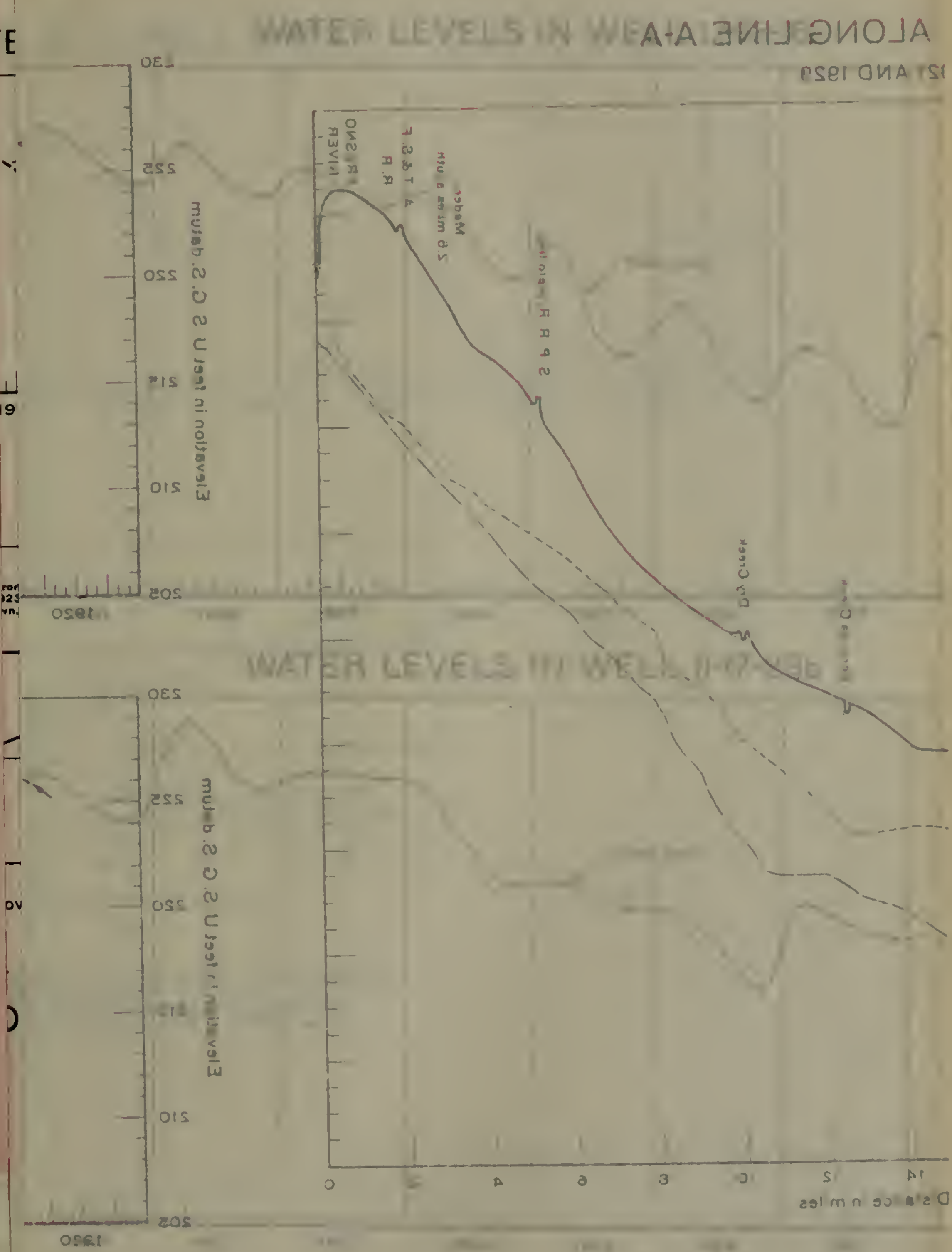
Hydrographs of three wells are shown on Plate XXII. Well 12–18–16 shows fairly uniform lowering from October, 1921, to October, 1929, with a total of about eighteen feet. Well 11–17–33b shows lowering from March, 1922, with some recovery in 1927 and about the same total lowering. Well 10–16–4 shows lowering from October, 1920, to October, 1929, with some recovery in 1922, 1923 and 1927 and a total lowering of about twelve feet.

Net Use in Ground Water Units of Upper San Joaquin Valley.

The foregoing analyses of net use in the several ground water units of the upper San Joaquin Valley indicate that where the use of water is predominately that for irrigation of crops and there is little outflow, the annual net use closely approximates 2.0 acre-feet per acre of irrigated crops. The greater net use indicated in certain of the areas such as the Kaweah, Tule-Deer Creek and Madera units is undoubtedly due to use of water in large areas of natural vegetation (trees, grass lands, etc.), a material amount of unmeasurable outflow or other irrecoverable losses, the combined amount of which is substantially greater in these units in relation to cropped area and crop use than in the units more intensely developed to crop production.

LOWER SAN JOAQUIN VALLEY

Irrigation development in the lower San Joaquin Valley divides itself naturally into three parts on the basis of sources of water supply. These sources of supply are the main San Joaquin River, the east side tributaries of the San Joaquin River and the channels of the San



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Hydrographs of three wells are shown on Plate XXII. Well 12–18–16 shows fairly uniform lowering from October, 1921, to October, 1929, with a total of about eighteen feet. Well 11–17–33b shows lowering from March, 1922, with some recovery in 1927 and about the same total lowering. Well 10–16–4 shows lowering from October, 1920, to October, 1929, with some recovery in 1922, 1923 and 1927 and a total lowering of about twelve feet.

Net Use in Ground Water Units of Upper San Joaquin Valley.

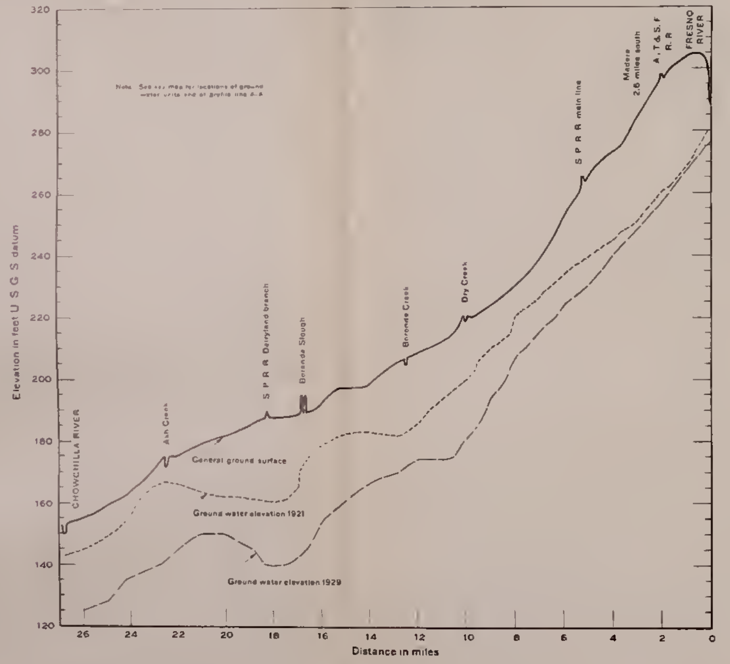
The foregoing analyses of net use in the several ground water units of the upper San Joaquin Valley indicate that where the use of water is predominately that for irrigation of crops and there is little outflow, the annual net use closely approximates 2.0 acre-feet per acre of irrigated crops. The greater net use indicated in certain of the areas such as the Kaweah, Tule-Deer Creek and Madera units is undoubtedly due to use of water in large areas of natural vegetation (trees, grass lands, etc.), a material amount of unmeasurable outflow or other irrecoverable losses, the combined amount of which is substantially greater in these units in relation to cropped area and crop use than in the units more intensely developed to crop production.

LOWER SAN JOAQUIN VALLEY

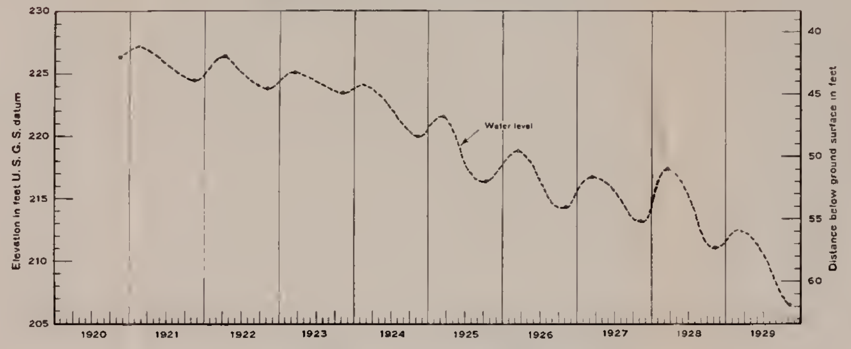
Irrigation development in the lower San Joaquin Valley divides itself naturally into three parts on the basis of sources of water supply. These sources of supply are the main San Joaquin River, the east side tributaries of the San Joaquin River and the channels of the San

PROFILES ALONG LINE A-A

1921 AND 1929

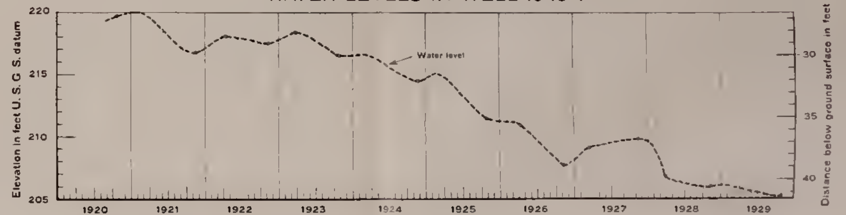


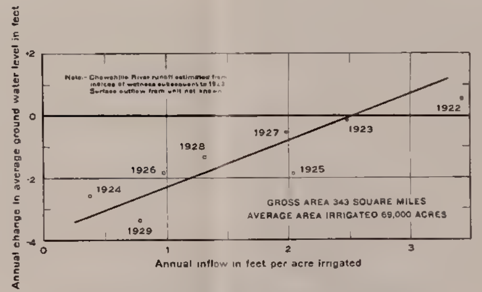
WATER LEVELS IN WELL 12-18-16



WATER LEVELS IN WELL 11-17-33b

WATER LEVELS IN WELL 10-16-4





RELATION OF INFLOW TO CHANGE IN LEVEL OF GROUND WATER

MADERA GROUND WATER UNIT

Joaquin Delta. As the run-off of west side tributaries is practically negligible in amount, the main San Joaquin River supplies all west side areas now developed from surface waters as well as some lower east side areas above the mouth of Merced River. The remaining east side areas are served from the east side tributaries.

The adequate water supply of the lower San Joaquin Valley has resulted in a different type of development from that used in the upper valley. Pumping from wells for irrigation is practiced to only a limited extent by individuals. Irrigation is accomplished by means of canal systems. Sufficient storage has been constructed on the three principal east side streams to yield practically a full seasonal surface supply for the areas now dependent thereon. Adequate supplies also are secured by the lower west side systems pumping from the San Joaquin River due to the availability of return flows from higher irrigated areas. The larger part of the development is now under the irrigation district form of organization. In order to show the location and extent of present irrigation development in the lower San Joaquin Valley, two plates have been prepared. Plate XXIII, "Lands With Irrigation Service from San Joaquin River Above Mouth of Merced River," shows canal systems, "Crop Lands," "Grass Lands" and lands considered riparian for the area specified. Plate XXIV, "Lands With Irrigation Service in San Joaquin Valley North of Merced," shows the boundaries of organized districts and canal systems for the area specified.

Lands with Irrigation Service from San Joaquin River Above Mouth of Merced River.

The areas described under this general heading cover the lands served by diversions from the San Joaquin River above the mouth of the Merced River. They include some land below the Merced River on the west side which is served from higher diversions. The larger part of existing development is served by canals controlled by Miller & Lux, Incorporated. These include canals serving the lands of that company as well as canals serving lands of mixed ownership.

Conditions regarding diversion and use on the San Joaquin River are quite complex. Uses under riparian and appropriative rights are intermingled; two classes of agricultural practice, crop and grass land, occur. There are differences in claims regarding title to use. Many efforts to work out agreements regarding present rights and efforts to increase the use of this stream have been made, and much has been accomplished.

Extensive storage for power has been built on the upper drainage area. The Southern California Edison Company in connection with the Big Creek development has storage capacities of 64,400 acre-feet above the Florence Tunnel, 88,800 acre-feet at Huntington Lake and 135,300 acre-feet at Shaver Lake. The San Joaquin Light and Power Corporation has storage of 45,000 acre-feet capacity at Crane Valley on the North Fork. Storage sites are available below present power plants for use for irrigation. The conditions of operation of the power storage are covered by contracts between the power companies and lower riparian owners.

Pumping plants used for generally small areas along the river serve a total of about 5000 acres from Friant to the Gravelly Ford diversion. The highest existing canal is the Gravelly Ford. This canal, together with the Aliso and the Brown and Lone Willow sloughs, from which the Columbia and Chowchilla canals are supplied, serve the lands on the north side of the river having diversions above Mendota. These diversions serve both crop and grass lands.

The San Joaquin River turns northward at Mendota, where Fresno Slough enters the San Joaquin River from the south. In all but dry years Kings River water reaches the lower portion of Fresno Slough. In high flows the San Joaquin River overflows through Lone Tree Slough and other channels across the Herminghaus lands to Fresno Slough. At lower stages San Joaquin River water is backed up Fresno Slough by the Mendota Weir. Pumping diversions by the James and Tranquillity irrigation districts, which comprise part of the area in the James Ranch, are permitted when the flow of the San Joaquin River at Friant exceeds 1360 second-feet.

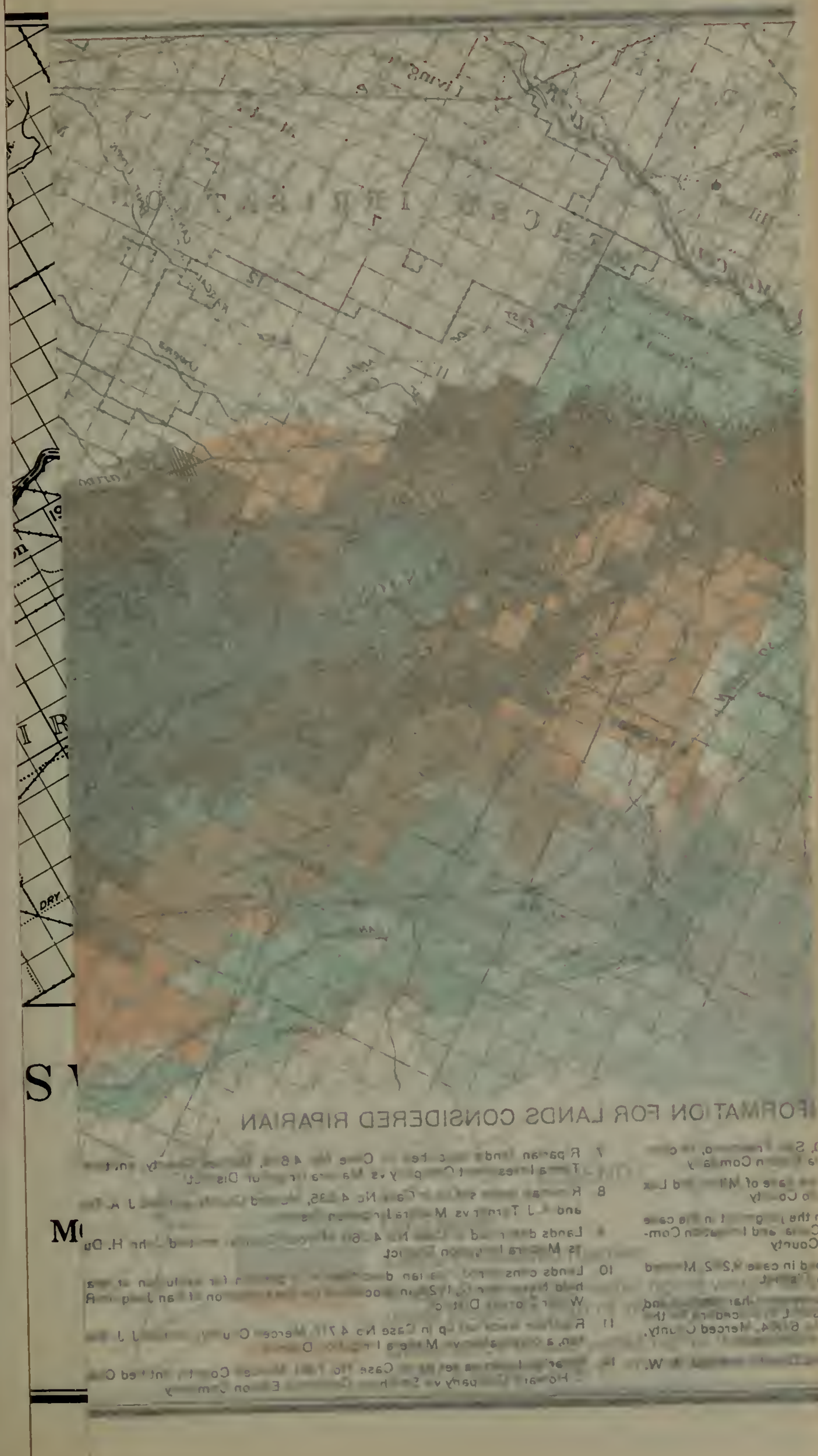
Several large canal diversions head at the Mendota Weir. The largest of these is the San Joaquin and Kings River Canal, including the Main and Outside canals, serving lands on the west side of the San Joaquin River. This system operates as a public utility and serves both crop and grass lands in an area extending northward to the area served by the pumping system of the Patterson Water Company,

TABLE 49

DIVERSION CAPACITIES OF CANALS AND AREAS OF IRRIGATION SERVICE FROM SAN JOAQUIN RIVER, ABOVE MOUTH OF MERCED RIVER

Diversion	Capacity, in second-feet		Irrigated areas, in acres			
			Crop land			Grass land
	Maximum	Operating	Now irrigated	Probable additional irrigation	Total	
Private pumping plants	138	138	4,500	500	5,000	----
Gravelly Ford	900	600	----	----	----	14,000
Aliso	700	500	----	----	----	22,000
Browns Slough[1]	300	200	----	----	----	----
Lone Willow Slough	500	400	----	----	----	23,000
Columbia[2]	----	250	16,000	----	16,000	----
Chowchilla[3]	----	120	3,000	7,000	10,000	(7)
Fresno Slough Diversion	140	140	10,000	4,000	14,000	----
Firebaugh	300	300	24,000	----	24,000	----
San Joaquin and Kings River (outside) (3, 5)	600	500	32,500	----	32,500	----
San Joaquin and Kings River (main) (3, 6)	1,300	1,000	81,000	----	81,000	37,500
San Luis Canal Company Helm Canal (4, 6)	700	600	40,500	----	40,500	58,500
Helm Ditch[3]	35	35	1,500	----	1,500	----
Blythe	----	450	----	----	----	14,000
Temple Slough[4]	----	500	47,500	----	47,500	----
Pick Anderson Slough[4]	1,000	Varies	----	----	----	----
San Luis Island[4]	----	200	----	----	----	----
East Side[1]	500	250	10,000	10,000	20,000	----
Herminghaus	----	----	----	----	----	16,000
Unregulated diversion and overflow	----	----	----	----	----	47,000
State Game Farm	14	14	3,000	----	3,000	----
Totals	----	----	273,500	21,500	295,000	232,000

[1] Diverts into Lone Willow Slough—areas shown under Lone Willow Slough.
[2] Diverts from Lone Willow Slough.
[3] San Joaquin and Kings River Canal Company.
[4] Areas included with San Luis Canal Company and Temple Slough diversions.
[5] Carries some water for San Luis Canal Company.
[6] Carries some water for San Joaquin and Kings River Canal Co.
[7] 6000 acres of grass lands recently irrigated from Chowchilla Canal.



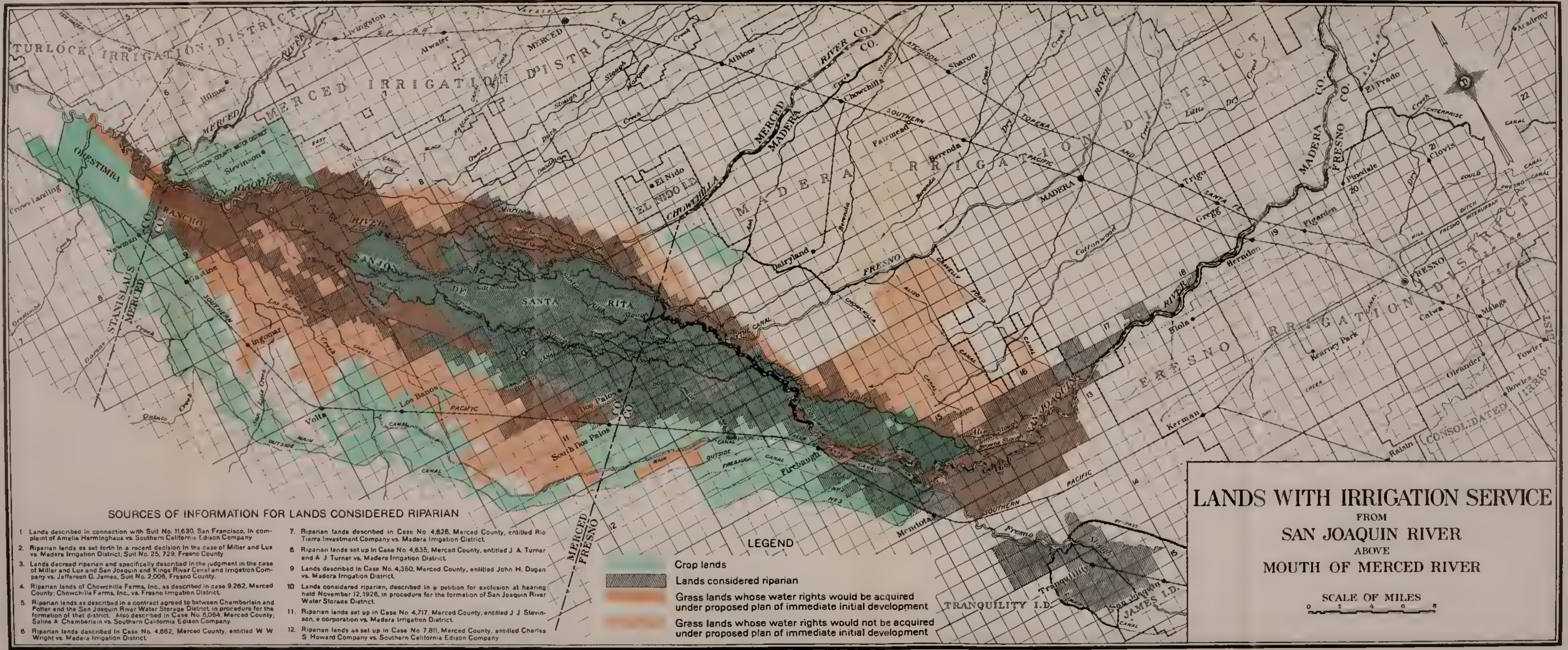

LANDS WITH IRRIGATION SERVICE
FROM
SAN JOAQUIN RIVER
ABOVE
MOUTH OF MERCED RIVER
SCALE OF MILES
0 2 4 6 8
LEGEND
Crop lands
Lands considered riparian
Grass lands whose water rights would be acquired under proposed plan of immediate initial development
Grass lands whose water rights would not be acquired under proposed plan of immediate initial development
SOURCES OF INFORMATION FOR LANDS CONSIDERED RIPARIAN
1 Lands described in connection with Suit No. 11,630, San Francisco, in complaint of Amelia Herminghaus vs. Southern California Edison Company
2. Riparian lands as set forth in a recent decision in the case of Miller and Lux vs. Madera Irrigation District, Suit No. 25, 729, Fresno County
3. Lands decreed riparian and specifically described in the judgment in the case of Miller and Lux and San Joaquin and Kings River Canal and Irrigation Company vs. Jefferson G. James, Suit No. 2,006, Fresno County.
4. Riparian lands of Chowchilla Farms, Inc., as described in case 9,262, Merced County; Chowchilla Farms, Inc., vs. Fresno Irrigation District.
5. Riparian lands as described in a contract agreed to between Chamberlain and Potter and the San Joaquin River Water Storage District, in procedure for the formation of that district. Also described in Case No. 6,064, Merced County; Saline A Chamberlain vs. Southern California Edison Company
6 Riparian lands described in Case No. 4,862, Merced County, entitled W W Wright vs. Madera Irrigation District.
7. Riparian lands described in Case No 4,626, Merced County, entitled Rio Tierra Investment Company vs. Madera Irrigation District.
8 Riparian lands set up in Case No 4,635, Merced County, entitled J A. Turner and A J Turner vs. Madera Irrigation District.
9 Lands described in Case No. 4,360, Merced County, entitled John H. Dugan vs. Madera Irrigation District.
10 Lands considered riparian, described in a petition for exclusion at hearing held November 12, 1926, in procedure for the formation of San Joaquin River Water Storage District.
11. Riparian lands set up in Case No 4,717, Merced County, entitled J J Stevinson, a corporation vs. Madera Irrigation District.
12. Riparian lands as set up in Case No 7,811, Merced County, entitled Charles S Howard Company vs. Southern California Edison Company
TURLOCK IRRIGATION DISTRICT
MERCED IRRIGATION DISTRICT
MADERA IRRIGATION DISTRICT
FRESNO IRRIGATION DISTRICT
EL NIDO I.D.
TRANQUILLITY I.D.
JAMES I.D.
CONSOLIDATED IRRIG. DIST.
RANCHO SANJON DE SANTA RITA
SAN JOAQUIN RIVER
MERCED RIVER
FRESNO RIVER
CHOWCHILLA RIVER
STANISLAUS CO.
MERCED CO.
MADERA CO.
FRESNO CO.
Livingston
Atwater
Merced
Athlone
Sharon
Chowchilla
Fairmead
Berenda
Madera
Trigo
Gregg
El Nido
Dairyland
Hilmar
Stevinson
Crows Landing
Newman
Gustine
Ingomar
Volta
Los Banos
Dos Palos
South Dos Palos
Firebaugh
Mendota
Tranquillity
San Joaquin
Kerman
Biola
Herndon
Pinedale
El Prado
Clovis
Pigarden
Fresno
Calwa
Malaga
Kearney Park
Oleander
Bowles
Fowler
Raisin
Academy

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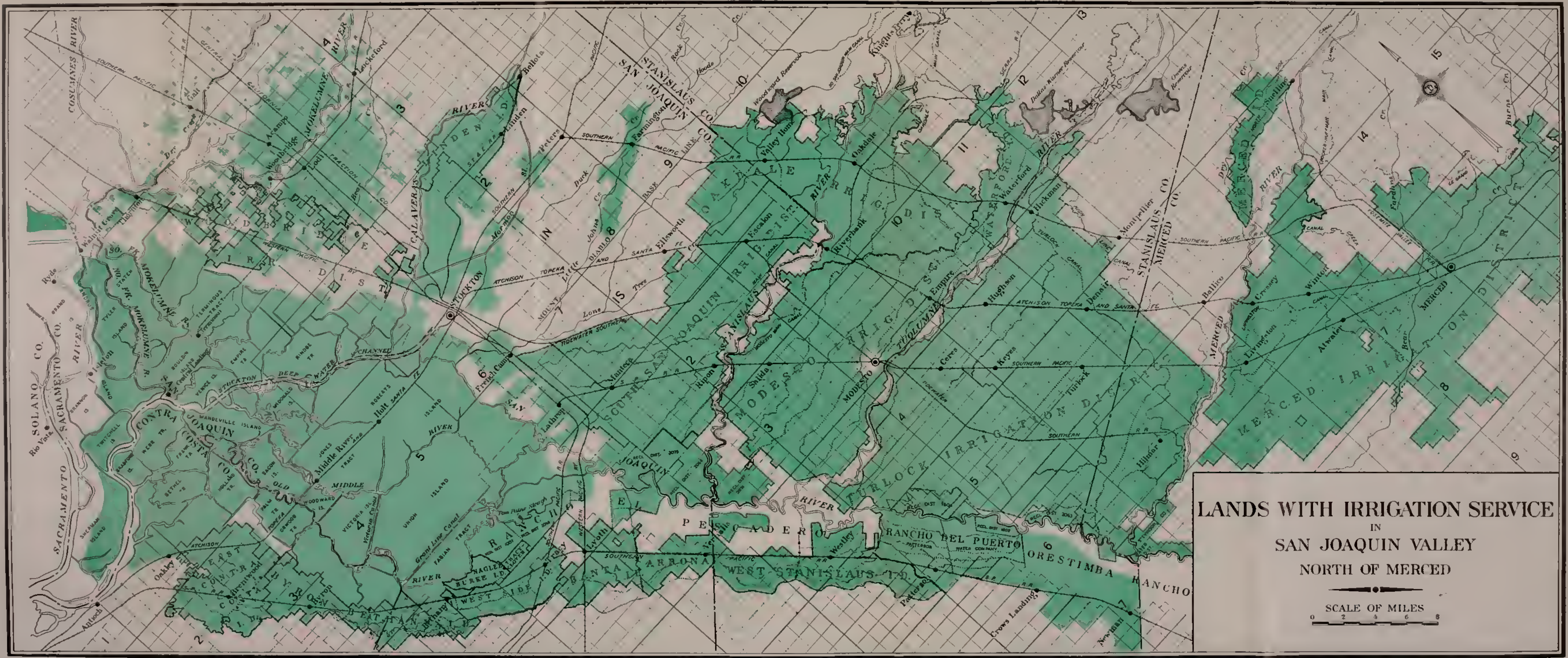
PLATE XXIV



LANDS WITH IRRIGATION SERVICE
IN
SAN JOAQUIN VALLEY
NORTH OF MERCED

80997


LAND

below the mouth of the Merced River. The Helm Canal is part of the San Luis Canal system and diverts for lands lying between the river and the areas served by the San Joaquin and Kings River Canal. The Firebaugh Canal System consists of a series of pump lifts serving lands northward from the Mendota diversion and above the Outside Canal. Below the Mendota Weir are several canals and sloughs which divert to adjacent lands. Blythe Canal and the East Side Canal serve lands on the east side; Temple and Pick Anderson sloughs serve lands on the west side. In addition to the definite diversions some areas secure water through other sloughs or by general overflow. Such areas include the Herminghaus lands above Mendota and several holdings along the river below Mendota. Table 49 gives general data on diversion capacities and areas served by these canals. Recently, 6000 acres of grass lands, not shown in the table, have been irrigated from the Chowchilla Canal.

The intake of the Gravelly Ford Canal, which has no headgate, is located near the southwest corner of the southeast quarter of Section 8, Township 13 South, Range 17 East, M. D. B. and M. The zero of a staff gage, established September 3, 1929, is set at elevation 192.00 feet, U. S. Geological Survey datum. The water surface elevation at maximum diversion is 201 feet.

The Aliso Canal diverts from the San Joaquin River at the east side of the northwest quarter of the northwest quarter of Section 22, Township 13 South, Range 16 East. The headgate is located about 1000 feet down the canal from its intake and a staff gage about 1000 feet below the headgate in the northeast quarter of the northeast quarter of Section 21. The zero of the gage is set at elevation 180.00 feet. The water surface elevation at maximum diversion is 186 feet.

Water is diverted through Brown and Lone Willow sloughs to the Columbia and Chowchilla canals. Brown Slough diverts from the San Joaquin River in the northeast quarter of the northwest quarter of Section 29, Township 13 South, Range 16 East. A headgate and a staff gage are located about 1000 feet down the canal from the intake. The zero of the gage is set at elevation 172.00 feet. The water surface elevation at maximum diversion is 176 feet. Lone Willow Slough diverts from the San Joaquin River in the southeast quarter of the northwest quarter of Section 25, Township 13 South, Range 15 East, at Whitehouse. The headgate is located at the point of diversion. A staff gage, established August 3, 1929, is located about 1500 feet down the canal from its intake in the northeast quarter of the northwest quarter of Section 25. The zero of the gage is set at elevation 164.00 feet and the water surface elevation at maximum diversion is elevation 171 feet. Brown Slough discharges into Lone Willow Slough at the headgate of the Columbia Canal in the southwest quarter of the northeast quarter of Section 23, Township 13 South, Range 15 East. The zero of a gage at the headgate is set at elevation 164.00 feet, and the water surface elevation at maximum diversion is elevation 168 feet. The Chowchilla Canal intake and headgate are located about one-half mile northerly, along Lone Willow Slough, from the Columbia Canal intake, near Whitehouse Ranch headquarters in the southeast quarter of the southwest quarter of Section 14. The gaging station at this point was discontinued August 2, 1929, and the staff gage removed.

The Firebaugh and Outside canals' intakes and headgates are located on Fresno Slough about four-fifths of a mile south of Mendota Weir, in the northeast quarter of the northeast quarter of Section 30, Township 13 South, Range 15 East. The zero of a gage on the Firebaugh Canal near its head, established February 12, 1930, is set at elevation 156.00 feet and the maximum recorded water surface elevation is 162 feet. There is a gaging station, established August 27, 1929, on the Outside Canal about one and one-half miles below its intake in the northeast quarter of the northeast quarter of Section 24, Township 13 South, Range 14 East. The zero of the gage is set at elevation 153.00 feet and the water surface elevation at maximum diversion is 159 feet.

The Main Canal, Helm Canal and Helm Ditch divert from the pool immediately above Mendota Dam in the southwest quarter of the northeast quarter of Section 19, Township 13 South, Range 15 East. The zero of a gage near the head of Main Canal is set at elevation 151.00 feet and the water surface elevation at maximum diversion is 160 feet. The Helm Canal has a drop just below its intake, on the lower side of which is located a staff gage. The zero of the gage is set at elevation 151.00 and the water surface elevation at maximum diversion is 156 feet. The Helm Ditch diverts just to the north of Helm Canal. It follows the high land adjacent to the river. The zero of a staff gage near its head is set at elevation 156.00 feet and the water surface elevation at maximum diversion is 159 feet.

The Blythe Canal is an artificial channel about six-tenths of a mile in length that diverts water from the east side of the San Joaquin River to the lower channel of Fresno River. Its point of diversion is located in the northeast quarter of the northeast quarter of Section 13, Township 11 South, Range 13 East. The zero of a gage on this canal near its head, (now discontinued) was set at elevation 122.00 feet and the water surface elevation at maximum diversion is 126 feet.

Temple Slough diverts from the west side of the San Joaquin River at a point about one-third of a mile below the Blythe Canal intake in the southeast quarter of the southwest quarter of Section 12, Township 11 South, Range 13 East. The zero of a gage below the headgate, established December 4, 1929, is set at elevation 118.00 feet and the water surface elevation at maximum diversion is 123 feet.

Chamberlain Slough diverts from the east side of the San Joaquin River below the mouth of Chowchilla River in northwest quarter of the northeast quarter of Section 31, Township 9 South, Range 13 East. The elevation of its water surface at maximum diversion is 111 feet.

Pick Anderson Slough diverts from the west side of the San Joaquin River through five channels. The locations of the points of diversion all of which are in Township 9 South, Range 12 East, and the elevations of their water surfaces at maximum diversion are set forth in a downstream order as follows:

1. Southwest quarter of the southeast quarter of Section 26, elevation 106 feet.

2. Southwest quarter of the southeast quarter of Section 26, elevation 106 feet.

3. Northeast quarter of the southwest quarter of Section 26, elevation 105 feet.

4. Northwest quarter of the southwest quarter of Section 26, elevation 103 feet.

5. Southwest quarter of the northeast quarter of Section 27, elevation 103 feet.

The San Luis Island Canal (also known as Clair Canal) is located between Salt Slough and the San Joaquin River. Its intake is located on the east side of Salt Slough in the southwest quarter of the northeast quarter of Section 14, Township 9 South, Range 11 East, at an elevation of about 95 feet. It receives water diverted from the San Joaquin River through Pick Anderson Slough and thence through Middle and Salt sloughs to its intake.

The East Side Canal diverts from the east side of the San Joaquin River in the northwest quarter of the northeast quarter of Section 17, Township 9 South, Range 12 east. The elevation of its water surface at maximum diversion is 98 feet.

As a result of extensive discussion among various interests on San Joaquin River, which were in 1929 connected with the proposed San Joaquin River Water Storage District, a suggested flow schedule was tentatively agreed upon and used in the formulation of plans for additional irrigation development. The schedule is based on the records of diversions during the different months of the year, and for various river stages. The river flow, as regulated by the upper power storage, is allocated to existing diversions in accordance with their priorities, up to an amount equal to the total requirements. Diversions totaling 5000 second-feet are listed.

A modified flow schedule was filed with the California Railroad Commission by the San Joaquin and Kings River Canal Company, in connection with an application by that company for authority to increase water rates. This schedule is mentioned in the commission's decision No. 22228 of March 19, 1930. It provides for the use of power released waters by the company, based upon an apparently reasonable and practicable exchange for use by Miller & Lux, Inc., of certain amounts of the company's natural flow waters in the early part of the irrigation season when usually all such waters are not required by the utility consumers. Operation under this flow schedule as stated in said decision was limited to the irrigation season of 1930, but might eventually result in minor modifications of the original San Joaquin River Water Storage District schedule, as herein applied. Such modifications would have resulted in an annual average water yield of about 20,000 acre-feet less for the crop lands involved than under the original schedule.

In Table 50 are summarized the maximum water yields for the crop lands that would have been obtained by the application of the proposed San Joaquin River Water Storage District schedule, to the stream flow, as regulated by existing power storage, for the period 1910–1927. The area irrigable under each right represents the land now considered for service thereunder. The totals differ from the corresponding figures shown in Table 49 because in Table 50 grass lands under the Blythe Canal are included with the crop lands. Blythe Canal waters are used in conjunction with crop land waters from the Chowchilla Canal. At this time it appears that it would not be feasible to differentiate between the two uses of water in this particular area as portions of the respective grass land and crop land are utilized together in individual enterprises. The estimated total diversion requirements for the 309,000 acres classified as crop lands, in Table 50, are 895,700 acre-feet per season.

TABLE 50

AREAS OF IRRIGATION SERVICE, CROP LAND REQUIREMENTS AND AVERAGE SEASONAL SCHEDULE YIELD FOR DIVERSIONS FROM SAN JOAQUIN RIVER, ABOVE MOUTH OF MERCED RIVER, 1910-1927

Service area	Crop lands		Average seasonal schedule yield, 1910-1927, in acre-feet	Grass land area, in acres
	Area, in acres	Maximum seasonal demand, in acre-feet		
Riparian lands above Gravelly Ford	5,000	12,200	No schedule	
Chowchilla Canal	10,000	51,200	51,200	
San Joaquin and Kings River Canal	155,500	482,000	495,600	37,500
Columbia Canal	16,000	40,000	43,200	
San Luis crop lands	47,500	117,700	135,700	
Firebaugh Canal	24,000	60,000	59,500	
Lone Willow Slough residual area			56,100	23,000
Aliso Canal			63,100	22,000
Gravelly Ford Canal			37,900	14,000
Fresno Slough areas	14,000	33,600	27,600	
San Luis grass lands			120,900	58,500
East Side Canal	20,000	48,000	54,200	
Blythe Canal (grass land)	14,000	42,000	42,300	
State Game Farm	3,000	9,000	9,000	
Herminghaus grass lands (overflow lands)				16,000
Chamberlain-Potter (overflow lands)				2,000
Lower East Side (overflow lands)				25,000
Lower West Side (overflow lands)				20,000
Totals	309,000	895,700		218,000

Table 51 shows the seasonal yield which would have been obtained from the San Joaquin River by the crop lands and grass lands during the 12-year period, 1917–1929, under the proposed schedule, with existing conditions of irrigation and power development.

TABLE 51

WATER YIELD OF SAN JOAQUIN RIVER IN ACCORD WITH PROPOSED SCHEDULE OF SAN JOAQUIN RIVER WATER STORAGE DISTRICT

Season	Crop land water, in acre-feet	Grass land water, in acre-feet	Surplus water, in acre-feet	Total impaired flow at Friant, in acre-feet
1917–1918	864,000	640,500	41,400	1,545,900
1918–1919	728,500	626,000	8,600	1,363,100
1919–1920	843,600	429,400	27,600	1,300,600
1920–1921	870,500	671,700	17,700	1,559,900
1921–1922	892,100	974,300	413,100	2,279,500
1922–1923	886,900	772,200	24,400	1,683,500
1923–1924	460,800	193,200	0	654,000
1924–1925	861,100	408,700	3,700	1,273,500
1925–1926	736,900	494,800	300	1,232,000
1926–1927	878,800	912,000	94,900	1,885,700
1927–1928	739,400	480,600	9,400	1,229,400
1928–1929	768,300	148,100	0	916,400
12-year averages	794,200	562,700	53,400	1,410,300

Lands with Irrigation Service in San Joaquin Valley, North of Merced.

Irrigation development, in this section of the lower San Joaquin Valley, segregates itself naturally into areas obtaining water from the main San Joaquin River, from east side tributaries and from San Joaquin Delta.

Service from Main San Joaquin River—On the west side of the lower San Joaquin Valley, diversions below the mouth of the Merced River are made by pumping from the main San Joaquin River. The water supply comprises the flow of the main San Joaquin River and its east side tributaries. The low water flow consists largely of return water from irrigation. From the south to the north the more important irrigation systems above the delta area are those of the Patterson Water Company and the West Stanislaus, Banta Carbona, and West Side irrigation districts. These systems pump by multiple lifts to maximum total heights of about 175 feet, in some cases. They serve practically all of the west side area up to the elevation of their maximum lifts, from vicinity of Patterson to Tracy. A total area of about 43,000 acres was irrigated by these systems in 1929.

Service from East Side Tributaries—Development along the east side of the lower San Joaquin Valley has been effected almost entirely under the irrigation district form of organization. These districts have been described in detail in another report [1] so that extensive discussion here is not required. In general, the conditions are materially different from those in the upper San Joaquin Valley and the methods used are therefore different. Surface storage works have been constructed on the three main tributary streams. The supply afforded by these reservoirs, together with the utilization of the return flow in the lower stream channels, enables the late summer requirements to be supplied from stream diversion rather than by use of ground water storage. As the canal systems cover the larger part of the area and afford adequate surface supplies, there is little development of wells by individual landowners. Ground water use for irrigation occurs mainly in the north end of the area near Stockton. Such ground water pumping, as practiced in other areas, is mainly for drainage to remove excess water resulting from irrigation rather than as a source of supplemental water, although a considerable amount of the water so pumped for drainage is being utilized also for irrigation. Such drainage pumping is handled by the district organizations rather than by the individual landowners.

The six irrigation districts on the east side of the lower San Joaquin Valley include nearly all of the better lands between the rolling hardpan or residual soils on the east and the lower and generally alkaline areas near the valley trough. Lands to the north of these districts are within the lower valley areas where the rainfall is larger and irrigation canal systems have not been generally constructed.

The Merced Irrigation District covers lands south of Merced River with a small area on the north side. The total area in the district is 189,682 acres of which 134,379 acres were irrigated in 1929. The crops

[1] Bulletin No. 21, "Irrigation Districts of California," Division of Engineering and Irrigation, State Department of Public Works, 1929.

are well diversified. The district has constructed storage on Merced River at Lake McClure of 279,000 acre-feet capacity. The direct stream flow with the storage and some re-use of water, pumped for drainage, furnish a generally adequate and well sustained water supply for this district. The district extends from the more rolling hardpan lands at the east to the lower and generally alkaline lands at the west. At the south there is an area between the Merced District and Chowchilla River for which canal facilities have not been provided. The recently organized El Nido Irrigation District comprises 9450 acres of this area, of which 4000 were irrigated in 1929. It has arranged to secure surplus water from the Merced District. There is some additional development by individual pumping plants, but these represent only a small part of the gross area outside of the El Nido District.

The Turlock Irrigation District embraces 181,498 acres extending from the Tuolumne River to the Merced River. There were 133,750 acres irrigated in 1929. This district and the Modesto District have constructed joint storage at Don Pedro on Tuolumne River. Pumping for drainage is also partly used for irrigation. The Turlock district covers the better lands between the Tuolumne and Merced Rivers and between the upper hardpan and lower alkali areas.

The Tuolumne River also supplies lands on the north side, in the Modesto and Waterford irrigation districts. The Modesto District includes 81,183 acres of which 66,370 acres were irrigated in 1929. The water supply is obtained from direct flow and storage with some ground water pumping for drainage. The Waterford District includes 14,110 acres of which 5079 acres were irrigated in 1929. This district covers lands near the river and above the Modesto District. Its boundaries are more irregular in order to include the valley areas in the more rolling topography of the lower foothills.

The Stanislaus River is the source of supply for the Oakdale and South San Joaquin irrigation districts. These districts have constructed storage jointly at Melones. The Oakdale Irrigation District has a gross area of 74,240 acres, of which 23,321 acres were irrigated in 1929. This district lies on both sides of Stanislaus River in the main valley and extends into some irregular areas of valley land, within the generally lower foothill areas. On the south side of the river the Oakdale District extends to the boundaries of the Modesto and Waterford districts. On the north side it extends to the eastern boundary of the South San Joaquin Irrigation District.

The South San Joaquin Irrigation District includes 71,112 acres, of which 54,340 acres were irrigated in 1929. In addition, there were 14,400 acres of nonirrigated crop land which are largely subirrigated. There is some pumping for drainage. The district covers the areas below the Oakdale District on the north side of the Stanislaus River.

The lower San Joaquin Valley, as this term is used herein, extends northward on the east side of the valley to the Cosumnes River, although it is proposed that the area north of the lands served from the Stanislaus River shall have deficiencies in water supply met by diversions from the Sacramento Valley. This area includes the lands adjacent to Calaveras and Mokelumne rivers. Present development is mainly by pumping from individual wells. The Woodbridge Irrigation District includes 13,851 acres of lower lands near the

Mokelumne River served by canal diversion from that stream of which 6184 acres were irrigated in 1929. The recently organized Linden Irrigation District of 13,700 acres proposes to secure water from the Calaveras River. About 6000 acres were irrigated in 1929.

Service from San Joaquin Delta—North of the areas served by the main San Joaquin River, on the west side of the lower San Joaquin Valley, are the Tracy-Clover, Naglee-Burk, Byron-Bethany and East Contra Costa irrigation districts pumping water from delta sloughs, supplied principally through Old River, with both Sacramento River and San Joaquin River waters. These systems pump by multiple lifts to maximum total heights of about 175 feet in some cases. They serve practically all of the west side area, up to the elevation of their maximum lifts, from the vicinity of Tracy to Oakley. A total area of about 28,000 acres was irrigated by these systems in 1929.

In Chapter III, a portion of the main Sacramento-San Joaquin Delta is listed with areas within the San Joaquin Valley. The gross area is 279,000 acres and the net irrigable 257,000 acres. Irrigation development in this area is fully covered in another report.* The entire area is reclaimed swamp and overflow land. Irrigation water is obtained either by pumping or siphoning from the channels surrounding or adjacent to the various tracts. A large part of the area is subirrigated naturally. There were 218,800 acres irrigated in the San Joaquin Delta, in 1929. As the larger part of the water supply for this area is derived from Sacramento Valley sources, the discussion of its development and the plans for its future service have been included in another report.**

Foothill Areas.

There are some irrigated and irrigable areas within the foothills of the Sierra Nevada adjacent to the lower San Joaquin Valley. Although there are some lands in the west side foothills that might be rated as irrigable, as far as soil is concerned, the lack of local water supplies has prevented development.

The results of a classification of the east side foothill areas have been presented in Chapter III. These areas all lie above the lands served by existing diversions for valley lands. There is very little irrigation in the foothills south of the Tuolumne River. Canals built for mining and used for some irrigation are now operated mainly for power purposes and still serving some lands. Such systems include those now owned by the Pacific Gas & Electric Company near Sonora and by the Utica Mining Company near Angels Camp. There are also some smaller diversions for irrigation of the scattered areas of irrigated bottom lands along the various local streams. The total area so irrigated is relatively small. The areas irrigated in Tuolumne, Calaveras and Amador counties, in 1929, totaled 6100 acres, in accord with the survey by the State.

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* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta," Division of Water Resources, State Department of Public Works.

** Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works.

Growth of Irrigated Area.

The growth of irrigation in the lower San Joaquin Valley is indicated by the census returns, which have been reported by counties. No means are available for determining what portion of the irrigated areas of counties lying only partially within the basin should be credited to other sections. For this reason, no data are included for Sacramento, El Dorado and Alameda counties, the larger part of whose agricultural lands lie outside of the San Joaquin River Basin. It is believed, however, that returns for Merced, Stanislaus, San Joaquin and Contra Costa counties indicate the general progress of irrigation development in the lower San Joaquin Valley. The available data are shown in Table 52.

TABLE 52

GROWTH OF IRRIGATED AREAS IN LOWER SAN JOAQUIN VALLEY, BY COUNTIES

County	Area irrigated, in acres				
	From U. S. Census of				State crop survey, 1929
	1899	1909	1919	1929	
Merced	111,330	151,998	212,851	318,244	236,300
Stanislaus	17,505	84,015	197,249	241,712	264,800
San Joaquin	18,466	59,811	183,923	281,629	410,300
Contra Costa	----	26,856	33,079	53,159	*67,500
Totals	147,301	322,680	627,102	894,744	978,900

*In San Joaquin River Basin, only.

For the special census of 1902 and the regular censuses of 1919 and 1929, the data have been segregated by stream sources and are shown in Table 53.

TABLE 53

GROWTH OF IRRIGATED AREAS IN LOWER SAN JOAQUIN VALLEY, BY STREAM BASINS

Data from U. S. Census Reports

Stream	Area irrigated, in acres		
	1902	1919	192
San Joaquin River	129,647	642,261	471,789
Merced River	19,636	65,151	140,131
Tuolumne River	(1)	165,533	207,347
Stanislaus River	13,840	75,359	81,981
Calaveras River	(1)	13,323	8,327
Mokelumne River	5,558	36,848	85,172
Cosumnes River	(1)	3,259	7,885
Other tributaries of San Joaquin River	41,241	55,015	143,349
Totals	209,922	1,056,749	1,145,981

[1] Not reported separately in 1902.

In the eastern foothills, adjacent to the lower San Joaquin Valley, there has been very little change in the area irrigated during the past 30 years. Available data are shown in Table 54. The area decreased in the last decade to about the amount irrigated in 1899 and 1909, showing practically no permanent increase.

TABLE 54

GROWTH OF IRRIGATED AREAS IN EASTERN FOOTHILLS OF LOWER SAN JOAQUIN VALLEY, BY COUNTIES

County	Irrigated area in acres, from United States Census of			
	1899	1909	1919	1929
Mariposa	574	376	66	26
Tuolumne	1,381	2,035	2,892	1,596
Calaveras	1,476	1,275	2,859	1,996
Amador	1,167	826	326	678
Totals	4,598	4,512	6,143	4,296

Present Irrigated Crops.

The detailed results of the crop classification for 1929 have been presented, by counties, in Table 20, Chapter III. The irrigated areas in the lower San Joaquin Valley, exclusive of portions in Sacramento and El Dorado counties and 194,300 acres in the San Joaquin Delta portions of San Joaquin and Contra Costa counties, are summarized by crops in Table 55.

TABLE 55

IRRIGATED CROPS IN LOWER SAN JOAQUIN VALLEY, 1929

Crops	Area, in acres
Citrus	200
Deciduous	107,500
Grapes	116,000
Grain	131,200
Alfalfa	211,600
Field	31,500
Cotton	66,400
Irrigated Pasture	61,500
Truck	84,200
Rice	15,600
Unclassified	6,100
Total	831,800

The table illustrates the wide diversity in crop production within the lower San Joaquin Valley. Practice varies from the culture of deciduous fruits of nearly all of the commercial varieties to the wild flooding of grass lands for pasturage purposes. Grape vineyards are prevalent throughout the area. They are devoted to the culture of grapes of the raisin, wine, and table varieties.

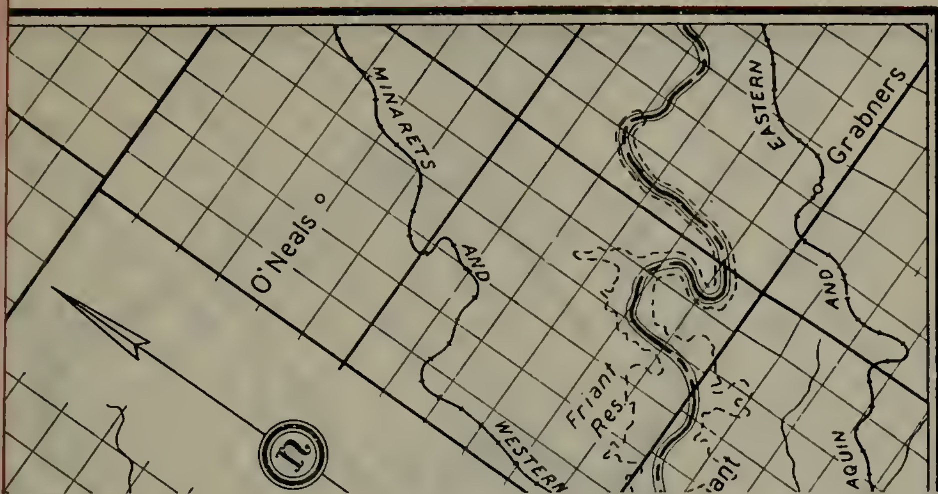
Among the deciduous fruits, peaches, prunes, figs, walnuts and almonds are the most important. Alfalfa is grown both for local use in connection with dairying and for exportation. The long growing season and adequate water supply results in exceptionally large yields. A wide variety of annuals is grown, including grain, cotton, rice, truck and field crops. In addition to the 131,200 acres of irrigated grain shown in Table 55, there were 259,600 acres of dry farmed grain in the lower San Joaquin Valley in 1929.

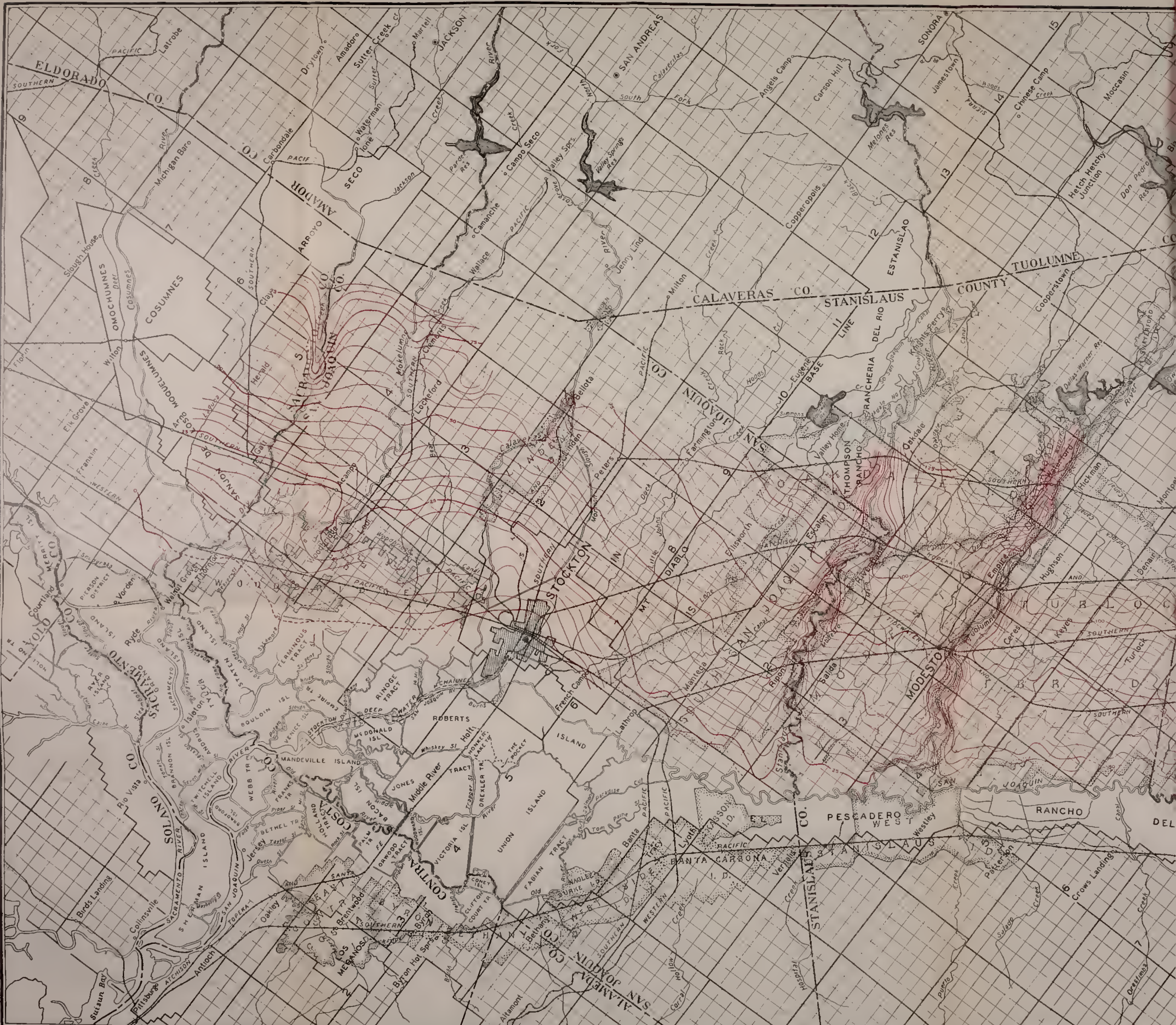
Ground Water Conditions.

Plate XXV, "Lines of Equal Elevation of Ground Water Table in Lower San Joaquin Valley, Fall of 1929," shows ground water levels for the east side of the valley. Data for showing similar lines on the west side areas are not available. On the east side of the valley practically all of the area covered by Plate XXV receives full canal service. The three principal tributary streams, Merced, Tuolumne and Stanislaus rivers, cross the area in deep channels cut below the level of the ground water in the adjacent irrigated lands. These stream channels act as drains. This is shown clearly by the extension of the ground water contours up each of these streams. In other parts of the area, the ground water contours generally parallel the ground surface contours.

Plate XI shows the zones of depth to ground water for the east side areas. Ground water is within ten feet of the surface over a large part of the area. The depth generally in these areas is from five to ten feet. Depths of less than five feet have been largely reduced by drainage pumping. There has been no ground water lowering due to overdraft. In recent years such lowering as has occurred has been beneficial as drainage.

On the west side of the valley, ground water is generally close to the ground surface in much of the canal served area south of Patterson. On the higher lands, above the canals, ground water is deeper and of uncertain quantity. North of Patterson it is sufficiently deep to give full drainage, except for a few areas along the river. There are few wells on the higher land and practically all irrigation water is secured by pumping from the San Joaquin River.


MINARETS
AND
WESTERN
O'Neals
Friant
Res.
EASTERN
Grabners
AND


ELDORADO CO.
AMADOR CO.
CALAVERAS CO.
STANISLAUS COUNTY
TUOLUMNE CO
SAN JOAQUIN CO.
SACRAMENTO CO.
CONTRA COSTA CO.
ALAMEDA CO.
SOLANO CO.
YOLO CO.
STANISLAUS CO.
JACKSON
SAN ANDREAS
SONORA
STOCKTON
MODESTO
Latrobe
Drytown
Amadoro
Sutter Creek
Martell
Ione
Waterman
Carbondale
Michigan Bar
Slough House
Clays
Arroyo
Seco
Campo Seco
Camanche
Wallace
Valley Sprs
Jenny Lind
Milton
Angels Camp
Carson Hill
Copperopolis
Jamestown
Chinese Camp
Moccasin
Hetch Hetchy Junction
Don Pedro Res
Melones Res
Pardee Res
Valley Springs Res
Coopersfown
Knights Ferry
Oakdale
Valley Home
Farmington
Eugene
Bellota
Lockeford
Herald
Galt
Acampo
Lodi
Woodbridge
Thornton
Walnut Grove
Vorden
Courtland
Ryde
Isleton
Rio Vista
Collinsville
Birds Landing
Suisun Bay
Pittsburg
Antioch
Oakley
Brentwood
Byron Hot Sprs
Bethany
Altamont
Tracy
Banta
Lathrop
French Camp
Manteca
Ripon
Salida
Escalon
Ellsworth
Peters
Empire
Hughson
Ceres
Keyes
Turlock
Denair
Hickman
Westley
Patterson
Crows Landing
Vernalis
Elk Grove
Franklin
Florin
Wilton
Arno
COSUMNES
OMOCHUMNES
MOQUELUMNES
SANJON DE LOS MOQUELUMNES
CAMPO DE LOS FRANCESES
DEL RIO
RANCHERIA DEL RIO ESTANISLAO
THOMPSON RANCHO
MT DIABLO BASE LINE
ROBERTS ISLAND
UNION ISLAND
MANDEVILLE ISLAND
VICTORIA ISL
JONES TRACT
RINDGE TRACT
STATEN ISLAND
TERMINOUS TRACT
BOULDIN ISL
VENICE ISL
McDONALD ISL
PESCADERO
WEST STANISLAUS I.D.
BANTA CARBONA I.D.
EL SOLYO
RANCHO DEL PUERTO
TURLOCK I.D.
SOUTH SAN JOAQUIN I.D.
OAKDALE I.D.
MODESTO I.D.
SOUTHERN PACIFIC
Middle River
Old River
San Joaquin River
Stanislaus River
Tuolumne River
Mokelumne River
Calaveras River
Sacramento River
Deep Water Channel

80927

LINES OF EQUAL ELEVATION
OF
GROUND WATER TABLE
IN LOWER SAN JOAQUIN VALLEY
FALL OF 1929

SCALE OF MILES
0 2 4 6 8 10

CHAPTER V

WATER REQUIREMENTS

The uses of water in the San Joaquin River Basin are many. They include domestic, municipal, irrigation, salinity control, industrial, navigation, power development and recreational uses. Of all these uses, however, that for irrigation predominates at the present time and probably will continue to do so. Recreational and navigation uses result in no actual consumption of water and in most instances do not alter the regimen of the stream. The use for development of hydroelectric energy, while altering in some instances the regimen of the stream, does not consume any water. For domestic service alone, the unit use within small cities is practically the same as for irrigation. For industrial and commercial areas in or near municipalities, the amount of water used may be somewhat larger than for the irrigation requirements for an equivalent area. In this basin, the water requirements for present and future ultimate developments have been based on irrigation use. It is believed that on this basis ample water would be provided for all uses, except that for salinity control in the Sacramento-San Joaquin Delta. In the State Water Plan, provision for that requirement is made primarily from the Sacramento River Basin.*

There is considerable variation both as to rate and period of use of water for various purposes. For irrigation, the period of use varies in different parts of the State. In the San Joaquin Valley, the greater part of the irrigation demand occurs during the months of March to October. However, irrigation is practiced in certain sections whenever water is available, even during the winter months.

Water requirements, for any particular area, vary not only in amount with the use to which the water is put, and in monthly demand, but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area and the opportunity afforded for reuse of water controlled by the topographic, geographic, and geologic conditions are factors that have an important bearing on water requirements. For these reasons, variations in treatment of the problems for the different areas necessitated the employment of different terms of use in this report, as follows:

> "Irrigation requirement" is the amount of water in addition to rainfall that is required to bring a crop to maturity. This amount varies with the crop to be supplied and the point at which the water is measured. As related to the point of measurement, it is the "gross allowance," "net allowance," or "net use." These

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, Department of Public Works, 1931.

terms together with the term "consumptive use," are defined as follows:

"Gross allowance" designates the amount of water diverted at the source of supply.

"Net allowance" designates the amount of water actually delivered to the area served.

"Consumptive use" designates the amount of water actually consumed through evaporation and transpiration by plant growth.

"Net use" designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

Unit Irrigation Requirements.

Irrigation requirements of California lands have been a subject of study by Federal and State agencies for many years. Much valuable data on the use of water for various crops under varying climatic and soil conditions have been collected and compiled. These data have been published in most instances. The Division of Engineering and Irrigation, Department of Public Works, made an investigation of irrigation requirements of the lands of the State in 1921.* These studies have been continued by the Division of Water Resources, since the publication of that report. Information on areas in the Sacramento Valley and portions of the San Joaquin Valley is published in the annual reports of the Sacramento-San Joaquin Water Supervisor.

In arriving at unit values for irrigation requirements of lands in the San Joaquin River Basin full use was made and consideration given to all those published and unpublished data. In addition to such data, however, detailed analyses and studies were made during this investigation of the use of irrigation water under actual operating conditions on more than one million acres of land in localities extending from the San Joaquin Delta to Kern River area in the southern end of the valley. The area on which the uses of water were determined represents one-half of the present irrigated area in the valley. These analyses have been discussed and the results thereof set forth in considerable detail for the upper San Joaquin Valley, in Chapter IV. Information on the other sections is presented later in this chapter. It should be pointed out that the areas studied are intensively developed, contain diversified crops, utilize various methods of obtaining supplies and are representative of practicable irrigation operations.

In estimating the irrigation requirements of the San Joaquin River Basin, it was divided into four sections; namely, upper San Joaquin Valley floor, lower San Joaquin Valley floor, foothill areas and San Joaquin Delta. The requirements for the basin will be discussed under these headings.

Upper San Joaquin Valley Floor—The upper San Joaquin Valley is the southern portion of the valley extending on the east side as far north as the Chowchilla River and on the west side to a line extending from Mendota to Oro Loma. In these studies, it embraces hydrographic divisions 1, 2, 3, 4, 5, 5B and 6. It is an area in which the tributary run-off is inadequate to meet present water requirements and in which full development will be possible only with importation of

* Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1921.

water from distant sources at relatively high costs. Along the eastern side of the valley, the topographic and geologic characteristics of the basin are such that extensive underground storage capacity is available. The development of ground water supplies, drawn from such storage, adds to the extent to which the locally tributary run-off may be efficiently utilized within the area under consideration. Where adequate ground water storage is available, the required surface inflow is equal to the net use. On the western slope of the valley, a large area of land overlies subsoil of such chemical constituents that the use of shallow ground water would be injurious to irrigated crops. Therefore, the application of water to these lands would be made on the basis of actual plant needs and the net allowance would exceed consumptive use only by the amount of percolation losses within the area. The inability to recover percolation losses makes it necessary to estimate on net use without recovery of percolation. This area has extremely limited local water resources and, if developed extensively, would require the importation of practically its entire supply.

On the eastern slope of the valley, records, continuous in most areas since 1921, of the extent of irrigation development effected through the utilization of surface and ground water supplies, together with those of the conditions of underground storage, afford the basis for estimating the average net use. A study of this subject has been presented in Chapter IV, based on data collected for all the developed areas along the eastern side of the valley and covering the period, 1921–1929. These data consist of the annual records of surface inflow, the areas irrigated and the depths to ground water in some 4000 wells scattered throughout the region. The following values of net use are summarized from Chapter IV and are based on present irrigation practice and use in representative areas intensively developed to diversified crops in the upper San Joaquin Valley:

Area	*Seasonal net use in acre-feet per acre*
Fresno Irrigation District	1.95
Consolidated Irrigation District	1.90
Alta Irrigation District	1.90
Kaweah River Area	2.17
Deer Creek Area	2.0
McFarland-Shafter Area	2.0

The foregoing figures are supported by a value of about 2 acre-feet per acre obtained in the Turlock Irrigation District in the lower San Joaquin Valley, where measurements of surface diversion into the district, the measured outflow and records of the net area of irrigated land, made possible the calculation of the seasonal net use per acre. In making the crop survey for determining the net area of irrigated land in that district, highways, railroads, county roads, incorporated and unincorporated towns, main canals, laterals, sublaterals, and building and minor uncropped areas of more than two acres were excluded. Private roads and ditches and building and minor uncropped areas of less than two acres situated within irrigated areas were included. The net area so estimated equals about 75 per cent of the gross irrigable area of the district. It is concluded, therefore, that while the net use value varies for different crops, a reasonable estimate of the seasonal net use for the types of crops now grown in the upper San Joaquin

Valley is two acre-feet per acre. In estimating the water requirements of the upper San Joaquin Valley, this figure has been applied to the net area of irrigable land in obtaining the average seasonal allowances.

This basis of estimating the water requirement for the area does not mean that the actual delivery of water upon irrigated land would be at a uniform rate, or restricted to two acre-feet per acre per season. On the contrary, it is recognized that, dependent upon the kind of crop served and the type of soil and subdrainage conditions, seasonal applications of water vary from a minimum of less than two acre-feet per acre to a maximum of perhaps as much as 100 per cent in excess of that figure. In any case, the only water actually used is that which supplies the needs of plant transpiration and surface evaporation. On nonabsorptive soils, applications in excess of these needs result in surface run-off to adjacent lands or drainage systems. On absorptive soils such excess applications are, to a large extent, accounted for by percolation losses which constitute one of the principal sources of replenishment to the underlying ground water. In areas where it is feasible to recover these percolation losses by pumping, the application of the water so recovered constitutes a reuse of the original supply and makes for a high degree of utilization, the limit of which is reached when the net use of water equals the consumptive use. The essential element of such a plan of utilization is the availability of adequate underground storage capacity so located that water drawn therefrom can be utilized upon overlying or adjacent lands.

Lower San Joaquin Valley Floor—The lower San Joaquin Valley is that portion of the valley extending northerly from the upper San Joaquin Valley to the southern limits of the Sacramento Valley. It comprises hydrographic divisions 7 to 13, inclusive. In Chapter IV, it has been pointed out that the water supplies for the present extensive irrigation development are generally adequate and dependable. These supplies are obtained from the San Joaquin River and its east side tributaries, for the most part, by surface diversions. Pumping from underground basins is not practiced extensively. Surface supplies are the primary sources. Pumping from wells is supplemental and of secondary importance in the greater part of the area, although the use of ground water for irrigation in connection with drainage operations is becoming more important each year. The water requirements, therefore, have been estimated on the basis of furnishing a full surface irrigation supply to the entire irrigable area in the valley.

The unit values of irrigation requirements within the valley vary with the geographic location and also with the topographic location in relation to sources of supply. These variations will be pointed out as the requirements for each hydrographic division are presented.

In hydrographic divisions 8, 9 and 11, the unit values for gross allowance, net allowance and net use have been taken as 3.3, 2.4, and 1.9 acre-feet per acre per season, respectively. These values are based largely on the results of a detailed analysis of irrigation use in the Turlock Irrigation District (181,500 acres) under actual operating conditions for the irrigation season of 1929. In that analysis, full and complete data were available on diversions, irrigated areas, and return waters.

In Hydrographic Division 7, the foregoing values for gross and net allowances were used for the present irrigated areas on the west side of the San Joaquin River lying southerly from the mouth of the Merced River. However, a higher value of 2.1 acre-feet per acre per year for net use was obtained by using a return flow factor of 35 per cent applied to the figures for gross allowance. For the remaining lands in Hydrographic Division 7, lying on the western side of the San Joaquin River, unit values of 2.0, 1.8 and 1.6 acre-feet per acre per season were used for gross allowance, net allowance and net use, respectively. These values were used also for Hydrographic Division 10, consisting of the uplands lying to the west of the San Joaquin Delta. The foregoing unit values were deduced from measured diversions and net applications on intensively developed lands now served by pumping systems of West Stanislaus, Byron-Bethany, and East Contra Costa irrigation districts.

In hydrographic divisions 12 and 13, the unit values for irrigation requirements are based on data and information obtained on irrigation operations in the Mokelumne River area in the investigation made by the U. S. Geological Survey during the period 1926 to 1929 and published in Water Supply Paper 619. In that paper, average weighted unit values of seasonal quantities of water pumped from wells on 82 different farms are set forth. These values are 1.34 acre-feet per acre for vineyards and orchards and 3.06 for alfalfa and miscellaneous crops. These unit values were applied to respective areas of irrigated crops listed in the 1929 crop survey for hydrographic divisions 12 and 13. The resulting weighted average value was 1.5 acre-feet per acre irrigated per season. This figure was used as the net use value in estimating the ultimate water requirements. The lands in these divisions are now irrigated largely by pumping from ground water. By assuming surface supply diversions that would result in an annual return flow factor of about 40 per cent, a gross allowance requirement of 2.7 acre-feet per acre per season was obtained. The seasonal net allowance was estimated at 1.8 acre-feet per acre.

Foothill Areas—In the irrigation of foothill lands, conveyance and application losses are in general relatively large because of the type of conduits generally used and of the uneven and sloping character of the irrigated lands. It is estimated that of the total amount of water diverted from the streams for irrigation use in the foothill areas, about 40 per cent is returned ultimately to the natural stream channels and is available for reuse. These conditions have been given full consideration in estimating the irrigation requirements of the foothill areas.

The unit values for irrigation requirements for the foothill areas are based entirely on data given in Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation. In that bulletin, an average annual net duty of 1.75 acre-feet per acre is given for the Sierra foothills and rolling plains east and south of the San Joaquin Valley floor. The area included in hydrographic divisions 6A, 8A, 9A and that portion of 11A in the Tuolumne River watershed of this report, corresponds in general to the foothill area set forth in Bulletin No. 6. Therefore, the value of seasonal net use for these areas has been assumed and taken as approximately the net duty or 1.8 acre-feet per acre. Assuming that the figure for seasonal net use is 60 per cent of the seasonal diversion which is allowing for 40 per cent conveyance and application losses, a figure for seasonal gross allowance of 3.0 acre-feet per acre is obtained. The seasonal net allowance for these hydrographic divisions is estimated at 2.4 acre-feet per acre.

In Bulletin No. 6, the average annual net duty for the Sierra foothills and rolling plains east and west of the Sacramento Valley floor is given as 1.50 acre-feet per acre. The climatic and soil conditions of the area included in hydrographic divisions 12A, 13A and that portion of 11A in the Stanislaus River watershed are more nearly comparable with these areas rather than those foothill areas south of the Tuolumne River. Therefore, in selecting a seasonal value of net use, the figure of 1.50, the annual net duty for the foothill area east of the Sacramento Valley floor, was adopted for these hydrographic divisions. Using a return flow factor of 40 per cent, as for the previously discussed foothill areas, a seasonal gross allowance of 2.5 acre-feet per acre is obtained. For these particular areas, the net allowance for the purposes of this report is considered to have the same value as the net use.

San Joaquin Delta—Because of the method employed in irrigating the lands of the San Joaquin Delta it is impracticable to differentiate between gross and net allowances and net use. Furthermore, in addition to use for irrigation, the water requirements for the delta include also, amounts to meet evaporation losses in the many delta channels, transpiration from tule and other natural vegetation and evaporation from levees and uncultivated land surfaces. It is estimated that during the irrigation season, the ultimate total net use of water for all demands on the entire area will average about 2.6 acre-feet per acre, and the total net use for irrigation only about 2.3 acre-feet per acre. A full discussion of this matter is given in another report,* to which reference is made.

Net Irrigable Areas.

Irrigation practice in California has demonstrated that the entire irrigable area of agricultural land in any particular project is not irrigated, even in intensively developed areas. In determining the water requirements for ultimate development of the various sections of the San Joaquin Valley, this experience has been recognized and it is not considered necessary to provide a water supply for the gross area of irrigable land set forth in Chapter III. In addition to minor areas which are not arable, such as stream channels and natural drains, an appreciable area is occupied by towns, highways, railroads, county roads, canals, ditches and incidental farm improvements such as dry yards, corrals and buildings. Furthermore, the percentage of the poorer agricultural land irrigated in any one year will be less than for the better lands. Based upon the experience of fully developed organized districts in the San Joaquin Valley, it has been determined that, in areas of good land, not over 80 per cent of the gross area will

* Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.

require water. In areas of poorer land the percentages will be smaller. The following factors have been used for the different classes of valley land in estimating the respective net irrigable areas:

Lands in Class 1	80 per cent
Lands in Class 2	80 per cent
Lands in Class 3	60 per cent
Lands in Class 4	20 per cent
Lands in Class 5	0

The foregoing percentages are considered to represent the maximum areas that will require a water supply under conditions of ultimate development. Some exceptions from these standards have been made in certain areas of foothill land, as set forth in Table 19, Chapter III. The application of the respective percentages to the gross areas of irrigable land, presented by hydrographic divisions in Tables 18 and 19, gives the net irrigable areas set forth in Table 56.

TABLE 56

NET IRRIGABLE AREAS IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions see Plate VI

Hydrographic division	Net area, in acres				
	Class of land				Totals
	1	2	3	4	
Upper San Joaquin Valley Floor—					
1	564,700	253,000	186,300	1,000	1,005,000
2	375,900	185,100	67,000	0	628,000
3	186,900	81,700	27,400	0	296,000
4	634,700	190,000	100,500	1,800	927,000
5	243,400	16,900	13,700	0	274,000
5 B	191,400	30,400	5,200	0	227,000
6	112,000	84,900	62,900	31,200	291,000
Totals	2,309,000	842,000	463,000	34,000	3,648,000
Lower San Joaquin Valley Floor, excluding San Joaquin Delta—					
7	244,700	99,400	38,000	25,900	408,000
8	91,500	123,300	50,200	17,000	282,000
9	147,200	107,700	57,100	0	312,000
10	57,300	8,100	3,600	0	69,000
11	128,500	85,400	46,100	0	260,000
12	161,100	40,000	16,900	0	218,000
13	20,700	76,100	29,100	1,100	127,000
Totals	851,000	540,000	241,000	44,000	1,676,000
Totals, San Joaquin Valley Floor, excluding San Joaquin Delta	3,160,000	1,382,000	704,000	78,000	5,324,000
Foothill areas—					
6 A	0	0	11,600	29,400	41,000
8 A	0	900	41,300	41,800	84,000
9 A	0	0	50,600	11,400	62,000
11 A	0	1,900	42,200	28,900	73,000
12 A	2,200	4,100	37,300	37,400	81,000
13 A	600	2,700	20,500	15,200	39,000
Totals	2,800	9,600	203,500	164,100	380,000
Totals, San Joaquin River Basin, excluding San Joaquin Delta	3,162,800	1,391,600	907,500	242,100	5,704,000
San Joaquin Delta	242,000	14,100	900	0	257,000
Totals, San Joaquin River Basin	3,404,800	1,405,700	908,400	242,100	5,961,000

For purposes of making water utilization studies, net irrigable areas in the lower San Joaquin foothill divisions have been divided further into areas located above and below the major foothill reservoir sites, as set forth in Table 57.

TABLE 57

NET IRRIGABLE AREAS IN FOOTHILL DIVISIONS ABOVE AND BELOW MAJOR RESERVOIR SITES

Hydrographic division	Net area, in acres		
	Above reservoir sites	Below reservoir sites	Totals
8 A	56,000	28,000	84,000
9 A	15,000	47,000	62,000
11 A	43,000	30,000	73,000
12 A	52,000	29,000	81,000
13 A	39,000	0	39,0C0

Ultimate Water Requirements.

The ultimate water requirements of the San Joaquin River Basin have been estimated and are set forth by sections in Table 58; namely, upper San Joaquin Valley floor, lower San Joaquin Valley floor, foothill areas and San Joaquin Delta. The irrigation requirements for the irrigable areas of classes 1, 2, 3, and 4 lands in the foothills and valleys were calculated by applying the per acre values for gross and net allowances and net use to the corresponding net irrigable acreages given in Table 56. The water requirements in the San Joaquin Delta were obtained from another report.* The ultimate seasonal net use for the entire Sacramento-San Joaquin Delta is estimated in Bulletin No. 26 as 1,200,000 acre-feet for the irrigation season extending from April to October, inclusive. For the San Joaquin Valley portion of the delta alone, it is estimated that the seasonal net use would be 824,000 acre-feet. In that portion of the delta there is a gross area of 328,000 acres, including channels and levees, a gross area of agricultural land of 279,000 acres and a net irrigable area of 257,000 acres.

In addition to net use requirements in the Sacramento-San Joaquin Delta, fresh water also will be required to prevent the invasion of saline water into the delta channels. It is concluded in a second report,§ that the control of saline invasion in the upper bay and delta region could be provided more feasibly and economically by fresh water releases from mountain storage to supplement the available stream flow than by any other means. Studies published in a third report† show that, in order to effect a positive control of salinity at Antioch to limit the increase of salinity at that point to a mean degree of not more than 100 parts of chlorine per 100,000 parts of water with decreasing salinity upstream, a flow of 3300 second-feet throughout the year, in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay, would be required. This would amount to

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, State Department of Public Works.

§ Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

† Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1922.

an average annual flow of about 2,390,000 acre-feet. The salinity control requirement for the San Joaquin Valley portion of the delta is estimated at about two-thirds of the total amount or 1,590,000 acre-feet.

TABLE 58

ULTIMATE WATER REQUIREMENTS OF SAN JOAQUIN RIVER BASIN

Hydrographic division	Net irrigable Area, in acres	Gross allowance, in acre-feet		Net allowance, in acre-feet		Net use, in acre-feet	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Upper San Joaquin Valley Floor—							
1	1,005,000	2,010,000	2.0	2,010,000	2.0	2,010,000	2.0
2	628,000	1,256,000	2.0	1,256,000	2.0	1,256,000	2.0
3	296,000	592,000	2.0	592,000	2.0	592,000	2.0
4	927,000	1,854,000	2.0	1,854,000	2.0	1,854,000	2.0
5	274,000	548,000	2.0	548,000	2.0	548,000	2.0
5 B	227,000	454,000	2.0	454,000	2.0	454,000	2.0
6	291,000	582,000	2.0	582,000	2.0	582,000	2.0
Totals	3,648,000	7,296,000	2.0	7,296,000	2.0	7,296,000	2.0
Lower San Joaquin Valley Floor, excluding San Joaquin Delta—							
7 (South of Merced River)	203,000	670,000	3.3	487,000	2.4	426,000	2.1
7 (Lower west side pumping projects)	62,000	124,000	2.0	112,000	1.8	99,000	1.6
7 (West side rim lands)	143,000	286,000	2.0	257,000	1.8	229,000	1.6
10	69,000	138,000	2.0	124,000	1.8	110,000	1.6
8	282,000	930,000	3.3	677,000	2.4	536,000	1.9
9	312,000	1,030,000	3.3	749,000	2.4	593,000	1.9
11	260,000	858,000	3.3	624,000	2.4	494,000	1.9
12	218,000	589,000	2.7	392,000	1.8	336,000	1.5
13	127,000	343,000	2.7	229,000	1.8	196,000	1.5
Totals	1,676,000	4,968,000	3.0	3,651,000	2.2	3,019,000	1.8
Foothill areas—							
6 A	41,000	123,000	3.0	99,000	2.4	74,000	1.8
8 A	84,000	252,000	3.0	202,000	2.4	151,000	1.8
9 A	62,000	186,000	3.0	149,000	2.4	112,000	1.8
11 A (In Tuolumne watershed)	36,000	108,000	3.0	86,000	2.4	65,000	1.8
11 A (In Stanislaus watershed)	37,000	93,000	2.5	56,000	1.5	55,000	1.5
12A	81,000	202,000	2.5	122,000	1.5	122,000	1.5
13 A	39,000	98,000	2.5	59,000	1.5	58,000	1.5
Totals	380,000	1,062,000	2.8	773,000	2.0	637,000	1.7
Totals, San Joaquin River Basin, excluding San Joaquin Delta	5,704,000	13,326,000	----------	11,720,000	----------	10,952,000	----------
San Joaquin Delta—							
Irrigation and other uses	257,000	824,000	----------	824,000	----------	824,000	----------
Salinity control	----------	1,590,000	----------	1,590,000	----------	1,590,000	----------
Totals	257,000	2,414,000	----------	2,414,000	----------	2,414,000	----------
Totals, San Joaquin River Basin	5,961,000	15,740,000	----------	14,134,000	----------	13,366,000	----------

The wide variety of crops produced in the San Joaquin River Basin is due to varying soil and climatic conditions and geographic location with respect to available markets. This results in considerable variation both as to rate and period of use of irrigation water. The greater part of the irrigation demand occurs during the months of March to October. The estimated monthly distribution of the uses of irrigation water in per cent of seasonal total, for each hydrographic division, based chiefly on use in present irrigated areas, is set forth in Table 59.

TABLE 59

MONTHLY DISTRIBUTION OF THE USE OF IRRIGATION WATER IN SAN JOAQUIN RIVER BASIN IN PER CENT OF SEASONAL TOTAL, BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Month											
	October	November	December	January	February	March	April	May	June	July	August	September
1. (Excluding west side area)	5.0	3.0	3.0	4.0	4.0	8.0	11.0	12.0	14.0	14.0	12.0	10.0
1. West side area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
2. (Excluding west side area)	5.0	3.0	3.0	4.0	4.0	8.0	11.0	12.0	14.0	14.0	12.0	10.0
2. West side area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
3.	5.0	2.0	2.0	3.0	3.0	8.0	11.0	13.0	15.0	15.0	13.0	10.0
4.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
5.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
5B.	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
6. (Excluding Columbia Canal area)	1.4	0.0	0.0	0.0	1.1	7.0	17.0	23.5	21.6	13.4	7.8	7.2
6. Columbia Canal area	5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0
7. West side area, south of Merced River	3.1	0.9	0.7	1.1	3.1	5.8	12.8	17.7	18.2	15.9	12.1	8.6
7. West side rim lands	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
7. Lower west side pumping projects	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
8. (Excluding area served from San Joaquin River)	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
8. Area served from San Joaquin River	3.1	0.9	0.7	1.1	3.1	5.8	12.8	17.7	18.2	15.9	12.1	8.6
9.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
10.	4.0	0.0	0.0	0.0	0.0	5.0	7.0	19.0	19.0	19.0	16.0	11.0
11.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
12.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
13.	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
6A. Above major reservoir sites						Monthly use not estimated						
6A. Below major reservoir sites						Monthly use not estimated						
8A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
8A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
9A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
9A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
11A. Above major reservoir site	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
11A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
12A. Above major reservoir site, in Calaveras River Basin only	6.0	1.0	0.0	0.0	1.0	3.0	10.0	16.0	18.0	18.0	16.0	11.0
12A. Above major reservoir sites, excluding Calaveras River Basin	5.0	1.0	0.0	0.0	0.0	2.0	2.0	15.0	20.0	22.0	20.0	13.0
12A. Below major reservoir sites	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0
13A. Above major reservoir site	5.0	1.0	0.0	0.0	0.0	2.0	2.0	15.0	20.0	22.0	20.0	13.0
13A. Below major reservoir site	4.0	0.0	0.0	0.0	2.0	5.0	11.0	17.0	18.0	18.0	15.0	10.0

Water Requirements Under Ultimate State Water Plan.

In Table 58, are given the ultimate seasonal irrigation requirements for all classes of irrigable land in the basin. For the upper San Joaquin Valley, full development will require importation of water at relatively high costs. It is believed that service under such conditions would be justified only for the better lands. Therefore, in evolving a plan for furnishing a water supply to that region, the area of service has been taken to include only lands in classes 1 and 2 and a small area of Class 3 land suitable for citrus development which could be irrigated by diversion from Tule River. There are 7000 acres of Class 2 land in Zone 1c and 22,000 acres of Class 1 land in Zone 1e which were not included in the areas of service. These lands are unfavorably situated topographically with respect to available water supply. The lands in Zone 1c are more than 200 feet higher in elevation than the canals which serve areas north of Kern River under the State Water Plan. The lands in Zone 1e lie at elevations higher than could be served by a lift of 350 feet above the proposed Kern River diversion canal around the southern end of the valley. The remaining areas of classes 3 and 4 lands have not been included in the area for service under the State Plan for the ultimate development of the upper San Joaquin Valley. In the lower San Joaquin Valley, a region wherein water supplies are adequate if conserved, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin.

The net areas and water requirements of lands, included for service under the ultimate State Water Plan in upper San Joaquin Valley, are set forth by hydrographic divisions in Table 60. The areas in the lower San Joaquin Valley and adjacent foothill divisions are the same as those set forth in Table 56 and their water requirements, by hydrographic divisions are the same as shown in Table 58. In Table 61, are summarized by sections the net irrigable area and water requirements for the San Joaquin River Basin as provided for under the State Water Plan. For comparison, similar information is given for the entire irrigable area in the basin.

TABLE 60

NET AREAS AND WATER REQUIREMENTS OF LANDS INCLUDED FOR SERVICE UNDER ULTIMATE STATE WATER PLAN IN UPPER SAN JOAQUIN VALLEY, BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Net area, in acres					Water requirements, in acre-feet
	Class of land			Municipal areas, omitted from land classification	Totals	
	1	2	3			
1	543,000	246,000		2,000	791,000	1,582,000
2	376,000	185,000	5,000		566,000	1,132,000
3	187,000	82,000		1,000	270,000	540,000
4	635,000	190,000		5,000	830,000	1,660,000
5	243,000	17,000			260,000	520,000
5 B	191,000	30,000			221,000	442,000
6	112,000	85,000			197,000	394,000
Totals	2,287,000	835,000	5,000	8,000	3,135,000	6,270,000

TABLE 61

SUMMARY OF NET AREAS AND WATER REQUIREMENTS OF SAN JOAQUIN RIVER BASIN

Section	Areas to be served under State plan				Entire irrigable area			
	Net area, in acres	Gross allowance, in acre-feet	Net allowance, in acre-feet	Net use, in acre-feet	Net area, in acres	Gross allowanee, in acre-feet	Net allowance, in acre-feet	Net use, in acre-feet
Upper San Joaquin Valley	3,135,000	6,270,000	6,270,000	6,270,000	3,648,000	7,296,000	7,296,000	7,296,000
Lower San Joaquin Valley, excluding San Joaquin Delta	1,676,000	4,968,000	3,651,000	3,019,000	1,676,000	4,968,000	3,651,000	3,019,000
Foothill areas	339,000	939,000	674,000	563,000	380,000	1,062,000	773,000	637,000
Totals, excluding San Joaquin Delta	5,150,000	12,177,000	10,595,000	9,852,000	5,704,000	13,326,000	11,720,000	10,952,000
San Joaquin Delta—								
Irrigation and other uses	257,000	824,000	824,000	824,000	257,000	824,000	824,000	824,000
Salinity control		1,590,000	1,590,000	1,590,000		1,590,000	1,590,000	1,590,000
Totals, San Joaquin River Basin	5,407,000	14,591,000	13,009,000	12,266,000	5,961,000	15,740,000	14,134,000	13,366,000

CHAPTER VI

MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the formulation of a plan for the development of the irrigation possibilities of the San Joaquin River Basin, full cognizance has been taken of all physical factors relating thereto. These comprise water resources, irrigable lands, water requirements, storage facilities and conveyance systems. Some of these factors have been discussed in previous chapters. In Chapter II, there is presented a complete summary of the available water resources of the basin for the 40-year period 1889–1929, including the locations, amounts and characteristics of occurrence of these waters. The classification of the lands as to their suitability for irrigation is presented in Chapter III. In Chapter V, an estimate of the water requirements for the full development of the entire irrigable area of the basin, including salinity control requirements in the San Joaquin Delta, is presented.

Relation Between Water Supply and Ultimate Water Requirements.

In order to show a general relation between the available water supply of the basin and water requirements for full development, the following data pertaining thereto have been assembled from previous chapters:

SEASONAL FULL NATURAL RUN-OFF

In acre-feet

	Available to Upper San Joaquin Valley	*Available to Lower San Joaquin Valley**	*Total San Joaquin River Basin*
Mean for 40-year period 1889–1929	3,651,200	8,328,800	11,980,000
Mean for 20-year period 1909–1929	3,128,300	7,031,300	10,159,600
Mean for 10-year period 1919–1929	2,527,400	6,019,500	8,546,900
Mean for 5-year period 1924–1929	2,355,700	5,781,300	8,137,000

* Includes run-off of San Joaquin River and delta tributaries.

NET IRRIGABLE AREA OF AGRICULTURAL LANDS

In acres

Upper San Joaquin Valley floor	3,648,000
Lower San Joaquin Valley floor	1,676,000
Foothill areas	380,000
Total, excluding San Joaquin Delta	5,704,000
San Joaquin Delta	257,000
Total San Joaquin River Basin	5,961,000

ULTIMATE WATER REQUIREMENTS

In acre-feet

	Gross allowance	*Net allowance*	*Net use*
Upper San Joaquin Valley floor	7,296,000	7,296,000	7,296,000
Lower San Joaquin Valley floor	4,968,000	3,651,000	3,019,000
Foothill areas	1,062,000	773,000	637,000
Totals, excluding San Joaquin Delta	13,326,000	11,720,000	10,952,000
San Joaquin Delta—			
Irrigation and other uses	824,000	824,000	824,000
Salinity control	1,590,000	1,590,000	1,590,000
Totals, San Joaquin Delta	2,414,000	2,414,000	2,414,000
Totals, San Joaquin River Basin	15,740,000	14,134,000	13,366,000

Table 62 shows the relation between the available water supplies and requirements of the various sections in the San Joaquin River Basin. For the upper San Joaquin Valley, the average annual water supply for the 40-year period 1889–1929, exclusive of the San Joaquin River supply which is used chiefly in the lower San Joaquin Valley, is but 50 per cent of the ultimate average annual water requirement; for the 20-year period 1909–1929, 43 per cent; for the 10-year period 1919–1929, 35 per cent; and for the 5-year period 1924–1929, 32 per cent. For the lower San Joaquin Valley and foothill areas, exclusive of San Joaquin Delta, the water supply is sufficient to meet the requirements. However, when San Joaquin Delta requirements are added, the average annual water supply, for the 40-year period only, comes close to meeting the gross allowance requirement, and the average for the 5-year period is less than the net use requirement. For the entire basin, the average annual water supplies for the 40-year, 20-year, 10-year and 5-year periods are 76, 65, 54 and 52 per cent, respectively, of the gross allowance requirement. The corresponding values in per cent of the net use requirement are 90, 76, 64 and 61.

TABLE 62

AVAILABLE WATER SUPPLY AND ULTIMATE WATER REQUIREMENTS SAN JOAQUIN RIVER BASIN

Section	Seasonal full natural run-off, in acre-feet				Seasonal water requirements, in acre-feet	
	40-year mean, 1889-1929	20-year mean, 1909-1929	10-year mean, 1919-1929	5-year mean, 1924-1929	Gross allowance	Net use
Upper San Joaquin Valley	3,651,200	3,128,300	2,527,400	2,355,700	7,296,000	7,296,000
Lower San Joaquin Valley* and foothill areas	*8,328,800	*7,031,300	*6,019,500	*5,781,300	6,030,000	3,656,000
San Joaquin Delta					2,414,000	2,414,000
Totals	11,980,000	10,159,600	8,546,900	8,137,000	15,740,000	13,366,000

* Includes run-off of San Joaquin River and delta tributaries.

Under present conditions of development, it has been definitely pointed out that there are many areas in the upper San Joaquin Valley which are overdrawing the water supplies locally available to them. The water supplies now utilized in the upper San Joaquin Valley comprise the run-off of the streams from the Chowchilla River south, excluding the San Joaquin River. With the present utilization of supplies from these sources, the amount of water available even in a series of wet years in some instances would be of no avail in relieving the water shortage situation. Some of the areas require water supplies far beyond those which are naturally available to them. In the lower San Joaquin Valley, it has been shown that the local water supplies furnished by the San Joaquin River and its east-side tributaries are generally adequate in amount and dependable in occurrence for the areas now under irrigation. However, in the San Joaquin Delta, the water supply now available thereto from the San Joaquin River and its tributaries comprises only such portions of the run-off of these streams in excess of the present net use in the entire lower San Joaquin Valley floor and adjacent foothills. This supply, together with supplies from the Sacramento River, in several recent years have been insufficient to meet the water requirements in the delta and the water in the delta channels has been rendered unfit for irrigation purposes in the summer and fall months by invasion of saline water from upper San Francisco Bay.

The full utilization of all of these available water supplies is not possible of accomplishment. The degree of utilization is limited by many factors, among which are: the availability of surface storage reservoir sites, the utilization of which involves evaporation losses; the availability of utilizable ground water reservoirs; the distance between sources of supply and areas of use, and consequent conveyance losses; and the geologic and topographic conditions which are controlling factors in the extent to which water applied in excess of net use can be recovered for reuse. As will be demonstrated in Chapter VII, it is physically feasible to utilize about 85 per cent of the run-off of the San Joaquin River Basin streams under conditions of ultimate development. This high degree of utilization requires proper coordination of all necessary physical works; namely, surface reservoirs, underground reservoirs, conveyance channels and other works for the diversion of return flows in stream channels for reuse. Therefore, it is obvious that the water supply of the San Joaquin River Basin falls far short of ultimate irrigation requirements and any plan for the ultimate irrigation development of the basin must be predicated on the importation of large volumes of water from an outside source of supply.

Source of Supplemental Supply.

It has been demonstrated in analyses presented in another report* that, by the utilization of the proposed ultimate physical works of the State Water Plan in the Sacramento River Basin including the Trinity River diversion, regulated supplies, without deficiency in amount and dependable in time, could have been made available in the principal streams during the dry period 1918–1929, to irrigate all of the net irrigable area in the Sacramento Valley, after allowing gross diversions for the irrigation of all of the irrigable foothill and mountain valley lands in the Sacramento River Basin. The analyses also show that there would have been a large surplus of water in every year, over and above all needs in the basin above the Sacramento-San Joaquin Delta.

Table 63 shows, for the Sacramento River Basin, the amounts of water contributed from the reservoirs and from unregulated run-off, the gross requirements for valley lands above the delta, the return flow from valley and from foothills not tributary to the reservoirs, and the remaining surpluses available in the delta in the maximum and minimum years and an average for all years during the 11-year period 1918–1929.

The total ultimate average annual requirement for the Sacramento-San Joaquin Delta, including salinity control, would amount to about 3,590,000 acre-feet. A portion of this would be contributed by water from the San Joaquin Valley streams. However, if the entire amount had been obtained from Sacramento Valley waters during the 11-year

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

period 1918–1929, there still would have been surpluses in the maximum and minimum years of 11,399,000 and 2,164,000 acre-feet, respectively, and an average annual surplus for the period of 6,702,000 acre-feet. The Sacramento River Basin is the only available practicable source of supply for exportation to the San Joaquin River Basin.

TABLE 63

SURPLUS WATER IN SACRAMENTO RIVER BASIN

Exclusive of Sacramento-San Joaquin Delta Requirements

Item	Amount of water, in acre-feet		
	Maximum year, 1927	Minimum year, 1924	Average annual, for period 1918-1929
Releases and spill from major reservoir units and unregulated run-off	19,837,000	10,608,000	15,141,000
Gross requirements for lands on Sacramento Valley floor	9,033,000	9,033,000	9,033,000
Surplus from releases and spill and unregulated run-off	10,804,000	1,575,000	6,108,000
Return water—from valley floor	3,843,000	3,843,000	3,843,000
Return water—from foothills not tributary to reservoirs	341,000	341,000	341,000
Total surplus available in delta	14,988,000	5,759,000	10,292,000

Ultimate Water Service Areas and Water Requirements Under State Water Plan in San Joaquin River Basin.

The ultimate development of the San Joaquin River Basin will require the importation of available surplus water supplies from the Sacramento River Basin. For the upper San Joaquin Valley, where supplies from outside sources will be required, the cost of such importation would be relatively high and in general would exceed that of develing local sources of supply. Therefore, it has been assumed that, under conditions of ultimate development, the maximum practicable utilization of all local sources of supply will be made and service will be justified only for the better lands. In evolving that portion of the State Water Plan pertaining to the furnishing of a water supply to the upper San Joaquin Valley, the area of service was taken to include only lands in Classes 1 and 2, and a small area of Class 3 land suitable for citrus development which could be irrigated by diversion from Tule River. Hydrographic divisions and zones of water service are delineated on Plate VI. There are 7000 acres of Class 2 land in Zone 1c and 22,000 acres of Class 1 land in Zone 1e which were not included in the areas of service. These lands are unfavorably situated topographically with respect to available water supply. The lands in Zone 1c are more than 200 feet higher in elevation than the canals which serve areas north of Kern River under the State Water Plan. The lands in Zone 1e lie at elevations higher than could be served by a lift of 350 feet above the proposed Kern River diversion canal around the southern end of the valley.

In the lower San Joaquin Valley, all classes of irrigable land have been included in estimating the required irrigation supply. This procedure was followed also in estimating the irrigation requirements for lands in the Sacramento River Basin. The service area and ultimate water requirements of the San Joaquin Delta have been discussed in Chapter V. The requirements of the Delta are to be met by storage development in the Sacramento River Basin. Plans for making this required supply available are discussed in other reports.* Table 64 sets forth, by hydrographic divisions, net service areas and seasonal water requirements of all lands to be supplied by the ultimate State Water Plan in the San Joaquin River Basin, excluding the San Joaquin Delta.

Although irrigation requirements have been the primary consideration in the study of the utilization of available supplies and the design of a system of physical works to effect such utilization, the requirements for domestic, municipal and industrial water supply, flood control, power development and navigation also have been considered in the formulation of that portion of the State Water Plan pertaining to the San Joaquin River Basin. Flood control and navigation features of the plan are discussed and presented in Chapters IX and X, respectively. The provisions for domestic, municipal and industrial water supply and power development features are presented with the discussions of the various units to which they are incidental.

TABLE 64

ULTIMATE WATER SERVICE AREAS AND WATER REQUIREMENTS UNDER STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, EXCLUDING SAN JOAQUIN DELTA BY HYDROGRAPHIC DIVISIONS

For boundaries of hydrographic divisions, see Plate VI

Hydrographic division	Net service area, in acres	Seasonal water requirements, in acre-feet					
		Gross allowance		Net allowance		Net use	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Upper San Joaquin Valley Floor							
1	791,000	1,582,000	2.0	1,582,000	2.0	1,582,000	2.0
2	566,000	1,132,000	2.0	1,132,000	2.0	1,132,000	2.0
3	270,000	540,000	2.0	540,000	2.0	540,000	2.0
4	830,000	1,660,000	2.0	1,660,000	2.0	1,660,000	2.0
5	260,000	520,000	2.0	520,000	2.0	520,000	2.0
5B	221,000	442,000	2.0	442,000	2.0	442,000	2.0
6	197,000	394,000	2.0	394,000	2.0	394,000	2.0
Totals	3,135,000	6,270,000	2.0	6,270,000	2.0	6,270,000	2.0
Lower San Joaquin Valley Floor							
7 South of Merced River	203,000	670,000	3.3	487,000	2.4	426,000	2.1
7 Lower west side pumping areas	62,000	124,000	2.0	112,000	1.8	99,000	1.6
7 West side rim lands	143,000	286,000	2.0	257,000	1.8	229,000	1.6
8	282,000	930,000	3.3	677,000	2.4	536,000	1.9
9	312,000	1,030,000	3.3	749,000	2.4	593,000	1.9
10	69,000	138,000	2.0	124,000	1.8	110,000	1.6
11	260,000	858,000	3.3	624,000	2.4	494,000	1.9
12	218,000	589,000	2.7	392,000	1.8	336,000	1.54
13	127,000	343,000	2.7	229,000	1.8	196,000	1.54
Totals	1,676,000	4,968,000	3.0	3,651,000	2.2	3,019,000	1.8
Foothills Areas							
8A	84,000	252,000	3.0	202,000	2.4	151,000	1.8
9A	62,000	186,000	3.0	149,000	2.4	112,000	1.8
11A (In Tuolumne watershed)	36,000	108,000	3.0	86,000	2.4	65,000	1.8
11A (In Stanislaus watershed)	37,000	93,000	2.5	56,000	1.5	55,000	1.5
12A	81,000	202,000	2.5	122,000	1.5	122,000	1.5
13A	39,000	98,000	2.5	59,000	1.5	58,000	1.5
Totals	339,000	939,000	2.8	674,000	2.0	563,000	1.7
Totals, San Joaquin River Basin, excluding San Joaquin Delta	5,150,000	12,177,000	---------	10,595,000	---------	9,852,000	---------

* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

Fundamental Elements of State Water Plan.

The basic objective of the State Water Plan is to provide and operate works for the conservation, development, control, utilization and distribution of the waters of the State so that all areas within the State, when completely developed, might have adequate water supplies for all uses and flood protection. Provision would be made for domestic, municipal, industrial, irrigation, mining and recreational water requirements, improvement of navigation on navigable streams, flood control, control of salinity and power development.

In the formulation of the plan, the following economic principles are recognized as fundamental:

1. It should be formulated with a long time viewpoint.
2. It should be a progressive development with the various units constructed only as necessity demands.
3. It should be in consonance with present rights and interests as far as practicable so as to result in the least possible interference with existing agencies and their operations.
4. The water requirements of all interests must be given consideration.
5. Accruing benefits must far outweigh the damages which might result from the execution of the plan.
6. The fullest practicable utilization of both local and imported waters should be made, particularly in areas of deficient water supply.
7. The initial units constructed for the rehabilitation of agriculture should now be extended only to developed areas of deficient local water supply.
8. Units of initial development should be so planned that they can be enlarged and extended at the minimum expense to allow for expansion as economies dictate and that they are in accord with an ultimate plan of development.
9. The plan should be so formulated and carried out that the greatest benefit will be obtained at the least cost.

The basic features included in the plan for the Great Central Valley are storage reservoirs, both surface and underground, and natural and artificial conveyance channels. Surface reservoirs would be constructed on the major streams and operated to equalize the erratic run-off in the interest of all desired purposes and uses. Hydroelectric power plants would be installed at those dams where such development would be justified in order to assist in defraying the cost of all features of the plan. Underground reservoirs, where available, would be utilized to the fullest practicable extent. Conveyance channels, both natural and artificial, would transport water supplies from areas having a surplus to areas of deficiency.

The proposed plan provides only the major units for storage, conveyance and utilization. In addition to these major units of the State Water Plan, many storage reservoirs, distribution canals and laterals, pumping plants and other works, both already constructed and to be constructed, would be required and utilized to provide for the full practicable conservation, regulation, distribution and utilization of the water resources.

Major Units for Ultimate Development in San Joaquin River Basin.

The physical works of that portion of the State Water Plan for the ultimate development of the San Joaquin River Basin are designed to provide for:

1. The fullest practicable utilization, through the combined means of surface and ground water storage, of all water supplies tributary to the San Joaquin River Basin.
2. The storage and regulation of main San Joaquin River water and its diversion to and utilization in the area on the east side of the upper San Joaquin Valley.
3. The conveyance and distribution of surplus Sacramento River Basin water, made available by storage and regulation with the major units of the State Water Plan for the Sacramento River Basin, to provide for that portion of the water requirements of the San Joaquin Valley which can not be met by the fullest practicable utilization of local water supplies.
4. The substitution, for the main San Joaquin River water now used on lands north of Mendota which the plan proposes to divert to the east side of the upper San Joaquin Valley, of imported Sacramento River Basin water and return flow waters of the lower San Joaquin River tributaries.
5. The conveyance and distribution of imported Sacramento River Basin water and return flow waters of the lower San Joaquin River tributaries to undeveloped lands along the west side of the San Joaquin Valley, north and south of Mendota.

In the remainder of this chapter, the major units of the plan for the San Joaquin River Basin, designed in accord with the foregoing provisions, are discussed under the following headings:

1. Surface storage reservoirs.
2. Underground reservoirs.
3. Conveyance units.

The location of these units are shown on Plate XXVI "Major Units of State Plan for Development of Water Resources of California."

The major units of the State Water Plan in the Sacramento River Basin which, by storage and regulation, would provide surplus waters in excess of the full requirements of the Sacramento River Basin for importation to the San Joaquin Valley, are described in detail in other reports.* They comprise ten surface storage reservoirs on the Sacramento River and its tributaries and one on the Trinity River with a diversion conduit into the Sacramento River Basin, with an aggregate storage capacity for the eleven reservoirs of 12,687,000 acre-feet. Detailed data on the operation and accomplishments of these reservoirs, particularly as to the amounts of surplus water made available for importation to the San Joaquin Valley, are presented in the reports cited and are summarized in Chapter VII. Since the ultimate development of the San Joaquin River Basin is materially dependent upon the furnishing of substantial amounts of water from the Sacramento River

* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930.
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

Basin, the major units of the State Water Plan for the Sacramento River Basin, as described in detail in the reports cited, are considered to be an essential part of the plan for the San Joaquin River Basin. The units in the two basins are interrelated and interdependent in their operations and accomplishments and taken together constitute a unified plan of development for the entire Great Central Valley Basin.

In addition to the major units of the State Water Plan for the Great Central Valley proper and combined therewith as a part of the Great Central Valley Project, provision is made for furnishing the immediately adjacent San Francisco Bay Basin with required supplemental water supplies from Great Central Valley sources by conveyance units extending from the Sacramento-San Joaquin Delta channels into the San Francisco Bay region. Conveyance units for this purpose are described in another report,* and other conduits either could be or have been provided. The city of San Francisco has nearly completed a conduit from the Hetch Hetchy watershed on the Tuolumne River to provide a municipal and domestic supply for San Francisco and adjacent territories, which will have an ultimate capacity of 400,000,000 gallons daily. The East Bay Municipal Utility District has already completed and is operating a conduit bringing in water from the Mokelumne River to the cities in the East Bay territory for municipal and domestic supply. The proposed ultimate capacity of this conduit is 200,000,000 gallons per day. Allowance has been made in the studies of water supply and utilization in the Sacramento and San Joaquin River basins for the ultimate exportation of these amounts of water to these San Francisco Bay metropolitan areas.

SURFACE STORAGE RESERVOIRS

The major surface storage units of the ultimate State Water Plan for the San Joaquin River Basin are thirteen in number, located generally immediately above the rim of the valley in the lower foothills. Salient physical data on these reservoir units, having an aggregate storage capacity of 5,130,000 acre-feet, are presented in Table 65.

The methods of operation of these reservoirs, the water yields obtained and the accomplishments effected are presented with the discussion of each reservoir in this chapter and further elucidated in Chapter VII. In selecting the locations and sizes of the surface storage units, careful consideration and study were given to the accomplishments sought or desired and the physical and economic limits of development. The objective was to obtain the maximum resulting benefits at minimum costs. Analyses were made of reservoirs at various sites on each major stream to determine the most feasible location and economic capacity for the purposes to be served. This procedure involved the preparation of cost estimates, both capital and annual, and analyses of water yield for each site and capacity investigated. For those reservoirs where hydroelectric power production appeared advantageous the economic installations of the power plants also were carefully considered.

The estimates of capital cost were prepared in considerable detail, based on prices of materials and labor as of 1929 and 1930. Unit prices

* Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

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* Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources, 1931.

MAJOR UNITS OF STATE PLAN FOR DEVELOPMENT OF WATER RESOURCES OF CALIFORNIA

TABLE 65

ULTIMATE MAJOR SURFACE STORAGE UNITS OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Reservoir	Stream	Tributary drainage area, in square miles	Average seasonal ultimate net run-off for 40-year period 1889-1929, in acre feet	Height of main dam, in feet	Capacity of reservoir, in acre-feet
Nashville	Cosumnes River	435	290 000	270	281,000
Ione	Dry Creek	[1]270	[2]348,700	120	610,000
Pardee (constructed)	Mokelumne River	575	820,000	343	222,000
Valley Springs	Calaveras River	363	189,000	200	325,000
Melones	Stanislaus River	900	1,239,000	460	1,090,000
Don Pedro	Tuolumne River	1,536	1,634,000	455	1,000,000
Exchequer (constructed)	Merced River	1,034	989,000	307	279,000
Buchanan	Chowchilla River	238	70,900	147	84,000
Windy Gap	Fresno River	102	55,200	206	62,000
Friant	San Joaquin River	1,631	1,993,000	252	[3]400,000
Pine Flat	Kings River	1,544	1,889,000	274	400,000
Pleasant Valley	Tule River	[4]264	99,700	125	39,000
Isabella	Kern River	2,080	714,000	190	338,000
Total reservoir capacity					5,130,000

[1] Area in Dry Creek Basin, only.
[2] Includes 280,000 acre-feet of Mokelumne River water spilled from Pardee Reservoir.
[3] Effective capacity 270,000 acre-feet.
[4] Area above Pleasant Valley site, only.

for each reservoir were selected after a study of physical conditions at each dam site and available information on similar projects with comparable conditions. In fixing excavation prices for each dam, a field examination and studies of geological reports and information developed by subsurface explorations were made. Field examinations also were made in the vicinities of the dam sites to determine the nearest and best sources of materials for concrete aggregates and earth fill embankments. This information was used in fixing unit prices for the dams. Transportation facilities available to each dam site were investigated. Analyses were made of the cost of delivering construction materials to the sites, both by railroad and motor truck. The unit prices used for the principal items of base cost for reservoirs are set forth in Table 66. Costs given are for materials in place. They do not include any amounts for administration, engineering and contingencies, or for construction roads and railroads, camps and other miscellaneous items which have been estimated separately for each reservoir in cost estimates thereof hereafter presented. There have been added to the base cost in each estimate, 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction, based on a rate of 4.5 per cent per annum. The total amount of interest was computed on a basis of financing each six months work at the beginning thereof and compounding the interest to the end of the construction period.

The unit price used in estimating the costs of power plants at dam sites, including penstocks, outlets, control works, by-passes and all other appurtenances is $50 per kilovolt ampere for all plants except Melones. The length of tunnel at the latter reservoir necessitated an increase in unit cost to $60 per kilovolt ampere. These prices include overhead and interest during construction.

TABLE 66

SUMMARY OF UNIT PRICES USED IN COST ESTIMATES OF RESERVOIRS

Item	Unit	Nashville Reservoir	Ione Reservoir	Valley Springs Reservoir	Melones Reservoir	Don Pedro Reservoir	Buchanan Reservoir	Windy Gap Reservoir	Friant Reservoir	Pine Flat Reservoir	Pleasant Valley Reservoir	Isabella Reservoir
Excavation, earth	Cubic yard		$0 35-$0 75	$1 00				$1 00	$1 00		$0 75-$2 00 wet-3 00	$0 50
Excavation, dry rock	Cubic yard	$3 00	2 00	3 00	$3 00	$3 00	$4 50	3 50	3 00	$3 50		3 00
Excavation, wet rock	Cubic yard	5 00		5 00	5 00	5 00		5 00	5 00	5 00		5 00
Concrete, mass	Cubic yard	7 85		6 30	7 90	7 20	8 25	8 25	6 30	6 50		9 00
Earthfill embankment	Cubic yard		75								75	75
Reinforced concrete—												
Spillway piers	Cubic yard	18 00	20 00	18 00	18 00	18 00	18 00	18 00	17 00	18 00		19 00
Roadway over spillway	Cubic yard	30 00		30 00	30 00	45 00	30 00	30 00	30 00	30 00		30 00
Parapets	Cubic yard	21 00		21 00	21 00	21 00	21 00	21 00	20 00	20 00		22 00
Spillway channel	Cubic yard		11 20-15 00	8 00-14 00		15 00	9 00	9 00	8 00	10 00	10 00-15 00	10 00
Inlet structures	Cubic yard	21 00	15 00-28 00	21 00	21 00	21 00	21 00	21 00	20 00	20 00	25 00	27 00
Cut-off walls	Cubic yard		15 00-16 50								15 00-18 00	18 00
Slope paving	Cubic yard		15 00								15 00	16 00
Outlet conduits	Cubic yard		16 50								15 00	27 00
Drilling grout holes and drainage wells	Linear foot	3 00		3 00	3 00	3 00	3 00	3 00	3 00	3 00		3 00
Pressure grouting	Cubic yard	70 00		70 00	70 00	70 00	70 00	70 00	70 00	70 00		70 00
Vertical drains in dam	Linear foot	50		50	50	50	50	50	50	50		50
Steel in trash racks	Pound	10	10	10	10	10	10	10	10	10	10	11
Reinforcing steel	Pound	06	05	06	06	06	06	06	06	06	05	0 06-0 07
Riveted steel pipe outlets through dam	Pound	10		10	10	10	10	10	10	10		11
Caterpillar type sluice gates	Pound	22	22	22					22		22	23
Slide gates	Pound	13		13	13	13	13	13	13	13		14
Needle valves	Pound	28		28	28	28	28	28	28	28		29
Segmental steel drum gates	Pound	10	10	10	10	10	11	11	10	10		12
Contraction seals	Linear foot	2 25		2 25	2 25	2 25	2 25	2 25	2 25	2 25		2 25

The estimated annual cost for each reservoir unit comprises interest and amortization on capital investment, and depreciation, operation and maintenance of physical works. The bases used in estimating the annual costs are as follows:

Interest on capital investment, in per cent	4.5
Amortization of capital investment (40-year bonds on 4 per cent sinking fund basis) in per cent of capital cost	1.05
Depreciation—	
Dam and reservoir, in per cent of capital cost	0.3
Power plant (40-year sinking fund basis at 4 per cent) in per cent of capital cost	1.05
Operating expense and maintenance—	
Dam and reservoir, in per cent of capital cost	0.15
Power plant——$10,000 plus $0.65 per kilovolt ampere of installed capacity.	

Nashville Reservoir on Cosumnes River.

The dam site for the Nashville reservoir on the Cosumnes River is located just below the confluence of the main river and Big Indian Creek in the northwest quarter of Section 14, Township 8 North, Range 10 East, M.D.B. and M., about five miles northerly from the town of Plymouth, in Amador and El Dorado counties. The reservoir would be of trifurcated shape, extending up the main river, North Fork and Big Indian Creek.

Two lower reservoir sites—one at Wisconsin Bar and the other at Michigan Bar, were investigated, but it was found that their potential capacities were inadequate to give proper regulation. The Nashville site was found to be the most favorable although it has a somewhat smaller watershed. The bulk of the run-off (about 93 per cent), however, originates above the Nashville site.

The drainage areas on the Cosumnes River watershed, above Nashville dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	84 square miles
Area between elevations 2500 and 5000 feet	212 square miles
Area below elevation 2500 feet	139 square miles
Total area above Nashville dam site	435 square miles

Present Development on Cosumnes River—Development both above and below the Nashville site is relatively small. No power plants have been constructed. Several ditches originally constructed for mining purposes divert water above the Nashville site for irrigation and domestic purposes. The total quantity of water diverted is small in comparison with the run-off of the watershed. The Enterprise Ditch, which heads on the Middle Fork, diverts water also from the South Fork and from a number of minor streams which it crosses on its way toward the town of Plymouth. The Crawford Ditch diverts water from Camp Creek below its junction with Sly Park Creek and serves certain scattered irrigated areas on the ridge between Webber Creek and the Cosumnes River, in the vicinity of El Dorado. The North Fork Extension Ditch diverts water from the North Fork just below its junction with Steeley Fork and supplements the supply of Crawford Ditch.

On the lower reaches of the river, certain riparian owners have irrigated farm lands for many years. Diversions are usually made by means of low dams. Also, lands adjacent to the river are flooded during high river stages. The Cosumnes Irrigation Association, a private company, has constructed diversion works about 1.5 miles below Michigan Bar and also a ditch running some six miles west, for the irrigation of certain riparian lands, about 1000 acres of which have been irrigated up to the present time. Small pumping plants are used at many points during the summer months. The total diversion capacity of riparian owners is estimated as 300 second-feet. No information is available as to quantities actually diverted.

Water Supply—The water supply considered as available for regulation would comprise the run-off of the Cosumnes River above the Nashville dam site after subtracting the gross diversions for certain lands in the American River Basin and all those to be ultimately irrigated above the reservoir, and adding the estimated return flow from the diversions within the Cosumnes River watershed above the reservoir. The net reservoir evaporation loss is estimated at 3.5 feet depth per season on the reservoir surface. For the 40-year period 1889–1929, it is estimated that the average seasonal ultimate net run-off would have been 290,000 acre-feet.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, was prepared by Stephen E. Kieffer from a survey made by him in 1925. A plane table survey of the dam site, scale one inch equals 200 feet, was made by the State in the same year. Table 67 sets forth areas and capacities for various heights of dam.

TABLE 67

AREAS AND CAPACITIES OF NASHVILLE RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
25	775	20	200
50	800	60	1,200
75	825	190	4,400
100	850	390	11,500
125	875	640	24,000
150	900	950	44,000
175	925	1,320	72,600
200	950	1,740	110,000
225	975	2,210	159,000
250	1,000	2,730	222,000
270	1,020	3,180	281,000
275	1,025	3,300	297,000
300	1,050	3,890	387,000
325	1,075	4,510	492,000
350	1,100	5,220	613,000

Based upon the ultimate net run-off of the Cosumnes River for the period 1918–1929, the studies show that the selected reservoir capacity of 281,000 acre-feet would have regulated the flow without waste. The reservoir would have a flow line elevation of 1020 feet and a submerged area of 3180 acres. It would back water up the North, Middle and South forks, and Big Indian Creek, and would be some 10 miles in length and one-half mile in average width. The reservoir area consists mostly of mountain land covered with brush and scattering timber of no commercial value. It is used principally for grazing purposes. Nashville, the remains of an old mining town, would be flooded. The value of the buildings is small. Several old gold mines and mining claims are within the proposed reservoir area. None are active with the possible exception of the Montezuma Mine. The Mother