STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION

BULLETIN No. 9

SUPPLEMENTAL REPORT

ON

WATER RESOURCES OF CALIFORNIA

By
PAUL BAILEY

A REPORT TO THE LEGISLATURE OF 1925

DEPARTMENT OF PVBLIC WORKS CALIFORNIA MCMXXI
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CALIFORNIA STATE PRINTING OFFICE
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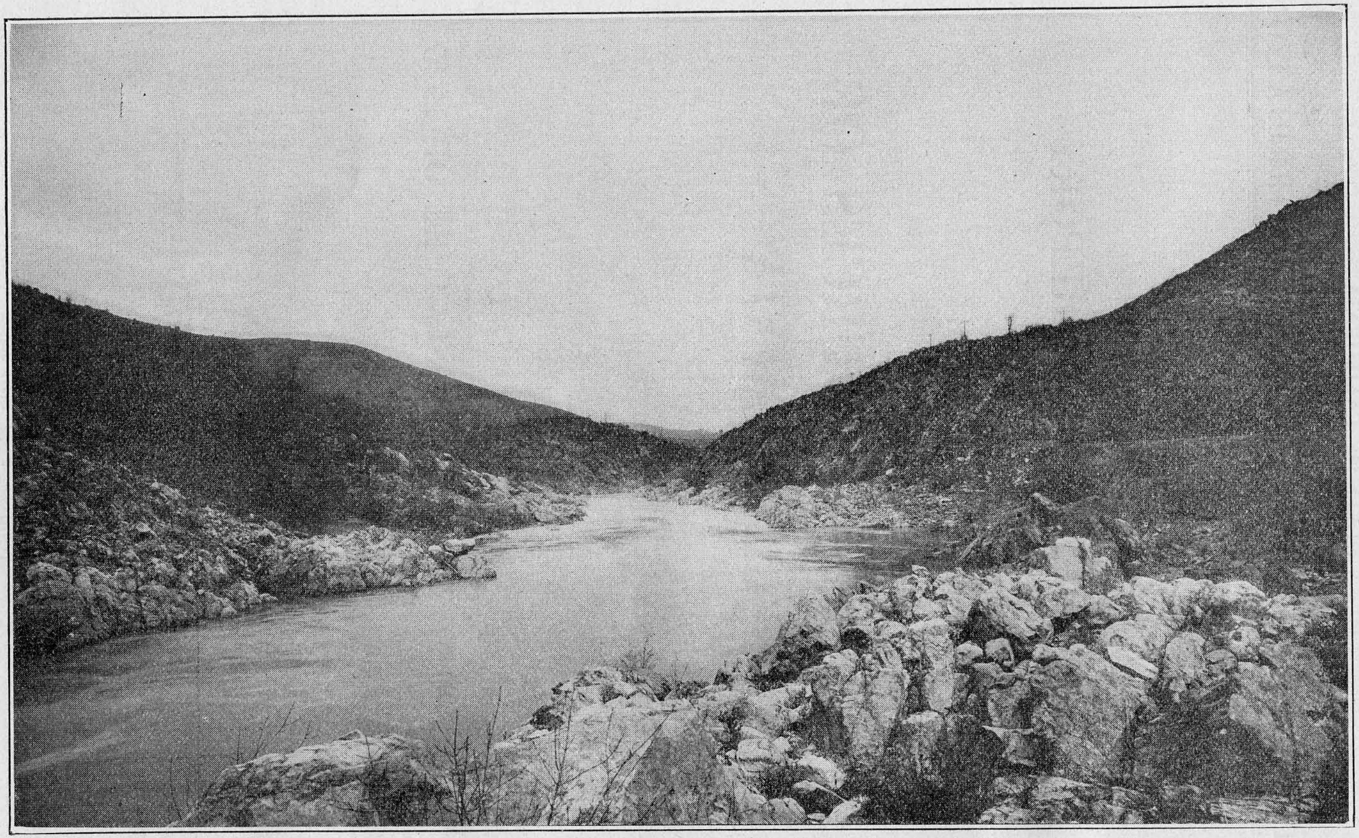

Kennett Dam Site in Sacramento Canyon.

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LETTER OF TRANSMITTAL.

March 23, 1925.

To the Members of the Legislature,
State of California,
Session of 1925.

In September, 1924, the Chambers of Commerce of San Francisco and Los Angeles placed a fund in the hands of the Division of Engineering and Irrigation for the continuation of the Water Resources Investigations. The appropriation in 1921, of $200,000, although inadequate for the completion of the task, produced a preliminary comprehensive plan for the maximum conservation of the state's waters. As requested by the Chambers of Commerce, the additional money has largely been spent in studies of a first unit of this comprehensive plan for the relief of some needy section of the state.

The report transmitted herewith describes an economic program of physical works for the importation of water into Tulare County. Your attention is especially invited to the great conservation of water and the reasonable costs that this plan attains for proposals of such magnitude. They are so interrelated with other developments, however, that they can not be successfully constructed and operated without complete coordination of the use of water throughout the Sacramento and San Joaquin Valleys. Extended studies are necessary to point out how this can be done. The state's water problems are becoming so complicated that economic progress in development can be assured only by working to some general plan based upon a complete assemblage and analysis of facts such as are under way in the Water Resources Investigations. For these reasons, the recommendations of the report are heartily endorsed.

In addition to studies of the first unit of the comprehensive plan, considerable work has been undertaken in investigating the practicability of certain controlling features. The brief period between the receipt of funds and the printing of this report has not permitted completion of this part of the work so that a progress report only is made on this phase.

In presenting this report, I desire to emphasize the valuable assistance rendered by the engineering profession through its members serving as consultants to the investigations. They have given freely of their time and thought in service to the state.

Respectfully submitted.

W. F. McClure

State Engineer and Director of Public Works.

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RECOMMENDATIONS TO THE LEGISLATURE OF 1925.

Plans have been completed and estimates made for relieving Tulare County in its rceding ground-water plane through the construction of a first unit of the comprehensive plan. The studies reveal that only by completely coordinating the development and use of water in both the Sacramento and San Joaquin Valleys, can these plans be successfully and economically carried out. A reconnaissance shows that other areas in the San Joaquin Valley and in southern California are approaching conditions similar to those in Tulare County. They too, can have permanent relief only through extensive works that require complete coordination of programs for constructing and distributing new supplies in order to make them practicable. Present information is inadequate to prepare advice for so doing. It is urged that ample provision be made for developing additional facts and maturing sound recommendations.

CHAPTER I.

COORDINATION OF THE USE OF CALIFORNIA'S WATERS.

THE PRELIMINARY COMPREHENSIVE PLAN.

In 1923, the Division of Engineering and Irrigation reported to the State Legislature upon the Water Resources of California. This work* assembled the first complete inventory of the state's waters that has ever been prepared. It analyzed the needs of water for all purposes, and summarized the water requirements of the state's agricultural lands. Comparison of these figures disclose that much of California's agricultural lands have less water in their vicinity than is required by them for maximum productivity and that the total supply, even with complete conservation, is barely adequate to meet the state's potential demands for water. In conclusion, a preliminary comprehensive plan was outlined for achieving the greatest service from the state's limited water supply.

The 260 reservoirs and long supply canals of this preliminary plan are indicated on the map opposite page 10. Without such reservoirs and long supply canals, much of the state's water must flow unused into the ocean while latent resources remain dormant for lack of water. These works are sufficient to equalize the erratic flow in California's streams and largely overcome the unequal geographic distribution of the state's waters. The plan utilizes all existent reservoirs, main canals and distributing ditches. Waters from new sources would be turned into the systems already in use upon their arrival in that locality. In no instance does it contemplate the abandonment of local supplies but rather the importation of supplemental volumes to replete their deficiencies. The main constructive features of the plan largely revolve about the distribution of water for agriculture. This use predominates so greatly over all others, that, at the present time, domestic and industrial supply is only one-twenty-fifth of the total, while most of the waters that generate electric power and operate mines, being applied on elevated lands, are employed a second time at lower levels for irrigation.

The studies demonstrate that a scientifically coordinated plan for developing the state's waters, will irrigate four-fifths of all the agricultural lands and still provide for the primary use in domestic supply and for industrial, mining, hydro-electric, navigation and all other needs. In diverting irrigation water below the twenty-five hundred foot contour, the comprehensive plan leaves the great mountain area free for the generation of hydro-electric energy except for the irrigation of the mountain valleys, and thereby insures an undiminished yield of electric energy.

Previous investigations,† whose estimates were based upon a continuation of the incoordinate development of the state's waters that is now in progress, limit the ultimate area that may be irrigated, to one-half of all the agricultural lands, a third less than the accomplish-

*Published as Bulletins of the Division of Engineering and Irrigation, State Department of Public Works:
No. 4 "Water Resources of California,"
No. 5 "Flow in California Streams,"
No. 6 "Irrigation Requirements of California Lands."
† Report of the State Conservation Commission of 1912.

ments of the comprehensive plan. While the current system by which each project secures an isolated supply as best it may, has enabled California agriculture through the introduction of irrigation, to respond for many years to the ever increasing demand for its products; the easily developed waters of the state are now in full use. The 1923 report therefore concludes, "Areas greater than are now under irrigation may be watered without coordinated development and distribution, but a limit is being approached whereby united endeavors almost statewide in extent will be necessary to secure greater service from the state's waters at reasonable costs."

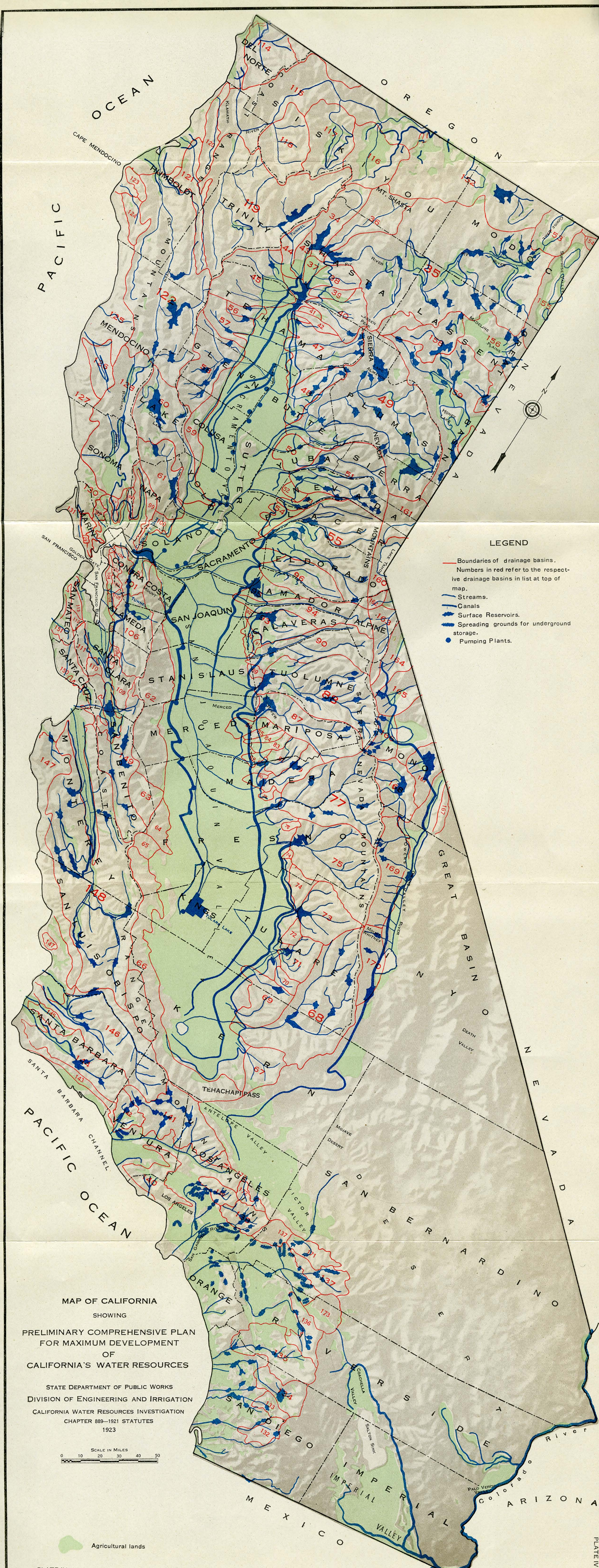
The cost for the ultimate irrigation development under the preliminary comprehensive plan of the 1923 report, would vary greatly in the different localities but averages eighty dollars per acre. This is the average cost for all lands whether they are now watered or not* and includes the cost of existing reservoirs and also of existing canals that form part of the plan. It comprises expenditures for construction and rights of way in storing water for a first-class irrigation supply and transporting it into the regions of use. It does not include the cost of constructing distributing canals, of acquiring water rights, of possible litigation over claims to water rights, or of damage suits. Neither have credit allowances been deducted for power that might be developed at or near the many dams for storing water that are part of the comprehensive plan.

Quoting from the 1923 report, "To effect the watering of so large an area at these costs, it is necessary over the bulk of California's lands to adopt a coördinated scheme of development and distribution of water, that comprise very large areas in interrelated works, * * * The plan herein set forth requires complete coordination of the distribution of water over large areas, as well as in the construction of the works. This is necessary in order to utilize the inexpensive storage sites to the greatest advantage. Dam sites of low cost often have limited catchment areas draining into their reservoirs that do not yield enough water to warrant the construction of high dams when the draft on them is uniform. But under the coordinated scheme of operation of the comprehensive plan, these dams may be erected to their full height and the cheap storage capacity thus created, utilized to the same advantage as the capacities behind other more expensive dams. To secure this advantage requires that the draft on all reservoirs be pooled so that in proportioning the total draft between the reservoirs in each season, the largest amounts may be taken from the reservoirs that are filling the quickest. In this way, * * * reservoirs with watersheds of small yield may be left to fill with accumulating waters during the seasons of plenteous run-off and may be drawn on only during the drier seasons. In so apportioning the draft, exactly the same results are attained in irrigating the land as by the customs in present use whereby the waters from each reservoir become attached to a particular tract of land and the reservoir is drawn on regularly each year at its maximum rate of yield. * * * In either case the same amount of

*It was found to be impossible to separate the costs between areas now under water and those yet to be irrigated without a detail design of the plan in each locality, a work of too great a magnitude for the means at hand. The segregation is intricate because large areas, now classed as irrigated lands, have supplies that are deficient during the latter part of summer and many projects are short of water during the entire season in years of subnormal streamflow. There is still much work to be done in perfecting these supplies.

DRAINAGE BASINS—Listed in numerical order.

34 Sacramento River (Upper).
35 Pit River.
36 McCloud.
37 Churn Creek Group.
38 Cow Creek
39 Bear Creek.
40 Battle Creek.
41 Ink's Creek.
42 Payne's Creek.
43 Backbone Creek Group.
44 Clear Creek.
45 Cottonwood Creek.
46 Sacramento River.
47 Mill Creek Group.
48 Butte Creek Group.
49 Feather River.
50 Honcut Creek Group.
51 Yuba River.
52 Dry Creek.
53 Bear River.
54 Coon Creek Group.
55 American River.
56 Red Bank Creek Group.
57 Elder Creek Group.
58 Stony Creek.
59 Willow Creek Group.
60 Cache Creek.
61 Putah Creek.
62 Orestimba Creek Group.
63 Panoche Creek.
64 Cantua Creek Group.
65 Los Gatos Creek.
66 Tejon Creek Group.
67 Caliente Creek.
68 Kern River.
69 Poso Creek Group.
70 Deer Creek.
71 Tule River.
72 Yokohl Creek Group.
73 Kaweah River.
74 Limekiln Creek Group.
75 Kings River.
76 Dry Creek.
77 San Joaquin River (Upper).
78 Cottonwood Creek.
79 Fresno River.
80 Daulton Creek Group.
81 Chowchilla River.
82 Dutchman Creek Group.
83 Mariposa Creek.
84 Owens Creek.
85 Bear Creek.
86 Burns Creek Group.
87 Merced River.
88 Tuolumne River.
89 Wildcat Creek Group.
90 Stanislaus River.
91 Littlejohns Creek.
92 Martells Creek Group.
93 Calaveras River.
94 Mokelumne River.
95 Sutter Creek Group.
96 Cosumnes River.
97 Petaluma Creek Group.
98 Sonoma Creek Tributaries.
99 Napa River Tributaries.
100 Suisun Creek Group.
101 Mt. Diablo Creek Group.
102 San Pablo Creek.
103 San Leandro Creek.
104 Claremont Creek Group.
105 San Lorenzo Creek.
106 Alameda Creek.
107 Mission Creek Group.
108 Penitencia Creek.
109 Coyote River.
110 Guadalupe River.
111 Los Gatos Creek Group.
112 San Francisquito Creek.
113 San Mateo Creek Group.
114 Smith River.
115 Klamath River.
116 Shasta River.
117 Scott River.
118 Salmon River.
119 Trinity River.
120 Redwood Creek.
121 Mad River.
122 Eel River.
123 Bear Creek.
124 Mattole River.
125 Noyo River Group.
126 Navarro River.
127 Gualala River Group.
128 Russian River.
129 Lagunitas Creek.
130 Salmon Creek Group.
131 Bolinas Creek Group.
132 San Diego River.
133 Santa Ysabel Creek.
134 San Luis Rey River.
135 Santa Margarita River.
136 San Jacinto River Tributaries.
137 Santa Ana River Tributaries.
138 San Gabriel River Tributaries.
139 Los Angeles River Tributaries.
140 Malibu River Group.
141 Santa Clara River Tributaries.
142 Ventura River.
143 Jalama Creek Group.
144 Santa Ynez River.
145 San Antonio Creek.
146 Santa Maria River.
147 San Luis Obispo Creek Group.
148 Salinas River Tributaries.
149 Pajaro River Tributaries.
150 Soquel Creek Group.
151 Pescadero Creek Group.
152 Tule Lake Group.
153 Goose Lake Group.
154 Cowhead Lake Basin.
155 Surprise Valley Group.
156 Madeline Plains Group.
157 Smoke Creek Group.
158 Eagle Lake Group.
159 Honey Lake Group.
160 Lake Tahoe Basin.
161 Truckee River.
162 West Fork Carson River.
163 East Fork Carson River.
164 West Walker River.
165 East Walker River.
166 Mono Lake Group.
167 Adobe Meadows Group.
168 Owens River (Upper).
169 Bishop Creek Group.
170 Owens Lake Group.
171 Mojave River.
172 Antelope Valley Group.
173 Whitewater River.



MAP OF CALIFORNIA
SHOWING
PRELIMINARY COMPREHENSIVE PLAN FOR MAXIMUM DEVELOPMENT OF CALIFORNIA'S WATER RESOURCES

STATE DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
CALIFORNIA WATER RESOURCES INVESTIGATION
CHAPTER 889—1921 STATUTES
1923

PLATE IV

water must be held in storage somewhere for the same length of time, but a great advantage in cost is gained over the customary system of individual reservoir-draft, by the selection of the cheapest sites for storing this water under the system of pooled draft. * * * The coordinated scheme of pooling the draft contained in the comprehensive plan would result in an average construction cost of storage works only slightly more than half that of the individual reservoir-draft system."

A GREAT PROBLEM OF IRRIGATED AGRICULTURE.

While it is necessary for the well-being of a state like California whose wealth is so largely taken from the soil, that the way be not obstructed for ultimately irrigating the maximum area of its farm lands, nevertheless, present concern does not altogether lie in the extension of irrigated areas but rather in the financial success of new projects as well. The 1923 report observes, "There are now perhaps, a million or more acres in California, fertile enough, and with water at hand, but which are failing to produce adequately to pay for all the costs including improvements on the land. Much of this is in large holdings and in new districts that have recently been brought under irrigation and, although it will undoubtedly be closely settled and produce to capacity within a few years, at present these lands are lacking in numbers of tillers of the soil to respond to the propitious agricultural environment of the state."

The cause of these large areas being only partly occupied, does not emanate from sluggishness in the rate of settlement on California's lands, for California is outstripping all other states of the Union in the rate of its increasing agricultural production. On the contrary, the cause of the only partly occupied irrigated lands issues directly from the large size of new projects, that in a year or two, bring under irrigation in one community, an area of land greater than can be absorbed by normal growth within as many decades. During these years, many tracts, making little use of the available water supply, are heavily taxed to pay the costs of works unused by them.

It has been suggested that state regulation should reduce the size of new projects or retard their initiation until lands already possessing a supply, become settled. Facts, however, prohibit the state from more than partially exercising such authority. The size of project proposals is ever expanding because of the increasing difficulties of obtaining new supplies in a state whose easily developed waters are already in use. Only through the organization of larger areas does further progress become practicable. Therefore, the cause for the increasing size of new projects is physical and is not subject to legislative enactment or human regulation. Combinations may sometimes be discovered that permit a reduction in their area but usually an extensive change raises the unit cost beyond feasibility. On the other hand, for state authority to prohibit one community from initiating a feasible project because some other community has unsettled lands, is the exercise of power that decides which community shall prosper. New projects, in most instances, are initiated by communities that feel the necessity of introducing irrigation for the preservation of their continued prosperity. It is witnessed by the past twenty years, that the thriving communities are the ones enjoying irrigated agriculture, while neighboring territories without irrigation supplies, fail to maintain normal growth.

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With complete utilization of the easily developed waters in the state, of necessity, new projects are becoming burdensomely large and risk failure through the construction of works that may not be put to full use for many years, because their community without irrigation, is doomed to a stagnant future. Many plans for rapid colonization have been evolved and much money has been spent during the past several years, to stimulate artificially the rate of settlement on unoccupied lands so that they might earn their tax payments. The only partly rewarded efforts are indicative perhaps, that some other solution should be sought.

At best, the artificial stimulation of the rate of settlement or methods devised to increase production on sparsely occupied lands in new projects can not be more than palliative remedies that fail to strike at the cause. Considering the problems as a whole, the lands now under irrigation are so extensive and the enhanced yield of California's soils when supplied with optimum moisture through irrigation so far surpasses the production by dry farming the same area, that, should by some extreme effort, all lands now under water produce to their new capacity, markets would be deluged beyond hope of profitable sales. The economic error in the irrigation development now in progress is, therefore, not the lack of production on the partly occupied areas but their taxation for water supplies that in the aggregate, they can not profitably apply to the land. To tax lands for heavy costs of irrigation when they can not earn the payments, savors of confiscation of the person's property who is in least favorable circumstances to farm intensively, for the benefit of those most favorably situated. With new projects ever increasing in size because of the physical conditions surrounding the development of the state's waters, and no just way to retard their initiation, concern for the solvency of new projects is justified and the danger is real.

A solution is desirable that will confer on all communities alike, as nearly as possible, an equal opportunity to enjoy the advance in wealth and prosperity normal to the introduction of irrigated agriculture. The coordination of the development and distribution of the state's waters, scientifically designed to overcome the adverse physical features of water supply and geography that are the direct cause of the large size of new projects, appears to offer possibilities of relief greater than any other plan.

The pooling of waters under the comprehensive plan, for a large part, would make unnecessary the construction of works by new projects far in excess of their immediate needs in order to obtain construction units sufficiently large to have reasonable costs. Under the pooled plan of distribution, the water from an economic construction unit might be temporarily served to several districts and so distribute the burden of development almost entirely to lands actually using water, while an orderly construction program might provide for increasing demands. If this could be done in entirety, the settlement and tax problem in new irrigation districts would be largely alleviated for the assessment against the lands not using water could be reduced. *The coordination of water development as proposed in the comprehensive plan, therefore, would provide as nearly as possible for the continued expansion of irrigated agriculture in all communities at reasonable costs, would lighten the burden of taxation against land failing to use water, and would* *achieve the greatest ultimate service from the state's limited water supply. For these reasons it is believed that the studies of the comprehensive plan should be continued until all the facts are known so that the economic practicability of the plan, in whole or in part, may be determined.*

THE LIMIT TO INCOORDINATE DEVELOPMENT OF THE STATE'S WATERS.

While the state as a whole may continue to expand and place greater areas under irrigation without immediate coordination of the use of water, many communities will soon reach the limit of incoordinate development. This will be reached first in those sections of the state whose local supply is least adequate for their agricultural requirements. Already, areas in the southern San Joaquin Valley and south of Tehachapi Pass are facing this limit to incoordinate development. They are areas that derive their supply from underground water and over which the combined draught from all the pumping wells has exceeded the natural replenishment to the subsurface basins. Wherever this has occurred, well levels have receded and, if additional sources of supply are not obtained, will continue to drop until the lift to raise water to the ground surface becomes so great that the cost of pumping exceeds the value of the water to many irrigators. Agriculture will then become unprofitable to the block of farms operating on the smallest margin of profit, and the profits of all will be greatly reduced. Relief has been partially secured in southern California through the artificial replenishment of underground basins by spreading flood water over the surface of gravel beds that it may sink to join the subsurface supply, as well as by constructing surface reservoirs to impound flood waters. In the southern San Joaquin Valley, however, there are areas of receding well levels whose local supplies, both surface and underground, are fully utilized.

The representations from such areas in Tulare County, in the summer of 1924, induced the Chambers of Commerce of San Francisco and Los Angeles to raise a fund for the preparation of this report. Measurements of the water level in the wells throughout Tulare County in the fall of 1924, showed large areas whose underground waters stand more than 50 feet below the ground surface and smaller areas as much as 100 feet below the ground surface. These lands are planted to trees, vines, alfalfa and general crops, are well settled, and support prosperous communities dependent upon irrigation for production. There is no local source of additional water available.* Investigation of the water resources of Tulare County in 1920* determined that the draft on the underground waters of the delta of the Kaweah River equaled the normal replenishment and on the Tule River delta, exceeded the normal supply and that the entire flow of the surface streams, except in seasons of very heavy run-off, is either diverted directly for irrigation or percolates from the stream channels into underground basins. Comparison of the measurements taken in the fall of 1924 with those taken in 1920, show that the well levels throughout Tulare County have dropped from five to thirty-five feet during the last four years. These are the areas

*Bulletin No. 3 of the Division of Engineering and Irrigation, State Department of Public Works, "Water Resources of Tulare County and Their Utilization," by Prof. S. T. Harding of the University of California.

in central California in acute need of an outside source of supply. Several wet seasons would help these communities but only additional water from a distant source can bring permanent relief.

There are also areas in Kern County, next southerly to Tulare County, that are approaching similar conditions. The lands in the southern San Joaquin Valley that are now overdrawing their local supplies together with those approaching a similar situation, approximate a half million acres as fertile as any in the state. Adjacent to these lands, also, are several million more acres of rich agricultural soil, unproductive without water, that will forever remain so unless an outside source of supply is obtained. Therefore, a very large quantity of imported water will eventually be needed in the southern San Joaquin Valley.

In southern California, there are also extensive irrigated areas drawing on ground water for their supply. Measurements of depth to water in a large number of wells in 1922 and again in 1924, show a general decline over practically the entire region with great variation in the different parts. In one section, the water plane dropped 100 feet during the two years. The recession over considerable areas was as much as 20 to 40 feet. Unlike Tulare County, however, there are some flood waters that pass off into the ocean, unused. Since reservoir sites are few in number and their dams are generally expensive, flood waters from several streams are being spread over gravel areas to artificially replenish the underground supply. The practice can be extended to advantage but the limit of relief from local sources is near at hand.

The investigations of 1921-23 indicate that hardly half of the 2,300,000 acres of agricultural land on the Pacific slope of southern California south of Santa Barbara Channel, can receive a full supply of water even under a completely coordinated development of all local sources. The rapid transition of much of this area from rural to urban communities does not lessen the total quantity of water needed, for cities of fair maturity use water about equal to former agricultural needs. These studies show that in total, not more than 250,000 acres of new lands can ever be watered from local sources.

A further survey of southern California conditions in the fall of 1924 corroborates the findings of the 1923 report and also indicates, that, instead of expansion being limited to 250,000 acres, about a million acres of new lands may be furnished domestic, irrigation or industrial supplies by coordinating local development with the importation of water. Three thousand cubic feet per second would eventually have to be obtained. There being no nearby source of additional supply, great works to bring in water from a distant source will be necessary. Preliminary reconnoissance indicates that such a supply may be had from the Colorado River. Because of the time required to evolve the completion of such large enterprises, the approach to the limit of incoordinate development in many localities, and the exceptionally rapid growth enjoyed by this territory, it is important for the uninterrupted expansion and continued prosperity of southern California that plans for the coordination and development of additional supplies from distant sources proceed at once.

CHAPTER II.

FIRST UNIT OF COMPREHENSIVE PLAN IN SAN JOAQUIN VALLEY.

AREA TO BE IRRIGATED.

The donors of the fund raised for the continuation of the Water Resources Investigation, requested that a first unit of the comprehensive plan be devised for the relief of a needy section of the state. Subsequent field examination indicated that certain areas in Tulare County on which the pumping from the underground basins has exceeded replenishment, are in immediate need of importations. Without other local sources of supply, parts of this most prosperous agricultural section face the recession of their well levels to depths that will force the abandonment of irrigation on many farms. Measurements show that already the well levels over 200,000 acres are from 30 to 100 feet below the ground surface.

There are also other areas in Tulare and Kern counties that are approaching like conditions. Normal growth of these communities will entail additional drafts on their underground waters and examination shows that but little additional is available. These areas in Tulare County are only the first to feel the press of an overdraft on their water supply. Proposals to bring in water from a distant source, therefore, should be capable of expansion for a large quantity of imported water will eventually be needed in order that normal growth may be maintained in the communities of the southern San Joaquin valley.

PRELIMINARY PLAN OF 1923.

The Water Resources Investigation of 1921-23 determined that, distributed by a coordinated plan, there is enough water in the Sacramento-San Joaquin drainage basin for all its agricultural lands. The plan evolved provides for taking the surplus water of the Sacramento River to areas of deficient supply in the San Joaquin Valley. It would collect the surplus in the river channel and divert it at sea level into the mouth of the San Joaquin River by a barrier across the bay below the confluence of the two rivers. From here it would be boosted by pumps into a grand canal running southerly along the west side of the San Joaquin Valley. Pumping plants at intervals along this canal would raise the water against the grade of the valley floor.

PLAN FOR CONVEYING WATER THROUGH SAN JOAQUIN VALLEY TO MOUTH OF FRESNO SLOUGH.

The more detailed studies preparatory to this report have determined upon means for conveying the importations into the San Joaquin Valley, superior to those of the preliminary comprehensive plan. Instead of excavating a huge canal on the west side of the valley, the present river channel would be utilized by placing low dams with pumping plants, at intervals along it. The dams would form a series of ponds in the river channel, each successively about ten feet higher than the one before. The pumps at each dam would boost the water from the lower to the higher level. An arrangement of this kind would cost less than half as much as a grand canal; would promote the conservation of water, for none could flow by these dams to the sea; would furnish a more flexible system of works for progressive development and have a lower maintenance and operating cost than a grand canal; and would create no new obstacles to communication and traffic on the land. As structures in a stream of the navigable class, plans for the dams would require the approval of federal authorities. However, such a series of dams could be adapted to the improvement of navigation should this be found desirable. In 1917, the Federal Board of Engineers for Rivers and Harbors reported upon a project to make the San Joaquin River navigable the year round by the construction of dams equipped with locks for passing vessels. They concluded that the cost of these facilities exceeded the benefit that might be derived from their use for navigation alone.

Preparatory to this report, field surveys were made for a series of dams for irrigation purposes. Fourteen dams were located, spaced 9 to 18 miles apart. A pumping plant at the side of each dam would boost the imported water 154 miles southward against the grade of the valley floor to the mouth of Fresno Slough. The average static lift at each dam would be 11.3 feet. The series would raise the water 159 feet above sea level.

The survey shows the channel of the San Joaquin River, upstream to the confluence of the Tuolumne, to average 320 feet wide with high banks. Southward from the Tuolumne, the channel becomes shallow and beyond the Merced the banks in many places are not more than seven or eight feet above the bottom of the channel. The first two dams which are downstream from the Tuolumne, would be less than bank height, but the other twelve would extend seven or eight feet above ground level. Levees would have to be constructed along the banks to confine the water to the river channel. However, the height of levees required for this purpose would be less than that needed to reclaim the adjacent lands from flood inundation. A levee system, designed for the reclamation of the overflow lands, would therefore answer all purposes for pumping irrigation water.

Wings would have to be constructed on either side of the dams upstream from the Tuolumne River, to join them with the flood control levees. These wings, as also the dams themselves, would have to be removed to pass floods during the high water season. The flow in the lower reaches of the river may become as great as 150,000 second-feet. The diversion weir of the San Joaquin and Kings River Canal and Irrigation Company, near the mouth of Fresno Slough, fulfills the requirements and has stood the test of several years. Its main features are permanent piers with removable flashboards and a gate opening for passing small boats. This type of dam was adopted for the estimates.

In holding the water behind the dams south of the Tuolumne River above ground level, the low land upstream from each dam on either side of the river will be affected by seepage. The maximum height above ground of the water level behind any dam, is eight feet. This would become progressively less until at the dam next upstream, it would be several feet below ground surface. These conditions, although more protracted, are less severe than during flood stage in the river, so that, for the most part, it is probable that drainage works adequate for the reclamation from floods will be sufficient.

The pumping plant at the side of each dam would lift the water directly from one pond into the other. The pumps would be installed in 500 second-foot units. The plants would consist of vertical, direct-connected, electric-driven, screw pumps. These pumps have good efficiencies at low heads. For the conditions here outlined, a plant efficiency of 70 per cent should be obtained. The plants would be constructed with the motors above the high-water level.

REDUCTION OF PUMPING LIFT BY EXCHANGE OF WATERS.

The lands in Tulare County in need of an outside supply lie at elevations of 250 to 350 feet above sea level. To pump the Sacramento River water from sea level would place a heavy charge against these lands, more than they could afford to pay at the present time. This can only be avoided by an exchange in supply with the lands of low elevation that are now irrigated from the San Joaquin River. By serving these lower lands from the Sacramento River, the equivalent amount of water served them could be conveyed southward by gravity from a high elevation on the upper San Joaquin River. Irrigation on the lower lands, in receiving the equivalent to their customary supply, would not be affected by the exchange. Under an arrangement of this kind, the San Joaquin River could be diverted southward from Friant at elevation 420 feet above sea level, while the lands receiving exchange water lie at elevations less than 160 feet. There are 320,000 acres now irrigating from the San Joaquin River with which such an exchange might be effected.

The canal conveying water southward from the San Joaquin River would meet the Kings, the next large river southerly from the upper San Joaquin, at elevation 340 feet. A second exchange of waters on the Kings River would make possible a gravity canal leading from the Kings River southward through the heart of the Tulare County lands in need of an outside supply. In this exchange, San Joaquin River water would be delivered to lands now irrigated from the Kings River, and an equivalent amount would be diverted southward from the Kings River at the highest possible elevation. Altogether, there are lands under water from the Kings River below crossings of the suggested canal from San Joaquin River whose full supply equals 8700 second-feet. As on the lower San Joaquin, such an exchange would not affect the irrigation now dependent upon Kings River, for these lands would receive their customary supply in time and in quantity, as usual. If these two exchanges in supply could be effected, a total pumping head of 340 feet could be saved in providing an outside source of supply for Tulare County without in any way impairing either the present or future supplies of other lands in the San Joaquin Valley.

PROPOSALS DEPENDENT UPON COORDINATING THE USE OF WATER IN SACRAMENTO AND SAN JOAQUIN VALLEYS.

It is improbable that the exchange of waters here described could be effected under the current system of isolated supplies for individual projects, each secured and maintained as best it may. If they were, the protection of the rights possessed by lands with which exchanges were made, would become so complicated that the risk of their loss would be great. Also, these exchanges would aggravate the complaint regarding incursions of salt water into the channels of the island region on the lower Sacramento and San Joaquin Rivers, that is now the subject of court action against all upstream diversions. Further, while the 1921-23 studies demonstrated that there is more than enough water in the Sacramento Valley for its own use, they also show that the surplus of easily developed water, is not so great but that its residents would be gravely concerned that the cost of their own water development might not be increased by exportations. Expensive reservoirs for impounding flood water will have to be constructed before much more Sacramento River water can be utilized. Again, the transportation of export water past the diversions along the main channel of the Sacramento River, especially during seasons of low flow, would be replete with strife and contention. Only as the development of surplus water for exportation is completely coordinated with local use in the Sacramento Valley, could its residents be expected to acquiesce. In fact, the whole discussion of the diversion of surplus waters from the Sacramento River into the San Joaquin Valley, must be predicated upon the institution of a coordinated development in both valleys that gives full protection against present or future loss to the owners of vested rights and to present users of water as well as to those potential users whose lands lie tributary to streams from which exportations of water are proposed.

For these reasons, the proposals for the first unit of the comprehensive plan, can at this time be presented only as a mark of progress in the solution of the great problem, as a solution of its physical aspects and illustrative of the possibilities of attainment through coordination of effort. At present, it can be declared feasible only as to the physical works required in its execution. There are still important problems to be solved in the protection of property rights and arrangement for guarantees before the plan can be declared feasible in all respects. An equitable solution requires the assemblage of more information than is now at hand and much further study.

DESCRIPTION OF FIRST UNIT OF COMPREHENSIVE PLAN IN SAN JOAQUIN VALLEY.

The locations of the suggested dams and pumping plants along the San Joaquin River for boosting imported water southward, are indicated on the accompanying map, opposite this page. For the first unit of the comprehensive plan, a project of 1000 second-feet capacity, only six of the fourteen dams on the main river channel are required. These six, with one dam and pumping plant on Salt Slough, a tributary to the San Joaquin extending westerly towards Los Banos, and three pumping plants on a cut extending from Salt Slough, would lift the water to elevation 119 on the main canal of the San Joaquin and Kings River Canal and Irrigation Company near Los Banos. There is a sufficiently large area served from this canal below elevation 119 for an exchange of a 1000 second-foot supply.

The second unit of the comprehensive plan would use all 14 of the suggested dams along the main channel of the San Joaquin River which would lift the water to elevation 159 at the mouth of Fresno Slough. There are areas irrigated from the San Joaquin below this

MAP OF CALIFORNIA
SHOWING
SPECIAL FEATURES OF COMPREHENSIVE PLAN
FOR
COORDINATING THE USE OF CALIFORNIA'S WATERS
ACCOMPANYING
SUPPLEMENTAL REPORT
ON
WATER RESOURCES OF CALIFORNIA
TO
LEGISLATIVE SESSION OF 1925

STATE DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
CALIFORNIA WATER RESOURCES INVESTIGATION
1925

elevation sufficient for a total exchange supply of 3000 second-feet. Sacramento River water could be carried still further up the San Joaquin Valley by continuing the series of dams and pumping plants in Fresno Slough.

A field survey was run for the canal conveying San Joaquin River water southward in exchange for which Sacramento River water would be imported to the lower lands along the San Joaquin. This line leaves Friant on the upper San Joaquin, at elevation 420 and passes through rolling foothills for a distance of nine miles. The first five miles of this are sidehill construction. It then emerges on the valley floor. Here it passes 4000 acres of first-class lands now farmed principally to grain or pasture and without a water supply. The line then crosses the Fresno and Consolidated Irrigation Districts and meets the Kings River at elevation 340. The total length of line from Friant to the Kings River is 32½ miles. It crosses the main canals of the Fresno and Consolidated Irrigation Districts that divert from the Kings River, above lands whose full irrigation supply is 3000 second-feet. It meets the Kings River above other diversions whose full supply is 5700 second-feet. There is, therefore, a supply of 8700 second-feet available on the Kings in exchange for San Joaquin River water.

Kings River water, to the amount of San Joaquin River water given in exchange, would be diverted at elevation 420, the head of the Alta Irrigation District main canal. The first 32 miles of the line southward from the Kings, would be an enlargement of the main canal of the Alta Irrigation District. This canal now has a maximum capacity of 1200 second-feet. It would have to be enlarged to carry both supplies. In diverting at elevation 420, the Alta canal flows along the base of the Sierra foothills, terminating at Seville. Its location is as high as can be obtained without running into very costly sidehill work. From the end of the Alta canal, the line takes off in a southerly direction through Tulare County as shown on the map opposite page 18.

Under this scheme of works, the actual water distributed in Tulare County would come from the Kings River. To supply this in the required volumes during the summer and fall months, necessitates storage. Without storage on the Kings River, an exchange would be limited to a few hundred second-feet during the latter part of the irrigation season except in years of large run-off, for the flow drops as low as 300 to 500 second-feet during the month of September. The Kings River Water Conservation District proposes to construct the Pine Flat reservoir on the Kings River that will serve an equalized supply to about 1,000,000 acres. This would furnish ample stored water for the Tulare County diversion.

In order to compensate Kings River diversions for stored water diverted into Tulare County, a reservoir would have to be constructed on the upper San Joaquin River. The San Joaquin River Water Storage District contemplates the construction of a large reservoir on the San Joaquin near Friant. On fruition of these plans, stored water would be available for compensation to the Kings River diversions. It would then have to be replaced in the San Joaquin diversions by water from the Sacramento drainage area. These exchanges would all be made by delivering an equivalent supply, both in time and in volume, to the lands receiving other water in place of their customary and rightful supply.

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Were a project of this character constructed under the comprehensive plan, the dams in the channel of the San Joaquin River would stop much unused water from running into the ocean. Mingled with the mountain run-off, would be a certain amount of return flow or water draining back into the channel after use on the land. Samples were taken at the mouth of each tributary during the fall of 1924, when all mountain water was being diverted and only return water was flowing in the channels. Chemical analyses of these samples indicate its suitability for irrigation use. The total amount of water intercepted by these dams would probably be enough for several years, to furnish a full supply to the first unit of the comprehensive plan without Sacramento River water.

Although most of this water would be subject to claim by owners of riparian and progressive appropriation rights, under the pooled system of distribution of the comprehensive plan, it would be temporarily available to the Tulare County project during the period in which the claimants failed to use it. The construction of works for developing Sacramento River water in the first unit of the comprehensive plan, therefore, might be deferred for a period after the initiation of the project.

After a time, however, Sacramento River water would be required by the first unit of the comprehensive plan. Except for possible legal entanglements, it could be developed either by the construction of a mountain reservoir in the Sacramento Basin or by the construction of the barrier below the mouth of the Sacramento and San Joaquin Rivers. If the equivalent to the water released from storage into the Sacramento River were pumped from the lower San Joaquin, it would not particularly disturb the conditions of low water flow in the two rivers. Thus, although the barrier is not a physical necessity to the first unit of the comprehensive plan in the San Joaquin Valley, it is an essential feature of the ultimate diversion of Sacramento River water into the San Joaquin, for without it, there can not be the complete conservation necessary to develop the large volumes of surplus Sacramento water for exportation; but unless its construction were assured, undoubtedly the first unit of the comprehensive plan would become embroiled in the water-right controversies surrounding the incursion of salt water into the delta region of the Sacramento and San Joaquin Rivers, and be subjected to court injunction.

If the barrier were constructed, the first unit of the comprehensive plan in the San Joaquin Valley would not need storage works in the Sacramento basin. The barrier would conserve the entire low flow of both the Sacramento and San Joaquin Rivers, more than sufficient for the first unit of the San Joaquin diversion.

ESTIMATE OF CONSTRUCTION COST OF FIRST UNIT OF COMPREHENSIVE PLAN ONE THOUSAND SECOND-FEET CAPACITY.

The following is the estimated cost of constructing the first unit of the comprehensive plan in the San Joaquin Valley. Assuming the completed construction of the reservoirs of the Kings River Conservation District and of the San Joaquin River Water Storage District, it contains the costs of all physical works necessary for its ultimate execution. It does not, however, contain a proportional charge for the barrier across the bay below the mouth of the two rivers but instead, contains the cost of storing flood water for release into the Sacramento River during the months of low flow. It is estimated that the charge for storing water in the Sacramento basin is a substantial equivalent to a proportional charge for the barrier, because, by constructing this storage, except for legal entanglements, the first unit could proceed without particularly disturbing the flow of the Sacramento or San Joaquin Rivers.

In entering a cost for storage on the Sacramento drainage area, no attempt was made to designate a particular reservoir since this need not be constructed for several years, but an amount was estimated that should not be exceeded if one were selected. The storage capacity needed could be most cheaply obtained in combination with some other reservoir project. Any storage in the Sacramento basin offering an advantageous combination is adaptable to the first unit of the comprehensive plan.

The entire cost of the dams in the channel of the San Joaquin River is entered although part of their expense should be a deferred charge to other units of the comprehensive plan for conveying surplus Sacramento River water into the San Joaquin Valley. Placing these dams in the river channel furnishes a conduit of adequate capacity for any quantity of water that may ultimately be pumped up the grade of the valley. The capacity of the pumping plants only, would have to be increased as additional units are added to the comprehensive plan. Also, it may prove desirable to plan these dams for combination with a navigation project. In such an event, the charge to the irrigation project may be less than the entire cost of the dams.

The full cost is entered of the levees that are required to confine the water behind the dams to the river channel, although levees of greater dimension would have to be constructed in reclaiming adjacent overflow lands; however, no charge is made for draining low lands along the river, for the drainage works required for reclamation against floods, would probably exceed those needed for this project and drainage would be of doubtful value to the lands unless reclaimed.

Summary of Construction Cost One Thousand Second-Foot Project.

Annual gross supply 330,000 acre-feet.
Gross duty 2.7 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 120,000 acres,
Storage capacity required 140,000 acre-feet.
Required 6 dams and pumping plants on San Joaquin River.
Required 1 dam and pumping plant on Salt Slough.
Required 3 pumping plants and connecting canal on Salt Slough extension.
Required 40 miles levee of variable height on each bank of San Joaquin River and Salt Slough.
Exchange water delivered into main canal of San Joaquin and Kings River Canal and Irrigation Company near Los Banos at elevation 119.
Required 112 miles of canal—Friant to Earlimart.

Immediate expense—	*Total*	*Cost per acre*
7 dams in San Joaquin River and Salt Slough	$1,364,000	$11 40
10 pumping plants	2,180,000	18 20
Salt Slough extension	196,500	1 60
Levees on banks of San Joaquin River and Salt Slough	1,257,600	10 50
Friant-Kings River canal	2,349,800	19 60
Kings River-Earlimart canal	2,028,900	16 90
Total immediate cost	$9,376,800	$78 20
Deferred expense—		
140,000 acre-feet storage capacity at $25	3,500,000	29 10
Total cost, immediate and deferred	$12,876,800	$107 30

ESTIMATE OF ANNUAL OPERATING COST FIRST UNIT OF COMPREHENSIVE PLAN ONE THOUSAND SECOND-FEET CAPACITY.

In estimating the annual costs of operation of the first 1000 second-foot unit of the comprehensive plan, it is thought that the dams in the channel of the San Joaquin River for many years, would intercept water sufficient that not more than the equivalent of one-half of the season's supply would have to be pumped from sea level. The amount of water intercepted by the several dams would vary from season to season and the cost of energy would vary accordingly. Attendance at the dams the year round is included in the costs so that the only increase in the total for pumping a greater amount of water would be in the energy charge. It would be a number of years before the power consumption in any season would exceed the cost entered as immediate. If the entire supply were pumped from sea level in any season, the total charge would be $4.60 per acre.

Summary—Annual Operating Cost One Thousand Second-Foot Project.

Immediate expense—	*Annual cost*	*Annual cost per acre*
Energy cost	$278,000	$2 30
Interest, maintenance, operation and depreciation—		
Dams and pumping plants on San Joaquin River and Salt Slough	407,600	3 40
Levees on San Joaquin River and Salt Slough	123,500	1 00
Friant-Earlimart canal	325,800	2 70
Total annual cost, immediate	$1,134,900	$9 40
Deferred expense—		
Energy cost	$278,000	$2 30
Interest, maintenance, operation and depreciation—		
Reservoir, capacity 140,000 acre-feet	238,500	2 00
Total annual cost, deferred	$516,500	$4 30
Total annual cost, immediate and deferred	$1,651,400	$13 70

DETAIL OF ESTIMATE OF CONSTRUCTION COST OF FIRST UNIT OF COMPREHENSIVE PLAN.

One Thousand Second-Foot Project.

Annual gross supply 330,000 acre-feet.
Gross duty 2.7 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 120,000 acres.
Storage capacity required 140,000 acre-feet.
Required 6 dams and pumping plants on San Joaquin River.
Required 1 dam and pumping plant on Salt Slough.
Required 3 pumping plants and connecting canal on Salt Slough extension.
Required 40 miles levee of variable height on each bank of San Joaquin River and Salt Slough.
Exchange water delivered into main canal of San Joaquin and Kings River Canal and Irrigation Company near Los Banos at elevation 119.
Required 112 miles of canal—Friant to Earlimart.

Dam No. 1—Length 280 Feet.

	Cost
Excavation, dry, 1400 cubic yards at $1.00	$1,400
Excavation, wet, 2800 cubic yards at $1.50	4,200
Concrete retaining walls, 1120 cubic yards at $25.00	28,000
Concrete cut-off walls, 672 cubic yards at $25.00	16,800
Concrete base, 1120 cubic yards at $25.00	28,000
Concrete piers, 672 cubic yards at $25.00	16,800
Concrete deck and superstructure, 467 cubic yards at $30.00	14,000
Piles, 8400 lineal feet at $2.00	16,800
Gates and hoisting apparatus	26,600
Navigation gate and drawbridge	14,000
Construction cost	$166,600
Interest during contruction at 6%	10,000
Contingencies at 15%	25,000
Engineering and administration at 10%	16,700
Total cost	$218,300

Dam No. 2—Length 340 Feet.

Excavation, dry, 1700 cubic yards at $1.00	$1,700
Excavation, wet, 3400 cubic yards at $1.50	5,100
Concrete retaining walls, 1360 cubic yards at $25.00	34,000
Concrete cut-off walls, 816 cubic yards at $25.00	20,400
Concrete base, 1360 cubic yards at $25.00	34,000
Concrete piers, 816 cubic yards at $25.00	20,400
Concrete deck and superstructure, 567 cubic yards at $30.00	17,000
Piles, 10,200 lineal feet at $2.00	20,400
Gates and hoisting apparatus	32,300
Navigation gate and drawbridge	17,000
Construction cost	$202,300
Interest during construction at 6%	12,100
Contingencies at 15%	30,300
Engineering and administration at 10%	20,200
Total cost	$264,900

Dam No. 3—Length 200 Feet.

	Cost
Excavation, dry, 1000 cubic yards at $1.00	$1,000
Excavation, wet, 2000 cubic yards at $1.50	3,000
Concrete retaining walls, 800 cubic yards at $25.00	20,000
Concrete cut-off walls, 480 cubic yards at $25.00	12,000
Concrete base, 800 cubic yards at $25.00	20,000
Concrete piers, 480 cubic yards at $25.00	12,000
Concrete deck and superstructure, 333 cubic yards at $30.00	10,000
Piles, 6000 lineal feet at $2.00	12,000
Gates and hoisting apparatus	19,000
Navigation gate and drawbridge	10,000
Construction cost	$119,000
Interest during construction at 6%	7,100
Contingencies at 15%	17,900
Engineering and administration at 10%	11,900
Total cost	$155,900

Dam No. 4—Length 340 Feet.

Excavation, dry, 1700 cubic yards at $1.00	$1,700
Excavation, wet, 3400 cubic yards at $1.50	5,100
Concrete retaining walls, 1360 cubic yards at $25.00	34,000
Concrete cut-off walls, 816 cubic yards at $25.00	20,400
Concrete base, 1360 cubic yards at $25.00	34,000
Concrete piers, 816 cubic yards at $25.00	20,400
Concrete deck and superstructure, 567 cubic yards at $30.00	17,000
Piles, 10,200 lineal feet at $2.00	20,400
Gates and hoisting apparatus	32,300
Navigation gate and drawbridge	17,000
Construction cost	$202,300
Interest during construction at 6%	12,100
Contingencies at 15%	30,300
Engineering and administration at 10%	20,200
Total cost	$264,900

Dam No. 5—Length 240 Feet.

Excavation, dry, 1200 cubic yards at $1.00	$1,200
Excavation, wet, 2400 cubic yards at $1.50	3,600
Concrete retaining walls, 960 cubic yards at $25.00	24,000
Concrete cut-off walls, 576 cubic yards at $25.00	14,400
Concrete base, 960 cubic yards at $25.00	24,000
Concrete piers, 576 cubic yards at $25.00	14,400
Concrete deck and superstructure, 400 cubic yards at $30.00	12,000
Piles, 7200 lineal feet at $2.00	14,400
Gates and hoisting apparatus	22,800
Navigation gate and drawbridge	12,000
Construction cost	$142,800
Interest during construction at 6%	8,600
Contingencies at 15%	21,400
Engineering and administration at 10%	14,300
Total cost	$187,100

Dam No. 6—Length 200 Feet.

Excavation, dry, 1000 cubic yards at $1.00	$1,000
Excavation, wet, 2000 cubic yards at $1.50	3,000
Concrete retaining walls, 800 cubic yards at $25.00	20,000
Concrete cut-off walls, 480 cubic yards at $25.00	12,000
Concrete base, 800 cubic yards at $25.00	20,000
Concrete piers, 480 cubic yards at $25.00	12,000

	Cost
Concrete deck and superstructure, 333 cubic yards at $30.00	$10,000
Piles, 6000 lineal feet at $2.00	12,000
Gates and hoisting apparatus	19,000
Navigation gate and drawbridge	10,000
Construction cost	$119,000
Interest during construction at 6%	7,100
Contingencies at 15%	17,900
Engineering and administration at 10%	11,900
Total cost	$155,900

Dam No. 7A—In Salt Slough—Length 150 Feet.

Excavation, dry, 750 cubic yards at $1.00	$750
Excavation, wet, 1500 cubic yards at $1.50	2,250
Concrete retaining walls, 600 cubic yards at $25.00	15,000
Concrete cut-off walls, 360 cubic yards at $25.00	9,000
Concrete base, 600 cubic yards at $25.00	15,000
Concrete piers, 360 cubic yards at $25.00	9,000
Concrete deck and superstructure, 250 cubic yards at $30.00	7,500
Piles, 4500 lineal feet at $2.00	9,000
Gates and hoisting apparatus	14,300
Navigation gate and drawbridge	7,500
Construction cost	$89,300
Interest during construction at 6%	5,400
Contingencies at 15%	13,400
Engineering and administration at 10%	8,900
Total cost	$117,000

Summary of Dams.

Dam No. 1	$218,300
Dam No. 2	264,900
Dam No. 3	155,900
Dam No. 4	264,900
Dam No. 5	187,100
Dam No. 6	155,900
Dam No. 7A	117,000
Total cost of dams	$1,364,000

Pumping Plants.

Typical Plant—1000 second-feet capacity.

Excavation, dry, 1800 cubic yards at $0.50	$900
Excavation, wet, 1600 cubic yards at $2.50	4,000
Concrete in retaining walls, 420 cubic yards at $25.00	10,500
Concrete in intakes and pump sumps, 275 cubic yards at $30.00	8,250
Concrete in Venturi tubes, 200 cubic yards at $35.00	7,000
Concrete in buildings and extras, 255 cubic yards at $35.00	9,000
Lining outlet canal, 5000 square feet at $0.25	1,250
Pumps and electrical equipment, 2 units at $42,870	85,750
Transformers, 4 at $5,000	20,000
Operators' houses, 3 with water supply	13,500
Roads, 2 miles at $2,500	5,000
Side levees, 6250 cubic yards at $0.20	1,250
Construction cost	$166,400
Interest during construction at 6%	10,000
Contingencies at 15%	25,000
Engineering and administration at 10%	16,600
Total cost of typical pumping plant	$218,000

Summary of Pumping Plants.

	Cost
On San Joaquin River and Salt Slough, 7 plants at $218,000	$1,526,000
On Salt Slough Extension, 3 plants at $218,000	654,000
Total cost of pumping plants	$2,180,000

Salt Slough Extension—Length 3 Miles.

Excavation, 250,400 cubic yards at $0.25	$62,600
Concrete lining, 728,640 square feet at $0.12	87,400
Construction cost	$150,000
Interest during construction at 6%	9,000
Contingencies at 15%	22,500
Engineering and administration at 10%	15,000
Total cost of Salt Slough Extension	$196,500

40 Miles Levee on San Joaquin River and Salt Slough.

Dredge bank, 4,800,000 cubic yards at $0.20	$960,000
Interest during construction at 6%	57,600
Contingencies at 15%	144,000
Engineering and administration at 10%	96,000
Total cost of levees	$1,257,600

Friant-Kings River Canal.

Five miles sidehill construction—

Intake structure at dam	$30,000
Excavation, broken schist, 96,900 cubic yards at $0.85	82,400
Excavation, loose rock and hardpan, 165,100 cubic yards at $0.75	123,800
Concrete lining, 1,082,300 square feet at $0.15	162,300
Flume or siphon, 1499 feet at $50	75,000
Two road siphons, 100 feet at $50	5,000
Right of way, 100 feet wide, 60 acres at $50	3,000
Construction cost	$481,500
Interest during construction at 6%	28,900
Contingencies at 15%	72,300
Engineering and administration at 10%	48,100
Total cost	$630,800

Four miles rolling ground—

Excavation, hardpan, 33,400 cubic yards at $0.60	$20,000
Excavation, hardpan, 40,600 cubic yards at $0.50	20,300
Excavation, sand, 39,300 cubic yards at $0.30	11,800
Excavation, earth, 32,000 cubic yards at $0.20	6,400
Concrete lining, 385,500 square feet at $0.15	57,800
Concrete lining, 434,700 square feet at $0.12	52,200
Dry Creek siphon, 1800 feet at $50	90,000
Road and railroad siphon, 60 feet at $50	3,000
Right of way, 100 feet wide, 24 acres at $50	1,200
Right of way, 100 feet wide, 12 acres at $100	1,200
Right of way, 100 feet wide, 12 acres at $300	3,600
Construction cost	$267,500
Interest during construction at 6%	16,000
Contingencies at 15%	40,100
Engineering and administration at 10%	26,800
Total cost	$350,400

23½ miles flat ground—	*Cost*
Excavation, earth, 622,800 cubic yards at $0.18	$112,100
Excavation, bottom land, 69,200 cubic yards at $0.20	13,800
Concrete lining, 5,069,900 square feet at $0.12	608,400
32 road siphons, 950 feet at $50	47,500
3 railroad siphons, 300 feet at $50	15,000
5 large canal crossings, 500 feet at $50	25,000
5 small canal crossings, 250 feet at $50	12,500
1 wasteway at Kings River	9,700
Right of way, 100 feet wide, 24 acres at $300	7,200
Right of way, 100 feet wide, 258 acres at $750	193,500
Construction cost	$1,044,700
Interest during construction at 6%	62,700
Contingencies at 15%	156,700
Engineering and administration at 10%	104,500
Total cost	$1,368,600

Summary of Friant-Kings River Canal.

Total, 5 miles sidehill construction	$630,800
Total, 4 miles on rolling ground	350,400
Total, 23½ miles on flat ground	1,368,600
Total cost of Friant-Kings River Canal	$2,349,800

Kings River-Earlimart Canal.

*Enlargement Alta Canal, *32.3 miles—*	
Excavation, earth, 1,355,000 cubic yards at $0.30	$406,500
Excavation, hardpan, 169,000 cubic yards at $0.50	84,500
Intake structure	25,000
4 railroad siphons, 300 feet at $50	15,000
23 road siphons, 690 feet at $50	34,500
Right of way, 100 feet wide, 60 acres at $100	6,000
Right of way, 100 feet wide, 157 acres at $300	47,100
Right of way, 100 feet wide, 140 acres at $700	98,000
Right of way, 100 feet wide, 60 acres at $1,000	60,000
Construction cost	$776,600
Interest during construction at 6%	46,600
Contingencies at 15%	116,500
Engineering and administration at 10%	77,700
Total cost	$1,017,400

Seville to Earlimart, 47 miles, flat ground—	
Excavation, earth, 2,040,500 cubic yards at $0.18	$367,300
48 road siphons, 1570 feet at $50	78,500
4 railroad siphons, 280 feet at $50	14,000
12 small canal siphons, 480 feet at $50	24,000
8 creek siphons, 700 feet at $50	35,000
Right of way, 100 feet wide, 216 acres at $200	43,200
Right of way, 100 feet wide, 108 acres at $350	37,800
Right of way, 100 feet wide, 212 acres at $700	148,400
Right of way, 100 feet wide, 24 acres at $1,000	24,000
Construction cost	$772,200
Interest during construction at 6%	46,300
Contingencies at 15%	115,800
Engineering and administration at 10%	77,200
Total cost	$1,011,500

*Enlarged to carry supply for Tulare County Project in addition to supply for Alta Irrigation District.

Summary of Kings River-Earlimart Canal.

	Cost
Total, enlargement of Alta canal	$1,017,400
Total, Seville to Earlimart section	1,011,500
Total cost of Kings River-Earliment canal	$2,028,900

Summary of Construction Cost, One Thousand Second-Foot Project.

Immediate Expense—	*Total*	*Cost per acre*
7 Dams in San Joaquin River and Salt Slough	$1,364,000	$11.40
10 Pumping palnts	2,180,000	18.20
Salt Slough Extension	196,500	1.60
Levees on banks of San Joaquin River and Salt Slough	1,257,600	10.50
Friant-Kings River canal	2,349,800	19.60
Kings River-Earlimart canal	2,028,900	16.90
Total immediate cost	$9,376,800	$78.20
Deferred Expense—		
140,000 acre-feet storage capacity at $25	3,500,000	29.10
Total cost, immediate and deferred	$12,876,800	$107.30

DETAIL ESTIMATE OF ANNUAL OPERATING COSTS FIRST UNIT OF COMPREHENSIVE PLAN.

One Thousand Second-feet Capacity.

Annual gross supply 330,000 acre-feet.
Gross duty 2.7 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 120,000 acres.
Storage capacity required 140,000 acre-feet.
Required 6 dams and pumping plants on San Joaquin River.
Required 1 dam and pumping plant on Salt Slough.
Required 3 pumping plants and connecting canal on Salt Slough extension.
Required 40 miles levee of variable height on each bank of San Joaquin River and Salt Slough.
Exchange water delivered into main canal of San Joaquin and Kings River Canal and Irrigation Company near Los Banos at elevation 119.
Requires 112 miles of Canal—Friant to Earlimart.

Dams and Pumping Plants on San Joaquin River and Salt Slough.

Energy cost—			*Annual cost*
Static head	119 feet		
Friction head	33 feet		
Total pumping head	152 feet		
Required 17,300 horsepower.			
Pumping 90 days, power consumption is 27,800,000 kilowatt hours.			
27,800,000 kilowatt hourts at 1¢			$278,000
Labor for operating pumping plants—			
One chief operator		$3,000	
Permanent operators, 10 at $1,200 per year		12,000	
Temporary operators, 10 for 90 days at $4.00		3,600	
Laborers, 10 for 90 days at $3.00		2,700	
			21,300
Interest, total cost of pumping plants and dams $3,544,000, at 6%			212,600
Carried forward			$511,900

		Annual cost
	Brought forward	$511,900
Depreciation of pumping plants and dams—		
10 Pumping Plants, construction cost $1,664,000, at 5%	$83,200	
7 Dams, construction cost $1,041,200, at 1%	10,400	
		93,600
Maintenance and repair of pumping plants and dams—		
10 pumping plants, construction cost $1,664,000, at 3%	$49,900	
7 Dams, construction cost, $1,041,200, at 1%	10,400	
Miscellaneous, incidentals and insurance	5,000	
		65,300
Total dams and pumping plants		$670,800

Salt Slough Extension.

Interest, total cost $196,500, at 6%	$11,800
Depreciation, contruction cost $150,000, at 1%	1,500
Maintenance, construction cost $150,000, at 1%	1,500
Total Salt Slough Extension	$14,800

Levees on Banks of San Joaquin River and Salt Slough.

Interest, total cost $1,257,600, at 6%	$75,500
Depreciation, construction cost $960,000, at 1%	9,600
Maintenance, construction cost $960,000, at 1%	38,400
Total levees	$123,500

Storage Reservoir.

Interest, total cost $3,500,000, at 6%	$210,000
Depreciation, construction cost $2,700,000, at 1%	27,000
One watchman at reservoir	1,500
Total reservoir	$238,500

Friant-Earlimart Canal.

Interest, total cost $4,378,300, at 6%		$262,700
Depreciation on structures, construction cost $538,700, at 2%		10,800
Maintenance and repair—		
Canal and structures, construction cost $3,342,100, at 1%		33,400
Labor for operation—		
1 Superintendent	$4,000	
11 Patrolmen, 6 months at $150	9,900	
		13,900
Miscellaneous, incidentals and insurance		5,000
Total Friant-Earlimart canal		$325,800

Summary of Annual Operating Cost, First Unit of Comprehensive Plan. One Thousand Second-Feet Capacity.

	Annual cost	Annual cost per acre
Immediate expense—		
Energy cost	$278,000	$2 30
Interest, maintenance, operation and depreciation—		
Dams and pumping plants on San Joaquin River and Salt Slough	392,800	3 30
Salt Slough extension	14,800	0 10
Levees on San Joaquin River and Salt Slough	123,500	1 00
Friant-Earlimart canal	325,800	2 70
Total cost, immediate	$1,134,900	$9 40
Deferred expense—		
Interest, maintenance, operation and depreciation		
Energy cost	$278,000	$2 30
on reservoir	238,500	2 00
Total annual cost, deferred	$516,500	$4 30
Total annual cost, immediate and deferred	$1,651,400	$13 70

CHAPTER III.

SECOND UNIT OF COMPREHENSIVE PLAN IN SAN JOAQUIN VALLEY.

DESCRIPTION OF SECOND UNIT OF COMPREHENSIVE PLAN.

Along with other works, the first unit of the comprehensive plan in the San Joaquin Valley would construct six dams in the channel of the San Joaquin River and equip the plants at each dam with pumps of 1000 second-feet capacity. These would boost the imported water from sea level to the mouth of Salt Slough. The second unit of the comprehensive plan would enlarge the pumping plants at these six dams from 1000 to 3000 second-feet total capacity. The additional supply of 2000 second-feet would be carried from the mouth of Salt Slough up the channel of the San Joaquin River by a continuation of the series of dams and pumping plants, while the 1000 second-feet of the first unit would be taken up Salt Slough.

Eight more dams and pumping plants in addition to the six of the first unit, would be necessary to boost the water to points where it might be delivered as exchange supplies. The last plant of unit number two would raise the water to elevation 159 at the mouth of Fresno Slough. The pumping plants at the first four dams of the second unit would have a capacity of 2000 second-feet. The delivery of exchange supplies would permit a reduction in the capacity of the plants at the four dams farthest upstream to 1500 second-feet.

The additional supply developed by Unit No. 2, would be carried into Tulare County by enlarging the capacity of the Friant-Earlimart canal from 1000 to 3000 second-feet principally by lining the canal section.

ESTIMATE OF CONSTRUCTION COST SECOND UNIT OF COMPREHENSIVE PLAN 2000 SECOND-FEET ADDITIONAL CAPACITY.

The cost of constructing the second unit of the comprehensive plan is estimated on the same basis as the first unit. It assumes that the reservoirs of the Kings River Conservation District and of the San Joaquin River Water Storage District are constructed. Likewise, instead of a proportional charge for the barrier below the mouth of the Sacramento and San Joaquin Rivers, a charge is entered for constructing storage in the Sacramento basin that would augment the low flow of the Sacramento River by as much water as would be taken out at the mouth of the San Joaquin River. It is thought that this is a substantial equivalent to a proportional charge for the barrier, because, by constructing this storage, except for legal entanglements, the second unit could proceed without particularly disturbing the low flow of the Sacramento or San Joaquin Rivers.

The reservoir charge in the Sacramento basin is entered without selection of a particular site, for the storage capacity needed could be most cheaply obtained in combination with some other reservoir project and any one offering an advantageous combination is adaptable. The estimated entry should not be exceeded if a selection were made.

The entire cost of the eight additional dams in the channel of the San Joaquin River, together with the cost of levees along the river banks to confine the water behind them to the river channel, is included, although part of their first cost should be a deferred charge to future units of the comprehensive plan for conveying surplus Sacramento River water into the San Joaquin Valley. No part of the cost of the first six dams nor of their levees along the river banks, is entered, however, because this entire cost was included in the cost of the first unit of the comprehensive plan. As in the estimate for the first unit, there is no inclusion for costs of draining low lands adjacent to the river.

Summary of Construction Cost—Second Unit of Comprehensive Plan 2000 Second-Feet Additional Capacity.

Annual gross supply 660,000 acre-feet additional to Unit No. 1.
Annual saving in seepage loss of unit number one water by lining canal, 60,000 acre-feet.
Total available supply, 720,000 acre-feet.
Gross duty 2.2 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 330,000 acres additional to Unit No. 1.
Storage capacity required 560,000 acre-feet.
Required additional pumping units of 2000 second-feet capacity at the 6 dams of Unit No. 1 in San Joaquin River.
Required 8 dams and pumping plants on San Joaquin River in addition to the 6 dams of Unit No. 1.
Required 63 miles of levee of variable height on each bank of San Joaquin River adjacent to the 8 new dams.
Exchange water delivered at the head gates of diversions from the San Joaquin River between elevations 117 and 159.
Required the enlargement of Friant-Earlimart canal, 112 miles in length, from 1000 to 3000 second-feet capacity.

Immediate expense—	*Annual cost*	*Annual cost per acre*
8 dams in San Joaquin River	$1,656,500	$5 10
4 pumping plants, 2000 second-feet capacity	1,482,400	4 50
4 pumping plants, 1500 second-feet capacity	1,179,600	3 60
6 pumping plants, enlarged from 1000 to 3000 second-feet capacity	1,828,800	5 50
63 miles levee on banks of San Joaquin River	1,980,700	6 00
Friant-Kings River canal, enlargement	1,700,400	5 10
Kings River-Earlimart canal, enlargmeent	4,837,800	14 60
560,000 acre-feet storage capacity at $20	11,200,000	33 90
Grand total cost	$25,866,200	$78 30

ESTIMATE OF ANNUAL OPERATING COST SECOND UNIT OF COMPREHENSIVE PLAN 2000 SECOND-FEET ADDITIONAL CAPACITY.

The annual cost of operating the second unit of the comprehensive plan is estimated as the additional cost of operating a project completed to a total capacity of 3000 second-feet, over that listed for unit one. Items are included for interest, depreciation, maintenance and repairs on the construction added to the first unit only. Similarly, the only charge for labor is in operating the pumping plants at the eight new dams on the San Joaquin River. The labor required to operate the six pumping plants of unit one on the San Joaquin River is adequate to operate the plants at their enlarged capacity. Likewise, no more labor would be required to operate the lined section of the Friant-Earlimart canal delivering 3000 second-feet than to handle the 1000 second-feet of Unit No. 1 in an unlined section.

The power cost for Unit No. 2 is placed at that of pumping 2000 second-feet from sea level to dam No. 10 and 1500 second-feet from dam No. 10 to dam No. 14, for 120 days each year. This allows for more pumping than would be necessary for some time except in the dry seasons.

The sum of the total operating costs tabulated for Units No. 1 and No. 2 would be the total cost of operating a project of 3000 second-feet total capacity.

Summary of Annual Operating Cost, Second Unit of Comprehensive Plan 2000 Second-Feet Additional Capacity.

Immediate expense—	*Annual cost*	*Annual cost per acre*
Energy cost	$1,190,700	$3 60
Interest, maintenance, operation and depreciation—		
8 dams and pumping plants on San Joaquin River	694,600	2 10
63 miles levees on banks of San Joaquin River	194,400	60
Friant-Earlimart canal, enlargement	467,500	1 40
Storage reservoir	759,000	2 30
Total annual cost, immediate	$3,306,200	$10 00
Deferred expense—		
Energy cost	446,500	1 40
Total annual cost, immediate and deferred	$3,752,700	$11 40

DETAIL ESTIMATE OF CONSTRUCTION COST SECOND UNIT OF COMPREHENSIVE PLAN 2000 SECOND-FEET ADDITIONAL CAPACITY.

Annual gross supply 660,000 acre-feet additional to Unit No. 1.
Annual saving in seepage loss of unit number one water by lining canal, 60,000 acre-feet.
Total available supply, 720,000 acre-feet.
Gross duty 2.2 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 330,000 acres additional to Unit No. 1.
Storage capacity required 560,000 acre-feet.
Required additional pumping units of 2000 second-feet capacity at the 6 dams of Unit No. 1 in San Joaquin River.
Required 8 dams and pumping plants on San Joaquin River in addition to the 6 dams of Unit No. 1.
Required 63 miles of levee of variable height on each bank of San Joaquin River adjacent to the 8 new dams.
Exchange water delivered at the head gates of diversions from the San Joaquin River between elevations 117 and 159.
Required the enlargement of Friant-Earlimart canal, 112 miles in length, from 1000 to 3000 second-feet capacity.

Dam No. 7—Length 200 Feet.

	Cost
Excavation, dry, 1000 cubic yards at $1.00	$1,000
Excavation, wet, 2000 cubic yards at $1.50	3,000
Concrete retaining walls, 800 cubic yards at $25.00	20,000
Concrete cut-off walls, 480 cubic yards at $25.00	12,000
Concrete base, 800 cubic yards at $25.00	20,000
Concrete piers, 480 cubic yards at $25.00	12,000
Concrete deck and superstructure, 333 cubic yards at $30.00	10,000
Piles, 6000 lineal feet at $2.00	12,000
Gates and hoisting apparatus	19,000
Navigation gates and drawbridge	10,000
Construction cost	$119,000
Interest during construction at 6%	7,100
Contingencies at 15%	17,900
Engineering and administration at 10%	11,900
Total cost	$155,900

Dam No. 8—Length 160 Feet.

Excavation, dry, 800 cubic yards at $1.00	$800
Excavation, wet, 1600 cubic yards at $1.50	2,400
Concrete retaining walls, 640 cubic yards at $25.00	16,000
Concrete cut-off walls, 384 cubic yards at $25.00	9,600
Concrete base, 640 cubic yards at $25.00	16,000
Concrete piers, 384 cubic yards at $25.00	9,600
Concrete deck and superstructure, 267 cubic yards at $30.00	8,000
Piles, 4800 lineal feet at $2.00	9,600
Gates and hoisting apparatus	15,200
Navigation gate and drawbridge	8,000
Construction cost	$95,200
Interest during construction at 6%	5,700
Contingencies at 15%	14,300
Engineering and administration at 10%	9,500
Total cost	$124,700

Dam No. 9—Length 200 Feet.

Excavation, dry, 1,000 cubic yards at $1.00	$1,000
Excavation, wet, 2,000 cubic yards at $1.50	3,000
Concrete retaining walls, 800 cubic yards at $25.00	20,000
Concrete cut-off walls, 480 cubic yards at $25.00	12,000
Concrete base, 800 cubic yards at $25.00	20,000
Concrete piers, 480 cubic yards at $25.00	12,000
Concrete deck and superstructure, 333 cubic yards at $30.00	10,000
Piles, 6000 lineal feet at $2.00	12,000
Gates and hoisting apparatus	19,000
Navigation gate and drawbridge	10,000
Construction cost	$119,000
Interest during construction at 6%	7,100
Contingencies at 15%	17,900
Engineering and administration at 10%	11,900
Total cost	$155,900

Dam No. 10—Length 240 Feet.

	Cost
Excavation, dry, 1200 cubic yards at $1.00	$1,200
Excavation, wet, 2400 cubic yards at $1.00	3,600
Concrete in retaining walls, 960 cubic yards at $25.00	24,000
Concrete cut-off walls, 576 cubic yards at $25.00	14,400
Concrete base, 960 cubic yards at $25.00	24,000
Concrete piers, 576 cubic yards at $25.00	14.400
Concrete deck and superstructure, 400 cubic yards at $30.00	12,000
Piles, 7200 lineal feet at $2.00	14.400
Gates and hoisting apparatus	22,800
Navigation gates and drawbridge	12,000
Construction cost	$142,800
Interest during construction at 6%	8,600
Contingencies at 15%	21,400
Engineering and administration at 10%	14,300
Total cost	$187,100

Dam No. 11—Length 280 Feet.

Excavation, dry, 1400 cubic yards at $1.00	$1,400
Excavation, wet, 2800 cubic yards at $1.50	4,200
Concrete in retaining walls, 1120 cubic yards at $25.00	28,000
Concrete cut-off walls, 672 cubic yards at $25.00	16,800
Concrete base, 1120 cubic yards at $25.00	28,000
Concrete piers, 672 cubic yards at $25.00	16,800
Concrete deck and superstructure, 467 cubic yards at $30.00	14,000
Piles, 8400 lineal feet at $2.00	16.800
Gates and hoisting apparatus	26,600
Navigation gate and drawbridge	14,000
Construction cost	$166,600
Interest during construction at 6%	10,000
Contingencies at 15%	25.000
Engineering and administration at 10%	16,700
Total cost	$218,300

Dam No. 12—Length 380 Feet.

Excavation, dry, 1900 cubic yards at $1.00	$1,900
Excavation, wet, 3800 cubic yards at $1.50	5,700
Concrete in retaining walls, 1520 cubic yards at $25.00	38,000
Concrete cut-off walls, 912 cubic yards at $25.00	22,800
Concrete base, 1520 cubic yards at $25.00	38,000
Concrete piers, 912 cubic yards at $25.00	22,800
Concrete deck and superstructure, 633 cubic yards at $30.00	19,000
Piles, 11,400 lineal feet at $2.00	22,800
Gates and hoisting apparatus	36,100
Navigation gate and drawbridge	19,000
Construction cost	$226,100
Interest during construction at 6%	13,600
Contingencies at 15%	33,900
Engineering and administration at 10%	22,600
Total cost	$296,200

Dam No. 13—Length 280 Feet.

	Cost
Excavation, dry, 1400 cubic yards at $1.00	$1,400
Excavation, wet, 2800 cubic yards at $1.50	4,200
Concrete in retaining walls, 1120 cubic yards at $25.00	28,000
Concrete cut-off walls, 672 cubic yards at $25.00	16,800
Concrete base, 1120 cubic yards at $25.00	28,000
Concrete piers, 672 cubic yards at $25.00	16,800
Concrete deck and superstructure, 467 cubic yards at $30.00	14,000
Piles, 8400 lineal feet at $2.00	16,800
Gates and hoisting apparatus	26,600
Navigation gates and drawbridge	14,000
Construction cost	$166,600
Interest during construction at 6%	10,000
Contingencies at 15%	25,000
Engineering and administration at 10%	16,700
Total cost	$218,300

Dam No. 14—Length 385 Feet.

Excavation, dry, 1925 cubic yards at $1.00	$1,900
Excavation, wet, 3850 cubic yards at $1.50	5,800
Concrete in retaining walls, 1540 cubic yards at $25.00	38,500
Concrete cut-off walls, 924 cubic yards at $25.00	23,100
Concrete base, 1540 cubic yards at $25.00	38,500
Concrete cut-off walls, 924 cubic yards at $25.00	23,100
Concrete deck and superstructure, 642 cubic yards at $30.00	19,300
Piles, 11,550 lineal feet at $2.00	23,100
Gates and hoisting apparatus	36,600
Navigation gate and drawbridge	19,200
Construction cost	$229,100
Interest during construction at 6%	13,700
Contingencies at 15%	34,400
Engineering and administration at 10%	22,900
Total cost	$300,100

Summary of Dams.

Dam No. 7	$155,900
Dam No. 8	124,700
Dam No. 9	155,900
Dam No. 10	187,100
Dam No. 11	218,300
Dam No. 12	296,200
Dam No. 13	218,300
Dam No. 14	300,100
Total cost of dams	$1,656,500

Pumping Plants.

Typical enlargement of 1000 second-foot pumping plant of Unit No. 1 to 3000 second-feet capacity.

Excavation, dry, 3600 cubic yards at $0.50	$1,800
Excavation, wet, 3200 cubic yards at $2.50	8,000
Concrete in retaining walls, 420 cubic yards at $25.00	10,500
Concrete in intakes and sumps, 535 cubic yards at $30.00	16,000
Concrete in Venturi tubes, 400 cubic yards at $35.00	14,000
Concrete in buildings and extras, 285 cubic yards at $35.00	10,000
Lining outlet canal, 3000 square feet at $0.25	800
Pumps and electrical equipment, 4 units at $42,870.00	171,500
Construction cost	$232,600

	Cost
Brought forward	$232,600
Interest during construction at 6%	14,000
Contingencies at 15%	34,900
Engineering and administration at 10%	23,300
Total cost	$304,800

Typical pumping plant—2000 second-feet capacity.

Excavation, dry, 3600 cubic yards at $0.50	$1,800
Excavation, wet, 3200 cubic yards at $2.50	8,000
Concrete in retaining walls, 630 cubic yards at $25.00	15,800
Concrete in intakes and sumps, 550 cubic yards at $30.00	16,500
Concrete in Venturi tubes, 400 cubic yards at $35.00	14,000
Concrete in buildings and extras, 400 cubic yards at $35.00	14,000
Lining outlet canal, 6400 square feet at $0.25	1,600
Pumps and electrical equipment, 4 units at $42,870.00	171,500
Transformers, 4 at $5,000.00	20,000
Operators houses with water supply, 3	13,500
Roads, 2 miles at $2500.00	5,000
Side levees, 6250 cubic yards at $0.20	1,200
Construction cost	$282,900
Interest during construction at 6%	17,000
Contingencies at 15%	42,400
Engineering and administration at 10%	28,300
Total cost	$370,600

Typical pumping plant—1500 second-feet capacity.

Excavation, dry, 2800 cubic yards at $0.50	$1,400
Excavation, wet, 2400 cubic yards at $2.50	6,000
Concrete in retaining walls, 532 cubic yards at $25.00	13,300
Concrete in intakes and sumps, 420 cubic yards at $30.00	12,600
Concrete in Venturi tubes, 300 cubic yards at $35.00	10,500
Concrete in buildings and extras, 330 cubic yards at $35.00	11,600
Lining outlet canal, 5600 square feet at $0.25	1,400
Pumps and electrical equipment, 3 units at $42,870.00	128,600
Transformers, 4 at $5,000.00	20,000
Operators houses with water supply, 3	13,500
Roads, 2 miles at $2500.00	5,000
Side levees, 6250 cubic yards at $0.20	1,200
Construction cost	$225,100
Interest during construction at 6%	13,500
Contingencies at 15%	33,800
Engineering and administration at 10%	22,500
Total cost	$294,900

Summary of Pumping Plants.

Pumping plants increased in capacity from 1000 to 3000 second-feet, 6 at $304,800	$1,828,800
Pumping plants, 2000 second-feet capacity, 4 at $370,600	1,482,400
Pumping plants, 1500 second-feet capacity, 4 at $294,900	1,179,600
Total cost of pumping plants	$4,490,800

63 Miles of Levee of Variable Height on Each Bank of San Joaquin River.

Dredge banks, 7,560,000 cubic yards at $0.20	$1,512,000
Interest during construction at 6%	90,700
Contingencies at 15%	226,800
Engineering and administration at 10%	151,200
Total cost levees	$1,980,700

Friant-Kings River Canal.

Enlargement to increase capacity from 1000 to 3000 second-feet;

Five miles sidehill construction—

	Cost
Intake structure (constructed in unit No. 1)	
Excavation, broken schist, 100,500 cubic yards at $0.85	$85,400
Excavation, loose rock and hardpan, 144,000 cubic yards at $0.75	108,000
Concrete lining 577,700 square feet at $0.15	86,700
Flume or siphon, 1499 lineal feet at $80	119,900
2 road siphons, 100 lineal feet at $80	8,000
Right of way, 100 feet wide (purchased for Unit No. 1)	
Construction cost	$408,000
Interest during construction at 6%	24,500
Contingencies at 15%	61,200
Engineering and administration at 10%	40,800
Total cost	$534,500

Four miles rolling ground—

Excavation, hardpan, 35,300 cubic yards at $0.60	$21,200
Excavation, hardpan, 40,600 cubic yards at $0.50	20,300
Excavation, sand, 48,100 cubic yards at $0.30	14,400
Excavation, earth, 42,900 cubic yards at $0.20	8,600
Concrete lining, 204,400 square feet at $0.15	30,700
Concrete lining, 230,600 square feet at $0.12	27,700
Dry Creek siphon, 1800 lineal feet at $80	144,000
Road and railroad siphon, 60 lineal feet at $80	4,850
Right of way (purchased for Unit No. 1)	
Construction cost	$271,700
Interest during construction at 6%	16,300
Contingencies at 15%	40,800
Engineering and administration at 10%	27,200
Total cost	$356,000

23½ miles flat ground—

Excavation, earth, 702,400 cubic yards at $0.18	$126,400
Excavation, river bottom, 94,600 cubic yards at $0.20	18,900
Concrete lining, 2,566,100 square feet at $0.12	307,900
32 road siphons, 960 lineal feet at $80	76,800
3 railroad siphons, 300 lineal feet at $80	24,000
5 large canal crossings, 500 lineal feet at $80	40,000
5 small canal crossings, 250 lineal feet at $80	20,000
Wasteway at Kings River	4,300
Right of way (purchased for Unit No. 1)	
Construction cost	$618,300
Interest during construction at 6%	37,100
Contingencies at 15%	92,700
Engineering and administration at 10%	61,800
Total cost	$809,900

Summary of Friant-Kings River Canal.

Enlargement to increase capacity from 1000 to 3000 second-feet—

Total 5 miles of sidehill construction	$534,500
Total 4 miles of rolling ground	356,000
Total 23½ miles, flat ground	809,900
Total cost Friant-Kings River canal	$1,700,400

Kings River-Earlimart Canal.

Enlargement to increase capacity from 1000 to 3000 second feet—

Enlargement Alta canal, 32.3 miles, constructed to carry Alta and Tulare supply.

	Cost
Intake structure (constructed for Unit No. 1)	
Concrete lining, 10,062,500 square feet at $0.12	$1,207,500
4 railroad siphons, 300 lineal feet at $80	24,000
23 road siphons, 690 lineal feet at $80	55,200
Right of way (purchased for Unit No. 1)	
Construction cost	$1,286,700
Interest during construction at 6%	77,200
Contingencies at 15%	193,000
Engineering and administration at 10%	128,700
Total cost	$1,685,600

Seville to Earlimart, 47 miles flat ground—

Excavation, earth, 937,400 cubic yards at $0.18	$168,700
Concrete lining, 16,625,700 square feet at $0.12	1,995,100
48 road siphons, 1570 lineal feet at $80	125,600
4 railroad siphons, 280 lineal feet at $80	22,400
12 small canal siphons, 480 lineal feet at $80	38,400
8 creek siphons, 700 lineal feet at $80	56,000
Right of way (purchased for Unit No.)	
Construction cost	$2,406,200
Interest during construction at 6%	144,400
Contingencies at 15%	360,900
Engineering and administration at 10%	240,600
Total cost	$3,152,100

Summary of Kings River-Earlimart Canal.

Enlargement in capacity from 1000 to 3000 second-feet—

32½ miles enlargement of Alta canal	$1,685,600
47 miles Seville to Earlimart	3,152,100
Total cost Kings River-Earlimart canal	$4,837,700

Summary Construction Cost—Second Unit of Comprehensive Plan, 2000 Second-Feet Additional Capacity.

	Total cost	*Cost per acre*
8 dams in San Joaquin river	$1,656,500	$5 10
4 pumping plants, 2000 second-feet capacity	1,482,400	4 50
4 pumping plants, 1500 second-feet capacity	1,179,600	3 60
6 pumping plants, enlarged from 1000 to 3000 second-feet capacity	1,828,800	5 50
63 miles levee on banks of San Joaquin River	1,980,700	6 00
Friant-Kings River canal, enlargement	1,700,400	5 10
Kings River-Earlimart canal, enlargement	4,837,800	14 60
560,000 acre-feet storage capacity at $20	11,200,000	33 90
Grand total cost	$25,866,200	$78 30

DETAIL ESTIMATE OF ANNUAL OPERATING COST— SECOND UNIT OF COMPREHENSIVE PLAN.

2000 Second-Feet Additional Capacity.

Annual gross supply, 660,000 acre-feet additional to Unit No. 1.
Annual saving in seepage loss of unit number one water by lining canal, 60,000 acre-feet.
Total available supply, 720,000 acre-feet.
Gross duty 2.2 acre-feet per acre.
Net duty 2.0 acre-feet per acre.
Area to be irrigated 330,000 acres additional to Unit No. 1.
Storage capacity required 560,000 acre-feet.
Required additional pumping units of 2000 second-feet capacity at the 6 dams of Unit No. 1 in San Joaquin River.
Required 8 dams and pumping plants on San Joaquin River in addition to the 6 dams of Unit No. 1.
Required 63 miles of levee of variable height on each bank of San Joaquin River adjacent to the 8 new dams.
Exchange water delivered at the head gates of diversions from the San Joaquin River between elevations 117 and 159.
Required the enlargement of Friant-Earlimart canal, 112 miles in length, from 1000 to 3000 second-feet capacity.

Dams and Pumping Plants On San Joaquin River.

Energy cost—

Static head sea level to Dam No. 10	117 feet
Friction head sea level to Dam No. 10	27 feet
Total pumping head	144 feet

Required 43,600 horsepower to pump 2000 second-feet against a 144-foot head.
Power required for 120 days pumping is 93,672,000 kilowatt hours.

Static head Dam No. 10 to Dam No. 14	42 feet
Friction head Dam No. 10 to Dam. No. 14	10 feet
Total pumping head	52 feet

Required 11,800 horsepower to pump 1500 second-feet against a 52-foot head.
Power required for 120 days pumping is 25,400,000 kilowatt hours.
Summary electrical energy required per season.

Sea level to Dam No. 10	93,672,000 kw. hrs.
Dam No. 10 to Dam No. 14	25,400,000 kw. hrs.
Total power required each season	119,072,000 kw. hrs.

		Annual cost
119,072,000 kilowatt hours at 1¢		$1,190,700
Labor for operation—		
8 Permanent operators at $1200 per year	$9,600	
8 Temporary operators, 120 days at $4.00	3,800	
8 Laborers, 120 days at $3.00	2,900	
		16,300
Interest, total cost $6,147,300, at 6%		368,800
Depreciation—		
8 dams, construction cost $1,264,400, at 1%	$12,600	
8 pumping plants, construction cost $2,032,000, at 5%	101,600	
6 pumping plants enlarged, construction cost $1,395,600, at 5%	69,800	
		184,000
Carried forward		$1,759,800

Maintenance and repairs—		*Annual cost*
	Brought forward	$1,759,800
8 dams, construction cost $1,264,400, at 1%	$12,600	
8 pumping plants, construction cost $2,032,000, at 3%	61,000	
6 pumping plants enlarged, construction cost $1,395,600, at 3%	41,900	
		115,500
Miscellaneous, incidentals and insurance		10,000
Total dams and pumping plants		$1,885,300

63 Miles Levee on Each Bank of San Joaquin River—

Interest, total cost $1,980,700, at 6%	$118,800
Depreciation, construction cost $1,512,000, at 1%	15,100
Maintenance and repair, construction cost $1,512,000, at 4%	60,500
Total levees	$194,400

Storage Reservoir—

Interest, total cost $11,200,000, at 6%	$672,000
Depreciation, construction cost $8,549,600, at 1%	85,500
One watchman	1,500
Total reservoir	$759,000

Friant-Earlimart Canal.

Interest, total cost $6,538,200, at 6%	$392,300
Depreciation on structure, construction cost $763,400, at 2%	15,300
Maintenance and repair, canal and structures, construction cost $4,991,000, at 1%	49,900
Miscellaneous, incidentals and insurance	10,000
Total canals	$467,500

Summary of Annual Operating Cost—Second Unit of Comprehensive Plan, 2000 Second-Feet Additional Capacity.

Immediate cost—	*Annual cost*	*Annual cost per acre*
Energy cost	$1,190,700	$3 60
Interest, maintenance, operation and depreciation—		
8 dams and pumping plants on San Joaquin River	694,600	2 10
63 miles of levees on banks of San Joaquin River	194,400	60
Friant-Earlimart canal, enlargement	467,500	1 40
Storage reservoir	759,000	2 30
Total annual cost, immediate	$3,306,200	$10 00
Deferred cost—		
Energy cost	446,500	1 40
Total annual cost, immediate and deferred	$3,752,700	$11 40

CHAPTER IV.

CONTROLLING FEATURES OF THE COMPREHENSIVE PLAN.

INVESTIGATIONS FOR FINAL REPORT ON COMPREHENSIVE PLAN:

Prior to the Water Resources Investigation of 1921-23, but little knowledge of reservoir sites had ever been assembled. It was not commonly known that many sites existed. In 1912, the State Water Commission published summary information on twenty-three sites in the Sacramento basin from the records of the United States Geological Survey and Reclamation Service. Since that time, engineers have discovered many potential reservoirs. Largely through the courtesy of the engineering profession engaged in private practice, with public utilities, and in state and federal offices, more or less complete information has been assembled on 1270 sites located in all parts of the state. One hundred and seventy-six of these were reconnoitered by field parties of the Division of Engineering and Irrigation.

The preliminary comprehensive plan was evolved from this great mass of information. Neither time nor funds has permitted a complete examination of the many dam sites nor of the lines of long supply canals that are part of the plan. However, before this plan, with its accomplishments, can be declared wholly practicable, examination in considerable detail must be made of its principal elements.

It is not necessary to include in detail study, all the sites for reservoirs nor the entire length of the canal lines. Many of the reservoirs, if later found impracticable or more expensive than cursory examination indicates, could be supplanted in the plan by others. Similarly, the terrain through which parts of the canal extend, is flat and unobstructed. Reconnoissance examination will determine their feasibility and future changes in alignment would not particularly affect their cost. However, other features of the plan that are essential to its success, are not easily replaced by alternate devices or are involved in such complicated problems that complete studies are essential to determine with certainty that they are practicable. It is with such features of the comprehensive plan that the continuance of the investigation is concerned.

Close study should also be made of the advantages to be gained in the construction and operation of these works in various combinations. In order to minimize the large expenditures that would be entailed in the construction of the comprehensive plan, it is essential that maximum service be obtained from all its component parts. To arrive at the combinations of fundamental importance to maximum service from the state's waters and the groups that will form practical construction units, is a heavy task. While much has already been accomplished, the multitude of considerations in working with a territory as large as the whole state, still leaves a great deal to be done in arriving at the desired goal.

FOOTHILL RESERVOIRS.

In general, the plan relinquishes the great mountain area for the generation of power, operation of mines and other pursuits of these regions without interference by the requirements of industries on the lower levels that will later use the same water. The flows emerging from their mountainous sources onto the valley floors, would be reregulated by reservoirs at the canyon mouths for dometsic, irrigation, industrial, navigation, and flood control purposes on the plains below. These foothill reservoirs are important features in avoiding complication of development that might hamper the efficient and advantageous operation of the works for both mountain and valley use of the water. They are consequently important factors in ultimately securing the highest use of the state's waters.

Unfortunately for low cost in construction, the foothill reservoir sites are usually situated along the easiest lines of communication between the plains and the high mountains. Consequently railways and highways are found traversing many of them. The moving of these to other satisfactory locations will be large items in their cost. The more reason, therefore, that these structures be utilized to the greatest advantage and for as many purposes as possible. To secure the highest use from the state's waters, the foothill reservoirs should be primarily allotted to storing water for domestic, irrigation or industrial supplies on the plains below. Incidental to this, some power may be generated and a measure of flood control be effected without impairing their value for the essential purposes.

Examination of these combined values has been initiated by the investigations of 1924. It is found that there is a large amount of potential power available while drawing water from the foothill reservoirs for use on the plains below. To secure the greatest conservation of water, this power must be generated at the time the water is withdrawn from the reservoirs for other purposes. Ultimately, therefore, the power generated at the foothill reservoirs will be seasonal power, varying in output with the level of the water surface in the reservoir, the amount of water released, and the load factor of the generating plant at the time of release. For many years, however, the water yield of these reservoirs would be greater than the immature demands for domestic, irrigation, industrial or other purposes on the lower areas. Through this period, withdrawals could be made to suit the particular needs of power generation, and still serve all other then existing demands. Therefore, public economy can best be served by coordinating these growing demands for water with the generation of power, so that, through the period of their immaturity, power can be generated to its full advantage, but ultimately, will be subservient to the primary uses of the foothill reservoirs.

FLOOD CONTROL BY RESERVOIRS.

The foothill reservoirs, having the entire drainage areas of their streams tributary to them, are the most favorably situated of all reservoirs to have flood control value. A complete analysis of their utility for this purpose has never been made. It has generally been conceived that reservoirs are useful for controlling floods by absorbing a large volume of the water. The report of the California Debris Commission of June 29, 1911, on flood control in the Sacramento Valley, states, "While favoring the use of reservoirs as far as possible, and considering that one of the advantages of the project herein proposed is that it lends itself to future storage possibilities, the commission believes that it is not economical to construct reservoirs for flood control, but that such construction should be deferred until these reservoirs prove desirable for power and irrigation purposes."

California is now entered upon the period of reservoir construction for power and irrigation purposes. Therefore, it is opportune at this time to ascertain the value of reservoirs for flood control. The possibilities of coordinating the use of reservoirs for flood control with that for other purposes, are not apparent at first sight, because for flood control, reservoires should be held empty during the seasons of heavy run-off, while for other purposes they should be allowed to fill. The investigations of 1924, however, show that it is practicable to utilize the flood control feature of reservoirs in harmony with their other functions.

The Division of Engineering and Irrigation has undertaken to establish the principles by which reservoirs may be operated for controlling floods and still maintain their full value as storage enterprises. Studies are now in progress that are expected to result in a statement of the necessary rules. It appears practical, in many instances at least, to cut the volume of maximum floods in half by operation of foothill reservoirs for flood control, without detracting from their other values. The studies are not yet sufficiently advanced to show what bearing this may have on flood control plans. The storage capacity required for flood control is large. On streams of heavy run-off, it is so large that economic considerations will probably prevent the construction of reservoirs for flood control purposes alone except in special instances. However, the possibility of operating reservoirs to control floods and also to secure their full value in storing water for domestic, industrial and irrigation supplies, generating power, or spreading water on gravel beds in the replenishment of ground water basins, may make combinations of values that will advance the use of reservoirs for flood control. Completion of the investigation alone can determine this.

In the preparation of this report, particular attention has been placed on a study of the foothill reservoirs in the Sacramento Valley, including an analysis of their flood control values. Reservoirs at the edge of the valley floor on the upper Sacramento, Feather, Yuba, and American Rivers are being investigated. The studies have not yet progressed to the point of drawing conclusions. It will undoubtedly be some time before as much storage capacity will be needed in the Sacramento Valley for irrigation supply as exists in these reservoirs. The potential power, however, is large. With 400-foot dams on the upper Sacramento, the Feather, and Yuba Rivers and a 300-foot dam on the American, three billion kilowatt hours of electric energy could be generated annually prior to the full use of these reservoirs for domestic, irrigation or industrial supply. This is equal to more than one-half of the total electric energy, both hydro-electric and steam, generated in all of California during the past year. Although it would take a number of years for the market to absorb such a large amount of hydro-electric power, further study may demonstrate that certain combination of units might form a progressive program that would have definite flood control values incidental to serving the demands for domestic and industrial supply, irrigation and power. To make these features of the comprehensive plan applicable to current development, requires study of many possible combinations.

WORK IN PROGRESS.

There are still many such studies to be made before a final report upon the comprehensive plan can be submitted. Pursuit to completion will mould the comprehensive plan into a practical form indicating the progressive steps that may serve as a general guide in the development of the state's water for the greatest public economy and to their maximum utility.

Examination in some detail of the practicability of salient features of the comprehensive plan has been undertaken with the funds raised for the preparation of this report. Time has not been sufficient for their completion, at this writing. The work is being continued with unspent funds. The features selected for examination in 1924, largely concern the conversion of the surplus waters of the Sacramento Valley to the purposes of the comprehensive plan. They are the barrier below the mouth of the Sacramento and San Joaquin Rivers, the Kennett reservoir on the upper Sacramento River, the Oroville reservoir on the Feather River, the Narrows reservoir on the Yuba River, and the Folsom reservoir on the American River.

BARRIER BELOW MOUTH OF SACRAMENTO AND SAN JOAQUIN RIVERS.

The barrier is an integral unit of the comprehensive plan for ultimately conserving the waters of the Great Central Valley. Without it, there will always be waste of water at the mouth of the two rivers, together with the attendant incursions of salt water into the lower reaches of the rivers during periods of low flow. In addition to acting as a dam diverting Sacramento River waters into the lower San Joaquin River, it would maintain a large fresh water pond in the bay above it and make practical the reclamation of the marsh lands along its margin, it would furnish unlimited quantities of fresh water to the manufacturing centers arising along the bay shore, together with many minor advantages. By constructing locks of adequate dimensions, the barrier would offer no particular obstruction to navigation. It would of necessity be designed with ample water way to pass the floods of the Sacramento and San Joaquin Rivers without raising flood heights on the lower rivers over those of the past.

The physical possibility of locating and constructing such a dam below the mouth of the Sacramento and San Joaquin Rivers, was investigated in 1921-23 as far as possible without exploration borings at the various possible sites for its location. Exploration borings are now being conducted at the three most promising locations, commonly known as the Army Point and the Dillon Point sites in the vicinity of Carquinez Straits and the San Pablo Point site near Richmond. Wash borings and diamond drill holes have been sunk along the cross-section of the channel at each one of these sites. Test holes are being drilled in the areas topographically suitable for the locks and flood gates. This work is being done in cooperation with the United States Reclamation Service. To date, the explorations show that it is physically possible to construct a barrier at any one of the three locations. The costs have not yet been determined.

Studies of the effect of such a dam on silt deposits in Suisun and San Pablo Bays, and on the flood heights in the lower river region are being conducted by the Division of Engineering and Irrigation, with funds raised for this report. Additional money will be necessary to complete them, however.

RESERVOIR SITES ON SACRAMENTO DRAINAGE AREA.

One-third of all the waters in the state are on the Sacramento drainage area. Therefore, plans for maximum use of the state's waters, of necessity, are associated with the conservation of the waters of this area. The bulk of the waters of the Sacramento drainage basin pass off into the ocean during the flood period of the winter and spring months. On an average, three-fourths of the entire run-off occurs during the months from December to May, inclusive. Immense reservoir capacity will be required to catch this water and hold it over for use during the summer months as well as to equalize, as much as possible, the variable flow from year to year. The 1921-23 investigations developed the fact that there are sufficient reservoir sites to accomplish this.

Some of these sites occupy strategic locations for ultimate economic development. Proof of their practicability is necessary before final conclusions may be drawn concerning the comprehensive plan. The 1924 investigations have undertaken the studies of four reservoir sites of strategic location on the Sacramento drainage area, one at the edge of the valley floor on each of the upper Sacramento, Feather, Yuba and American Rivers.

KENNETT RESERVOIR ON UPPER SACRAMENTO RIVER.

The Sacramento River upstream from the mouth of the Feather River, is the most important of all the streams tributary to the Great Central Valley. Its mean seasonal run-off is 12,400,000 acre-feet, one-half the run-off of the entire Sacramento drainage area and one-third of all the waters of the Great Central Valley. The bulk of the surplus waters of the Sacramento Valley are in this stream. Without large storage reservoirs to equalize the flow, only a small fraction of the mean seasonal run-off can be put to use. Therefore, a major conservation project is contingent upon the feasibility of storing a large part of these waters.

A reconnoissance survey has been run the entire length of the main channel of the Sacramento River in search of possible reservoir sites. Only one such site has been found at low enough elevation to catch a large part of the water and of sufficient potential capacity to equalize its erratic flow. This is the Kennett reservoir with its dam in the Sacramento Canyon five miles downstream from the confluence with the Pit. Two other dam sites were found in the Sacramento Canyon but the cost of storage exceeds that at Kennett and their reservoirs overlap the larger Kennett reservoir. Next in size to the Kennett reservoir, is that in Iron Canyon on the main channel of the Sacramento, fifty miles downstream from the Kennett site. It, however, is limited in capacity by the dam foundations and valuable improvements flooded.

Large storage sites exist on the Pit River and quite a number of smaller ones on the lesser tributaries. These will be useful and necessary in the full development of the Sacramento River, however, the volume of water controlled by them is too small to make possible the use of a big fraction of the entire run-off without a very large reservoir on the main channel.

The Kennett reservoir is the only site lying upstream from the Feather River adequate to control a large fraction of the run-off. The dam site lies on the main channel of the Sacramento five miles below the confluence with the Pit. It backs water up the upper Sacramento, the Pit, the McCloud, Squaw Creek, and numerous small streams and gulches so that, although the reservoir is comparatively narrow, it has large capacity. A four hundred foot dam would back the water for 32 miles up the Sacramento and Pit Rivers.

The reservoir site is traversed by the main line of the Southern Pacific Railroad and a branch line running up the Pit River to Copper City. A four hundred foot dam would flood twenty miles of the main Southern Pacific line and require the relocation of at least 35 miles of track. Fourteen and one-half miles of the branch line along the Pit River would also be submerged. Nine miles of the State Highway would also have to be reconstructed. Besides, the towns of Kennett, Antler, Copper City and Pollock would be submerged, along with two smelters, one mine, the State Fish Hatchery on the McCloud River, and other minor improvements. The flooding of all these makes a very heavy charge in the estimate of cost of the Kennett reservoir. Consequently, the unit cost of storage for low dam heights is high, but the physiography is so favorable for a large reservoir, that even including the cost of flooding improvements, the unit storage cost for high dams is moderate.

Surveys of the part of the Kennett reservoir lying in the Sacramento Canyon were made up to the 400-foot level during the investigations of 1921–23 while searching for possible reservoir sites. The field survey of the entire reservoir was completed in the fall of 1924. The capacity for several dam heights is as follows:

Capacity of Kennett Reservoir On Sacramento River.

Height of dam 5 feet freeboard	*Area of water surface in acres*	*Capacity of reservoir in acre-feet*
100 feet	900	30,000
125 feet	1,400	58,000
150 feet	2,100	102,000
175 feet	3,000	165,000
200 feet	4,200	257,000
225 feet	5,800	381,000
250 feet	7,200	543,000
275 feet	8,700	740,000
300 feet	10,500	983,000
325 feet	12,800	1,270,000
350 feet	15,100	1,620,000
375 feet	17,700	2,030,000
400 feet	20,500	2,510,000
425 feet	23,700	3,057,000
450 feet	27,200	3,700,000
475 feet	30,900	4,422,000
500 feet	34,700	5,242,000
525 feet	38,600	6,160,000
550 feet	42,500	7,171,000
575 feet	46,500	8,280,000
600 feet	50,800	9,501,000

Because of the importance of the Kennett reservoir to any scheme for developing the surplus waters of the Sacramento drainage basin, a geologic examination with diamond drill explorations has been undertaken. Professor George D. Louderback, of the University of California, has been engaged to report upon the dam foundations. To date, the explorations have been completed on the westerly bank of the stream. They are now in progress on the easterly bank. A preliminary report of the geologist indicates that the formation is very massive and appears favorable for a high dam.

Preliminary cost estimates have been prepared as follows:

Preliminary Cost Estimate Of Kennett Reservoir.

Height of dam 5 feet freeboard	*Total cost*	*Capacity in acre-feet*	*Cost per acre-foot of capacity*
250 feet	$21,400,000	543,000	$39 00
300 feet	26,400,000	983,000	27 00
350 feet	34,000,000	1,620,000	21 00
400 feet	44,100,000	2,510,000	18 00

A dam 400 feet high at Kennett will yield an irrigation supply for 700,000 acres of land after passing sufficient water to satisfy the claims of rights now vested on the Sacramento River. The delivery of this into the river channel at the rates required for irrigation would augment the flow during August by 6000 second-feet even in years of small run-off like 1920 and 1924. A dam 320 feet high would afford sufficient capacity, if operated for flood control, to cut the maximum flood flows in two. on the Sacramento above the mouth of the Feather River. If this were done it would make possible the reclamation of 100,000 acres of land in Butte Basin at a cost for levees and rights of way, but without a reservoir charge, of about $30 per acre. This basin lies on the easterly bank of the Sacramento River westerly and northwesterly from the Marysville Buttes. It is subject to overflow from the Sacramento River. The cost of constructing levees to reclaim against the maximum flood without reservoir control, would be very much greater than $30 per acre.

OROVILLE RESERVOIR SITE.

The Feather River is the second most important stream of the Sacramento system. It has a mean seasonal run-off of 5,280,000 acre-feet. The canyon of the Feather River has a much steeper grade than that of the main channel of the Sacramento and is consequently less favorable for reservoir sites. Reconnoissance during the fall of 1924 located two dam sites on the main channel below the confluence of the four branches and a short distance upstream from Oroville.

A survey of the reservoir capacities yield the following:

Capacity Of Oroville Reservoir.

	Upper dam site		*Lower dam site*	
Height of dam 5 feet freeboard	*Area of water surface acres*	*Capacity of reservoir acre-feet*	*Area of water surface acres*	*Capacity of reservoir acre-feet*
100	300	12,000	300	12,000
125	500	21,000	500	22,000
150	700	36,000	800	39,000
175	900	54,000	1,200	64,000
200	1,100	78,000	1,500	97,000
225	1,400	109,000	2,000	140,000
250	1,700	146,000	2,400	195,000
275	2,000	194,000	3,000	264,000
300	2,400	248,000	3,500	345,000
325	2,800	314,000	4,100	440,000
350	3,300	390,000	4,700	549,000
375	3,800	480,000	5,300	676,000
400	4,400	582,000		
425	5,000	699,000		
450	5,700	832,000		
475	6,300	982,000		

The Oroville dam sites have not been drilled. The office studies are only partly completed. Preliminary estimate of cost on the one dam investigated to date, a 400-foot dam at the upper site, is $75 per acre-foot of capacity. This includes the cost of relocating 27.3 miles of main line track of the Western Pacific Railroad as its enters the Feather River Canyon, 2.3 miles or broad gage track of the Hutchinson Lumber Company, and 8.5 miles of the narrow gage road of the Swayne Lumber Company, and other improvements. Four miles of the Oroville-Quincy county road would be flooded requiring relocation of 6.4 miles of road. The town of Bidwell Bar would be submerged, as would also 8 miles of canal of the Oroville Wyandotte Irrigation District. The Las Plumas plant of the Great Western Power Company, a 65,000 K. V. A. installation, would have to be rebuilt at an elevation 160 feet higher than its present location with consequent loss of power. The estimated cost of flooding all these improvements totals 40 per cent of the cost of the reservoir.

It may be that a dam of lower height, that will not require the reconstruction of the Las Plumas power plant, or one located at the lower dam site, will have a smaller cost than $75 per acre-foot of capacity.

There are no agricultural lands of any extent on the reservoir site. The surface is mostly steep and rocky and in use for grazing.

NARROWS RESERVOIR SITE.

The Yuba River is the fourth most important tributary of the Sacramento system. Its mean seasonal run-off is 2,650,000 acre-feet. The only dam site below the junction of the forks is at the Narrows, near the town of Smartsville.

Information on the dam site was obtained from borings made by the California Debris Commission and the Yuba River Power Company. A survey of the reservoir has not been made. Preliminary estimates of cost have been made as follows:

Preliminary Cost Estimate Of Narrows Reservoir On Yuba River.

Height of dam 5 feet freeboard	*Total cost of reservoir*	*Capacity in acre-feet*	*Cost per acre-foot of capacity*
350	$16,750,000	247,000	$68.00
400	20,500,000	353,000	58.00

The lands flooded in this reservoir site are of little value and the only improvement of importance is the Colgate power plant of the Pacific Gas and Electric Company, a 15,575 k.v.a. installation. This plant would have to be rebuilt at a higher elevation with a consequent loss of power.

FOLSOM RESERVOIR SITE ON AMERICAN RIVER.

The third largest stream of the Sacramento system is the American River. It has a mean seasonal run-off of 3,180,000 acre-feet. The canyon of this stream rising from the valley floor is steep and narrow. A dam site was found below the confluence of the North, Middle and South Forks. It is a short distance upstream from Folsom. The topography limits a dam to 300 feet in height. The crest length is long for this height and there are four auxiliary dams. The water backs up both the North and South Forks of the American River. Surveys of 1924 determined the capacity as follows:

Folsom Reservoir On American River.

Height of dam 5 feet freeboard	*Area of water surface acres*	*Capacity of reservoir acre-feet*
100	1,200	51,000
125	1,800	89,000
150	2,800	147,000
175	4,200	234,000
200	6,500	366,000
225	8,400	552,000
250	10,000	782,000
275	11,600	1,053,000
300	13,100	1,361,000

The Folsom reservoir would submerge 19 miles of the main canal of the North Fork Ditch Company and 14 miles of that of the Natomas Company. About one-third of the lands are under cultivation, the rest is used for grazing purposes. A preliminary estimate of the cost of this reservoir has been made for three heights of dam although the dam site has not been explored by the diamond drill.

Preliminary Estimate Of Cost Of Folsom Reservoir On American River.

Height of dam 5 feet freeboard	*Total cost of reservoir*	*Capacity of reservoir in acre-feet*	*Cost per acre-foot of storage capacity*
200	$11,662,000	366,000	$32.00
250	21,865,000	782,000	28.00
300	47,376,000	1,361,000	35.00

The Folsom reservoir is in a position to have considerable flood control value. The maximum flood flow on the American River, estimated by the California Debris Commission, is 120,000 cubic feet per second. This may be much reduced by a large reservoir at the Folsom site. A reduction in the maximum flood flow would lessen the cost of reclaiming 12,000 acres of overflow lands along the American River, would decrease the flood hazard in the city of Sacramento and would permit the construction of the levee along the northerly bank of the American River close to the present channel. This would bring North Sacramento much closer to the city of Sacramento on the south bank and so eliminate awkward traffic crossings on the area between the river channel and the present northerly levee that is set back from the river to afford sufficient room in the river channel to pass the maximum floods. The present separation hinders the expansion of Sacramento in a northerly direction.

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