UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

STORAGE OF WATER

ON

KINGS RIVER, CALIFORNIA

BY

JOSEPH BARLOW LIPPINCOTT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Division of Hydrography,
Washington, D. C., June 29, 1901.

Sir: I have the honor to transmit herewith a manuscript prepared by Mr. J. B. Lippincott, giving the results of surveys and investigations for water storage and power development on Kings River, California. This investigation was begun as part of the general plan for ascertaining the water resources of the country and the extent to which the Arid Lands could be redeemed by irrigation.

In order to assist this work and make it more complete the California Water and Forest Association, organized to promote the irrigation developments of the State, placed at the disposal of the Geological Survey the sum of $1,000, which had been raised by private subscription. In addition to this a local organization known as the Kings River Storage Association, cooperating with the other body, increased the amount by $1,500, to be used for field expenses.

In this work the drainage basin of Kings River has been explored and preliminary surveys and estimates prepared sufficient to justify the statements that works can or can not be economically constructed at certain localities. It is not the object of this investigation to make finished working plans or final surveys upon which specifications or contracts could be made, that detail being left to those who may have in charge the actual construction of the works. It is believed, however, that the estimates are sufficiently broad and conservative to enable general conclusions to be drawn. It is understood that the officers of this Survey have no concern with the question whether such works are to be built by private capital or by public funds, their object being to ascertain the important physical features.

The situation on Kings River is to a certain extent typical of that along a number of important streams of the West, and as a result of this investigation it is believed that the reclaimable area can be greatly extended by the construction of storage works and also of power plants by means of which, through electrical transmission, pumps can be operated at small expense out on the broad valleys. The demonstration of these conditions will prove one of the most important steps toward the transformation and utilization of the fertile but arid lands.

Very respectfully,

F. H. Newell,
Hydrographer in Charge.

Hon. Charles D. Walcott,
Director United States Geological Survey.

MAP OF DRAINAGE BASIN OF KINGS RIVER, CALIFORNI

…HOWING ROUTE TRAVERSED BY EXPLORING PARTIES

15 20 25 MILES

JULIUS BIEN & CO. LITH. N.Y.

STORAGE OF WATER ON KINGS RIVER, CALIFORNIA.

By Joseph Barlow Lippincott.

LOCATION AND PHYSICAL FEATURES.

Kings River rises on the western slope of the Sierra Nevada, in Fresno County, Cal., draining the crest from Mount Whitney on the south to Mount Goddard on the north. Mount Whitney, with an elevation of 14,898 feet, is the highest mountain in the United States. The divide to the north culminates in numerous peaks, which reach elevations greater than 14,000 feet. This crest probably displays the most rugged and the grandest scenery in our country. Above the 10,000-foot contour the drainage basin of the river is largely bare granite, supporting a scanty vegetation and carved by the action of glaciers. This is clearly shown in Pl II, *A*, and in Pl. III. Between the 10,000- and the 1,000-foot contours the mountains are covered with underbrush and large timber, the most extensive forest of *Sequoia washingtoniana* growing here. (See Pl. IV, *A*, a view southeast of Millwood, at an elevation of 6,000 feet.) The distance from the crest of the mountains to the mouth of the canyon of the river, on a direct line, is approximately 50 miles. Fully 80 per cent of the drainage basin is now included within the boundaries of the Sierra Forest Reserve, which is patrolled for the prevention of fires and illegal herding. The Government will grant no more private holdings within the reserve except for mining or the development of the water resources. This is of prime importance to the irrigated lands below, for it means the conservation of the stream, and the action has been taken none too soon, for great destruction of the forests has already been occasioned by fires and lumbermen. The largest grove of big trees in the State is now being sawed up at Millwood. Pl. IV, *B*, is a view in the Converse Basin, and shows the wasteful, destructive lumbering that has been carried on there.

The river debouches from its mountain drainage basin upon the plains of Fresno, Kings, and Tulare counties. These lands are sometimes referred to as the Kings River delta. They are near the geographic center of the State. Fresno and Hanford are the principal towns. They are about 200 miles distant from San Francisco and Los

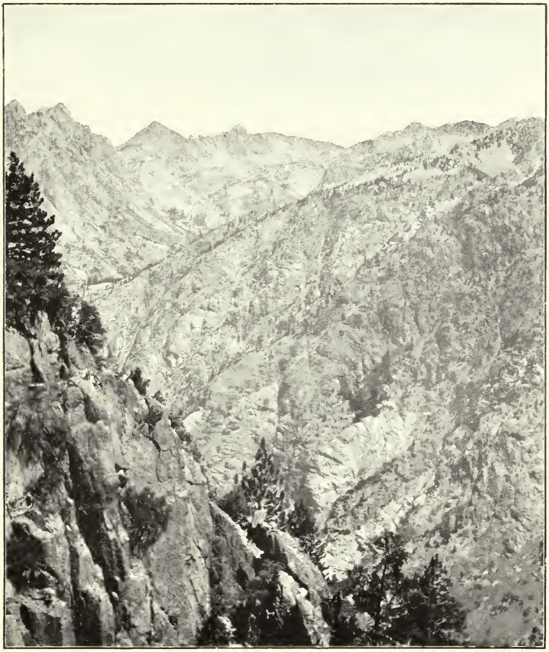
Angeles. The counties referred to present a variety of climatic conditions and soils. The altitudes vary from 250 to 14,000 feet. The Coast Range on the west consists of rolling hills, and the country between those mountains and the Sierra Nevada, to the east, is a valley comprising river bottoms and uplands. The Sierra Nevada is divided into three regions—the foothill region, the timber or forest region, and the region of snow and ice. It will readily be understood that with so varied a topography a variety of climatic conditions would necessarily exist. The yearly seasons in San Joaquin Valley are two—a dry season and a wet season. The former usually begins about May 1 and lasts until about the middle of October or the first of November, when the rainy season begins. The average rainfall is 8.79 inches annually at Fresno. There are about 275 days of sunshine in the year. The rains in the winter seldom last more than two or three days at a time. With the exception of very rainy days there is no time during the year that men and teams can not work out of doors. The mean average winter temperature is about 60°; the average summer temperature is 80°. The atmosphere during the summer months is dry, and the heat is not nearly so oppressive as in localities where the atmosphere is damp. The health reports show that Fresno has the lowest death rate of any city in the State. The mountain regions of the eastern portion of the district are always cool. They can be reached in about eight or ten hours' drive from Fresno.

There are probably few equal areas of country where a greater variety of valuable commodities are produced than here. Lumber, gold, copper, petroleum, grain, oranges, lemons, many varieties of deciduous fruits, grapes, raisins, wines, and brandies are produced in commercial quantities. There are more than 500,000 deciduous fru[it] trees in Fresno County, and the number is being increased each se[a]son. There are about 40,000 acres of vineyards producing raisin a[nd] wine grapes.[a]

Irrigation is necessary for the production of all varieties of agric[ul]tural products, with the possible exception of grains. There a[re] about 625 miles of main irrigation canals, covering 380,000 acres [of] land on the Kings River delta. It is believed that a good water rig[ht] on valley lands will add $50 per acre to their value and $90 per a[cre] to the value of the so-called frostless foothill lands. The duty [of] water may be taken at 2 acre-feet, or 24 inches in depth, each ye[ar]. Thus an acre-foot of water is worth from $25 to $45 delivered [to] the land.

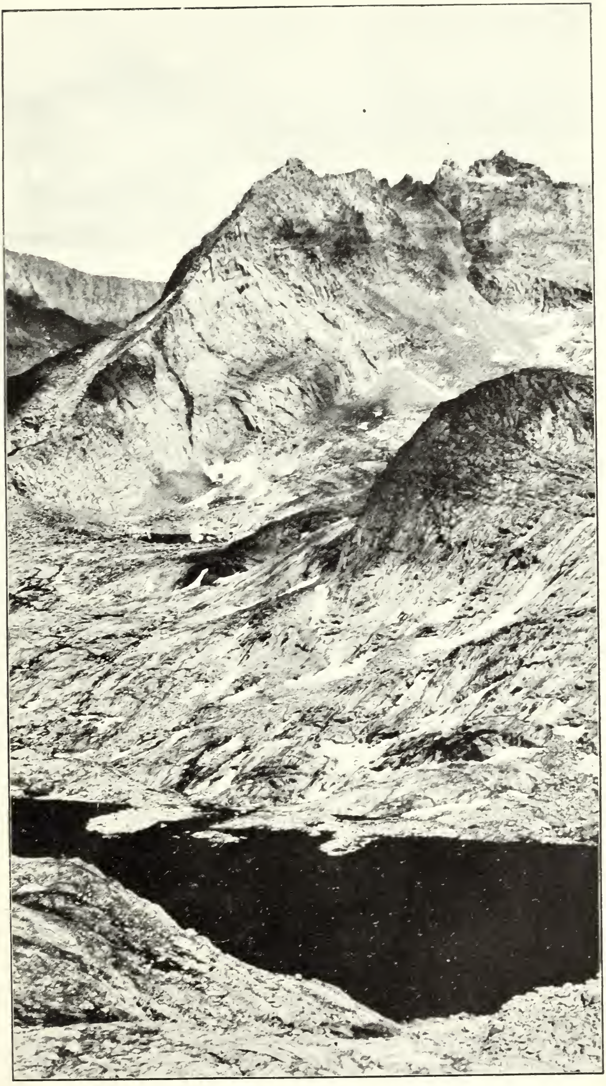
As Kings River leaves its canyon, about 12 miles east of Sange[r], [in] Fresno County, it is immediately diverted by a series of canals, sh[own] on the map of the valley lands (Pl. V). The areas irrigated from [the] river, extending from Fresno on the north to Hanford on the so[uth]

[a] In the fall of 1901 1,400 carloads of oranges were shipped from the district between [...] and Porterville, and this industry is only in its infancy.



A. GENERAL VIEW OF UPPER DRAINAGE BASIN OF KINGS RIVER.

B. HEADWORKS OF FRESNO CANAL AND IRRIGATION COMPANY'S SYSTEM.



CREST OF SIERRA NEVADA ABOVE TIMBER LINE, KINGS RIVER BASIN.

are the most extensive that are watered from any one stream in the State. The canal companies which associated themselves in the Kings River Storage Association decided to contribute for the investigation amounts proportional to the areas of land served. For this purpose each company filed with the association statements of the areas irrigated. These figures, which are given below, possibly represent the areas that are irrigated in good years during the period of spring flood of the river, and in some cases may be in excess of the land actually watered. These canals all have headworks of a rather temporary nature, consisting of rock-filled cribs or brush and rock dams, as shown in Pl. II, *B*.

Lands served by canal companies diverting water from Kings River.

	Acres.
Fresno canal, whole system	160,000
Laguna canal	25,000
Alta Irrigation Company's canal	50,000
Peoples' canal	25,000
Last Chance canal	25,000
Centerville and Kingsburg canal	20,000
Murphy Slough Association	20,000
Lower Kings River	15,000
Fowler Switch canal	12,000
Stinson canal	12,000
Crescent canal	12,000
Emigrants' canal	3,000
Liberty canal	750
Total	379,750

During the May and June flood period there is usually water for the full capacity of all of the diverting canals, estimated at 4,000 second-feet, but the available supply diminishes rapidly after the middle of June, as prior rights take precedence in the diversion. The area watered is on the eastern side of the middle portion of San Joaquin Valley. The lands have a gentle westerly slope from the foothills to the thalweg of the valley. The area irrigable from the river is far in excess of the available water supply. The distance from the foothills to the central drainage lines of the valley is about 0 miles.

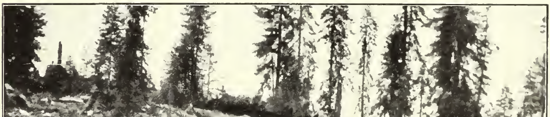
This is the great raisin district of California. As already stated, many varieties of deciduous fruits are also successfully grown, and along the foothills it has been demonstrated that semitropical fruits can be matured with success where water is available for continuous irrigation. Porterville, about 50 miles to the south, is one of the most successful orange and lemon districts in the State, and it has been shown, by many scattered orchards, that these fruits can profitably be grown to the east of Sanger. Along the foothills of San Joaquin Valley marked increase in winter temperature occurs within a rise of a few hundred feet. The citrus belt, as is the case in southern California, is a narrow strip of land at the base of the mountains.

The first irrigators on Kings River naturally diverted the water to the lower flat lands, where canals could be more cheaply constructed. In that way the water rights of the river have been applied to those lands, which are relatively low in elevation and upon which the citrus fruits, the most valuable crop, can not be raised. An increase in the water supply will therefore permit the application of a portion of this water to the valuable foothill lands. The deciduous fruits, which are gathered largely during the month of July, do not require extensive late summer irrigation. The reverse is true of citrus fruits, which do not ripen until November or December and which require irrigation throughout the summer. In a similar way alfalfa, the staple forage crop of the State, must be irrigated throughout the summer season. In this portion of California lands which are sown to grain are capable of producing two crops in case a water supply is available for late summer irrigation. An increase in the water supply will therefore permit improved irrigation for areas now served, as well as an extension of the irrigated area.

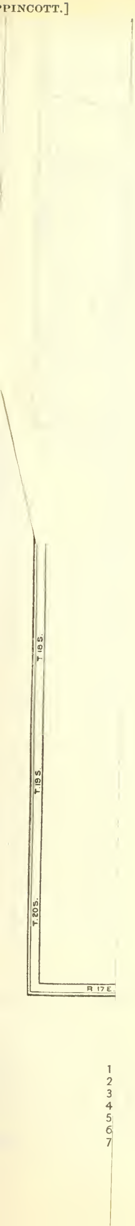
The combined capacity of the canals leading out of Kings River is stated to be approximately 4,000 cubic feet per second. In September, 1898, the low-water summer supply of the river fell as low as 145 cubic feet per second. Possibly the canals during spring floods can divert more than 4,000 second-feet of water, but not more than 4,000 second-feet if applied beneficially. It is therefore evident that the late summer supply is wholly inadequate for the demands of the water companies. (This is clearly shown in the discharge diagrams, Pls. VII and VIII.) The division of this late water has resulted in much litigation, and it is estimated that the canal companies have expended annually about $40,000 in legal controversies over it. This represents 4 per cent interest on $1,000,000, and results in much bad feeling and in no increase in the supply. During the spring and early summer there is an excessive water supply for all companies, and much water is unused. Little if any water is diverted during the midwinter season. If summer water could be supplied with certainty it is believed that midwinter irrigation would be practically abandoned. The water power development considered in this report is on the Middle Fork of Kings River, above all diversions for irrigation and above the contemplated diversion of storage water to Clarks Valley, so that neither one would interfere with the proposed power plant.

During the last season (1900) the profits from the irrigated district around Fresno have exceeded, it is estimated, $2,000,000. This illustrates what could be accomplished by extending the irrigation system throughout the central valley of California. Land favorably situated and with a good water right sells for about $60 an acre when unimproved, and when in vineyard or orchard it will earn very good return

A. FOREST COVER IN SIERRA NEVADA AT ALTITUDE OF 6,000 FEET.



B. DESTRUCTIVE LUMBERING IN SIERRA NEVADA.


T.18 S.
T.19 S.
T.20 S.
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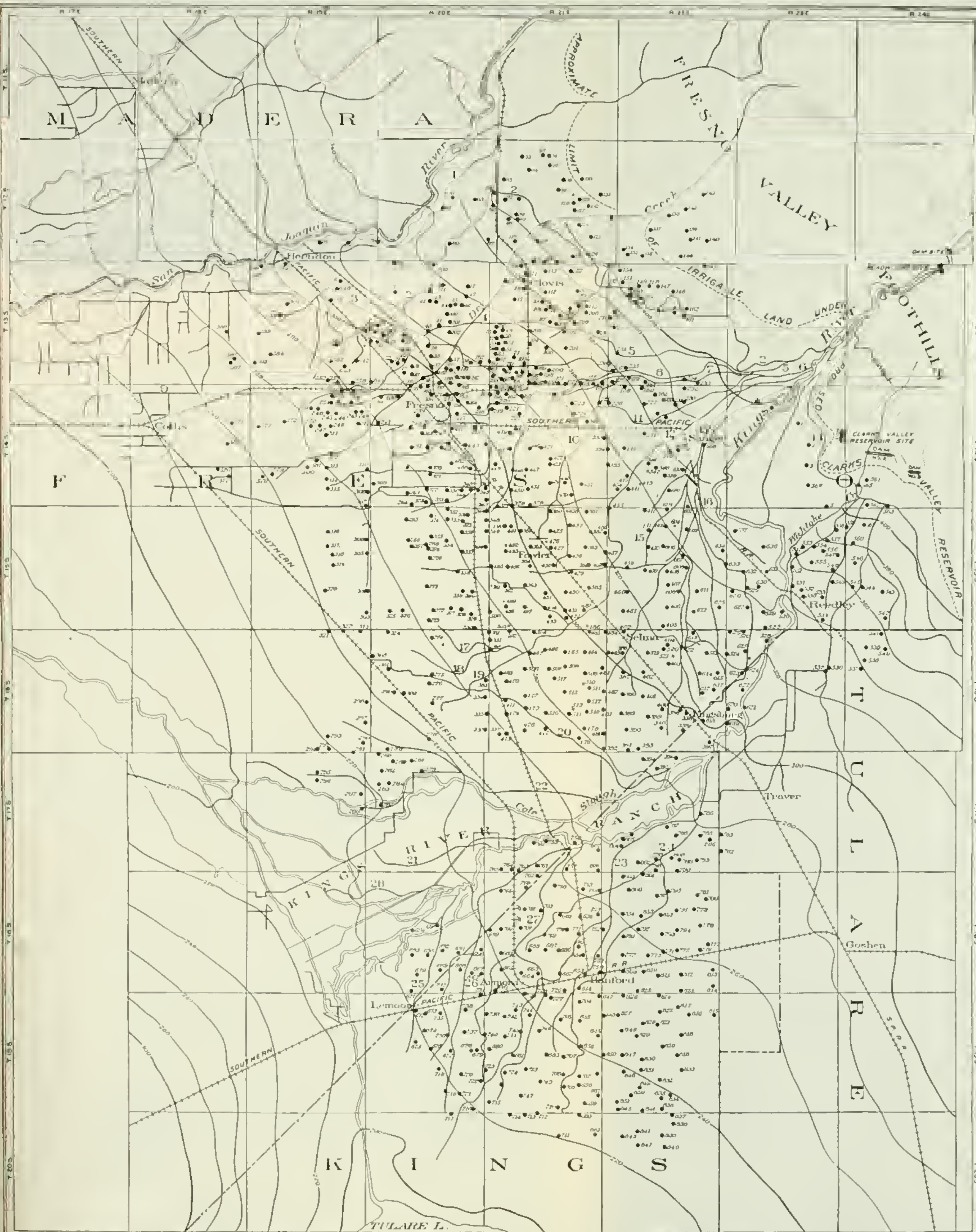


MAP OF KINGS RIVER DELTA, SHOWING DISTRIBUTION CANALS AND LOCATION OF WELLS.

Numbers of wells correspond with the numbers in the table on pages 56 to 79. The following is a list of the canals.

1. Upper San Joaquin canal.
2. Enterprise canal.
3. Herndon canal.
4. Stitt ditch.
5. Gould canal.
6. Fresno canal.
7. Roeding ditch.
8. Diversion canal.
9. Houghton canal.
10. Briggs ditch.
11. Hansen ditch.
12. Fowler Switch canal.
13. Lone Tree canal.
14. '76 canal.
15. McCall ditch.
16. Highland ditch.
17. Harland ditch.
18. Caruthers ditch.
19. Elkhorn ditch.
20. Emigrants' canal.
21. Jaines canal.
22. Liberty canal.
23. Mussel Slough Association canal.
24. People's canal.
25. Rhodes canal.
26. Lower Kings River canal.
27. Last Chance canal.
28. Zalda canal.

on that value. The same class of land without an irrigation supply sells for about $10 an acre. The water supply therefore represents a value of $50 an acre. The water has usually been sold with the land. Under the Fresno canal a continuous flow of 1 second-foot originally sold for $1,600 and was made to apply to 160 acres of land, or at the rate of $10 an acre. An additional charge of 62 cents per acre per year is also made for conveyance of water and repairs. Water rights for 160,000 acres of land have been sold by this canal. In the Alta irrigation district the first cost of water was $5 an acre, with an annual charge of 40 cents per acre for cost of operating. There are 130,000 acres under this system. The rights of the Alta district to the river water are subsequent to those of the Fresno canal. A detailed description of these canals and their rights is contained in Water-Supply and Irrigation Paper No. 18, entitled Irrigation near Fresno, by C. E. Grunsky. The lands of the Kings River delta are described by Mr. Grunsky as follows:

Near Centerville the soil of the upland is a red sandy loam, resting on a yellow clay hardpan, which is usually at 4 to 6 feet below the surface. Hardpan is not continuous; it disappears frequently at about one-half mile from the margin of the upland, where the surface soil becomes lighter and more sandy. At depths of 10 feet or more beds of cobble and gravel are found, which in proximity to the low river bottoms afford thorough underdrainage to these lands. The soil is very productive. Ground water is at 12 to 15 feet below the surface.

Westward from Centerville toward Fresno the soil of the plains is a loamy sand. This generally rests on a firm clay hardpan, which is sometimes impregnated with sand. Soil is from 1 to 3 feet deep. At the sinks of the several creeks near Fresno the soil is a deep, heavy, red loam, baking on the surface after being wet. Where a hardpan substratum is encountered at all it is at 10 to 30 feet below the surface. Westward from the immediate vicinity of the sinks of the creeks the soil is a loamy sand, several feet deep, resting on a firm clay hardpan. The soil far toward the southwest merges into the sandy soils of the alkali belt which skirts the edge of Fresno Swamp, and these in turn are succeeded by the rich peaty alluvium of the swamp lands. To the south of Fresno the sandy soil of Fresno and central California colonies changes to the light so-called ash of Washington colony. The hardpan dips farther below the surface toward the south, and there are points in the latter colony where it has disappeared altogether. In the southern and southeastern portion of the region commanded by this canal system sand predominates. The surface of the country is comparatively smooth, though occasionally crossed by low sand ridges. Firm hardpan partaking of the nature of cemented sand, immediately below the surface soil is rarely found. It occurs most frequently where the surface presents the peculiar hog-wallow appearance.

PRECIPITATION.

The precipitation on the plains between Fresno and Hanford varies from 6 inches in the central portion of the valley to 9 inches at Fresno and 16 inches at Centerville. The only crop raised without irrigation is grain, and this fails except when the rains are opportune. The precipitation in the drainage basin ranges from 9 inches in San Joaquin Valley, at Fresno, to fully 50 inches on the crest, where it is largely in the form of snow, which lies in great depths on the high divide until melted by the summer's heat. The accompanying tables give the annual precipitation at Fresno from 1877 to 1900, both inclusive, and at Sacramento from 1849 to 1900, both inclusive.

Annual precipitation, in inches.

FRESNO, CAL.

[Latitude, 36° 43′; longitude, 119° 49′; elevation, 293 feet; observer, Pacific Railway System.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total
1877-78	0.00	0.00	0.88	0.42	3.20	1.76	1.91	0.78	T.	0.00	0.00	0.00	8.9[illegible]
1878-79	0.00	.20	.56	.22	1.28	.56	.66	1.33	0.06	0.00	0.00	0.00	4.8[illegible]
1879-80	0.00	.55	.48	1.67	.46	2.14	.61	1.97	.15	0.00	0.00	0.00	8.4[illegible]
1880-81	0.00	0.00	.44	3.05	2.21	.87	.55	1.00	.10	0.00	T.	T.	8.2[illegible]
1881-82	.46	.36	.27	.16	.42	1.04	1.26	1.23	.10	0.00	0.00	0.00	5.3[illegible]
1882-83	.34	.05	.73	.70	0.00	.57	2.46	.95	1.36	0.00	0.00	0.00	7.1[illegible]
1883-84	0.00	2.00	T.	.34	2.29	3.18	2.81	2.85	1.11	1.29	0.00	0.00	15.8[illegible]
1884-85	0.00	.35	.08	3.98	.45	0.00	.53	1.11	.15	0.00	0.00	0.00	6.6[illegible]
1885-86	0.00	.06	7.92	1.90	2.38	.58	1.21	2.57	0.00	0.00	0.00	0.00	16.6[illegible]
1886-87	0.00	.47	.70	.34	.31	2.80	.09	2.65	.03	.02	0.00	0.00	7.41
1887-88	.49	.15	.32	1.16	1.75	.13	1.95	.22	.56	T.	T.	T.	6.7[illegible]
1888-89	.06	0.00	2.38	1.71	.34	.32	2.07	.54	.57	0.00	0.00	T.	7.9[illegible]
1889-90	0.00	3.17	1.39	3.87	2.12	.80	1.04	.17	.45	0.00	0.00	T.	13.01
1890-91	1.26	0.00	.22	2.30	.79	2.03	.81	.55	.03	.02	0.00	0.00	8.01
1891-92	.39	0.00	.21	3.08	.37	.68	1.31	.22	1.30	0.00	0.00	0.00	7.5[illegible]
1892-93	0.00	.31	.52	2.02	.74	1.75	3.09	.27	0.00	0.00	0.00	0.00	8.7[illegible]
1893-94	0.00	T.	.13	.99	1.73	2.95	.25	.10	1.30	1.08	0.00	0.00	8.5[illegible]
1894-95	......	.75	.18	3.67	1.60	1.32	1.95	.78	.62	0.00	0.00	0.00	10.87
1895-96	.05	0.00	.34	.32	2.89	.06	1.21	2.82	.02	0.00	.07	.15	7.9[illegible]
1896-97	.06	1.28	1.46	1.00	1.93	2.65	1.64	.30	0.00	T.	0.00	T.	10.3[illegible]
1897-98	T.	1.19	.22	.48	.42	1.14	.71	0.00	.79	0.00	0.00	0.00	4.95
1898-99	1.12	.03	.34	.43	1.92	.02	2.90	.36	.06	.66	0.00	0.00	7.84
1899-1900	0.00	2.01	1.51	1.09	1.52	.08	.88	1.21	1.97	T.	T.	0.00	10.27

SACRAMENTO, CAL.

[Elevation, 71 feet; observers, Dr. Thomas M. Logan, Central Pacific Railroad Company, and United States Signal Service.]

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Total.
1849-50	0.25	1.50	2.25	12.50	4.50	0.50	10.00	4.25	0.25	0.00	0.00	0.00	36.00
1850-51	0.00	0.00	T.	T.	.65	.35	1.88	1.14	.69	0.00	0.00	0.00	4.71
1851-52	1.00	.18	2.14	7.07	.58	.12	6.40	.19	.30	0.00	0.00	0.00	17.98
1852-53	T.	0.00	6.00	13.41	3.00	2.00	7.00	3.50	1.45	T.	T.	0.00	36.36
1853-54	T.	T.	1.50	1.54	3.25	8.50	3.25	1.50	.21	.31	0.00	T.	20.06
1854-55	T.	1.01	.65	1.15	2.67	3.46	4.20	4.32	1.15	.01	0.00	0.00	18.62
1855-56	T.	0.00	.75	2.00	4.92	.69	1.40	2.13	1.84	.03	0.00	0.00	13.76
1856-57	T.	.20	.65	2.40	1.38	4.80	.68	T.	T.	.35	.01	T.	10.47
1857-58	0.00	.66	2.41	2.63	2.44	2.46	2.88	1.21	.20	.10	0.00	T.	14.99
1858-59	T.	3.01	.15	4.34	.96	3.91	1.64	.98	1.04	0.00	.03	0.00	16.06
1859-60	.03	0.00	6.49	1.83	2.31	.93	5.11	2.87	2.49	.02	.55	0.00	22.63
1860-61	.06	.91	.18	4.28	2.67	2.92	3.32	.48	.59	.14	0.00	0.00	15.55
1861-62	0.00	T.	2.17	8.64	15.04	4.26	2.80	.82	1.81	.01	0.00	.01	35.56
1862-63	0.00	.36	.01	2.33	1.73	2.75	2.36	1.69	.36	0.00	T.	T.	11.59
1863-64	T.	0.00	1.49	1.82	1.08	.19	1.30	1.08	.74	.09	0.00	.08	7.87
1864-65	T.	.12	6.72	7.87	4.78	.71	.48	1.37	.46	0.00	T.	0.00	22.51
1865-66	.01	.48	2.43	.36	7.70	2.01	2.02	.48	2.25	.10	.02	0.00	17.86
1866-67	T.	T.	2.43	9.51	3.44	7.10	1.01	1.80	.01	0.00	0.00	0.00	25.30
1867-68	.01	0.00	3.81	12.85	6.04	3.15	4.35	2.31	.27	T.	0.00	0.00	32.78
1868-69	0.00	0.00	.77	2.61	4.79	3.63	2.94	1.24	.65	.01	0.00	0.00	16.64
1869-70	T.	2.12	.85	1.96	1.37	3.24	1.64	2.12	.27	T.	T.	T.	13.57
1870-71	0.00	.02	.58	.97	2.08	1.92	.69	1.45	.76	T.	0.00	0.00	8.47
1871-72	T.	.21	1.22	10.59	4.04	4.74	1.94	.61	.28	.02	0.00	0.00	23.65
1872-73	T.	.22	1.93	5.39	1.23	4.36	.55	.51	0.00	T.	.02	T.	14.21
1873-74	0.00	.31	1.87	10.12	5.30	1.86	3.05	.89	.37	0.00	0.00	0.00	23.77
1874-75	.05	2.26	3.80	.44	8.81	.03	1.26	0.00	.04	1.06	0.00	0.00	17.75
1875-76	0.00	.04	6.20	5.52	4.99	3.75	4.15	1.10	.15	0.00	.21	.02	26.13
1876-77	0.00	3.45	.30	0.00	2.77	1.04	.56	.19	.64	0.00	0.00	0.00	8.95
1877-78	0.00	.73	1.07	1.43	9.26	8.04	3.09	1.07	.17	0.00	0.00	0.00	24.86
1878-79	.29	.55	.51	.47	3.18	3.88	4.88	2.66	1.30	.13	T.	T.	17.85
1879-80	0.00	.88	2.05	3.41	1.64	1.83	1.70	14.20	.76	0.00	T.	T.	26.47
1880-81	0.00	0.00	.05	11.81	6.14	5.06	1.37	1.64	T.	.50	T.	T.	26.57
1881-82	.30	.55	1.88	3.27	1.89	2.40	3.78	1.99	.35	.10	T.	T.	[illegible]
1882-83	.57	2.63	3.22	1.13	2.23	1.11	3.70	.67	2.85	0.00	0.00	0.00	[illegible]
1883-84	.90	.97	.61	.44	3.43	4.46	8.14	4.32	1.16	1.45	0.00	0.00	[illegible]
1884-85	.60	2.01	0.00	10.45	2.16	.49	.08	.68	T.	.11	T.	0.00	16.58
1885-86	.08	.02	11.34	5.76	7.95	.29	2.68	4.08	.07	0.00	0.00	0.00	32.27
1886-87	0.00	.68	.21	2.21	1.12	6.28	.94	2.53	T.	0.00	0.00	T.	13.97
1887-88	.02	0.00	.45	2.09	4.81	.57	3.04	.10	.40	.08	T.	T.	11.56

A. RED MOUNTAIN GAGING STATION ON KINGS RIVER.

B. FALLS IN CREEK ABOVE EAST LAKE.

Annual precipitation in inches—Continued.

SACRAMENTO, CAL.—Continued.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1888-89	0.55	0.00	4.28	4.63	0.15	0.33	6.25	0.26	3.25	0.25	0.00	0.00	19.95
1889-90	0.00	6.02	3.15	7.82	6.62	4.06	3.00	1.33	1.80	0.00	0.00	T.	33.80
1890-91	.80	T.	0.00	3.34	.53	6.61	1.78	2.04	.66	.05	T.	0 00	15.81
1891-92	.10	.10	.48	3.28	1.78	2.84	3.02	1.20	2.38	T.	0.00	0.00	15.18
1892-93	.18	.70	6.60	4.90	3.27	2.66	3.51	1.08	1.05	0.00	T.	0.00	23.95
1893-94	.22	.12	2.92	1.76	4.17	3.92	.74	.34	1.70	.46	T.	T.	16.35
1894-95	.88	1.06	.48	8.86	8.42	1.84	1.20	.86	.51	0.00	.04	T.	24.15
1895-96	1.26	.17	1.54	1.54	9.76	.09	2.57	5.34	.92	0.00	T.	.20	23.39
1896-97	.31	.55	3.56	1.76	3.66	4.15	2.54	.25	.30	.04	0.00	0.00	17.12
1897-98	.16	1.96	.61	1.64	.98	3.19	.04	.28	1.50	.14	0.00	0.00	10.50
1898-99	.36	.64	.61	2.30	3.94	.04	6.02	.10	.54	.49	0.00	.02	15.06
1899-1900	0.00	4.46	2.62	2.91	3.54	.32	1.61	1.88	2.88	T.	T.	0.00	20.22

T indicates trace.

No rainfall records of extended duration have been maintained in the higher portion of the drainage basin. A few miles to the north, on the same slope, at Summerdale, the record from 1896 to 1899 shows an average of 47.86 inches. At Sequoia, on the same range and slope, 50 miles to the north, the average for three years, from 1897 to 1900, was 46.90 inches, the elevation being 4,452 feet. At Second Garrotte, about 60 miles to the northwest, on the same slope of the Sierra, a thirteen-year record shows an average rainfall of 38.98 inches, the elevation being 2,900 feet.

The rainy season in California extends from about the first of October until about the first of April. The maximum monthly precipitation probably occurs during the month of January. In the foothills and valleys there is practically no rainfall during the summer. In the mountains above 10,000 feet in elevation, however, frequent thunderstorms occur in the afternoons, particularly during the months of July and August. The rainfall on the western slope of the sierras, in the basin of the Tuolumne, increases at the rate of about 0.8 inch per 100 feet until an elevation of approximately 7,000 feet is reached, beyond which there probably is no increase, though data bearing on the subject are meager. The mean annual rainfall for the basin is probably about 40 inches and the stream run-off about 40 per cent of the rainfall.

REGIMEN OF RIVER.

The period of minimum flow of the streams is in September and October. The rains falling in the foothills in the late autumn increase somewhat the fall discharge of the river, but the heavier precipitation on the higher mountains is retained until melted during the following summer. The river gradually increases in volume after the first of February, in normal years usually reaching a maximum between May 20 and June 10. This spring water comes from the melting of the great snow banks above the 4,000-foot contour. Probably the greatest floods that occur in this drainage basin are brought about by warm spring rains falling upon the snow in the foothills. During mid summer the flow of the river is maintained mostly from the melting of the snow banks and small glaciers near the crest. These never entirely disappear. It is probable that during the mid and late summer period there is a greater volume of water in the drainage lines at the 3,000- or 4,000-foot contour than there is in the main stream at the mouth of the canyon, as the lower elevations of the drainage basin do not then contribute materially to the flow, and considerable loss by evaporation occurs in the lower reaches of the river.

In November, 1878, the California State engineering department began measurements of the discharge of Kings River at the base of the foothills and continued them until October, 1883. The point of measurement was above all diversions by the canals and shows the total discharge of the stream. [a] The results of these measurements are given in the following tables:

Estimated monthly discharge of Kings River at Slate Point, Cal.

[Drainage area, 1,742 square miles.]

Month.	Mean discharge in second-feet.	Total for month in acre-feet.	Run-off.	
			Depth in inches.	Second-feet per square mile.
1878-79.				
November	300	17,851	0.19	0.17
December	290	17,831	.18	.16
January	370	22,750	.24	.21
February	870	48,317	.52	.50
March	1,970	121,130	1.30	1.13
April	4,750	282,645	3.03	2.72
May	5,090	312,972	3.37	2.92
June	3,760	223,736	2.40	2.15
July	1,650	101,455	1.08	.94
August	380	23,366	.25	.22
September	770	16,066	.16	.14
October	280	17,217	.18	.16
The year	1,665	1,205,336	12.90	.95
1879-80.				
November	400	23,802	.26	.23
December	1,440	88,542	.94	.82
January	720	44,271	.47	.41
February	1,040	60,396	.65	.60
March	1,120	68,866	.74	.64
April	5,230	311,207	3.30	3.00
May	7,120	437,792	4.63	4.01
June	9,540	567,669	6.06	5.41
July	4,800	295,141	2.44	2.11
August	1,150	70,711	.76	.66
September	370	22,017	.23	.21
October	220	13,527	.15	.13
The year	2,763	2,003,941	20.63	1.52
1880-81.				
November	220	13,091	.13	.12
December	510	31,359	.33	.29
January	870	53,494	.58	.50
February	2,430	134,955	1.45	1.39
March	1,900	106,876	1.26	1.09
April	5,800	345,174	3.71	3.33
May	8,220	505,428	5.44	4.71
June	5,010	298,116	3.21	2.88
July	4,790	294,526	3.17	2.75
August	650	39,967	.43	.37
September	340	20,231	.21	.19
October	250	15,372	.16	.14
The year	2,583	1,858,489	20.08	1.48

[a] Physical Data and Statistics of California, p. 452.

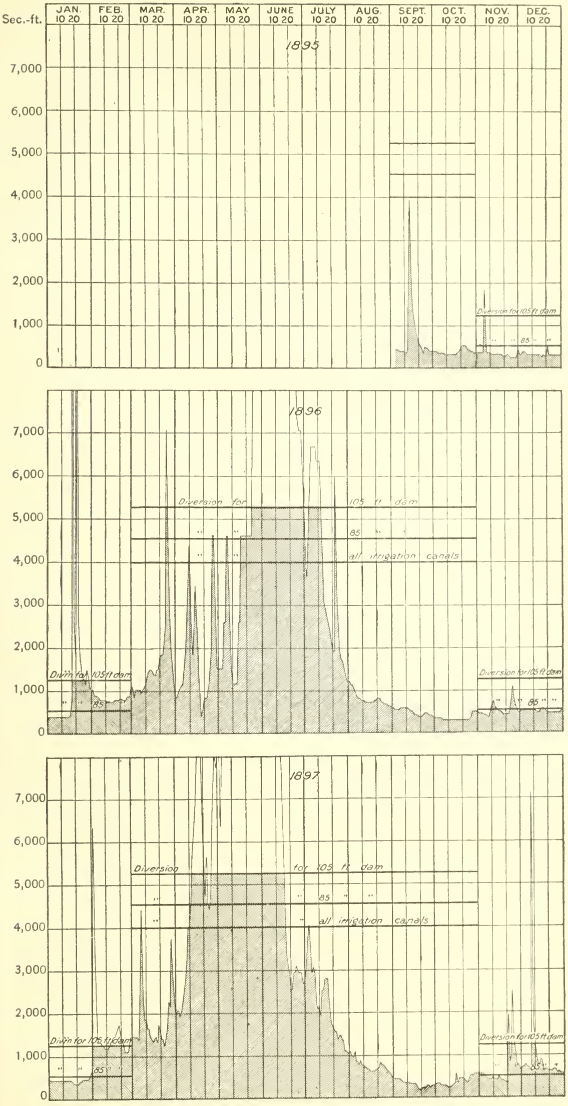


DIAGRAM SHOWING DISCHARGE OF KINGS RIVER AT RED MOUNTAIN GAGING STATION FOR YEARS 1895 TO 1897.

DIAGRAM SHOWING DISCHARGE OF KINGS RIVER AT RED MOUNTAIN GAGING STATION FOR YEARS 1898 TO 1900.

Estimated monthly discharge of Kings River at Slate Point, Cal.—Continued.

Month.	Mean discharge in second-feet.	Total for month in acre-feet.	Run-off.	
			Depth in inches.	Second-feet per square mile.
1881-82.				
November	230	13,686	0.14	0.13
December	260	15,987	.17	.15
January	380	23,366	.25	.22
February	440	24,436	.26	.25
March	1,250	76,859	.83	.72
April	3,170	188,628	2.03	1.82
May	9,190	565,071	6.12	5.28
June	6,410	381,421	4.10	3.68
July	2,020	124,205	1.34	1.16
August	620	38,122	.41	.36
September	390	23,207	.24	.22
October	610	37,507	.40	.35
The year	2,081	1,512,495	16.29	1.20
1882-83.				
November	470	27,967	.30	.27
December	340	20,906	.22	.19
January	320	19,676	.21	.18
February	340	18,883	.22	.19
March	1,050	64,562	.69	.60
April	2,220	132,099	1.42	1.27
May	6,700	411,967	4.48	3.85
June	6,730	400,463	4.10	3.68
July	1,460	89,772	.97	.84
August	600	36,893	.39	.34
September	480	28,562	.30	.27
October	420	25,825	.28	.24
The year	1,761	1,277,575	13.58	.99

Since September, 1895, the United States Geological Survey has made measurements of the total flow of Kings River above the diversion of all canals. The point of observation is known as Red Mountain. (See Pl. VI, *A*.) It is 3 or 4 miles above the mouth of the canyon and within a mile of the proposed point of diversion of Kings River to the Clarks Valley reservoir, described further on. The data showing the daily fluctuation of the river as measured by the California State engineering department are not available, but the aggregate monthly and seasonal discharge for the years given by the State engineer show greater volume than the aggregate discharge as measured by the Geological Survey for the minimum year—1898. The record kept by the Geological Survey is given in the following tables and is shown graphically in the diagrams forming Pls. VII and VIII:

Estimated monthly discharge of Kings River at Red Mountain, Cal.

[Drainage area, 1,742 square miles.]

Month.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
September	3,920	360	778.0	46,294	0.50	0.45
October	520	320	371.0	22,812	.24	.21
November	1,834	250	368.0	21,898	.23	.21
December	520	250	328.0	20,168	.22	.19
Four months	3,920	250	461.0	111,172	1.19	.27

Estimated monthly discharge of Kings River at Red Mountain, Cal.—Continued.

Month.	Discharge in second-feet.			Total for month in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
January	11,020	390	1,474.8	90,682	0.98	0.85
February	1,140	728	825.4	47,477	.51	.47
March	7,020	820	1,710.6	105,181	1.13	.98
April	4,600	390	1,938.5	115,349	1.24	1.11
May	22,100	1,140	5,918.1	363,890	3.90	3.40
June	18,920	5,160	12,737.3	757,922	8.15	7.31
July	6,680	1,212	3,742.2	230,110	2.48	2.15
August	1,212	590	759.9	48,938	.52	.45
September	590	390	491.3	29,234	.31	.28
October	510	310	350.0	21,520	.23	.20
November	1,076	390	538.5	32,043	.35	.31
December	550	470	498.4	30,645	.33	.29
The year	22,100	310	2,585.1	1,872,991	20.13	1.48
1897.						
January	624	360	437.0	26,870	.29	.25
February	6,344	1,100	1,631.0	90,581	.96	.92
March	4,408	1,240	1,884.0	115,843	1.22	1.06
April	9,380	1,930	5,318.0	316,442	3.33	2.99
May	22,732	6,344	14,470.0	889,731	9.40	8.15
June	10,580	2,520	6,145.0	365,652	3.87	3.45
July	4,040	1,036	2,177.0	133,859	1.41	1.22
August	1,100	440	739.0	45,440	.47	.42
September	480	250	329.0	19,577	.20	.18
October	572	270	394.0	24,226	.25	.22
November	2,520	360	692.0	41,177	.44	.39
December	8,348	572	985.0	60,566	.63	.55
The year	22,732	250	2,933.0	2,129,964	22.47	1.65
1898.						
January	624	440	506.0	31,113	.33	.29
February	1,170	480	705.0	39,154	.41	.40
March	1,170	520	895.0	55,032	.58	.50
April	7,820	1,036	3,547.0	211,061	2.23	2.00
May	6,520	2,450	3,536.0	217,422	2.29	1.99
June	3,280	1,310	2,122.0	126,267	1.34	1.20
July	1,310	440	696.0	42,796	.45	.39
August	400	215	320.0	19,676	.21	.18
September	780	145	204.0	12,139	.13	.12
October	728	215	320.0	19,676	.21	.18
November	285	215	231.0	13,745	.14	.13
December	1,450	180	315.0	19,369	.21	.18
The year	7,820	145	1,116.0	807,450	8.53	.63
1899.						
January	1,310	250	513.0	31,543	.33	.29
February	1,036	440	660.0	36,655	.39	.37
March	20,200	624	2,165.0	133,121	1.41	1.22
April	7,300	1,834	4,512.0	268,483	2.83	2.54
May	4,780	1,450	3,568.0	219,388	2.32	2.01
June	10,300	2,852	6,077.0	361,607	3.81	3.42
July	2,852	676	1,411.0	86,759	.91	.79
August	624	250	411.0	25,271	.26	.23
September	285	180	215.0	12,793	.13	.12
October	1,205	180	378.0	23,242	.24	.21
November	1,240	345	638.0	37,964	.40	.36
December	5,096	400	991.0	60,934	.64	.56
The year	20,200	180	1,795.0	1,297,760	13.67	1.01
1900.						
January	12,700	849	1,689.0	103,853	1.12	.97
February	849	676	748.0	41,542	.45	.43
March	2,584	728	1,712.0	105,267	1.13	.98
April	2,852	1,546	2,098.0	124,840	1.34	1.20
May	9,400	1,930	5,881.0	361,609	3.90	3.38
June	7,900	2,986	5,127.0	305,078	3.27	2.94
July	2,584	572	1,278.0	78,581	.84	.73
August	624	250	398.0	24,472	.26	.23
September	520	215	301.0	17,911	.19	.17
October	440	215	309.0	19,000	.21	.18
November	15,700	250	1,310.0	77,950	.83	.75
December	972	572	726.0	44,640	.48	.42
The year	15,700	215	1,798.0	1,304,743	14.02	1.03

The last five years, during which records have been kept by the Geological Survey, have been years of relative drought in California, as will be seen by the Fresno rainfall records (page 16), which are continuous since 1877. The twenty-three-year mean at Fresno is 8.79 inches, and that of the last five years is 8.26 inches. The precipitation during the winter of 1897–98 was within 0.08 inch of the smallest ever recorded. It is believed that the records of the Geological Survey represent a minimum annual flow of the river, and that estimates based upon them will be conservative.

Perhaps once in ten years seasons of extremely low discharge may occur, when there may be a shortage of water for the systems contemplated in this report, but it is believed that the shortage will not be great enough to be seriously detrimental to the interests depending upon the water supply for either storage or power. It would hardly seem to be necessary, or good engineering, to plan works for a minimum flow, which probably will not occur more than once in ten years, if during the minimum year 80 or 90 per cent of the water supply needed be available. A notable case in point is the Sweetwater reservoir, which was entirely dry during the season of 1899–1900, yet by continued cultivation of the orchards and the use of temporary pumping plants a good crop was harvested from a very reduced supply of water. It may be stated that Kings River, which drains 1,742 square miles of the western slopes of the Sierra Nevada, from banks of perpetual snow and from some of the finest forests of the State, can be relied upon for a great water supply. It is one of the largest streams in the State from which water is obtained for irrigation purposes.

The following is a general summary of the total volume of the river. The figures for the first five years are from the records of the State engineering department, those for the last five years are from the records of the Geological Survey.

Annual discharge of Kings River.

	Acre-feet.
1878–79	1,205,336
1879–80	2,003,941
1880–81	1,858,489
1881–82	1,512,495
1882–83	1,277,575
Five-year mean	1,571,567
1896	1,872,991
1897	2,129,964
1898	807,450
1899	1,297,760
1900	1,304,838
Five-year mean	1,482,601

The available supply from the river is discussed further in connection with the Pine Flat reservoir site (pages 30 to 33) and the Clarks Valley reservoir site (pages 39 to 42).

EVAPORATION AND SEEPAGE.

Evaporation observations were made by the State engineering department of California from November, 1881, to October, 1885, inclusive, at Kingsburg, on Kings River, at an elevation of 297 feet above sea and 20 miles southwest from the proposed Clarks Valley reservoir site. The results of these observations are given in the following table. A pan was floated in the river and observations were made daily thereon, the pan being kept at practically the same temperature as the water in the stream. The total mean annual evaporation observed was 3.851 feet.

Evaporation at Kingsburg, on Kings River.[a]

[Elevation, 297 feet.]

Month.	Depth in feet.			
	1881–82.	1882–83.	1883–84.	1884–85.
November	0.220	0.115	0.170	0.200
December	.050	.085	.080	.180
January	.090	.060	.105	.010
February	.115	.100	.050	.140
March	.180	.305	.090	.240
April	.260	.270	.160	.160
May	.305	.160	.320	.340
June	.475	.500	.295	.660
July	.660	.760	.380	.710
August	.665	.920	.370	.930
September	.475	.730	.320	.640
October	.135	.400	.350	.470
The year	3.630	4.405	2.690	4.680

[a] Physical Data and Statistics of California, p. 378.

The amount of water lost by seepage and evaporation by the Kings River canals was made the subject of careful study by C. E. Grunsky, for the California State engineering department, in the summer of 1882, the results of which are given in Water-Supply and Irrigation Paper of the United States Geological Survey No. 18, page 74. The actual loss by evaporation from the surface of the water while in transit in the canals is very small; probably 1 per cent would cover it. The greater loss is occasioned by seepage. The canals of this district are not all built on true grades, and some of them have swamps and pools along their courses. In one instance—on the Centerville and Kingsburg canal—a loss of 52 second-feet was shown in 1 mile. The observations by Mr. Grunsky were made nearly twenty years ago when the water plane was not so near the surface as it now is, and consequently the seepage losses were greater than now. The genera esult of his observations shows a loss of 307.11 second-feet in 50.8 iles out of a total diversion of 860.83 second-feet. This amounts to 05 second-feet to the mile, or 36 per cent of the total diversion. he measurements on the river and on the Fresno canal were made om about a half mile to 20.3 miles below its head, and showed a loss f 64.3 second-feet out of 133.83 second-feet diverted. On the Fresno anal the loss from about $1\frac{1}{4}$ to $23\frac{1}{2}$ miles below the headworks was)4.52 second-feet out of 381 second-feet diverted. On the Centerville nd Kingsburg canal, from a half mile to 7 miles from the headworks, e loss was 138.29 second-feet out of 346 second-feet diverted. Relavely, the greater rate of loss in the canals was in the first few miles om the headworks, where they are in porous soils, close together, nd approximately parallel.

The loss of water from a canal by seepage is governed by the rate f percolation, the area through which percolation occurs, and the eriod of time during which a given unit of water is exposed. The eater the depth of water in a canal the greater the velocity of flow, nd consequently the less time is a given unit of water exposed to loss y percolation in any section of the canal. This increase of velocy due to greater depth is relatively larger than the increase of etted area through which percolation takes place. For instance, if n earthen canal 40 feet wide has a slope of 5.28 feet to the mile and depth of water of 2 feet it would discharge 220 second-feet with a elocity of 2.74 feet per second. With other conditions the same, if e depth of water were increased to 4 feet the discharge would be 70 second-feet with a velocity of 4.19 feet per second. Thus, while e wetted area exposed to percolation increases 9 per cent the disharge trebles. For the sake of comparison, suppose the velocity of ercolation were 0.10 foot per hour. Then in the canal flowing 2 et deep the loss per second per lineal foot of canal would be 0.00122 econd-foot, and with the canal flowing water 4 feet in depth it would e 0.00133 second-foot. Comparing this loss with the respective olumes carried by the two canals, we find that the relative loss f water in the large canal is but 40 per cent of that in the small anal.

If the three canals referred to had been consolidated and all water un through the Kings River and Fresno canal, then using Mr. Grunky's data and the foregoing reasoning it would be safe to say that the first $11\frac{1}{4}$ miles of the Fresno canal 95.51 second-feet would ave been saved, and in the first 6.5 miles of the Centerville and ingsburg canal 138.29 second-feet would have been saved, or 233.80 econd-feet out of a total loss of 307.11 second-feet. This would educe the loss to 8.5 per cent of the whole, instead of 36 per cent, hich Mr. Grunsky found.

It must be remembered, however, that the losses described occurred 50.8 miles of main canals, during the early stages of irrigation development, and that probably there would be on an average much more lost in the distribution laterals. Enough data are not hand to draw accurate conclusions, but it is believed that unc favorable conditions fully 25 per cent of the river water would be lo in reaching the land to be irrigated.

If water be drawn from reservoirs to supplement the low-water su ply of the canals it will be water added to most of the canals a not subject to so heavy a rate of loss as, say, 25 per cent of the wat first diverted; probably 15 per cent would be nearer the actu amount.[a]

RECONNAISSANCE OF BASIN.

In the investigation of the large basin of Kings River, which fro a hydrographic point of view was practically unknown, it was decid to equip two parties for the season's work. Accordingly a reconnai sance party was organized and placed in charge of Mr. E. G. Hamilto topographer from the United States Geological Survey. The work this party was largely exploratory, but at the close of the season t Clarks Valley reservoir site was surveyed by Mr. Hamilton. T reconnaissance party was instructed to visit all portions of the drai age basin, make instrumental examinations of all possible reservo sites, and at the end of each month report the character of the sit found. A second party was organized, under the direction of M H. E. Green, an engineer of extended experience in the constructi of storage reservoirs, for the purpose of making more detailed su veys of the better sites found by the exploration party. The reco naissance party reported upon and sketched seven reservoir sites, fo of which were surveyed under the direction of Mr. Green.

The following instructions were given to the engineers for the guidance in making reports:

Report on reservoir survey.

(1) Give name of engineer in charge and date of survey.
(2) Name of locality.
(3) Streams tributary to site.
(4) Land title to site.
(5) If possible tie reservoir surveys to land surveys. The point of reservoir su vey to be tied in is preferably the ends of the dam.
(6) If the land is not subdivided, tie reservoir survey to prominent natu objects.
(7) Estimate area of tributary drainage basin.
(8) Give general statement of elevation of drainage basin and elevation of res voir site.
(9) State whether drainage basin is timbered or bare hills.
(10) Compute water supply.
(11) Give capacity of reservoir with various heights of dam.
(12) State character of material for dam; earth, rock fill, or concrete.

[a] See addenda on page 99.

(13) For purposes of preliminary estimate consider—

Earthen dam 20 feet wide on top; $2\frac{1}{2}$ to 1 slope on inner face, $1\frac{1}{2}$ to 1 on outer face. Describe the quality of the available earth, which should be a clay, sand, and rock, also give length of haul.

Rock-fill dam 20 feet wide on top; $1\frac{1}{2}$ to 1 outer slope, 1 to 1 inner slope. State position of available rock supply, give probable cost of cement delivered on the ground, and available timber for inner face and cost thereof.

Concrete dam. State the proximity and relative elevation of quarries, and the cost per barrel of cement delivered on the ground.

(14) Report on probable foundations for dam.

(15) Estimate on the cost of dam.

(16) State cost per acre-foot of water stored.[a]

The requisites of a reservoir site are numerous and exacting, as fol-ws:

(1) There must be an available water supply sufficient to fill the ısin.

(2) There must be a basin to hold this supply.

(3) There must be a good dam site.

(4) There must be good materials of which to make a dam.

(5) The foundations must be able to sustain the dam.

(6) There must be available lands upon which to put the water.

(7) The entire project must be on a commercial basis.

There are a large number of sites on the river which were popu-rly supposed to be good but which proved to be objectionable, owing the lack of some one of the foregoing vital requisites.

The field party, which consisted of a topographer, a rodman, and a ›ok, left Sanger, in Fresno County, a station on the Southern Pacific ailroad at an elevation of 370 feet, on May 22, 1900. The route of avel is shown on the map, Pl. I, which was furnished by Mr. J. N. e Conte for use in connection with this report.

The first site investigated was the upper Clarks Valley, 16 miles ast of Sanger, 10 miles north of Reedley, and 1 mile north of where ıe stage road from Sanger to Millwood crosses Wahtoke Creek; ele-ation, 500 feet. This site is at the upper end of the main Clarks 'alley reservoir site, and is included by it. It is shown on the map of ıe Clarks Valley site (Pl. XIII), and is not estimated upon separately.

From Clarks Valley the party went back to Kings River, and fol-›wing along its east bank to the mouth of Mill Creek ascended that reek 4 miles, to McHaley's ranch, at an elevation of 650 feet. A half ıile above McHaley's ranch a reservoir site was surveyed, and it was ›und that a concrete dam 195 feet in height would store 3,500 acre-eet of water at a cost of $130 per acre-foot, which of course is rohibitive.

After spending two days in the hills between Mill Creek and Kings River the party went by trail from McHaley's ranch to Squaw Valley, hen along the Millwood stage road to Dunlap. At Dunlap a stay of

[a] An acre-foot of water is an amount sufficient to cover 1 acre to a depth of 1 foot.

three days was made to permit an investigation of the drainage Mill Creek. After leaving Dunlap the party followed the stage road Millwood, then took the trail through the General Grant National Pa to Huckleberry Meadow, a small meadow 8 miles northeast of Millwo and at an elevation of 6,000 feet. With Huckleberry Meadow a base of supplies, trips were made to the meadows and basins withi radius of 20 miles. The largest of these meadows are Converse Bas 10 miles northwesterly from Huckleberry Meadow; Bearskin Meado 6 miles to the east; Burton Meadow, 10 miles to the east; Squawsk Meadow, 14 miles to the east; and Big Meadows, 16 miles to the sout Big Meadows is the only one of these reservoir sites that has a go dam site, but as it is on the divide between Kings and Kawe rivers and has only 8 square miles of watershed it was not mappe The Long Meadow reservoir site, which is in this locality, was su veyed by Mr. Green, and the results of the survey are given on pag 44 to 46.

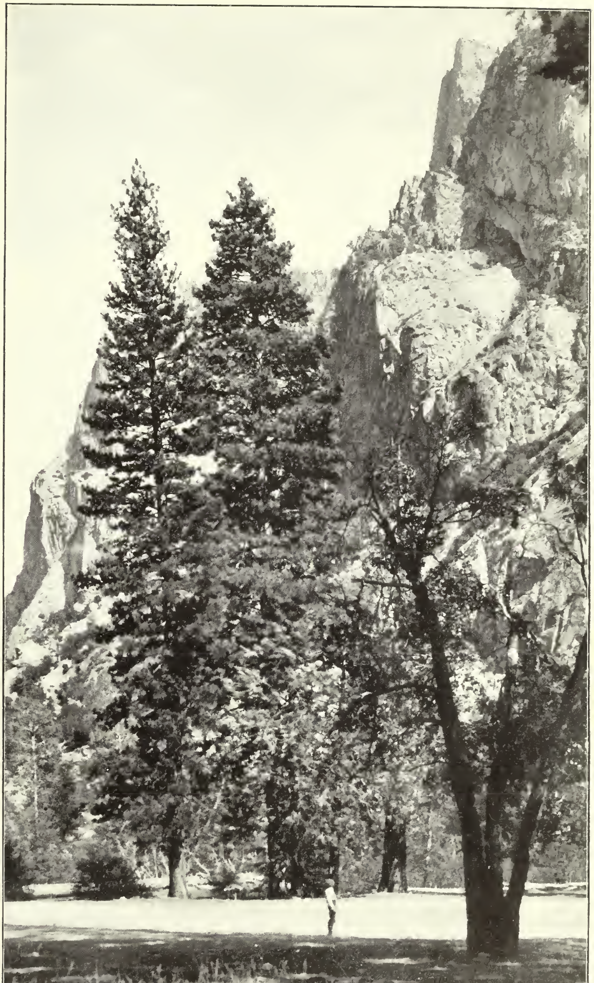
SOUTH FORK.

There are two trails leading from Huckleberry Meadow to the gra canyon of Kings River. The upper trail is the shorter and bett but there is no bridge across Boulder Creek and it is dangerous attempt to ford it during high water. On the lower trail, howev there is a bridge, which made it possible to move the camp fro Huckleberry Meadow to the grand canyon of the Kings, where t sites were surveyed, one with the dam site a half mile below t junction of Copper Creek and the South Fork of Kings River, in se 14, T. 13 S., R. 31 E., Mount Diablo base and meridian, at an elev tion of 5,000 feet; the other, 5 miles farther down the South Fork Kings River, with the dam site a half mile below the mouth of Lew Creek, in sec. 10, T. 13 S., R. 30 E., at an elevation of 4,300 feet.

At either of these sites it would be necessary to construct an ove flow dam on the South Fork. A 210-foot dam at the site below t mouth of Copper Creek would store approximately 29,378 acre-fe of water. The estimated cost of storage is about $67 per acre-foot f a rubble masonry dam. A 200-foot dam at the lower site would sto 14,100 acre-feet, and the estimated cost of storage is $178 per ac foot. These dams would have to be made of hydraulic-ceme masonry. In both of these cases the excessive cost per acre-fo stored renders the construction of the dams impracticable.

A view in the canyon of the South Fork near the mouth of Copp Creek is shown in Pl. IX.

From the site at the mouth of Lewis Creek the bed of the Sou Fork down to its junction with the Middle Fork is narrow and has heavy grade.



CLIFFS ON SOUTH FORK OF KINGS RIVER

BUBBS CREEK AND HEADWATERS OF SOUTH FORK.

The channels of both of these streams are narrow, averaging from 500 to 1,000 feet in width, with high granite walls on either side, and with a fall of from 50 to 200 feet to the mile. Near their headwaters are numerous small lakes, one of which, Lake Charlotte, was mapped. (See fig. 1.) This lake is on the headwaters of Bubbs Creek, near the divide between that stream and the South Fork of Kings River, at an elevation of 10,500 feet, and has a drainage area of about 8 square miles. The surface area of the lake is 24 acres and the depth of the water about 30 feet. Owing to its inaccessibility and to the lack of a good dam site it was not considered as a possible storage basin.

Pl. VI, *B*, is a view of the falls in a creek above East Lake in the South Fork drainage.

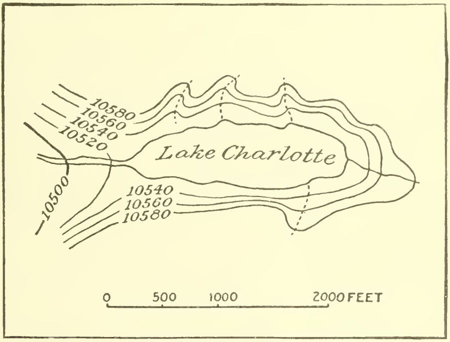


FIG. 1.—Lake Charlotte reservoir site.

PARADISE VALLEY.

Paradise Valley, on the South Fork of Kings River, 5 miles above the mouth of Bubbs Creek and at an elevation of 6,500 feet, was explored, but its floor, although in places 2,000 feet wide, has a fall of 40 feet in 1,000 feet, and it therefore is not a good reservoir site. It is also inaccessible.

ROARING RIVER AND SUGARLOAF CREEK.

Near the headwaters of these streams are numerous small meadows, but not one that was visited has a good dam site. The channels of the main streams are narrow gorges with falls or slopes varying from 50 feet to 500 feet to the mile. Leaving the South Fork of Kings River the third week in July, the party started for Simpson Meadows, on the Middle Fork, spending several days in reconnaissance en route, but with one exception (Granite Basin) no reservoir sites of any value were found. The Granite Basin site was examined by Mr. Green, the results of the examination being given on page 48.

SIMPSON MEADOWS.

The Simpson Meadows, on the Middle Fork of Kings River at a elevation of 6,000 feet, have an average width of 3,000 feet. Th larger part of the meadows is on the east side of the river, an extends a mile above the mouth of Goddard Creek and 3 miles belo it. A dam 200 feet in height would be required to flood the meadow Its top length would be 3,000 feet, and the cost would be so great a to make it prohibitive. While camped in Simpson Meadows the part spent several days in exploring Cartridge, Palisade, Goddard, an Disappearing creeks and the headwaters of the Middle Fork, bu found no storage basins of value.

Leaving Simpson Meadows the second week in August the part followed the Tunema and Collins trail to Cliff Camp, on the Nort Fork of the river. (See Pl. X.) Between the Middle and North fork are numerous small meadows, most of them near the summits of th ridges, with from 3 to 5 square miles of watershed, but not one o them has a good dam site or an extensive drainage basin.

DUSY MEADOWS.

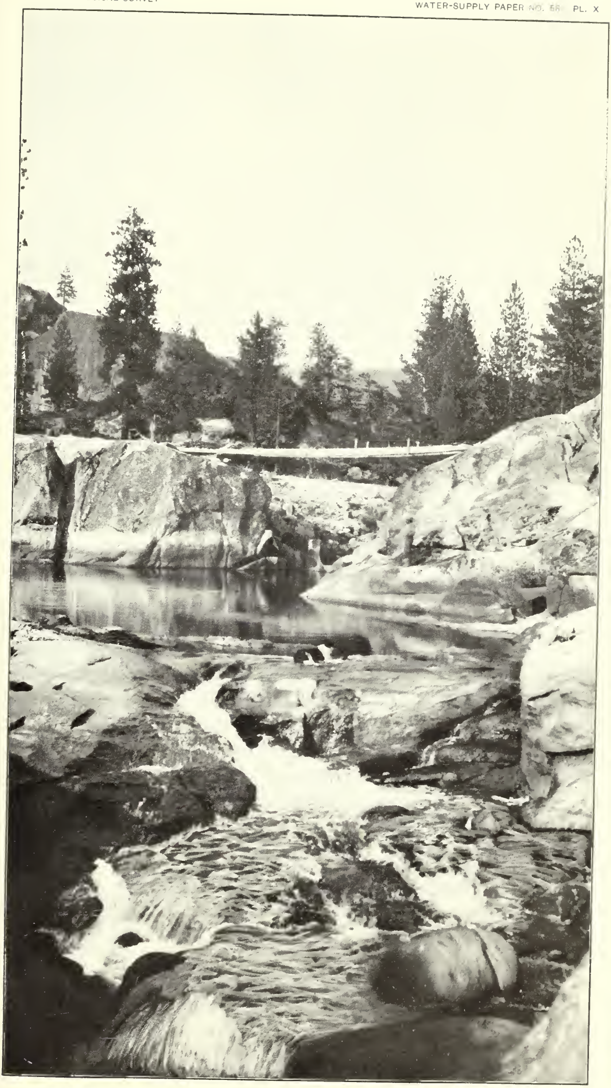
On the North Fork two reservoir sites were mapped—the Dus Meadows site and one three-fourths of a mile farther upstream. A the latter site, which is the smaller of the two, a concrete overflo dam 150 feet high would store 5,440 acre-feet of water, but at a pro hibitive cost—about $276 per acre-foot stored.

The Dusy Meadows reservoir site is in Fresno County, on the Nort Fork of Kings River, in sec. 36, T. 10 S., R. 27 E., and sec. 31, T. 1 S., R. 28 E., Mount Diablo base and meridian. The drainage are of the basin of the North Fork above the reservoir site is 144 squar miles, at an average elevation of 9,000 feet above sea level. Assum ing the average annual rainfall to be 39 inches and 620 acre-feet th annual run-off per square mile, we have 88,280 acre-feet as th amount of water available for storage purposes from the drainag basin. The elevation of the dam site, as determined from aneroi measurements, is 6,300 feet above the sea, and the capacity of th reservoir at different heights of the water would be as follows:

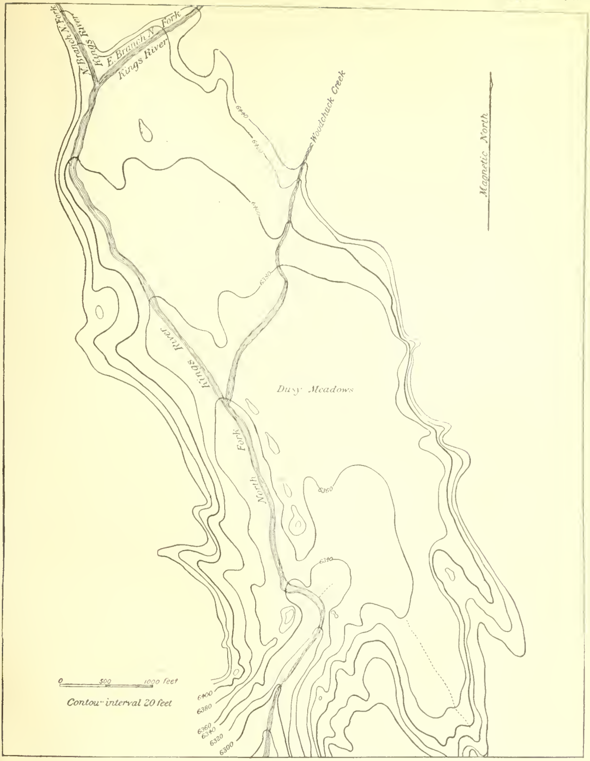
Capacity of Dusy Meadows reservoir site.

	Acre-feet.
Between 20- and 40-foot levels	180
Between 40- and 60-foot levels	860
Between 60- and 80-foot levels	2,930
Between 80- and 100-foot levels	5,460
Between 100- and 120-foot levels	7,420
Total	16,850

The reservoir site is mapped in Pl. XI, *A*, and the dam site in P XI, *B*. A loose rock dam 125 feet in height, faced with timber,



CLIFF CAMP, ON NORTH FORK OF KINGS RIVER, AT LOW-WATER STAGE OF STREAM.



A. CONTOUR MAP OF DUSY MEADOWS RESERVOIR SITE.

B. CONTOUR MAP OF DUSY MEADOWS DAM SITE.

estimated upon for this site. There is plenty of granite rock on both sides of the dam site which could readily be transported by cable or other mechanical devices, and there are at hand large quantities of standing timber, both yellow pine and fir.

In the following estimate of cost the quantities given are for a dam with slopes of ½ to 1 and 1 to 1, with a width of 20 feet on top, a plank face 6 inches thick, and sills 12 inches by 12 inches, with 12 feet between centers.

Estimate of cost of Dusy Meadows dam.

Rock, 378,000 cubic yards at $0.75	$283,500	
Planking for face, 656,000 feet, B. M., at $40	26,240	
Sills, 111,000 feet, B. M., at $40	4,440	
Labor in laying 767,000 feet, B. M., at $6	4,600	
		$318,780
Two spillways, one on each side of the dam, each having a capacity of 3,300 second-feet, 45,000 cubic yards of rock at $1		15,000
Arched outlet tunnel 4 feet by 6 feet by 400 feet long, cement lined, at $10 per lineal foot	$4,000	
Tower and gates	8,000	
Machinery, cables, etc	25,000	
		37,000
Building road from the end of the present road at Russel's camp to the dam site (20 miles) and about the works (2 miles), 22 miles at $3,000		66,000
Engineering expenses and contingencies		72,080
Total cost of dam		538,860

The total capacity of the reservoir being 16,850 acre-feet and the total cost of the dam $538,860, the cost per acre-foot stored would be $32.

DINKEY CREEK.

After leaving the North Fork the trail runs almost due west for 15 miles, to Russel's camp, on Dinkey Creek, through a flat, open country heavily timbered, mostly with fir, until within 3 miles of the creek, when the trail begins to descend from the 7,000-foot level to the 6,000-foot level, the sugarpine trees become more plentiful, and occasionally, in the beds of the streams, a few sequoias are seen. Dinkey Creek does not flow through any large basins or meadows. The average fall of the creek is from 25 to 75 feet in 1,000, except near the headwaters, where the bed is in solid, glaciated granite channels, with a fall of from 10 to 25 feet in 1,000.

From Russel's camp west to Ockenden, a distance of 15 miles, there is a road built to enable the lumbermen to haul sugarpine shingles to a market at Fresno. There is probably no place in California where there is more reckless destruction of timber than along this road: On either side of it hundreds of fine sugarpines have been cut. Trees 3 to 5 feet in diameter, with the lowest limbs 60 and 70 feet from the ground, have been felled to use perhaps from 6 to 9 feet of the base for shingles, leaving the rest of the timber to rot.

PINE FLAT.

After exploring the drainage basins of Big and Sycamore creek the party made a detailed survey of the Pine Flat reservoir site (se Pl. XII), on the main Kings River, 5 miles below Trimmer, in secs. 12, 19, 24, 25, 26, 35, and 36, T. 12 S., R. 24 E., Mount Diablo base an meridian. The dam site is in section 35. The elevation at the bas of the proposed dam is 600 feet. The bed rock is a blue slate, soli and bare in the creek bed but seamy on the east side.

The following estimates of the capacity and cost of the reservoir ar only preliminary and approximate. Careful examinations should b made before construction is begun. A section of the proposed wei is shown in fig. 2.

Capacity of Pine Flat reservoir.

Height of dam.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0.0		
20	57.2	572	572
40	187.0	2,442	3,014
60	372.3	5,593	8,607
80	568.7	9,410	18,017
100	912.7	14,814	32,831
120	1,125.0	20,377	53,208
140	1,373.9	24,989	78,197
160	1,642.9	30,168	108,365
180	1,902.4	35,453	143,818
200	2,174.0	40,764	184,582

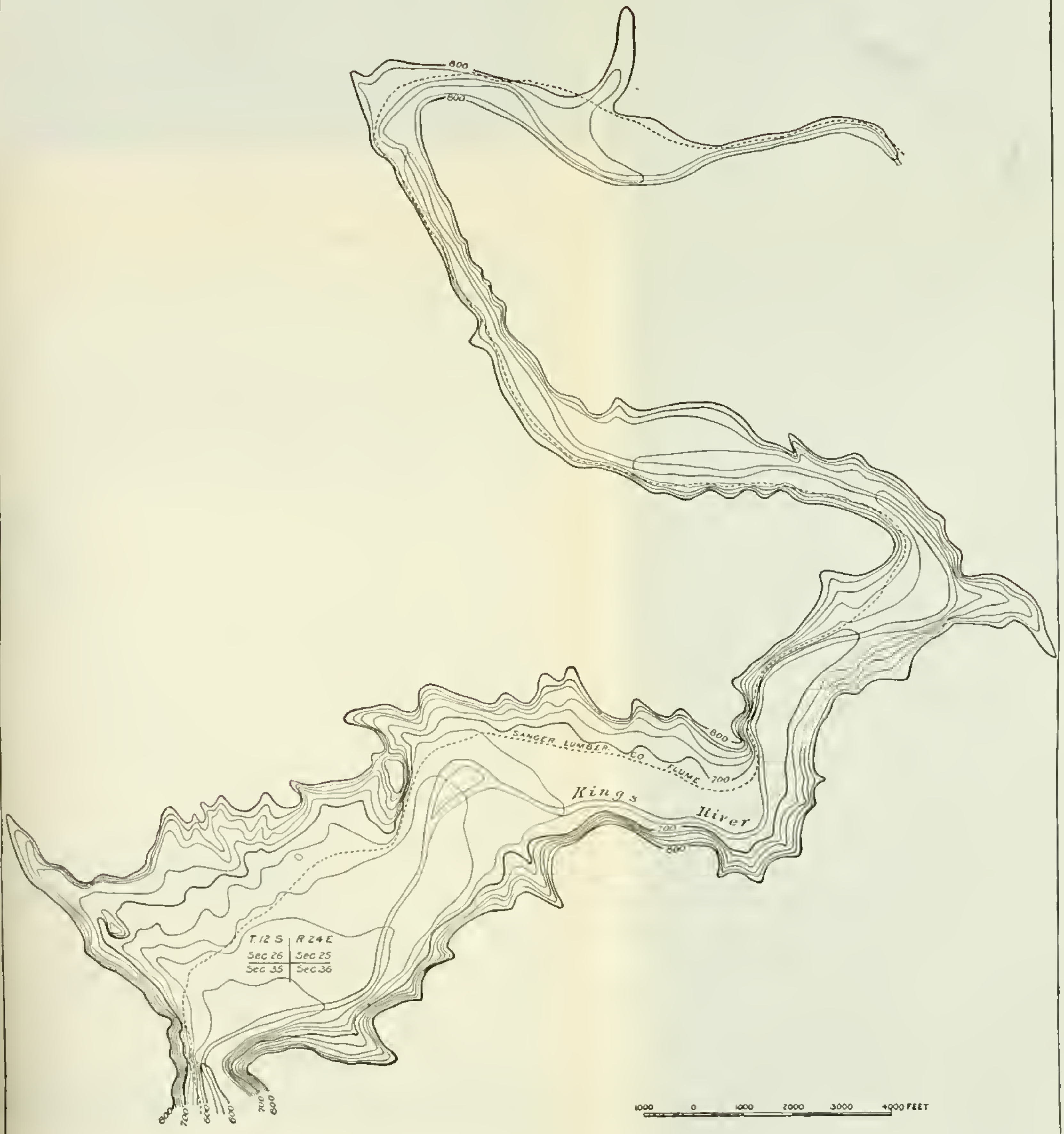
Estimated cost of dam 200 feet in height.

485,000 cubic yards of rubble masonry at $7	$3,395,00
Concrete apron at lower toe of dam, 1,400 feet long, 60 feet wide, and 3 feet thick, 9,333 cubic yards at $9	84,00
Gates, outlet pipes, etc	50,00
Right of way	25,00
Engineering, 2½ per cent	88,85
Contingencies, 7½ per cent	266,55
Total	3,909,40

Estimated cost of dam 140 feet in height.

212,000 cubic yards of rubble masonry at $7	$1,484,00
Concrete apron at lower toe of dam, 1,100 feet long, 50 feet wide, and 3 feet thick, 6,111 cubic yards at $9	55,00
Gates, outlet pipes, etc	50,00
Right of way	25,00
Engineering	50,00
Contingencies	86,00
Total	1,750,00

The cost per acre-foot of water stored is $21.18 for the 200-foo dam and $22.38 for the 140-foot dam. In the case of the 140-foot dam if the interest on the cost of the works be taken at 6 per cent, th taxes at eight-tenths of 1 per cent, and maintenance at $10,000 pe annum, the annual charge for operation will be $129,000, or $1.65 fo each acre-foot stored in the reservoir. If 20 per cent of the wate



CONTOUR MAP OF PINE FLAT RESERVOIR SITE.

stored is lost by seepage and evaporation before reaching the lands to be irrigated, the annual charge per acre-foot delivered will be $2.06.

The estimates are for a dam made of large blocks of granite bedded in a hydraulic-cement mortar. It would be 16 feet wide on top, and with such side slopes that the resultant of all pressures would fall well within the central third with 10 feet of water passing over the crest. With the 200-foot dam, the length of which is 1,400 feet, the maximum observed flood, 40,000 second-feet, would have had a depth on its crest of 4.2 feet; and with the 140-foot dam, which is 1,100 feet

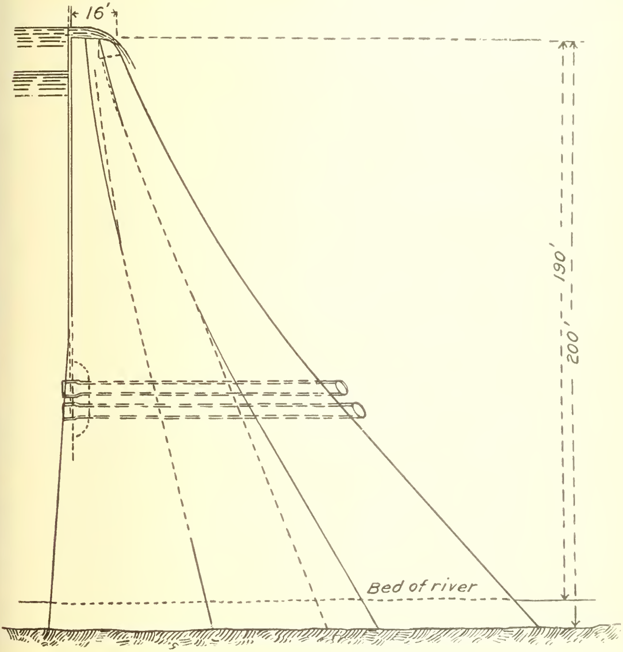


FIG. 2.—Section of proposed Pine Flat weir.

long, this depth would have been 4.8 feet, assuming that all water passed over the crest. Bed rock is at the surface on the sides and bottom of the canyon at the dam site. It is a firm blue slate. The estimate is for the entire structure bedded 10 feet deep in the rock. A trench of greater depth would have to be sunk and filled with concrete at the upper toe. The bed rock should be given most careful study before construction is begun. The estimate includes an apron of concrete extending from 50 to 60 feet below the lower toe of the dam across its entire width, for the protection of the lower toe.

While estimates are given for both a 140-foot and a 200-foot dam, the 140-foot is considered the better for the location.

This reservoir site, although costing nearly double that of Clarks Valley per acre-foot of storage capacity, is of importance in the ultimate development of the lands under Kings River. Being on the main stream it would catch the flood discharge up to its full capacity. It is just above the diversions of all irrigation canals and above the proposed diversion canal line to the Clarks Valley reservoir site, which is not on the river. (See map of drainage basin, Pl. I.) Thus it could be used as a regulator or governor to the river for the conveyance of water to the Clarks Valley reservoir, and, after that had been filled, for the holding of the surplus water. For example, it is obvious that so great a volume as passed in January, 1896 (see discharge diagram, Pl. VII), when on the 18th the discharge increased to 8,500 second-feet and on the 11th to 11,020 second-feet, must be in large part lost in passing the headworks of the diversion canal (capacity 1,250 second-feet) to the Clarks Valley site and the irrigation canals (combined capacity of 4,000 second-feet); but with this large regulator on the main stream all of the water would be saved and gradually discharged into the Clarks Valley canal, leaving the Pine Flat reservoir empty and in readiness for the next flood. The indirect benefit of the Pine Flat reservoir as a governor would be as great as its direct utility as a storage reservoir, and the site should be controlled by the irrigation interests of Kings River.

Discharge of Kings River, showing amounts of water available for storage.[a]

Seasonal year, November to October, inclusive.	Total seasonal discharge Nov. 1 to Oct. 31.	Total seasonal diversion Nov. 1 to Oct. 31.[b]	Diversion Nov. 1 to Feb. 28.[c]	Summer.	Irrigation diversion Mar. 1 to Oct. 31.[d]	Surplus after summer diversion Mar. 1 to Oct. 31.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*		*Acre-feet.*	*Acre-feet.*
1895-96	1,852,425	1,070,900	134,152	1896	936,748	915,676
1896-97	2,088,924	1,198,691	168,846	1897	1,029,845	1,059,079
1897-98	876,079	820,522	164,220	1898	656,302	219,777
1898-99	1,227,217	996,307	102,348	1899	893,959	333,258
1899-1900[e]	1,281,051	1,032,158	214,527	1900	817,631	463,420
Mean	1,465,139	1,023,716	156,819	----------	866,897	598,242

[a] From gagings of the United States Geological Survey at Red Mountain station.
[b] This assumes a diversion from the river of 4,000 second-feet (the full capacity of the irrigation canals) between March 1 and October 31 and 2,000 second-feet between November 1 and February 28, when the water in the river is available.
[c] Total flow of river up to 2,000 second-feet.
[d] Total flow of river up to 4,000 second-feet.
[e] The season of 1900-01 was one of abundant supply.

It is believed that if an ample summer supply is assured midwinter irrigation will be largely if not entirely discontinued.

By reference to the table on page 21, giving a summary of the stream measurements by the California State engineering department and by the United States Geological Survey, it will be seen that during a period of observation of ten years the season of 1897–98 (summer of 1898) had the lowest flow, the season of 1878–79 being next, with a discharge of 397,886 acre-feet more than in the former season. A twenty-three year rainfall record at Fresno (see table on page 16) shows the year of lowest precipitation to have been 1878–79, when 4.87 inches fell, the next lowest being the season of 1897–98, when 4.95 inches were observed. The official rainfall record at Sacramento (see table on page 16) shows the lowest precipitation during the period over which the record extends (1877–1900) to have been in the season of 1897–98, the amount being 10.50 inches. It will be noted that stream measurements have been made during the years of lowest observed rainfall at Fresno, and that both five-year periods (page 21) were during cycles of low rainfall. In fact not one of these years was a wet year. An old rainfall record kept at Sacramento by Dr. Thomas Logan since 1849 shows dry-year records as follows: 1850–51, 4.71 inches; 1863–64, 7.87 inches; 1870–71, 8.47 inches. The Central Pacific Railway shows a record of 8.95 inches in 1876–77. All of these are below the observed rainfall of 10.50 inches at Sacramento in 1897–98. It is not believed that a standard rain gage was available at Sacramento in the winter of 1850, and the record of 4.71 inches is so much below any other record during the fifty-one years of observation that it may be seriously questioned.

In view of all the facts, the following conclusions seem justifiable:

(1) The observed flow of Kings River for the season of 1897–98 may be assumed to be a very low discharge but not an absolute minimum. For the purpose of this report it may, however, be taken as a minimum.

(2) These minimum years probably will occur about once in ten years.

(3) There will be enough water during November to February, inclusive, in excess of the 4,000 second-feet summer diversions (March to October), to fill the Pine Flat reservoir every year if the dam is built to a height of 140 feet, capacity 78,197 acre-feet.

(4) In nine out of ten years there will be enough water to supply all winter and summer irrigation on the present basis and leave the Pine Flat reservoir full for use after July 1.

(5) The water that would be stored in the Pine Flat reservoir is water that otherwise would be lost.

(6) The Pine Flat reservoir would irrigate the most valuable lands in Fresno and Tulare counties, now dry and unproductive.

(7) The cost of reservoir would be $22.38 per acre-foot stored, and the earning powers of the reservoir many times that amount.

The available water supply is discussed further in connection with the Clarks Valley reservoir site (pages 39 to 42).

CLARKS VALLEY.

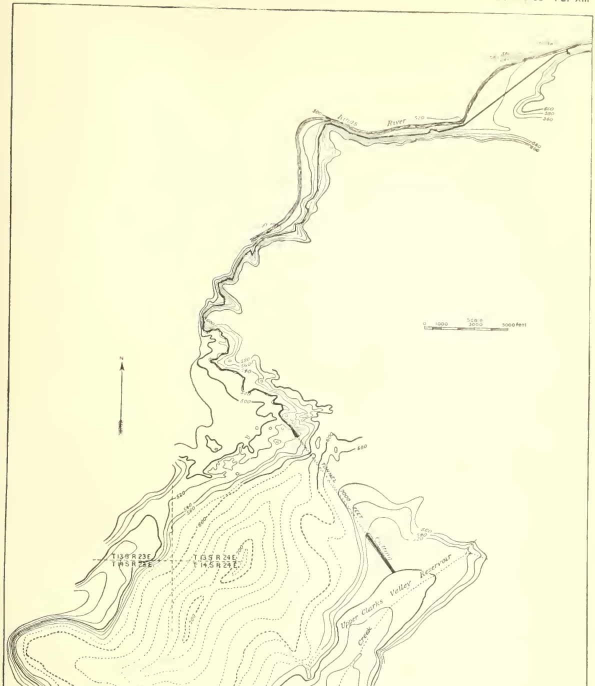
After completing the work in the drainage basin of Kings River a reconnaissance of the foothills was made, extending as far as the mouth of San Joaquin River on the northwest and on the southeast to 15 miles from the mouth of Kings River, with a view to finding, if possible, a storage basin to which the flood waters of the river could be diverted. The only basin found was Clarks Valley. This rese voir site is in Fresno County, 16 miles east of Sanger. The stage roa from Sanger to Millwood runs from west to east through the center the site. In elevation it commands all of the canals diverting wat from Kings River except the Gould canal, and is within 2 or 3 mil of the intake of most of those systems. It is about 1½ miles distan from the main drainage line on Kings River opposite the reservo and approximately 100 feet higher. It is proposed to fill this rese voir, by means of a diversion canal, with the flood and excess wate of Kings River. The diversion canal would be 53,600 feet in lengtl The headworks would be above the mouth of Mill Creek and at tl Pine Flat dam site.

One rather peculiar feature of Clarks Valley is that three isolate buttes partially inclose a portion of San Joaquin Valley betwee themselves and the foothills of the main range. To make the rese voir complete the openings between these hills will have to be close by three separate dams. The arroyo of Wahtoke Creek, which pass through the center of the reservoir site, is about 75 feet wide and feet deep. The maximum height of dam is considered from the bo tom of this arroyo, which gives a somewhat exaggerated idea of i (See Pl. XIII.) The location will permit the construction of a da 105 feet maximum height, which will impound water to a maximu depth of 100 feet. For the purpose of this report it was decided give estimates on the cost of building a dam of 105 feet maximu height and also one of 85 feet maximum height, to impound water maximum depths of 100 feet and 80 feet, respectively. The heigh of the two smaller dams will depend upon the height of the larger central dam, as shown in the tables on pages 35 and 37.

The drainage area of the basin of Wahtoke Creek, in which tl Clarks Valley site is located, is 33 square miles. The average elev tion of the drainage basin is 1,000 feet. Assuming the average annu rainfall to be 20 inches and the run-off 12 per cent, we have 4,2 acre-feet as the amount of water available for storage from the loc drainage basin. The assumed elevation at the base of the dam 400 feet, which is the elevation used for maps and calculations. F sea level 29 feet should be added. The capacity of the reservoir different heights of the water is given in the following table. Tl elevation of the outlet is 420 feet.

Capacity of Clarks Valley reservoir site.

Maximum depth of water.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0.0		
20	248.3	Below outlet.	
40	1,146.0	13,943	13,943
60	2,592.2	37,382	51,325
80	4,325.2	69,174	120,499
100	5,344.5	96,697	217,196



CONTOUR MAP OF CLARKS VALLEY RESERVOIR SITE AND PROPOSED DIVERSION CANAL.

The dams would be of earth, the material in each case being near enough to the dam site to readily be transported by cables or other mechanical devices. A reddish clay containing about 10 per cent of coarse gravel and some sand can be used.

105-FOOT DAM.

The following quantities are for a large dam 105 feet high, 20 feet wide on top, with a slope of 2½ to 1 on the upstream side and 1½ to 1 on the lower side.[a] The maximum depth of water will be 100 feet and the storage capacity 217,196 acre-feet.

Quantities of material for 105-foot dam and the two side structures.

Dam.	Length on crest.	Greatest depth.	Earth.
	Feet.	*Feet.*	*Cu. yds.*
No. 1	3,370	83	885,020
No. 2	8,865	105	5,272,990
No. 3	2,830	65	556,460
Total			6,714,470

At 20 cents per cubic yard the cost of the dams would be $1,342,895.

To fill the reservoir to the 100-foot level (217,196 acre-feet) a conduit with a capacity of 1,250 cubic feet per second would be required. The total length of this conduit, from the headworks on Kings River to the reservoir, would be 53,600 lineal feet, as follows: 7,000 feet of tunnel into reservoir, 3,600 feet of cutting at entrance and discharge of tunnel, and 43,000 feet of canal partly in rock.

Intake tunnel.—The elevation of the bottom of the inlet tunnel at its reservoir end is fixed at 20 feet above the maximum flow line for the larger (105-foot) dam, so as to permit raising the dam in the future. The elevation of the intake at Kings River is estimated at 558.5 feet. The elevation of the Pine Flat dam site is approximately 600 feet. The cross section of the inlet tunnel will be 10½ feet by 12 feet, and the velocity of the water will be 10 feet per second. The tunnel will be in granite. The estimated cost, unlined, is $12 per running foot, or a total of $84,000, exclusive of the tunnel approaches, the cost of which will be as follows:

Cutting at entrance to tunnel:	
13,700 cubic yards of rock at $1	$13,700
27,410 cubic yards of earth at $0.20	5,482
Cutting at discharge end of tunnel:	
10,072 cubic yards of rock at $1	10,072
5,036 cubic yards of earth at $0.20	1,007
Total	30,261

[a] This section is assumed for the purpose of this estimate and is not necessarily final. This important matter should be most carefully considered before construction is begun and determined only after detailed examination of the material available and of the foundations.

Diversion canal.—The canal will have a capacity of 1,250 cubic feet per second and a grade of 1.056 feet to the mile in earth and loose rock and 3.168 feet to the mile in solid rock section. The bottom width will be 17 feet and the cost as follows:

Earth, 362,000 cubic yards at $0.20	$72,40
Loose rock, 401,505 cubic yards at $0.50	200,75
Solid rock, 78,600 cubic yards at $1	78,60
Total	351,75

Sections of the canal in earth and loose rock and in solid rock are shown in Pl. XIV.

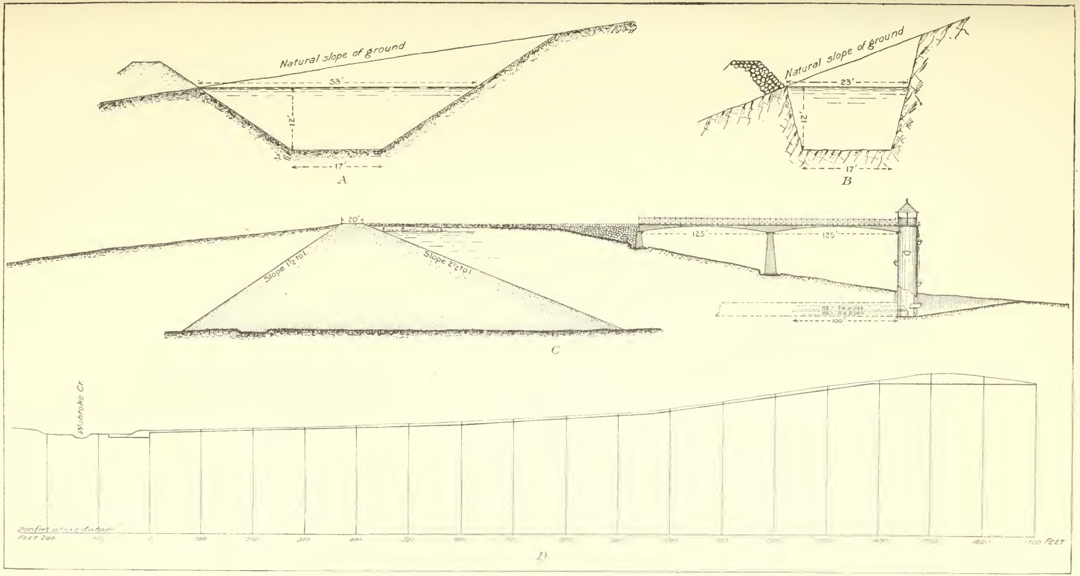
Spillway at dam No. 2.—This spillway will be 100 feet wide, with a capacity of 1,698 cubic feet per second and a depth of water of 3 feet. The cost will be as follows:

25,886 cubic yards of rock at $1	$25,88
16,650 cubic yards of earth at $0.25	4,16
Concrete walls and foundations in earth	24,72
Water cushion at foot of spillway	3,00
Total	57,78

The spillway will have to provide for floods in the local drainage basin (53 square miles) of Wahtoke Creek only. The area of the reservoir at the 100-foot level is 5,344 acres, and if there were no spillway it would require a flood of 2,672 second-feet for one day to raise the water level 1 foot. The top of the dam will be 5 feet above the spillway. The west end of dam No. 2 is shown in plan and section in Pl. XV, *A*, and a longitudinal section of the spillway in Pl. XIV, *D*.

Outlet tunnel, tower, gates, etc.—Pl. XV, *B*, shows a cross section and a longitudinal section of the outlet channel, and Pl. XIV, *C*, combined sections with tower. The cost of the outlet tunnel, tower, gates, etc., is as follows:

Outlet tunnel, 1,100 lineal feet, 10 feet by 12 feet clear section, cement lined, at $12		$13,20
Cutting approach to tower:		
1,381 cubic yards of rock at $1	$1,381	
2,762 cubic yards of earth at $0.25	690	
Cutting at discharge end of tunnel:		
741 cubic yards of rock at $1	741	
1,481 cubic yards of earth at $0.25	370	
		3,18
Concrete valve tower, 12 feet inside diameter and 85 feet high	3,352	
Concrete dam, 100 feet long, connecting tower with tunnel	2,782	
Four pipes through concrete dam, each 48 inches in diameter by 100 feet long, with gates attached, at $1,500	6,000	
Tower valves and appliances, seven at $500	3,500	
House on top of tower	500	
Concrete and iron footbridge to tower, two spans of 125 feet each	5,000	
Concrete and iron footbridge over spillway, 100 feet	2,000	
		23,13
Total		39,51



DETAILS OF PROPOSED RESERVOIR IN CLARKS VALLEY

A, Section of canal in earth and loose rock; *B*, section of canal in solid rock; *C*, combined sections, showing tower; *D*, longitudinal section of spillway.

Headworks on Kings River.—The estimated cost of diverting dam, sand box, gates, etc., is $25,000.

Summary of cost.—Summarizing, the cost of the works with large dam 105 feet high, storing 217,196 acre-feet, is as follows:

Dams Nos. 1, 2, and 3	$1,342,895
Inlet tunnel, or feed conduit	84,000
Cutting at each end of inlet tunnel	30,261
Canal between intake and tunnel approach	351,750
Spillway at dam No. 2	57,780
Outlet tunnel	13,200
Cutting at each end of outlet tunnel	3,182
Valve tower, gates, etc	23,134
Intake works on Kings River	25,000
Right of way	75,000
	2,006,202
Engineering and contingencies, 10 per cent	200,620
Total	2,206,822

The cost per acre-foot of water stored is $10.15.

Annual cost per acre-foot of water delivered.—Figuring the interest at 6 per cent of the cost of the works ($2,206,822), the taxes at eight-tenths of 1 per cent of the cost, and maintenance for the reservoir and diversion canal at $10,000 per annum, we have an annual charge against the plant of $160,064. We have found that the evaporation would amount to 3½ per cent of the entire storage capacity of the larger reservoir; but if we take the evaporation at 5 per cent and the seepage in the canal at 15 per cent we have 173,757 acre-feet available for delivery. This divided into the annual charge of $160,064 gives an annual cost per acre-foot of water delivered from the reservoir to the lands of $0.92.

85-FOOT DAM.

The following quantities are for a large dam 85 feet high, 20 feet wide on top, with a slope of 2½ to 1 on the upstream side and a slope of 1½ to 1 on the downstream side. The maximum depth of water will be 80 feet and the storage capacity 120,499 acre-feet.

Quantities of material for 85-foot dam and the two side structures.

Dam.	Length on crest.	Greatest depth.	Earth.
	Feet.	*Feet.*	*Cu. yds.*
No. 1	3,100	63	504,189
No. 2	8,640	85	3,085,171
No. 3	2,585	43	248,468
Total			3,837,828

At 20 cents per cubic yard the cost of the dams would be $767,566.

To fill the reservoir to the 80-foot level (120,499 acre-feet) a conduit with a capacity of at least 525 cubic feet per second would be required. The total length of the conduit from the headworks on Kings River to the reservoir would be 53,600 feet, divided the same as for the 105-foot dam, i. e., 7,000 feet of tunnel, 3,600 feet of cutting at entrance and exit of tunnel, and 43,000 feet of diversion canal.

Intake tunnel.—The feed tunnel will be of the same dimensions and grade and in the same location as for the 105-foot dam—7,000 lineal feet in solid rock, unlined, at $12 per lineal foot, $84,000, plus the cost of cutting at the entrances, $24,790. The elevation of the lower end of the inlet tunnel is fixed at 520 feet, the same as for the larger reservoir, so as to permit increasing the height of the dam in the future, if desired. The elevation of the intake is taken at 558.5 feet.

Diversion canal.—The canal will have a capacity of 525 cubic feet per second and a grade of 1.584 feet to the mile in earth and loose rock and 4.224 feet to the mile in solid rock section. The bottom width will be 10 feet and the cost as follows:

151,330 cubic yards of earth at $0.20	$30,266
30,840 cubic yards of rock at $1	30,840
166,140 cubic yards of loose rock at $0.50	83,070
Total	144,176

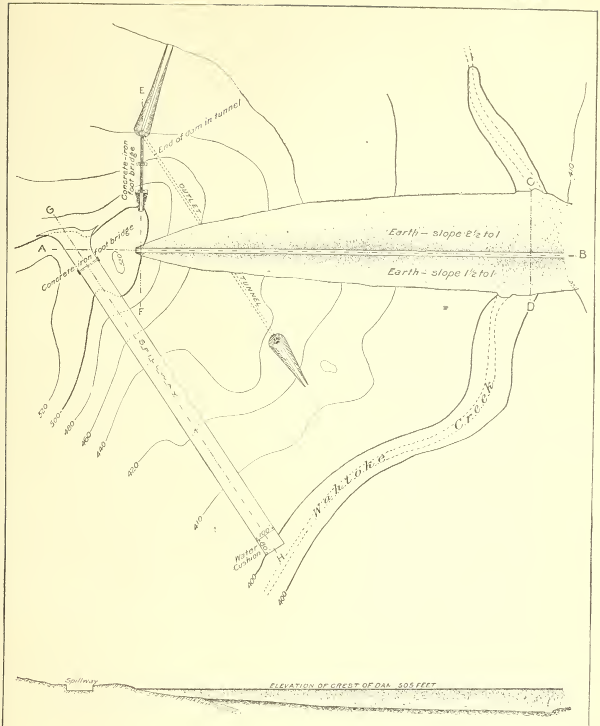
Spillway at dam No. 2.—The spillway will be 100 feet wide, with a capacity of 940 cubic feet per second and a depth of water of 2 feet. The cost will be as follows:

13,625 cubic yards of earth at $0.25	$3,406
27,251 cubic yards of rock at $1	27,251
Foundation in earth, 3,000 cubic yards at $0.50	1,500
Concrete in walls and bottom, 3,000 cubic yards at $6	18,000
Total	50,157

Outlet tunnel, tower, gates, etc.—The cost of the outlet tunnel and of cutting approach to tower and at discharge end of tunnel would be practically the same as for the 105-foot dam. The estimate of cost of tower, gates, etc., is as follows:

Concrete valve tower, 12 feet inside diameter and 85 feet high	$3,352
Concrete dam 100 feet long, connecting tower with tunnel	2,782
Four pipes through concrete dam, each 48 inches diameter by 100 feet long, with gates attached, at $1,500	6,000
Tower valves and appliances, seven at $500	3,500
House on top of tower	500
Concrete and iron footbridge to tower, two spans of 125 feet each	5,000
Concrete and iron footbridge over spillway, 100 feet	2,000
Total	23,134

Headworks on Kings River.—The estimated cost of diverting dam, sand box, gates, etc., is the same as for the 105-foot dam, viz, $25,000.



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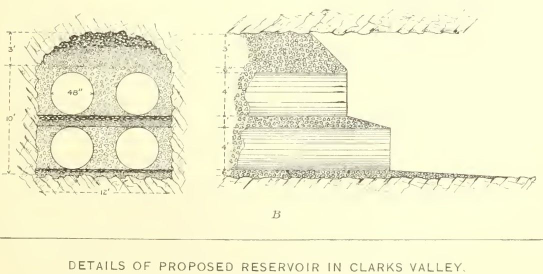


B

DETAILS OF PROPOSED RESERVOIR IN CLARKS VALLEY.

A, Plan and section of west end of dam No. 2; *B*, cross section and longitudinal section of outlet tunnel.

Summary of cost.—Summarizing, the cost of the works with large dam 85 feet high, storing 120,499 acre-feet, is as follows:

Dams Nos. 1, 2, and 3	$767,566
Feed tunnel	84,000
Cutting at each end of inlet tunnel	24,790
Diversion canal between intake and tunnel approach	144,176
Spillway at dam No. 2	50,157
Outlet tunnel	13,200
Cutting approaches at each end of outlet tunnel	3,000
Valve tower, gates, etc	23,134
Headworks on Kings River	25,000
Right of way	75,000
	1,210,023
Engineering and contingencies, 10 per cent	121,002
Total	1,331,025

The cost per acre-foot of water stored is $11.05.

Annual cost per acre-foot of water delivered.—Figuring the interest at 6 per cent of the cost of the works ($1,331,025), the taxes at eight-tenths of 1 per cent of the cost, and maintenance for the reservoir and diversion canal at $10,000 per annum, we have an annual charge against the plant of $100,510. We have found that the evaporation would amount to 4.7 per cent of the entire storage capacity of the reservoir, but if we take the evaporation and seepage at 20 per cent, as for the 105-foot dam, it would leave 96,399 acre-feet available for delivery. This divided into the annual charge of $100,510 gives an annual cost per acre-foot of water delivered from the reservoir of $1.04.

WATER SUPPLY.

Assuming the annual rainfall to be 20 inches over the 33 square miles of drainage area of Wahtoke Creek, and the run-off to be 12 per cent, we have 4,224 acre-feet. The storage capacity of the 105-foot dam is 217,196 acre-feet. This, less the 4,224 acre-feet from rainfall in the local drainage basin, gives 212,972 acre-feet of water to be brought by diversion conduit from Kings River. In order to determine whether a canal with a capacity of 1,250 second-feet would fill the reservoir, the following assumptions have been made:

(1) That all of the water in Kings River up to the capacity of the canal (1,250 second-feet) can be diverted during the months of November, December, January, and February.

(2) That the combined capacity of the canals diverting water from the river during the remaining months is 4,000 second-feet, and the surplus above that amount is available, to 5,250 second-feet, for storage.

The following statement, based on the daily discharge of the river at the Red Mountain gaging station of the United States Geological Survey, which is practically at the proposed point of diversion, shows the amounts of water which could have been diverted with a dam 105 feet high and a canal of 1,250 second-feet capacity, under the fore-going conditions.

Available water supply, in acre-feet, of Clarks Valley reservoir site with 105-foot dam

Month.	Season 1895-96.	Season 1896-97.	Season 1897-98.	Season 1898-99.	Season 1899-1900.
November	20,838	31,989	36,935	13,741	37,87
December	20,067	30,591	45,438	18,929	48,23
January	47,742	26,841	31,312	31,395	66,48
February	47,398	67,855	39,105	36,575	41,49
March	3,663	808		5,444	
April	3,564	44,368	25,404	39,497	
May	30,393	76,725	12,474	8,890	46,18
June	74,072	38,662		47,144	41,71
July	26,758	79			
Total	274,495	317,918	190,668	201,595	281,99

[a] The season of 1900-01 was one of abundant supply.

Taking the season of least available flow (1897-98) we have 190,66[illegible] acre-feet. If we add to this the amount of water available from th[e] local drainage basin (4,224 acre-feet) we have a total of 194,892. Thi[s] is 22,304 acre-feet, or 9½ per cent, less than the maximum capacity of th[e] reservoir for a year of extreme drought, which is not likely to occur bu[t] once in ten years. For the season of 1898-99 the amounts would b[e] 201,595 acre-feet from the river and 4,224 acre-feet of rainfall stored, giving a total of 205,819 acre-feet, or 11,377 acre-feet less than th[e] maximum storage capacity. That year also was one of drought. Fo[r] the remaining three seasons of observation the flow is more than suf-ficient. The rainfall records at Fresno indicate the last five years t[o] have been the driest observed since 1877, and it is believed that the[y] may be accepted as a minimum.

In connection with the foregoing figures there is an important poin[t] to be considered, viz: If the people who now are using the flow of th[e] river in March and October to flood their lands could be assured of [a] sufficient quantity of water later in the season, part of the flow of th[e] river for those months could be diverted to the reservoir, and thu[s] the reservoir be filled to its maximum capacity each year. The follow-ing table shows the quantities of water that could have been diverte[d] from Kings River by a canal of maximum capacity of 525 second-fee[t] and an 85-foot dam, under conditions similar to those prevailing fo[r] the 105-foot dam:

Available water supply, in acre-feet, of Clarks Valley reservoir site with 85-foot dam

Month.	Season 1895-96.	Season 1896-97.	Season 1897-98.	Season 1898-99.	Season 1899-190[0].
November	19,394	28,403	28,086	13,741	28,8[illegible]
December	20,067	30,444	32,224	17,494	30,8[illegible]
January	28,185	26,552	30,650	28,225	32,2[illegible]
February	30,145	29,106	28,819	28,453	29,1[illegible]
March	2,079	808		2,673	
April	3,118	20,638	12,929	18,572	
May	18,711	32,224	6,049	7,286	20,3[illegible]
June	31,185	16,632		22,879	21,2[illegible]
July	12,432	79			
Total	165,316	184,886	138,757	139,323	162,5[illegible]

Using the season of minimum observed flow (1897–98) we have 138,757 acre-feet available flow from the river, which with the 4,224 acre-feet from the local basin gives a total of 142,981 acre-feet, or 22,482 acre-feet more than the maximum storage capacity of the reservoir.

If the Pine Flat and the Clarks Valley dams are both built the following tables will show the available supply. These tables (determined by planimeter from the diagrams of stream flow) are based (1) upon a diversion by the irrigation canals of water to their full capacity, viz, 4,000 second-feet, from March 1 to October 31, and (2) upon the fact that with the regulating reservoir at Pine Flat the Clarks Valley reservoir could have been completely filled, to either the 100-foot or the 80-foot level, each year.

The entire capacity of the Clarks Valley reservoir less the supply from the local drainage basin (4,224 acre-feet) is therefore also deducted from the seasonal flow of the river each year. All of the water remaining in the river is considered available for storage at Pine Flat. It is reasonably certain that both reservoirs would have been completely filled during the five-year period of observation by the State engineering department, i. e., 1878 to 1883. It must be remembered that the ten years for which we have records were below the average in rainfall and run-off. The year 1897–98 may be taken as the minimum of a ten-year period of low rainfall. The season of 1900–1901 is now (June 1, 1901) far enough advanced to show that the supply for this year would have been more than ample to fill both reservoirs. The table shows that with the larger dam at Clarks Valley (the 105-foot) there would have been one year out of the eleven that the Pine Flat reservoir could not have been filled.

Available water supply, in acre-feet, for 140-foot dam at Pine Flat reservoir site with 105-foot dam at Clarks Valley reservoir site.

Season Nov. 1 to Oct. 31.	Total discharge of river.	Clarks Valley diversion.	Irrigation diversion Mar. 1 to Oct. 31.	Available for Pine Flat reservoir (capacity, 78,197 acre-feet).
1895-96	1,852,425	212,972	936,749	703,704
1896-97	2,088,924	212,972	1,029,845	846,107
1897-98	876,079	212,972	656,302	6,805
1898-99	1,227,217	212,972	893,959	120,286
1899-1900	1,281,051	212,972	817,631	250,448
Five-year mean	1,465,139	212,972	866,897	385,470

The foregoing table shows the possibility of having used 79 per cent of the average flow of Kings River during the last five years.

Available water supply, in acre-feet, for 140-foot dam at Pine Flat reservoir site with 85-foot dam at Clarks Valley reservoir site.

Season Nov. 1 to Oct. 31.	Total discharge of river.	Clarks Valley diversion.	Irrigation diversion Mar. 1 to Oct. 31.	Available for Pine Flat reservoir (capacity, 78,197 acre-feet).
1895-96	1,852,425	116,275	936,749	800,401
1896-97	2,088,924	116,275	1,029,845	942,804
1897-98	876,079	116,275	656,302	103,502
1898-99	1,227,217	116,275	893,959	216,983
1899-1900	1,281,051	116,275	817,631	347,145
Five-year mean	1,465,139	116,275	866,897	482,167

The foregoing table shows that both reservoirs could have been filled every year during the period given.

Normally the reservoir at Clarks Valley, as previously stated, would be full at the end of June and empty at the end of September. The period during which evaporation will have to be considered is the months of July, August, and September. The evaporation observations given herein show that the mean evaporation during those months is 1.89 feet each year. The total storage capacity of the reservoir at the 100-foot level is 217,196 acre-feet; the area at the 100-foot level is 5,344 acres and at the 80-foot level 4,325 acres. For the purpose of this estimate the average area for the larger reservoir exposed to evaporation may be considered as 4,000 acres, losing in depth 1.89 feet each year, or 7,560 acre-feet, which is 3½ per cent of the total storage capacity of the reservoir. With the smaller dam the evaporation would amount to 4.7 per cent, or 5,670 acre-feet.

SPILLWAY.

The Clarks Valley reservoir will be almost entirely free from attacks of floods, as the local drainage basin contains only 33 square miles, and its annual discharge will probably be equal to a depth of about 1 foot in the reservoir at the 100-foot level. The diversion canal, having a capacity of 1,250 second-feet, or 2,500 acre-feet, per day, would require two days' flow to raise the water in the reservoir 1 foot in height when it stands at the 100-foot level. The capacity of the outlet from the reservoir will be 1,280 cubic feet per second (greater than that of the intake), with 10 feet head on the valves. This will be in addition to the capacity of the spillway.

The months during which the maximum amount of water is available for storage from Kings River are May and June. This is after the expiration of the rainy season, and it will be the discharge of the diversion canal during these two months that will finally fill the reservoir each year. Since 1877 the greatest rainfall that has occurred in May was 1.97 inches, in 1900. On this basis the water that fell in the local drainage basin of Wahtoke Creek would amount to 3,380 acre-feet. The area of the reservoir at the 100-foot level is 5,344 acres.

Since 1877 there have been only three occasions when rain has fallen at Fresno during the month of June, the greatest precipitation for that month being 1.29 inches, in 1884. It is therefore reasonable to assume that during the time the reservoir is full the local drainage basin can never deliver a volume of water sufficient to raise the level of a full reservoir more than 1 foot, even if the discharge gate and the spillway are both closed. It is proposed to make the elevation of the spillway 7 feet below the top of the dam and to maintain the water in the reservoir at that height during the entire rainy season. After the expiration of the rainy season—say the first of June—it would be safe to place flashboards in the spillway, so as to store 2 feet more of water. This would bring the water to the maximum depth of 100 feet, would add about 10,000 acre-feet to the storage capacity, and would still leave the top of the reservoir 5 feet above the level of the water. If it should be considered desirable to increase the interval between the water level and the top of the dam it could most economically be done by increasing the height of the dam 2 or 3 feet on slopes of $1\frac{1}{2}$ to 1 on each side. It will be remembered that there probably would not be more than two weeks intervening between the complete filling of the reservoir and the beginning of the discharge from it.

A longitudinal section of the spillway proposed is shown in Pl. XIV, *D*.

RESERVOIR SURVEYS.

On June 19 the party reported at Sanger, Fresno County, on the Southern Pacific Railroad, where camp equipment was received. A pack train of 5 mules and 4 saddle horses was purchased in the neighborhood, at an average cost of $40 per animal. The party, which was in charge of Mr. H. E. Green, consisted of a topographer, two rodmen, a packer, and a cook. After July 12 one rodman was dispensed with, reducing the party to four.

On June 22 the party left Sanger, at an elevation of 370 feet, and started for Millwood. Following the county road and crossing to the south of Kings River near Centerville, the foothills were reached about 16 miles from Sanger, the road traversing the lower Clarks Valley reservoir site. From Clarks Valley to Millwood the road ascends 4,710 feet in a distance of 30 miles, the elevation of Millwood being 5,210 feet, aneroid measurement. From Millwood the party went into camp at Long Meadow, where the first survey work was done on the Long Meadow reservoir site.

LONG MEADOW.

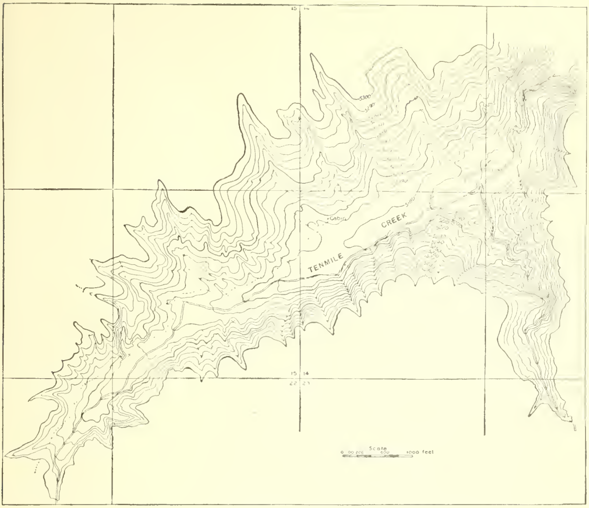
Long Meadow can be reached in 11 miles from Millwood by takin the Sanger Lumber Company's wagon road to their sawmill, a distanc of 6 miles, and then following the trail for 5 miles, crossing the divid at an elevation of 6,770 feet; or it can be reached without surmoun ing such an elevation by keeping the wagon road via the sawmill t Converse Meadow, 12 miles distant and at an elevation of 5,900 fee and following the trail for 2 miles across the low divide separatin Converse Meadow from Long Meadow.

Long Meadow, which is at an elevation of 5,200 feet, is on Tenmi Creek, about 4 miles above its junction with Kings River, which junc tion is less than a quarter of a mile west of the junction of the Midd and South forks of the river. The reservoir and dam sites are in sec 14, 15, 22, and 23, T. 13 S., R. 28 E., Mount Diablo base and meridian The land is owned by the Sanger Lumber Company and is well tim bered with pine. The dam site is in the northeast quarter of sec. 14 T. 13 S., R. 28 E. The average elevation of the watershed of th meadow or valley is 7,000 feet above sea level, and the supply o water will be largely from melting snow in the spring. Contour map of the reservoir and dam sites are shown in Pl. XVI.

The drainage area tributary to Long Meadow is estimated at 2 square miles. The estimated mean rainfall is 45.3 inches, making th run-off per square mile 900 acre-feet, or $900 \times 25 = 22,500$ acre-feet pe year. If we assume a rainfall of 40 inches and a run-off of 50 pe cent the average yield would be 26,560 acre-feet per year; or if w assume 2 second-feet run-off per square mile we have 50 second-fee or 100 acre-feet, per day, which is equal to 36,500 acre-feet per yea The capacity of the reservoir with a dam 170 feet high is 25,334 acre feet.

Owing to the heavy grade to be surmounted in hauling materia from the Southern Pacific Railroad at Sanger via Millwood, which the shortest approach, a loose rock-fill dam with plank face is con sidered the most economical. Freight from Sanger to Millwood (4 miles) costs $9 per ton of 2,000 pounds, or 45 cents per hundred pounds From Millwood freight would go, by the mill road already mentioned 12 miles to Converse Meadow, elevation 5,900 feet. From there road would have to be graded over the low divide separating Con verse Meadow from Long Meadow. This can be done, with easy grad ents, at an estimated length of 4 miles. The proposed method o building the dam is by the use of two Lidgerwood cables, one on th axis of the dam, with traveling towers, and the other crossing th dam, working two quarries, one above and one below the dam site.

The bed rock at the proposed dam site is granite, solid and bare i the creek bed but seamy on the north side of the canyon. It is i



A. CONTOUR MAP OF LONG MEADOW RESERVOIR SITE.

B. CONTOUR MAP OF LONG MEADOW DAM SITE.

strata from 5 to 10 feet thick, with a dip to the south of about 30 degrees. The south side of the canyon will require stripping, probably 8 or 10 feet. It was impossible to carry tools to determine the depth to bed rock, and the estimate of the amount of stripping required is obtained from surface indications. A view of the dam site on the north side of the creek is shown in Pl. XVII, *A*.

Data regarding Long Meadow dam.

Elevation at base of dam	feet	5,130
Elevation of floor of wasteway	do	5,290
Elevation of crest of dam	do	5,300
Elevation of outlet	do	5,150
Height of dam	do	170
Drainage area	square miles	25
Run-off, estimated	acre-feet	22,500
Capacity of reservoir below wasteway	do	25,334
Capacity of reservoir at crest level	do	30,033

Following is the preliminary estimate of cost:

Estimate of cost of loose rock-fill dam at Long Meadow.

Loose rock, 673,000 cubic yards at $0.75	$504,750
Plank face, area 144,800 square feet:	
Two layers of 3-inch plank on lower half of face, 324,000 feet, B. M., at $30	9,720
Two layers of 2-inch plank on upper half of face, 360,000 feet, B. M., at $30	10,800
Sills, 12 inches by 12 inches, spaced 4 feet between centers, equal to a layer of 3-inch timber over entire surface, 432,000 feet, B. M., at $30	12,960
Labor on plank face	6,000
Wasteway, 50-foot bottom width, slopes ¼ to 1, 6 feet depth of water, capacity 2,400 second-feet, length 400 feet, lined with cement:	
Excavation, 15,000 cubic yards of rock at $1	15,000
Cement lining, 3,000 square yards (200 barrels of cement at $8, $1,600; labor, 3,000 square yards at $0.10, $300)	1,900
Outlet tunnel in solid rock, cement lined, 4 feet by 6 feet, arched top and bottom, 500 lineal feet at $10	5,000
Tower, including house and bridge, valves, gates, etc	8,000
Machinery and cable (75-horsepower engine, 2½-inch cable, two traveling towers to handle 10 tons)	26,000
Road from Converse Meadow to Long Meadow (4 miles) and to cable towers and around works (2 miles), 6 miles at $3,000	18,000
Clearing reservoir, 500 acres at $5	2,500
	620,630
Engineering and contingencies, 15 per cent	93,085
Total	713,715

The cost per acre-foot of water stored is $28. Plan, elevation, and maximum cross section of the proposed dam are shown in Pl. XVIII.

The cost of a concrete dam at this site would be much greater than that of a rock-fill dam. The estimate is as follows:

Estimate of cost of concrete dam at Long Meadow.

171,000 cubic yards of masonry at $10	$1,710,000
Wasteway, 50 feet by 10 feet	16,900
Outlet tunnel, 4 feet by 6 feet	5,000
Tower, etc	8,000
Machinery and cable	26,000
Roads	18,000
Clearing reservoir	2,500
	1,786,400
Engineering and contingencies	100,000
Total	1,886,400

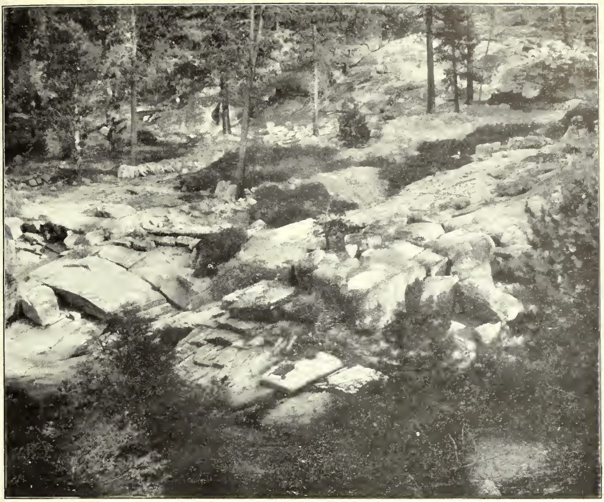
With a concrete dam the cost per acre-foot of water stored is $74, against $28 with a loose rock-fill dam.

EAST LAKE.

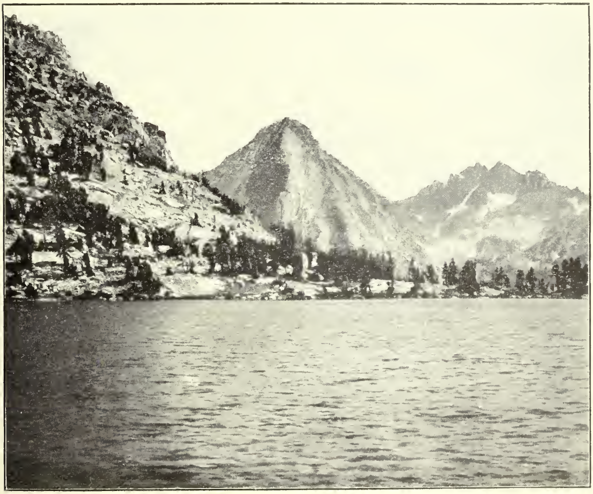
From Long Meadow the party moved to East Lake, where the next survey work was done in July. This lake is about 2 miles up the South Fork of Bubbs Creek, which is about 5 miles above the junction of Bubbs Creek with the South Fork of Kings River. The best way to reach the lake is by way of Millwood and Long Meadow, though it can be reached by a shorter route by packing from Independence, Inyo County, by way of Kearsarge Pass.

Starting with Long Meadow as a base (elevation 5,200 feet) the trail goes first to Bearskin Meadow, 5 miles distant and at an elevation of 6,000 feet; then to Horse Corral Meadow, 20 miles distant and at an elevation of 7,820 feet; then to Summit Meadow (overlooking Kings River Canyon), 23 miles distant and at an elevation of 8,150 feet; then to Kings River Canyon, 28 miles distant and at an elevation of 5,000 feet, a descent of more than 3,000 feet in 5 miles. About a mile upstream from the foot of this trail and approximately 12 miles above the junction with the Middle Fork of Kings River, is the log building known as the hotel and a sheep bridge across Kings River. The trail then leads up the South Fork of Kings River to Bubbs Creek, 37 miles distant and at an elevation of 5,370 feet, where the river makes a sharp bend to the north; then up Bubbs Creek to its south fork, 49 miles distant and at an elevation of 8,120 feet; up the South Fork of Bubbs Creek to East Lake, 52 miles from Long Meadow and 63 miles from Millwood, at an elevation of 9,350 feet. From where the trail enters Bubbs Creek it is very steep and rocky, and the 3 miles of it along the south fork of that creek would require a great deal of work to make it passable as a freight trail.

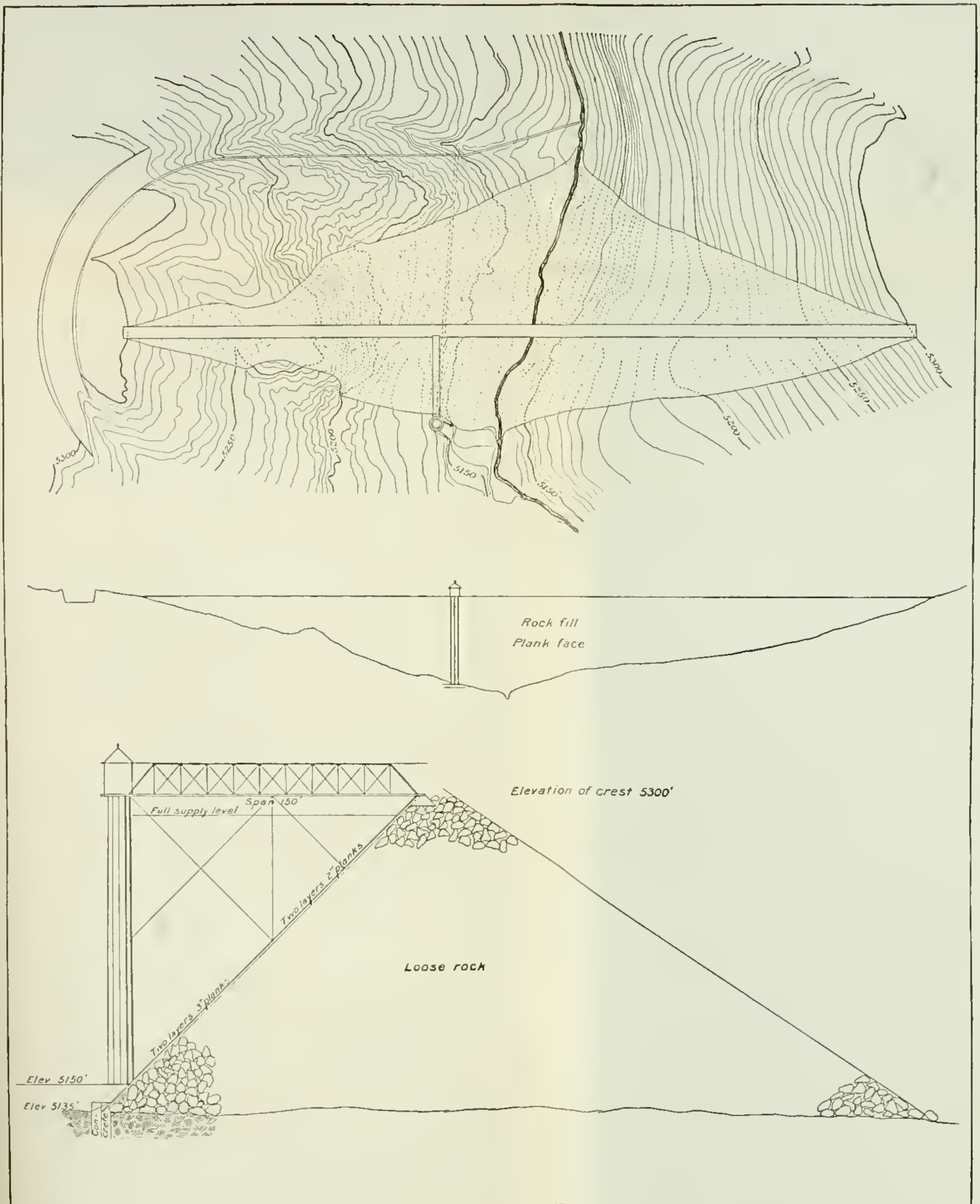
At East Lake the country in all directions is rugged and bare (see Pl. XVII, *B*), being near the limit of the timber line. Only a thin



A. LONG MEADOW DAM SITE.



B. EAST LAKE RESERVOIR SITE.



PLAN, ELEVATION, AND MAXIMUM CROSS SECTION OF PROPOSED LONG MEADOW RESERVOIR DAM scattering of tamaracks is to be seen. At the time of the survey (July) considerable snow was still lying on the northern slopes and was feeding the South Fork of Bubbs Creek and its numerous lakes, which make this locality very picturesque.

About 2½ miles above East Lake is Reflection Lake (see Pl. XXI, *A*), which has a water surface of about 30 acres. It is a deep body of water between high, precipitous walls, and is at an elevation of 10,000 feet. Above Reflection Lake, at an elevation of 11,000 feet, are numerous small lakes of from 1 to 3 acres area, all perfectly calm, and reflecting the surroundings as in mirrors. Monuments were found at East Lake which showed that the California State engineering department had made a survey there. A topographic survey was made, under the direction of Mr. Green, with the following results:

East Lake is formed by an immense slide or moraine from Ouzel Creek Canyon on the west, which has dammed the South Fork of Bubbs Creek at that point. The creek formed a lake behind this moraine until it overflowed and washed out the channel where the dam would be located, but the bed of the channel is probably 50 or 60 feet above the old channel bottom, and the mass beneath and to the west is formed of huge blocks of granite embedded in granite débris. That it is not water-tight is proved by the fact that several small streams, caused by melting snow on the solid rock cliffs above the moraine, disappear at the contact of the moraine and appear as springs on the slope immediately above the lake.

There was a stream of water, estimated at 10 second-feet, flowing out of East Lake at the end of July, 1900. A weir dam which would raise the water 70 feet above the lake level would bring enough pressure to bear on the moraine to cause considerable leakage, but it could not wash out, there being too much rock in it, and there is the possibility that it might silt tight.

The area of the watershed tributary to East Lake is estimated at 12 square miles; the average elevation is 11,000 feet. The capacity of a reservoir raised 70 feet above the lake level, which was 9,350 feet at the time of the survey in July, would be 4,154 acre-feet. The lake itself could be utilized to some extent by deepening its mouth so as to permit of an outlet tunnel or pipe being placed low enough to draw off 30 or 40 feet of the water. This would add perhaps 400 acre-feet to the capacity of the reservoir. In like manner Reflection Lake could be utilized, and would yield probably 700 acre-feet additional, making a total of 5,250 acre-feet. No estimate has been made of the cost of a dam, because of the remoteness and inaccessibility of the locality, the cost of transporting material rendering such a project expensive to a degree out of all proportion to the limited capacity of the reservoir. There is no timber available with which to face the dam, and cement would cost from $15 to $20 a barrel delivered. A contour map of the East Lake reservoir site is shown in Pl. XIX.

While the camp was at East Lake a visit was made to Bull Frog Lake, on the north side of Bubbs Creek, about 4 miles east of the south fork of that creek and close to the summit of Kearsarge Pass. On examination no dam site was found and the area of the lake was ascertained to be so small as not to warrant any topographic work. The elevation of the lake is 10,600 feet; the elevation of Kearsarge Pass, 3 miles east of the lake, is 12,000 feet. The drainage area of the lake is about 5 square miles.

GRANITE BASIN.

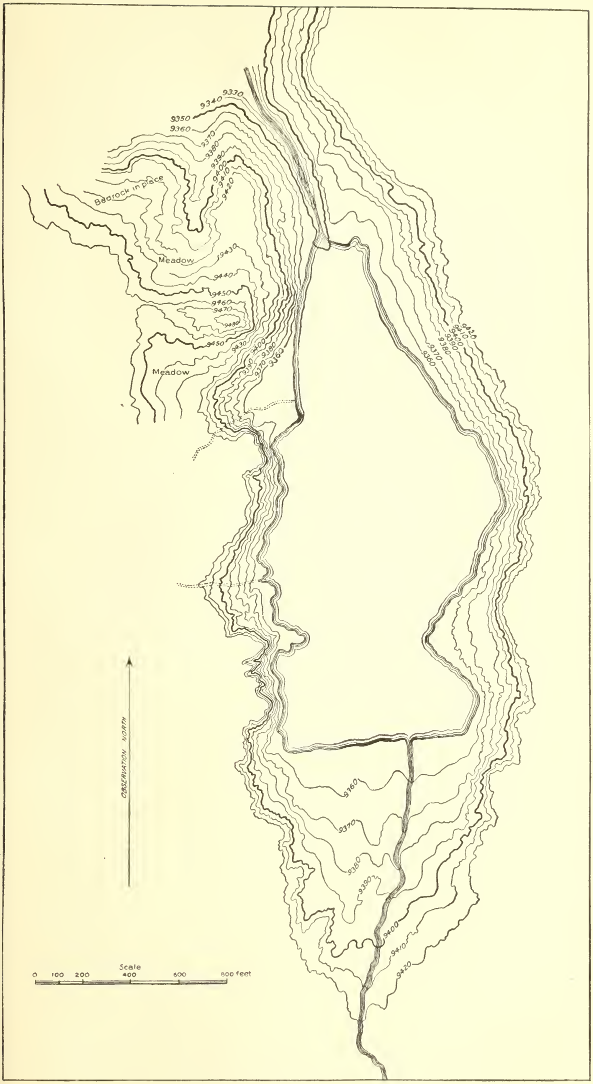
Granite Basin was the next place examined. It is on Granite Creek, at the summit of the divide between Kings River Canyon on the South Fork and the Middle Fork of Kings River. It is reached by trail from Kings River Canyon. Starting at Kanawyer's cabin, elevation 5,200 feet, the trail ascends the steep spur on the west side of Copper Creek, follows Copper Creek for about 7 miles, and crosses the divide at an elevation of 10,300 feet into Granite Creek on the west, 10 miles from Kings River Canyon and at an elevation of 10,000 feet. A contour map of the reservoir site is shown in Pl. XX and a view of the site in Pl. XXI, *B*.

There are two outlets, divided by a butte. The outlet to the northwest would require a dam 750 feet long at the crest and 140 feet high; the outlet to the southeast of the butte would require a dam 900 feet long on the crest and 130 feet high to raise water to the plane of the 10,000-foot contour. A view of one of the outlets is shown in Pl. XXII, *A*. The area within the 10,000-foot contour is 144 acres and the capacity of the reservoir 10,350 acre-feet.

The drainage area tributary to Granite Basin does not exceed 6 square miles and averages 10,800 feet in elevation. There is a sparse growth of tamarack scattered over the basin, the whole of which, however, is practically bare and barren. The bed rock is granite. The capacity of the reservoir compared with the cost of the two large dams necessary to create it and the difficulty of access render the project impracticable.

ELECTRIC-POWER DEVELOPMENT.

In a study of the various irrigation possibilities of Kings River it was deemed advisable to investigate the water power obtainable for the purpose of generating electric energy for transmission to local pumping plants in the valley. This requires an investigation of three distinct phases of the problem: (1) The available power; (2) the available ground-water supply for pumping at or near the irrigated lands; and (3) the generation and transmission of electric power and the installation of pumping plants. The subject will be treated in that order. Mr. H. E. Green was detailed to investigate the water power, Mr. Louis Mesmer the water supply for pumping, and Mr. Lewis A. Hicks the power transmission and pumping plants.



CONTOUR MAP OF EAST LAKE RESERVOIR SITE.

CONTOUR MAP OF GRANITE BASIN RESERVOIR SITE.

POWER POSSIBILITIES.

From Granite Basin the trail passes over a nude and rugged granite country until it drops suddenly into the beautiful Middle Fork Canyon (see Pl. XXII, *B*), at Simpson Meadows, 10 miles from Granite Basin and at an elevation of 6,000 feet. Tehipiti Valley is about 15 miles down the canyon from Simpson Meadows, but the canyon is practically impassable, so the party went by way of Collins Meadow.

Leaving the Middle Fork, elevation 6,000 feet, the trail ascends the West Branch of Goddard Creek and in a distance of 4 miles climbs nearly 5,000 feet up a hard, rocky mountain, with only one bench on which to rest animals and adjust packs. From the top of the ridge, elevation 10,600 feet, a magnificent view is obtained of the country to the south and east across the South Fork of Kings River and Bubbs Creek to the watershed between Kings and Kern rivers. The trail then follows easy country to Collins Meadow, 30 miles from Simpson Meadows, elevation 7,600 feet. Coming from Fresno by way of Ockenden this point is the natural entrance to Tehipiti Valley. From Ockenden there is a wagon road for 15 miles, to Russel's camp, southeast of that place. From Russel's camp the trail follows undulating and pine-covered country presenting easy grades for a continuation of the wagon road toward the North Fork of Kings River. The trail reaches the North Fork at Cliff camp, about 15 miles from Russel's camp and about 3 miles below the Dusy Meadows dam site. The trail to Dusy Meadows branches off about 3 miles before reaching the North Fork.

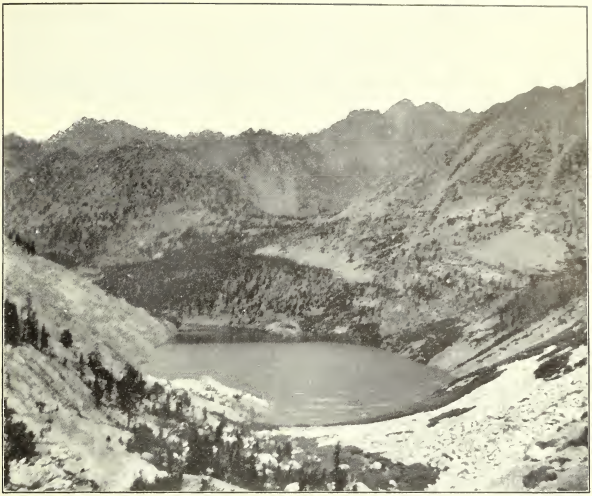
There is a good bridge site at the North Fork crossing, where the stream is confined between perpendicular walls of granite about 70 feet apart. (See Pl. X.) From the North Fork crossing the trail continues over rolling ground covered with pine and traverses many open glades which have good feed in the spring of the year. Collins Meadow is reached at a distance of 10 miles from the North Fork. From that meadow the trail to Tehipiti Valley turns south and follows easily along a sloping bench between the saw-tooth Tombstone Ridge on the west and Crown Creek, to the head of the steep descent (2,500 feet in 3 miles) to Tehipiti Basin. The elevation at the top of this steep trail is 6,500 feet and at the bottom 3,950 feet. At the junction of Crown Creek with the Middle Fork, in Tehipiti Valley, and dividing the two creeks, rises sheer from the bottom of the basin, 3,350 feet in elevation, the remarkable Tehipiti Dome.

A survey of the basin was made with enough detail to give roughly the capacity of a reservoir with a dam 150 feet high. The area of the reservoir would be 218 acres and the capacity 10,000 acre-feet. The dam would be 1,000 feet long on its crest. On the west side the material is all loose, being a talus from a high cliff. On the east side some bed rock is visible where a spring torrent has washed out a channel, but there is no really good dam site. On August 26 the river was measured at a favorable place in the valley and 153 second-feet were recorded.

Having connected the survey with Tehipiti Dome a traverse line was run down the Middle Fork Canyon toward the South Fork junction, to ascertain the fall that would be available for power development. (See profile of river, Pl. XXIII.) The canyon is a difficult one to traverse, and without a very expensive trail the traverse would have been impossible had the water in the river not been low enough to permit the continual crossing and recrossing of the stream. Five miles of the canyon were traversed from the camp at Tehipiti, and this being the limit of walking distance for a day's work, and the junction not being in sight, the camp was moved, by way of the North Fork and the main river, to the junction. A typical view of the canyon of Kings River near the junction of the South and Middle forks is shown in Pl. XXIV, *B*. Pl. XXIV, *A*, is a view looking up the Middle Fork, and shows in the foreground its junction with the South Fork.

Leaving Tehipiti the trail by way of Collins Meadow (elevation 7,600 feet) and Garlic Meadows (elevation 8,000 feet) was taken to the mouth of the North Fork of Kings River (elevation 800 feet), a distance from Tehipiti of 35 miles. By this time the pack animals were in very poor condition from scarcity of feed, owing to the repeated dry seasons, and forage had to be carried up Kings River during all subsequent work. On September 13 the party started a traverse up Kings River from the mouth of Mill Flat Creek, where the Sanger Lumber Company's flume enters the canyon (elevation 880 feet), to the junction of the Middle and South forks, a distance of 14 miles by traverse line and estimated to be 30 miles by trail. The elevation at the junction was found to be 1,950 feet. The junction of the Middle and South forks was reached October 8, after an arduous trip, for a great deal of brush-cutting and considerable pick and shovel work had to be done to get the animals safely over bad places.

The Middle Fork work was continued from 5 miles below Tehipiti and was joined to the main river survey. A traverse line was then started with a view to ascertaining the distance and grade of the South Fork Canyon up to the "hotel." This survey, however, was prevented by an impassable canyon 2½ miles above the junction, and it being near the end of October further exploration work was postponed. On October 20 the river was measured below the junction of the Middle and South forks and a flow of 346 second-feet was recorded. The traverse of the main river developed the fact that from the junction of the Middle and South forks the grade for 14 miles down the river, or to the mouth of Mill Flat Creek, averages 76.4 feet to the mile. For 3 miles below the junction the grade is only 72 feet to the mile. It then increases to a maximum of 103 feet per mile, gradually



A. REFLECTION LAKE.

B. GRANITE BASIN RESERVOIR SITE.

A. OUTLET OF GRANITE BASIN RESERVOIR SITE.

B CANYON OF MIDDLE FORK ABOVE TEHIPITI BASIN.

lessening, until above Mill Flat Creek for 3 miles it averages 54 feet per mile.

The survey of the South Fork was not finished, but the work that was done warrants the belief that as good a power plant can be developed there as on the Middle Fork. For this reason the site for the power house was chosen on the peninsula between the Middle and South forks (see Pl. XXV), so that either or both could be used. A conduit from the South Fork brought down the North Fork side of the canyon could be taken to the same penstock, if necessary, as the Middle Fork conduit. In any event the site proposed for the power house is in the most advantageous position to utilize water power from both forks. A preliminary estimate was made of the cost of a conduit to carry sufficient water out of the Middle Fork to generate 6,500 horsepower at the junction of the Middle and South forks. The estimate embraces the necessary works from the intake to the penstock. The location on the Middle Fork was selected because of the heavy fall of the stream at that point. The works would be in the canyon of the Middle Fork and would be reached by way of Millwood and the Sanger Lumber Company's road, already described, which runs to within 6 miles of the junction of the Middle and South forks. The descent in those 6 miles is about 3,000 feet, and will require a 10-per cent graded road. To reach the site of the proposed power house a bridge will be necessary across the South Fork and 6 miles of trails will be needed up the canyon of the Middle Fork and around the works. The intake or headworks would be between 3 miles and 3½ miles up the Middle Fork, whence the water will be conveyed in a series of short tunnels with a maximum single length of 1,500 feet. The tunnels will be in granite, unlined, and 6 feet by 6 feet in the clear. Adits in canyons will be arched over, allowing storm water a clear way. This form of construction is not only of a permanent nature, but it requires the minimum hauling of material and supplies into the canyon.

Following is the estimate of cost:

Cost of conduit out of Middle Fork.

Road into canyon, 6 miles at $8,500	$51,000
Bridge across South Fork	2,500
Trails in canyon of Middle Fork, 6 miles at $500	3,000
Tunnels (Burleigh drill work), 14,000 feet at $12	168,000
Headworks, including masonry diverting dam, shaft for inlet, tower, entrance gate, screen, etc	5,000
Adits to tunnels, 14 at $500	7,000
	236,500
Engineering and contingencies, 15 per cent	35,475
Total	271,975

The elevation of the intake would be 2,700 feet, the elevation of the penstock 2,660 feet, and the elevation of the power house 1,980 feet. The available head is 650 feet. The estimated mean minimum horsepower equals

$$\frac{\overset{\text{h.}}{650}\times\overset{\text{s.-f.}}{100}\times\overset{\text{lbs.}}{62.5}}{550}, \text{ or } \frac{650\times100}{8.8}, = 7{,}386.$$

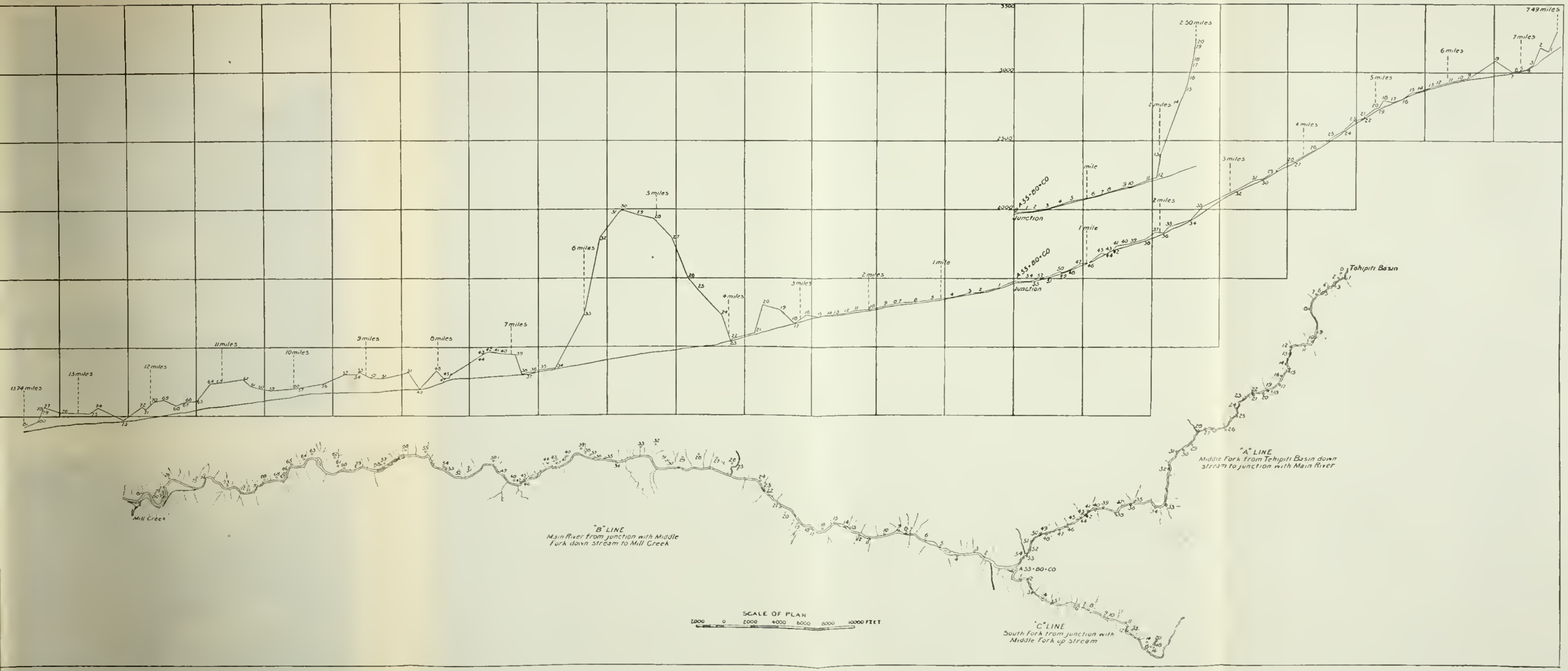
With 150 second-feet passing through the tunnel the horsepower equals

$$\frac{650\times150}{8.8} = 11{,}000.$$

With 180 second-feet passing through the tunnel the horsepower equals

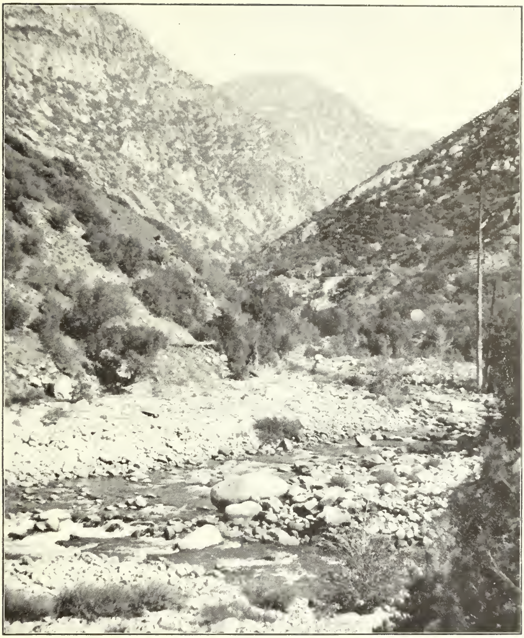
$$\frac{650\times180}{8.8} = 13{,}300.$$

During the late summer, when Kings River is at its minimum stage, practically all of its water is coming from the higher mountains drained by the Middle and South forks. In dry years the North Fork delivers in September about 10 second-feet, which is perhaps enough to make good the loss by evaporation in the main river from the junction to the Red Mountain gaging station. It is believed that there is as much water at the junction as at Red Mountain. Observations on the main river at Red Mountain covering the months of July, August, and September of the years 1896 to 1900, inclusive, indicate that had the proposed tunnel conduit been in operation during that time it could have been filled to its maximum capacity of 180 second-feet during the whole of the month of July of each year. During the whole of August of the same years the tunnel could have been supplied with 100 second-feet of water, and for 75 per cent of the time it could have had 150 second-feet. During September of the same years a supply of 100 second-feet could have been obtained three-fifths of the



PROFILE AND PLAN OF KINGS RIVER CANYON.

The upper irregular line of the profile is profile of the line of survey; the lower line is the profile of the river.



A. MIDDLE FORK OF KINGS RIVER ABOVE JUNCTION OF SOUTH FORK.

B. KINGS RIVER CANYON.

time and an average of 85 second-feet during the remaining two-fifths of the time—the exceptionally dry years of 1898 and 1899. With 650 feet head the 85 second-feet would yield

$$\frac{\overset{\text{h.}}{650} \times \overset{\text{s.-f.}}{85}}{8.8} = 6{,}250 \text{ horsepower.}$$

This means that during every month of each of the foregoing years, excepting the two months of August and September, the conduit could have carried its maximum capacity of 180 second-feet.

Careful measurements should be made of the Middle and South forks to determine their respective volumes of flow before construction is attempted.

GROUND WATER OF KINGS RIVER DELTA.

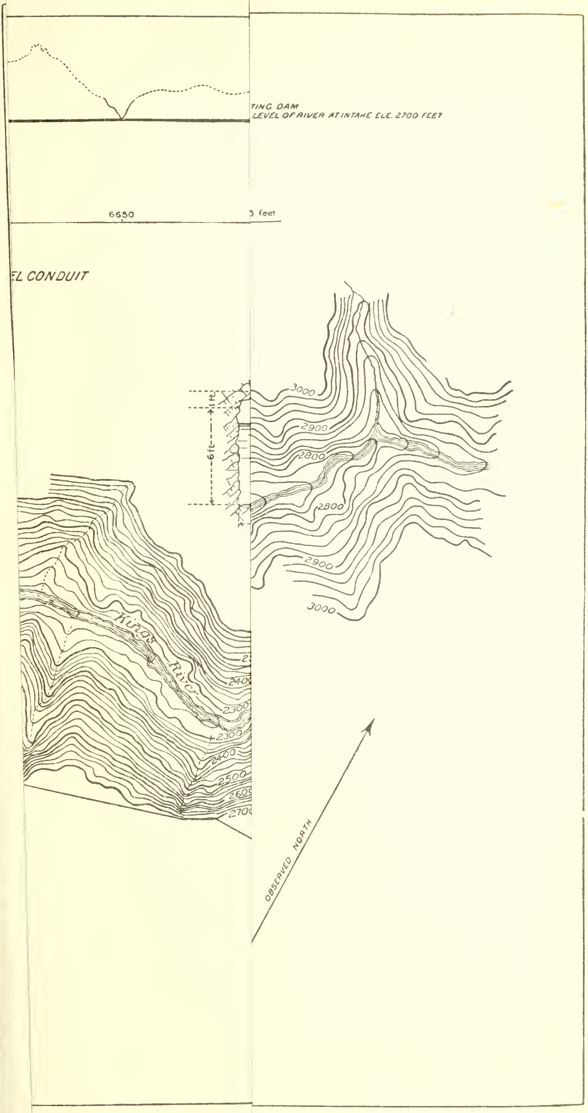
The territory with a deficient water supply is that covered in the main by the Fowler Switch, the Alta District, the Kingsbury, and the Last Chance canals, Peoples' ditch, and the Fresno canal. A late summer supply would permit the production of alfalfa and other products. The natural drainage of these lands is toward the southwest, at the rate of about 6 feet to the mile. The soil is largely granitic sand, and below an average depth of 10 or 15 feet it is saturated with water. The surface water is somewhat alkaline, and therefore it is not advisable to pump it for irrigation. Water below a depth of 50 feet can be considered satisfactory for irrigation. This is based on tests of more than 800 wells in the district, some of them being in sections where there were the strongest surface alkaline indications. In every case this lower water was found to be good, and when the strata near the surface are penetrated it rises to the elevation stated.

There have been few attempts to pump water in larger quantity than is required for domestic purposes. A 2-inch screw pipe put down to an average depth of 50 feet, landing the pipe on a stratum of clay and then boring through the clay and allowing the water to come in from the bottom of the hole, is always ample for this purpose. Locally it is the common impression that by boring through two or three strata of clay or hardpan all of the surface water is shut off, thus exempting the consumers from one of the supposed causes of malaria. An abundant supply of water at 20 or 30 feet could be obtained, but the quality would not be so good.

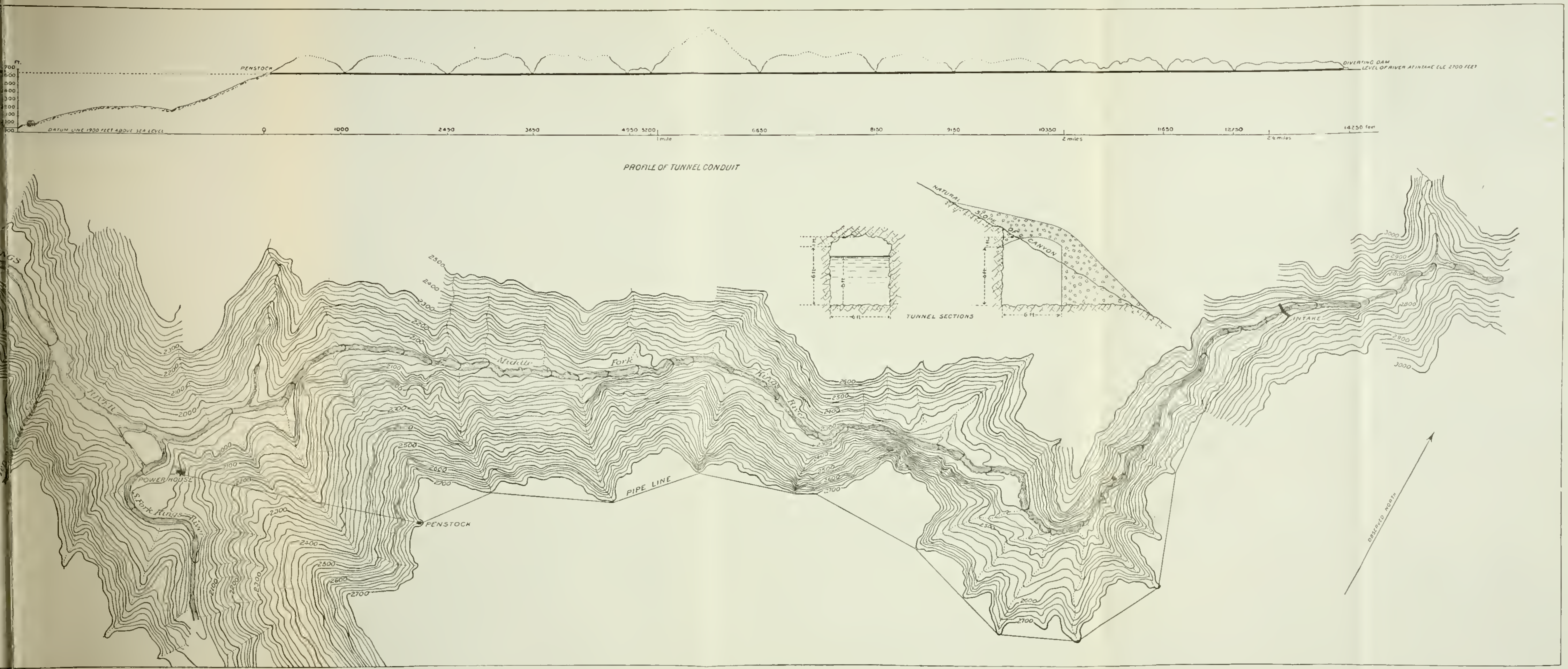
One of the largest pumping plants in this vicinity is that of the Fresno Domestic Water Company, the water supply for which is obtained from unperforated wells at a depth of 600 feet. In this case an ample supply (about 4 second-feet) for a city of 12,000 inhabitants is obtained from a city lot 50 feet by 150 feet. In and around Fresno a number of wells have been put down for street sprinkling. These wells are 8 inches in diameter and do not exceed 70 feet in depth. They are unperforated, excepting perhaps the lower joint or two of the pipe, and practically all of the water comes from the bottom. With a 2½-horsepower engine they fill a 1,250-gallon tank 9 feet above the surface in five minutes, or at the rate of more than 0.5 second-foot, lowering the water plane during the pumping not to exceed 5 or 6 feet below its normal elevation. A few small pumping plants have been installed—one 5 miles east of Fresno, on Minnewawa ranch; several around Selma, and two near Wild Flower—which yield at least 0.5 second-foot to a 7-inch unperforated well not more than 70 feet deep, with a lift not to exceed 20 feet in any case.

Wells of about 10-inch or 12-inch casing should be put down to a depth of about 100 feet on an average, and should not be perforated above 50 feet below the surface, thus shutting off all possible chance of drawing from the more or less alkaline surface water. It is probable that wells of this size and depth would each furnish 1.5 second-feet. A well driller in Selma states that he will put 12-inch wells down to a depth of 150 feet and guarantee them to furnish 1.5 second-feet each, without perforations, at a cost not to exceed $300 per well.

Pl. V is a map of Kings River delta showing the distribution canals and the location of the wells visited during the investigation. The numbers of the wells on that map correspond with the numbers in the following table, which gives the details concerning each well. The principal facts regarding the wells are given in abbreviated form. In the first column is the number of the well, as shown on the map, Pl. V. In the next column is the name of the owner, and following that the location, by township, range, and section; the date completed; and the class of well, the latter being indicated by symbol, *D* meaning dug well, *Dr* driven well, and *B* bored well, the accompanying figures giving the average diameter or width, in inches—for example, *D36* means a dug well 36 inches across. The depth of the well, the depth to water, and the depth of the water in the well, all in feet, are given in the next columns. These columns are followed by one giving the character of the strata, which is indicated by initials, *C* meaning clay, *G* gravel, *Gr* decomposed granite, *L* loam, *S* sand, *Q* quartz rock, *Qs* quick-sand, and *Hp* hardpan. To illustrate: *LSG* is equivalent to loam, sand, and gravel. The next column (right-hand page) gives the quality of the water, whether hard, soft, alkaline (*alk*), or sulphurous (*sul*). The next one gives the method by which the water is obtained, the word *hand* meaning hand pump, *horse* a horse-power machine, and *wind* a windmill. In the latter case the accompanying figures give the diameter of the windmill, in feet. For example, *14 wind* is intended to imply that water is pumped by a 14-foot windmill. The cost of the well and of the machinery is given in the next



HOWING LOCATION OF POWER



CONTOUR MAP OF A PORTION OF MIDDLE FORK OF KINGS RIVER, SHOWING LOCATION OF POWER HOUSE, ETC., AND PROFILE OF TUNNEL CONDUIT.

two columns. Following that is the character of the supply, *good* indicating a good supply and *small* a small or deficient supply; where the quantity is given it is in gallons per day of twenty-four hours. In the next column, headed "Use of water," the abbreviation *dom* implies domestic use, *st* implies use for watering cattle and horses, and *irr* that water is also used for irrigation. The last column gives the relative salinity of the water in parts per 100,000. As a rule the water in most of the wells varies in quantity as a result of irrigation, the fluctuation being within limits of a few feet.

Wells in Kings River delta—

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			*Feet.*	*Feet.*	*Feet.*	
1	R. A. James	14	23	10	1893	D36	14	12	2	GB
2	L. W. Hobler	14	23	14	1894	Dr2½	14	10	4	GB
3	Mount Camel Vineyard.	14	23	23		D36		12		Gr
4	'76 Company					B4		33		
5	W. S. Goodfellow				1894	Dr1½		10		LSGB
6	E. J. Bullard	13	19	2		B2		65		
7	P. M. Hart	13	20	8		B7				
8		13	20	10		B5				
9	H. Johnson	13	20	3		B				
10	J. H. Funck	13	20	3	1892	B7	80	32	48	
11	H. V. Parker	13	20	10	1891	B8	105	30	75	
12		13	20	11		B5		28		
13	Gus Ploetz	13	21	6	1895	B5	80	28	52	
14	W. M. Shortridge	13	21	5	1897	B5	36	8	28	GCQs
15	R. T. Owen	13	21	8	1881	B7	90	13	77	LHpCG
16	T. L. Hunter	14	20	4	1898	B7	55	5	50	LG
17	Mr. Roeding	13	20	32		B3	60			
18	M. Dunlavey	13	20	33	1895	B5	90	7	83	LG
19	William Shepp	13	20	33	1898	B2	56	9	47	LGCS
20	do	13	20	29		B2		10		
21	J. Mills	13	20	29	1892	B5	80	8	72	LG
22	M. Jensen	13	20	29	1888	B2	85	12	73	
23	J. P. Green	13	20	19	1898	B2	104	14	90	
24	August Bopp	13	20	19	1892	B3	65	15	50	Hp
25	Conrad Bopp	13	20	19	1898	D36	17	16	1	Hp
26	Mrs. E. G. McCardle	13	19	24	1900	B6	96	27	69	SG
27	W. N. Harris	13	20	19	1894	B2		22		
28	E. G. Dickinson	13	20	19	1894	B2	44	20	24	G
29	F. G. Foster	13	20	19	1898	B5	104	28		
30	S. E. Ward	13	20	19	1892	B6	95	25	70	HpS
31	A. S. Coon	13	20	20	1880	B6	125	18	107	
32		13	20	20		B2		16		
33	B. T. Tipton	13	20	20		B6	70	16	54	
34	Wm. N. Fuller	13	20	29	1897	B2	76	6	70	HpSG
35	G. M. Boles	14	20	4	1897	B6	65	6	59	
36	Abraham Wade	13	20	33	1898	B3	70	6	64	
37	Jno. Barry	13	20	34	1895	B2	50	6	44	
38	C. D. Edgerly	13	20	27	1890	B2½	85	10	75	
39	Mr. Bailey	13	20	28	1896	B2	55	9	46	
40		13	20	21		B6		17		
41	T. C. White	13	20	22		B7	50	18	32	
42		13	20	10		B7	40	21	19	
43	J. Wallers	13	20	10	1890	B6	65	24	41	
44	C. W. Stevens	13	20	14	1892	B7		17		
45	Wm. Bitner	13	20	14		B2½		15		
46	H. J. Lorgenson	13	20	14	1892	B2	35			
47	M. J. Miles	13	20	11		B3				
48	Mr. Helm	13	20	12		B7				
49	G. G. Besigger	13	21	19	1891	B6	82	9	73	
50	Jno. Swenson	13	21	19		B	80	8	72	
51	Mr. Wolf	13	21	19		B				
52	Eggars estate	13	21	30	1897	B				
53	Ger. S. and L. Bank	13	21	19		B6		9		
54	C. G. Anderson	13	21	30	1880	B6	53	8	47	G
55	Esmeralda Vineyard Co.	13	20	35	1891	B2	65	7	58	
56		13	20	34		D3x5	9	7	2	
57	Geo. I. Helm	13	20	26		B		7		
58	W. J. Dickey	13	20	25	1892	B7	120	7	113	
59	J. P. Thomas	13	20	25	1884	B2	76	6	70	
60		13	21	30		B		7		
61	E. J. Azbderian	13	21	31		Dr				
62	F. M. Roessler	13	21	30	1890	B2	50	6	44	SLGHpQs
63	G. R. Shipp	13	21	30	1892	B3	83	8	75	
64	Guthrie Co	13	21	31	1890	B	80	6	74	
65	E. Kennedy	13	21	31	1887	B6	72	8	64	
66	Mr. Forsyth	13	21	32		B				
67	Guthrie & Co	13	21	32		B4		7		
68	G. R. Taylor	13	21	33		B	90			
69	Y. Locan	13	21	32		B2	100	7	93	
70	L. L. Desnhar	13	21	32	1884	B	85	6	79	
71	Eggars estate					B8		6		
72	Olsen estate	13	21	19	1899	B6	80	7	73	SLHpCG

[a] Where the quantity is given it is in gallons per day of 24 hours.

Fresno, Tulare, and Kings counties.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.[a]	Use of water.	Salts, parts per 100,000.
Soft	Hand			Good	Dom	14
do	do	$10.00		do	do	8
	do				do	10
	Horse				Stock	
Hard	Hand		$4.00		Dom	8
	Wind				Dom; st	12
Soft	do			3,000 gallons	do	11
do	Hand			Good	Dom	8
do	Wind			do	Dom; st	11
do	Hand			do	Dom	11
do	14 wind			2,000 gallons	Dom; st	11
	Hand				Dom	10
Soft	Wind				do	9
do	12 wind	18.00	45.00		do	15
do	Wind			Good	do	11
do	Hand			do	do	11
do	12 wind			do	Dom; st	12
do	Hand		105.00	do	Dom	12
do	do	15.00	1.50	do	Dom; st	10
	do			do	Dom	8
Soft	do	40.00	25.00	do	do	8
do	Wind	34.00	75.00	do	do	10
do	Hand		55.00	do	do	9
do	do	30.00	5.00	do	Dom; st	9
do	Rope			Small	Dom	9
	Hand				do	8
Soft	do		4.00	Good	Dom; st	8
do	do				Dom	8
do	do	75.00		Good	do	8
do	do	45.00	15.00	do	do	8
do	do		6.75	do	do	10
	do				do	
Soft	do		3.00	Good	do	8
do	8 wind	20.00	41.00	do	do	8
do	Wind			do	Dom; irr	12
do	8 wind			do	do	11
Hard	Hand		25.00	do	Dom	10
Soft	18 wind		35.00	do	do	11
do	Hand			do	do	
	Wind				do	8
Soft	do			Good	do	8
do	Hand			do	do	12
do	do		80.00	do	do	11
do	8 wind			do	do	10
do	Hand		5.00	do	do	10
Hard	do			do	do	10
Soft	do			do	do	12
do	14 wind			do	Dom; st	10
do	Hand			do	Dom	12
do	do		5.00	do	do	8
do	do			do	do	8
do	Wind			do	do	12
do	Hand			do	do	8
do	Wind			do	do	8
do	Hand		5.00	do	do	8
	Lever	6.00	1.50	Small	Dom; irr	15
Soft	Wind			Good	Dom	14
do	Gas; hand			do	do	12
do	do		5.00	do	do	10
do	Hand			do	do	8
do	do		5.00	do	do	9
do	Wind			do	do	12
do	do	83.00	170.00	do	do	12
do	do			do	do	13
do	do			do	do	
do	do			do	do	11
do	do			do	do	9
do	do			do	Dom; st	10
do	do			do	Dom	8
do	do	85.00	130.00	do	do	9
do	Steam			30,000 gallons	Winery; dom	13
do	Steam; wind	100.00		Good	do	12

Wells in Kings River delta—Fresn

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	Feet.	Feet.	
73	Paul Leonhart	13	21	19	1889	B1¾	70	9	61	
74		13	21	19		B7		10		
75	S. P. Co.	12	19	5	1887	D12 / B8	140	85	55	LHpGCS
76	Thornton estate	12	19	34		B8				
77	Lee Cobb	12	19	35		B7				
78	E. J. Bullard	12	20	31	1886	B8		70		HpSGC
79	do	13	20	5		B8		100		
80	J. H. Randel	12	20	34		B6	70	60	10	
81	E. J. Lane	12	20	22	1894	B8	99	85	14	CSG
82	Frank Lane	12	20	15	1886	B		85		
83	J. P. Williams	12	20	14		B6	115	90	25	
84	Sacramento Bank	12	20	13		B6		80		
85	A. B. Ball	12	21	7	1892	B6	145	80	65	G
86	Gudlip Ambrosia	12	20	24	1891	B6		68		
87	Harry Maupin	12	20	25	1885	B6	113	48	65	CGS
88	Geo. Johnson	12	21	19		B5		38		
89	F. E. Brown	12	21	20	1890	B7		34		
90	W. Foster	12	21	19	1892	B7	75			
91	B. F. Parker	12	21	17	1881	B7	93	35	58	CG
92	J. W. Brown	12	21	18	1882	B7	100	45	55	CSG
93	Milo Rowell	12	21	5	1880	B7	130	60	70	
94	J. M. Heiskell	12	21	8	1880	B7	100	63	70	C
95	Chas. Brown	12	21	4	1900	D48		50+		CG
96	Mrs. Birkhead	12	21	4		D48	26	18	8	[a]
97	V. B. Cobb	12	21	9		D54	47+	33	14+	[b]
98	J. M. Heiskell	12	21	10		D-B		22		
99	Fresno National Bank	12	21	15	1889	B8	86	18	68	CG
100	J. H. Barker	13	20	15	1891	B2	60	15	45	
101	F. M. Merrit	13	20	14		B7	100+	14	86	
102	Mr. Moon	13	20	23		B2	45	13	32	
103	Bismarck Vineyard	13	21	29		B2		6		
104	P. H. McGarry	13	21	21	1891	B5	80	6	74	
105	M. F. Tarpey	13	21	21		B2	110	7	103	
106	Mr. Hein	13	21	28		B2		6		
107	Andrew Palm	13	21	15	1891	B2	85	6	79	L
108	G. J. Tyler	13	21	16	1900	B2	81	14	67	L
109	H. J. Clifford	13	21	9	1894	B1¼	80	14	66	
110	C. R. Damon	13	21	8	1898	B5	54	10	44	LHpCG
111	J. W. Sharer	13	21	15	1890	B6	80	9	71	L
112	J. Darnold	13	21	9		B7		8		
113	G. W. Green	13	21	4		B5		9		
114	A. Henderson	12	21	33	1888	B5	77	10	67	
115		12	21	33		B		11		
116		13	21	5	1896	B5	50	15	35	
117		12	21	34		B5		14		
118	Sheppard & Teague	12	21	28		B8		12		
119	Chas. A. Owens	12	21	30	1879	D	90	26	64	
120	H. B. Bissell	12	21	28		B8		12		
121	W. E. Parker	13	21	5	1895	B5	50	12	38	LHpAshSG
122	Cates estate	13	21	2	1894	B7	40	10	30	
123	J. W. Potter	12	21	34	1892	B6	50	12	38	
124	do	12	21	26	1877	B8	60	20	40	G
125	do	12	21	26	1899	B8	50	12	38	
126	do	12	21	35	1873	D60	45	18	27	
127	Miss. schoolhouse	12	21	22		B6		9		
128	T. C. White	12	21	22	1895	D60	14	9	5	
129	T. P. Nelson	12	21	14	1888	B6	25	13	12	LHpC
130	Bank	12	21	11		D60	40	20	20	C
131	Reese estate	12	21	13		B9		13		
132	J. E. Dickerson	12	21	23	1880	B8	50	11	39	
133	J. D. Collins	12	21	24	1880	B6	54	14	40	
134	Clovis Cole	12	22	31		D48	31	25	6	
135	Bank	12	22	31		B6		16		
136	D. C. Sample	12	22	32		D60	40	30	10	
137	do	12	22	29		D48	25	24	1	CHp
138	do	12	22	21		D48	14	12	2	
139	Marvin Simpson	12	22	27	1899	D60	25	24	1	Soil
140	Alfred Beard	12	22	26	1890	D60	18	14	4	Gr
141	do	12	22	27	1893	D60	13½	6	7½	QsHpCG
142	Jack Simpson	12	22	22	1898	D60	25	20	5	GCSGr
143	B. Simpson	12	22	14	1890	D60	22	15	7	CGr
144		12	22	34		D60	17	14	3	

[a] Heavy soil and adobe rock.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand	$30.00	$5.00	Good	Dom	8
do	Wind			do	do	8
do	Steam			3,125 gallons	Dom; boilers of S. P. Co.	9
do	14 wind			Good	Dom; st	9
do	12 wind			do	do	10
do	14 wind			do	do	8
do	8 wind			do	do	11
do	Horse			do	do	13
do	8 wind	145.00	41.00	do	do	12
do	16 wind			do	do	12
do	do			do	do	11
do	Hand			do	do	
do	16 wind			do	do	11
do	do			do	do	12
do	14 wind	113.00	90.00	do	do	11
do	Hand			do	Dom	11
do	Wind			do	Dom; st	9
do	do			do	Dom	10
do	16 wind	100.00	125.00	do	Dom; st	12
do	Wind			do	do	11
do	14 wind		174.00	do	Dom	10
Hard	do			do	Dom; st	13
do	16 wind				do	14
do	Hand		5.00	Small	do	13
do	Rope				do	24
Soft	14 wind			Good	do	12
Hard	11 wind		30.00	do	do	15
Soft	Hand		5.00	do	Dom	11
do	Wind			do	Dom; st	13
do	Hand		5.00	do	Dom	8
do	12 wind			do	do	13
do	Hand	40.00	50.00	do	do	13
	8 wind	33.00		do	Dom; st	13
Soft	Hand		6.00	do	do	15
do	do	25.00	5.00	do	do	10
do	8 wind	25.00	100.00	do	Dom	8
do	Hand	60.00	5.00	do	Dom; st	13
do	do	175.00	18.00	do	do	12
do	do			do	do	8
do	do			do	Dom	13
do	Wind			do	Dom; st	10
do	8 wind			do	do	16
do	Hand		5.00	do	Dom	13
do	do		5.00	do	Dom; irr	11
do	do	22.00	5.00	do	Dom; st	13
do	8 wind			do	Dom	11
do	12 wind			do	Dom; st	9
do	8 wind			do	do	11
do	Hand	37.50	48.00	Small	do	13
do	Wind		5.00	Good	do	13
do	Hand			do	do	11
do	8 wind		35.00	do	do	15
do	Hand		5.00	do	do	13
do	8 wind			do	do	21
do	Hand		5.00	do	Dom	
do	Rope			Small	Dom; st	
Alk	Hand		5.00	do	do	13
Soft	do		5.00	do	do	13
	Horse			Good	Stock	20
Soft	14 wind			do	Dom; st	16
Hard	Hand			Small	do	21
do	16 wind			do	do	
do	Hand			Good	do	21
Soft	8 wind		55.00	do	do	13
Alk	16 wind		25.00	Small	do	28
do	8 wind			Good	Stock	25
Soft	Hand			Small	Dom; st	
Hard	8 wind	50.00	45.00	Good	do	12
do	Hand	9.00	5.00	do	Dom	13
Alk	8 wind	10.00	36.00	Small	Dom; st	18
do	Wind			Good	do	14
Hard	Horse			Small	Stock	

[b] Heavy soil.

Wells in Kings River delta—Fresn

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	Feet.	Feet.	
145	Bank of Sacramento	13	22	2		D36	14	10	4	
146	W. M. Harbison	13	22	10	1882	B6	82	37	45	CHpG
147	T. C. White	13	22	9	1882	B8	75	35	40	
148	C. J. Reyburn	13	22	9	1882	B8		33		
149	Redbanks schoolhouse.	13	22	8		B7		26		
150	A. Gordon	13	22	8		D60	20	14	6	
151	B. F. Griffen	13	22	6	1880	D60	50	28	22	
152	A. H. Hamilton	13	22	7	1875	D60	60	25	35	CHpG
153	Fresno L. and S. Bank	13	22	6	1882	D60	37	18	19	G
154	do	13	22	6	1880	B7		32		G
155	R. G. Hewitt	13	21	14	1892	B2	90	12	78	
156	Sam Ebe	13	22	8		D48		11½		
157	S. F. Bank	13	22	8	1882	D60		21		
158	Sacramento Bank	13	22	8	1880	D48	60	22	38	
159	Jno. Lee estate	13	22	16	1880	B6	60	23	37	
160	J. M. Ellmore	13	22	15	1884	B8	80	37	43	G
161	Alfred Beard	13	22	15	1885	B8	75	38	37	
162	Mr. Gibson	13	22	14	1880	D54		30		
163	Mr. Meyers	14	20	2	1890	B2	30	15	15	
164	County of Fresno	14	20	2	1897	B7		10		
165	J. Nishkian	14	21	6		B2		8		
166	L. Dalton	14	21	6	1892	B2	80	15	65	L
167	J. Steinivaud	14	21	6	1882	B6	45	6	39	LHpCG
168	St. George Winery	14	21	5	1894	B10	300	6	294	
169	W. E. Carrico	13	21	33	1885	B5	78	9	69	LHpGC
170	H. J. Eaton	13	21	33		B2		9		
171	S. E. Mill	13	21	34	1899	B2	70	12	58	G
172	Miss Ethel Shell	13	21	34	1898	B2	79	12	67	LCSG
173	Geo. C. Roeding	14	21	3	1885	B8	90	8	82	G
174	Judge Wallace	13	21	35	1899	B2	45	20	25	S
175	G. B. Passon	13	21	36	1893	B2	40	14	26	
176	M. E. Laymensce	13	21	36	1891	B2	60	8	52	CHp
177	E. L. Curtis	13	22	31		B		7		
178	Mr. Wright	14	22	6	1898	B2	65	10	55	SG
179	R. B. Baird	13	22	32	1900	B2	75	11	64	S
180	Sacramento Bank	14	22	5		B5		9		
181	S. F. Savings Union	13	22	32		B6	85	16	69	
182	W. O. Blasingame	14	22	4		B72	60	10	50	
183	Dr. Chester Rowl	14	22	4	1897	B2	95	14	71	LHpCS
184	Fresno Milling Co.	14	20	3	1897	B2	81	12	69	SLGC
185	Jno. D. Rutledge	14	20	4	1897	B2	75	6	69	SG
186	C. W. Forsman	13	20	34	1888	B2	60			S
187	A. Vogel	13	20	34	1888	B4	60	8	52	SC
188	Mr. Hayes	13	20	35	1882	B7	70	11	59	
189	Joseph Bocarde	14	20	2	1895	B3	75	20	55	LHpQsSGC
190	Mr. Dickerson	13	20	35	1884	B1¼		8		
191	J. W. Martin	13	20	35	1888	D2	12	7	5	L
192	G. T. Hawley & Bro.	13	20	35	1895	B2	90	15	75	G
193	San Ricardo Vineyard	13	21	31		B		10		
194	H. M. Rustigian	14	21	6	1891	B2	60	12	48	
195	J. Rustigian	14	21	6		B2		10		
196	C. D. Wright	14	21	5	1896	B2	80	8	72	
197	Geo. Goodrich	13	21	33		B2	75	7	68	
198	Frank Green	13	21	33	1892	B2	60	9	51	G
199	N. C. Skoegard	13	21	33	1885	B2		8		
200	Alice Treadwell	13	21	34	1887	B2	85	10	75	SG
201		13	21	27	1899	B2		9		
202	L. M. Fincher	13	21	22	1880	B8	75	6	69	CS
203		13	21	15		B2		7		
204	N. A. Shelling	13	21	15		B2		8		
205	E. E. Irwin	13	21	14	1885	B8	85	9	76	CGS
206	W. Davenhill	13	21	14	1894	B2		7		
207	J. D. Reyburn	13	21	11	1892	B7	85	12	73	LHpS
208	Geo. P. Byreborg	13	21	14	1890	B2	90	16	74	GCHpQsCG
209	A. J. Cass	13	21	14	1891	B2	60	9	51	
210	Mr. Herman	13	21	24	1897	B2	40	8	32	CHpCSG
211	McDonald estate	13	22	18	1877	D48	80	15	65	
212		13	22	18		D48		11		
213		13	22	19		B2	17	14	3	
214	Samuel Funck	14	20	3	1890	B1	75	12	63	LHpCSG
215	R. J. Robinson	14	20	3	1900	B2	73	10	63	S
216		14	20	2		B2		10		
217	Thos. Hughes, vin	14	20	11		B		8		
218	D. J. Vaughn	14	20	12	1882	B5	65	9	56	LCSG

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hard	Hand		$5.00	Small	Dom; st	15
do	10 wind		90.00	Good	do	15
do	Hand		6.00	do	do	12
do	Wind			do	do	12
do	Hand			do	Dom	14
do	Rope				Dom; st	
Soft	8 wind		40.00	Good	Dom	11
Hard	Wind	$50.00	130.00	do	Dom; st	15
Soft	do		14.00	do	do	17
Hard	14 wind			do	do	17
Soft	Hand		5.00	do	do	12
do	do			do	do	14
Hard	Wind			do	do	14
do	do			do	Dom	13
do	8 wind		40.00	do	Dom; st	12
do	10 wind	80.00	165.00	do	do	15
Soft	Wind		35.00	do	do	13
Hard	Rope			do	do	15
do	Hand	15.00	4.25	do	do	12
do	Gas			288,000 gallons	Streets	20
Soft	Hand		4.25	Good	Dom; st	11
do	8 wind	30.00	79.00	do	do	8
do	Hand	40.00	10.00	do	do	8
do	Steam	120.00		120,000 gallons	Winery	11
do	Hand		4.25	Good	Dom; st	8
do	do		4.25	do	do	11
Hard	8 wind	23.00	46.00	do	do	12
Soft	do	23.50	52.00	do	do	11
Hard	Gas			24,000 gallons	Irr; dom	9
Soft	Hand	23.00	5.00	Good	Dom	8
do	8 wind	20.00	75.00	do	do	8
do	Hand			do	Dom; st	8
do	do			do	do	12
do	do	28.00	5.00	do	do	8
do	do	20.00	6.00	do	do	8
do	do		4.25	do	do	8
do	do		6.00	do	do	8
do	do		5.00	do	do	13
do	do			do	do	11
do	do	20.00	4.00	do	do	14
do	do	16.00	4.00	do	Dom	15
do	do			do	Dom; st	14
do	8 wind			do	do	11
do	Hand		6.00	do	do	14
do	do		15.00	do	do	10
do	8 wind		45.00	do	do	8
do	Hand		5.00	do	do	11
Hard	do		4.00	do	do	10
Soft	8 wind		50.00		do	11
do	Hand	25.00	4.00	Good	do	11
do	do			do	do	11
Hard	do		4.00	do	Dom	10
do	do	30.00	4.00	do	Dom; st	8
do	do	30.00	4.00	do	do	14
Soft	do		4.00	do	Dom	8
do	do	40.00	4.00	do	do	10
do	do		4.00	do	do	13
Hard	do		6.00	do	Stock	13
Soft	do		4.25	do	Dom; st	11
do	do		4.00	do	do	8
do	8 wind		65.00	do	do	12
do	Hand		4.25	do	Dom	16
do	12 wind	85.00	125.00	do	Dom; st	15
do	Hand	27.00	4.25	do	Dom	18
do	do	30.00	8.00	do	do	16
	do	12.00	6.00	do	Dom; st	12
Soft	Rope			do	do	
do	do			do	do	
do						
do	8 wind	22.00	100.00	Good	Dom	13
do	Hand	29.00	4.25	do	do	11
do	do		4.00	do	Dom; st	12
do	8 wind			do	do	12
	Wind	45.00	9.00	do	Dom	8

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			Feet.	Feet.	Feet.	
219	A. B. Butler	14	21	7		B7		9		
220	Hughs Richler	14	21	6	1880	B2	40	10	30	CS
221	Fresno Vineyard Co	14	21	7		B6		9		
222	J. Rogers	14	21	8		B8		8		
223	Fred Roeding	14	21	2	1887	B7	110	17	93	
224	Bonner Vineyard Co.	14	21	11	1885	B8	104	14	90	LHp
225	A. F. Albrecht	14	21	1	1899	B2	54	8	46	CS
226	Judge Risley	14	22	6	1893	B2	90	18	82	CS
227	Fresno Bank	14	22	5		D36	14	10	4	
228	John Crol	14	22	9	1892	B6	50	17	33	CSHp
229	M. J. Roeder	14	22	9	1892	B1½	20	16	4	
230	Cora Wickersham	14	22	3	1880	B7		14		
231	F. P. Wickersham	14	22	3		B2		14		
232	Mr. Burness	14	22	3		B6	18	25	3	
233	Jno. Snyder	13	22	35	1897	B7	65	20	45	S
234	Chas. Lyman estate	13	22	34	1880	B7	80	0	60	
235	R. W. Edmiston	13	22	31	1898	B2	100	5	95	LHpCSG
236	do	13	22	30	1890	B2	45	18	37	CLHpS
237		13	22	31	1899	B2		0		
238	Kutner School	13	22	30		B2		9		
239	Victor Marten	14	20	9	1897	B2	82	10	72	S
240	J. H. Hass	14	20	16	1890	B2	70	8	62	
241	Mr. Keamey	14	20	7		B		7		
242	J. J. Luce	14	19	12	1886	B2	72	8	64	
243	Dr. A. E. Small	14	19	12	1890	B2		7		
244	Andrew Nelson	14	19	11	1891	B2	60	8	52	CHpG
245	Kearney estate	14	19	10	1890	B2.5		8		
246	Dolph Shields	14	19	14	1890	B2		9		
247	M. Koller	14	19	15	1890	B2	68	10	58	L
248	F. M. Burnham	14	19	10	1889	B2	73	8	65	LHpCS
249	Maddison School	14	19	12	1897	B2	93	6	87	LHpCG
250	T. H. Burgess	14	19	15	1898	B2	90	8	82	SGC
251	W. W. Underhill	14	19	10	1894	B2		8		
252	S. J. Walton	13	19	34	1900	B8	55	10	45	HpCSG
253	Oscar Carlson	14	19	2	1891	B2	35	6	29	LHpC
254	C. D. Smith	14	19	2	1890	B3	70	8	62	SQsS
255	Mrs. H. L. Granger	14	19	2	1891	B2	55	7	48	SC
256	N. H. Fuglsang	14	19	2	1893	B2	80	7	73	
257		13	19	35		B2		9		
258	Balfour, Guthrie & Co.	13	19	36	1880	B5	30	17½	12½	
259	Lew Showyer	14	19	1	1899	B2		8		
260	Mrs. C. B. Lyman	14	19	1	1900	B6	97	9	88	LHpSC
261	O. D. Garrison	14	20	21	1888	B2	120	8	112	CG
262	E. Tommasini	14	20	29	1897	B2	82	12	70	LHpS
263	M. Robison	14	20	32	1890	B2	70	10	60	SCG
264	G. C. Cheuvraut	14	20	33	1892	B2	75	6	69	S
265	N. Jansen	15	20	5	1889	B2	50	10	40	S
266	J. Gowanlock	15	20	8	1890	B2	60	10	50	
267		15	20	9		B2		12		
268	Dickerson	15	20	9	1885	B2		10		
269	Mrs. L. Walker	15	20	9	1890	B2	60	10	50	Hp
270	Sonensen	15	20	15		B2		12		
271	John Smith	15	20	21	1890	B2	35	10	25	S
272	Bank	15	20	34		B6	50	12	38	
273	Stevens & Harland	15	20	33		B6	+50	16	+34	
274	do	16	20	3		B5	+50	15	+35	
275	Sacramento Bank	16	20	15	1890	B6		12		
276	White	16	20	16		B6	24	16	8	
277	Geo. B. Zigler	16	20	22	1899	B6		17		
278	David Crawford	16	20	33	1887	B6	80	18	62	LHpS
279	McDonald	17	20	4		B6	39	6	33	
280	Geo. Magn	17	20	5		B6		10		
281	Lone Sav. Bk. Co	17	20	4	1886	B6	104	10	94	S
282	Lewis Gibbons	17	20	6	1880	B5	118	10	108	LHpSGC
283	John Walker	17	20	7	1880	B8	75	8	67	SQs
284	Fred Coleman	17	20	8	1893	B6	27	7	20	S
285	Elisha Harlon	17	20	18	1890	B5	70	8	62	LCS
286	Lewis Gobbi	17	19	13	1892	Dr7	20	7	13	S
287	Ger. Savings Bk	17	19	13	1893	Dr1¼	15	10	5	S
288	Wm. Bullard	17	20	6		B		14		
289	Chas. S. Pierce	16	20	31	1890	B6	45	12	33	S
290	Capt. Cuttle	16	19	36	1880	B	75	14	61	
291	Mrs. H. Worswick	17	19	1	1890	B6	68	10	58	SC
292	Fred Eaton	16	19	34	1892	B5	72	15	57	S

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand			Good	Dom; st	8
do	do	$16.00	$4.25	do	do	11
do	Gas			do	do	10
do	do			do	do	10
do	14 wind			do	Dom	15
do	Horse	100.00	100.00	do	Dom; st	12
do	Wind; hand	25.00	4.00	do	Dom	11
Hard	Hand	25.00	4.00	do	Dom; st	10
do						10
Soft	Hand	55.00	4.00	Good	Dom; st	----
do	do	11.00	4.00	do	Dom	12
Hard	8 wind			200 gallons	Dom; st	12
Soft	Hand		4.00	Good	do	12
do	do	20.00	5.00	Small	do	----
Hard	do	20.00	4.00	Good	do	9
Soft	do		4.00	do	Dom	8
do	8 wind	35.00	250.00	do	Dom; st	13
do	Hand	20.00	40.00	do	Dom	----
do	do		4.00	do	Dom; st	----
do	do		4.00	do	do	11
do	8 wind		200.00	do	Dom	17
do	do			do	Dom; st	8
do	Hand		4.00	do	do	9
do	do			do	do	8
do	do		4.00	do	Dom	18
do	do	25.00	4.00	do	Dom; st	12
Hard	do		4.00	do	do	15
do	do		4.00	do	do	12
Alk	Wind	28.00	66.00	do	do	10
Hard	Hand	29.00	4.00	do	Dom	11
Hard; alk	8 wind	33.00	38.00	do	do	13
Soft	do	29.00	41.00	do	Dom; st	11
do	Hand		11.00	do	do	12
do	Horse	38.00	47.00	do	do	11
Alk	Hand	14.00	4.00	do	Dom	14
Soft	8 wind	42.00	50.00	do	Dom; st	13
Alk	Hand	22.00	4.00	do	do	20
Hard	do		11.00	do	Dom	8
	do		4.00	do	Dom; st	----
Alk	do		4.00	do	do	11
Hard	do		4.25	do	do	10
Alk	8 wind	60.00	270.00	do	do	12
Soft	do	48.00	4.25	do	Dom	13
Hard	Hand		26.00	do	Dom; st	29
do	do		3.00	do	do	20
do	do	25.00	4.00	do	do	26
do	do		4.00	do	do	27
Hard; alk	do	25.00	4.00	do	do	37
Hard	Wind		6.00	do	do	16
Hard; alk	Hand		4.00	do	do	89
Hard	do	24.00	4.00	do	do	26
do	do		4.00	do	do	33
Alk	do	15.00	6.00	do	do	35
do	do		4.00	do	do	8
Hard	do		4.00	do	do	----
Alk	Wind			do	do	24
do	Wind; hand			do	do	23
Hard	Hand		4.00	do	do	11
Soft	Wind			do	Dom	11
do	do	65.00	14.00	do	Dom; st	9
Hard	Hand		4.00	do	do	13
do	do		5.00	do	do	16
Soft	do		10.00	do	Dom	15
Hard	8 wind	95.00	45.00	do	Dom; st	18
Soft	Hand		25.00	Small	Dom	36
do	12 wind	23.00		Good	Dom; st	45
do	do	70.00	140.00	do	do	10
Hard	Hand	5.00	4.00	do	do	14
do	do	4.00	6.00	do	do	29
do	do		4.00	do	do	24
Soft	Wind	45.00		do	do	12
Hard	14 wind			do	do	35
do	Hand	50.00	4.00	Small	do	34
do	10 wind	51.00		Good	do	23

Wells in Kings River delta—Fresnc

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	*Feet.*	*Feet.*	
293	Mrs. M. J. Hatch	16	19	34	1890	B5	48	15	33	S
294	Mrs. W. M. F. Jenkins	16	19	34	1886	B	130	14	116	
295	Elkhorn School	17	19	10	1896	B6	100	9	91	
296	Mrs. M. J. Hatch	17	19	10	1884	B5	34	10	24	CS
297		16	19	25		B6	25	20	5	
298		16	19	24		B5	+50	18	+32	
299	G. Kowser	16	20	20		B5	42	17	25	
300	Mrs. M. Sloan	16	20	20		B		16		
301	S. F. Bank	16	20	7	1888	B7	+30	20	+10	
302		16	20	7		B5	+21	14	7	
303	S. F. Bank	15	19	36		B6	36	10	26	
304	John Smith	15	19	25		B5		13		
305	John Rottger	15	19	13		B3		8		
306	C. A. Hager	15	19	12	1890	B		8		
307	R. L. Epperson	14	19	36	1894	B2	60	8	52	S
308	R. L. Dunham	14	19	36	1900	B2	44	8	36	SLHp
309	C. J. Smith	14	20	30	1896	B2	+20	7	13	S
310	Mr. Parker	14	19	25	1898	B2	70	6	64	S
311		14	19	15		B8		7		
312	Herman Boyce	14	19	23		B2		8		
313	August Weye	14	19	27	1881	B6	+80	7	73	LSC
314	Burley Bros	14	19	27	1887	B7	65	8	57	S
315	F. Duhring	14	19	34	1887	B6		8		
316	A. Christian	15	19	10	1890	B2	100	9	91	
317	J. W. Creelman	15	19	10	1890	B6		10		
318	Mike Andres	15	19	14	1890	B2		10		SC
319	Geo. Keslang	15	19	14	1891	B2	65	10	55	SC
320		15	19	27		B5	+50	16	+34	
321		16	19	3		B5	30	19	11	
322		16	19	2		B5	20	19½	½	
323	Louis Montego	16	19	1		B5	+50	17	+33	
324	A. B. Trautwein	16	20	6	1891	B2	150	12	138	
325	D. W. Smith	15	20	31	1887	B7	80	12	68	SHp
326		15	20	32		B8	20	15	5	S
327	G. A. Pell	15	20	26	1890	B2	60	12	48	SCHp
328	C. Nelson	15	20	26		B2	54	12	42	
329		15	20	36		B5		10		
330		15	20	36		B2		12		
331	E. R. Haycroft	16	21	6		B6	50	12	38	
332	C. M. Rasmussen	16	21	6	1885			12		
333	Bank	16	20	13		B		14		
334	Wm. Gibson	16	20	24	1880	B6	26	12	14	SLHp
335	J. H Hudson	16	20	25	1880	B5	60	12	48	
336		16	20	25		B5	20+	10	10+	
337	Wm. Gibson	16	21	31		B5		10		
338	Levi Garret	16	22	26	1880	B6		15		
339	Cemetery	16	22	27		B5		13		
340	C. H. Van Horn	16	22	28	1896	B5	82	12	70	SHpC
341	Mrs. S. M. Smith	14	20	15	1899	B2	90	10	80	S
342	F. Burnham	14	20	36	1882	B6	50	8	42	SHpC
343	H. U. Carver	14	20	36		B2		8		
344		15	30	1		B6		10½		
345		15	20	1		B2		10		
346	J. F. Ward	15	20	12	1888	B2	90	8	82	
347	Fresno Nat. Bk.	14	20	36	1890	B2	94	8	86	SHpL
348	Y. Maglio	14	20	36	1890	B2		8		
349	J. F. Cartright	14	20	35		B2		8		
350		14	20	34		B2		8		
351	Geo. A. Coughell	14	20	34	1885	B2	40+	8	32+	SHp
352	Henry Brooks	15	20	3	1885	B2	80			S
353	Jacob Fisher	15	20	3	1885	B6	83	9	74	CS
354	Gus. Johanson	15	20	10	1890	B2		10		S
355	N. M. Nelson	15	20	10		B2	75	10	65	
356	A. Buckland	15	20	11	1881	B5	51	8	43	SHp
357	S. Nelson	15	20	14	1894	Dr2	20	8	12	S
358		15	20	23		B1		8		
359	Philip Koekler	15	20	26	1897	B2	60	12	48	
360	Schoolhouse	15	20	25		B2		10		
361		15	21	19			(a)	(a)	(a)	
362	Dexter & Payne	15	21	19	1890	B1½		10		
363	C. B. Scott	15	21	20	1895	B2	60			
364	W. A. Mills	15	21	16	1900	B5	48	14	34	S
365	Mo. Vineyard Co	15	21	9	1890	B4	60	11	49	
366	S. J. Goree	15	21	8	1891	B4	60	10	50	S

[a] Swale water 10 feet below.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hard	12 wind			Good	Dom	8
do	Hand		$4.00	do	Dom; st	8
do	do			do	Dom	11
do	12 wind	$30.00		do	Dom; st	36
	Hand	25.00	5.00	do	do	
	do		5.00		do	
Hard	do		5.00	Good	do	11
Hard; alk.	Wind			do	do	18
Soft	16 wind			do	Dom	11
	Hand		4.00	do	Dom; st	10
Hard	Hand			Good	Dom; st	11
do	do		4.00	do	do	
do	do		4.00	do	do	8
Soft	do	24.00	4.00	do	Dom	16
do	do	19.00	4.00	do	Dom; st	16
do	do		4.00	do	do	23
do	do		4.00	do	do	12
Hard	12 wind			do	do	15
Soft	Hand		4.00	do	do	18
do	Horse; wind	60.00	120.00	do	do	14
do	8 wind	43.00	60.00	do	do	16
Hard	Hand		4.00	do	Dom	16
Soft	14 wind	40.00	95.00	do	Dom; st	28
Alk	Hand			do	do	37
do	do			Small	do	20
Hard	do	25.00	4.00	Good	do	20
do				do	do	
					do	
				Small	do	
Soft				Good	do	
do	8 wind		35.00	do	do	8
do	10 centrifugal	100.00		do		9
do	Hand		5.00	do	Dom; st	
do	10 wind	24.00	47.50	do	do	18
Hard	Hand	22.00	4.00	do	do	10
do	do		5.00	do	do	16
do	do		4.00	do	do	11
Soft	do	62.00	4.00	do	do	16
do	do		4.00	do	do	26
do	Wind			do	do	11
do	Hand	26.00	4.00	do	Dom	8
do	do		4.00	do	do	20
do	do		4.00	do	Dom; st	
do	8 wind			do	Stock	
	Wind			do	Dom; st	18
Alk	do			do	Irr	11
Soft	10 wind	41.00		do	Dom; st	11
do	Hand	36.00	4.00	do	do	
do	do		4.00	do	do	12
do	do		5.00	do	do	14
do	do		4.00	do	do	13
do	do		4.00	do	do	13
Hard	do	36.00	4.00	do	do	8
Alk	Wind	37.00	72.00	do	do	10
Soft	Hand		4.00	do	do	9
	do		4.00	do	Dom	
	Wind			do	Dom; st	11
Soft	Hand		4.00	do	do	14
	do	32.00	4.00	do	do	19
Soft	12 wind	70.00	115.00	do	do	14
do	Hand		4.00	do	do	9
do	do		4.00	do	do	19
do	do	46.00	4.00	do	do	12
do	do	8.00	4.00	do	do	8
do	do		3.00	do	do	15
do	do	25.00	46.00	do	do	10
do	do		4.00	do	do	11
Soft	Wind; hand			Good	Dom; st	16
do	Hand	25.00	4.00	do	do	14
Hard	do	30.00	4.00	do	do	11
Soft	do	30.00	11.00	do	do	11
do	do	24.00	4.00	do	do	11

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	Feet.	Feet.	
367	John Morgan	14	20	16	1890	B2		16		
368	L. A. Gould	14	20	16	1890	B2	80	7	73	
369	T. H. Mallory	14	20	21	1900	B2	69	10	59	SHp
370	W. A. White	14	20	27	1900	B2	57	10	47	CHpSC
371	H. Roff	14	20	27	1897	B2	80	10	70	S
372	do	14	20	33	1880	B8	90	9	81	
373	Richard White	14	20	33	1884	B8	52	6	46	SCG
374	Geo. B. Rowell	15	20	3	1881	B8	94	10	84	S
375	Robt. Boot	15	20	2	1880	B6	90	12	78	CS
376	A. J. Rudy	15	20	2	1898	B2	75	11	64	SC
377		14	21	31		B2		10		
378	A. A. Smith	14	21	32	1890	B2		12		
379	H. M. Eddy	14	21	33	1887	B2	65	9	56	SC
380	R. E. Oliver	15	21	3	1899	B5	29	16	13	S
381	Wylie M. Giffen	15	21	2		B5		12½		
382	do	15	21	12	1880	B		20		
383	J. M. Pugh	15	21	11	1882	B5	42	12	30	SCHp
384	W. O. Edgerly	15	21	13	1880	B6		11		
385	Wm. Dosdon	15	21	24	1894	B2	60	15	45	SCHp
386	J. A. T. Peterson	16	22	7		B5		13		
387	Mrs. C. A. Hammer	16	22	18	1898	B5	40	12	98	SHp
388	S. J. Pelton	16	22	19	1888	B5	86	10	76	
389	Mr. Wilker	16	22	30		B		12		
390	J. C. Bell	16	22	29	1880	B5	54	9	41	S
391	Eschol School	16	22	32	1895	B2	45			CS
392	J. W. Ryce	16	21	36	1886	B5	106	10	96	LS
393	Sacramento Bk	16	22	32	1875	B5	35	10	25	S
394	do	17	22	4	1875	B5	50	10	40	
395	do	17	22	4	1888	B5	50	15	35	
396	Laguna de Tach	17	22	3	1895	B5	107	12	95	
397	S. P. Co	16	22	36	1891	B3	50	20	30	HpS
398	Mrs. M. A. Cowan	16	22	22	1895	B2		15		S
399	John Clark	16	22	28		B5		14		
400	Larse Anderson	16	22	21	1888	B5	60	21	39	SHp
401		16	22	20		B1½		13		
402	W. T. Prather	16	22	17	1880	B6		15		SHpC
403	A. J. Allen	16	22	10	1870	B5	90	16	74	SCHp
404	T. C. Clayton	16	22	3	1893	B5	102	15	87	S
405		15	22	33		B		15		
406	F. -C	15	22	27		B		16½		
407	F. P. Wall	15	22	22	1894	B1½	60	17	43	SHp
408	A. Proctor	15	22	22		B2		13		
409		15	22	20		B2		17		
410	Charley Woods	15	22	9	1885	B5		13		
411	Ben Swanson	15	22	9	1890	B2		16		
412	A. T. Wilkinson	15	22	5	1889	Dr1½	30	18	12	SCHp
413		14	22	29			(a)	(a)	(a)	
414	S. A. Tyler	14	22	32	1900	B8	75	15	60	SCGHp
415	A. Hall	14	22	30	1880	B8		14		
416	Chas. Preuss	14	22	19	1892	B5	38	12	26	HpCS
417	Fresno L. and S. Bk	14	20	14	1880	B6	65	8	57	S
418	Estrella de Ora Drying Co.	14	20	13	1891	B2	75	5	70	CS
419	St. George Vineyard	14	21	17		B8		10		
420	M. E. Sherman	14	21	17	1899	(2 wells) B6	40 120	10	30 110	SHp
421		14	21	21		B8		13		
422	Lone Star School	14	21	22	1897	B2	60	12	48	SG
423	A. C. Funch	14	21	22	1895	B2	80	12	68	SC
424	A. Malter	14	21	27	1894	B2		12		
425		15	21	10		B2		10		
426		15	21	9			(b)	(b)	(b)	
427	A. R. Brown	15	21	10	1900	B5	54	12	42	CS
428	W. R. Shannon	15	21	14	1890	B5	52	11	41	CSHp
429	A. Harris	15	21	23	1881	B5	100+	14	86+	HpS
430	Mrs. C. E. Gower	15	21	27	1894	B5	85	14	71	SHpC
431	M. Leeper	15	21	34	1887	B2	60	14	46	SHpC
432	W. J. Zimmerman	15	21	34	1899	B6	28	12	16	SL
433	Fresno L. and S. Bk	15	21	34	1888	B5	100+	12	88+	
434	J. B. Galbreath	15	21	28		B6		14		
435	J. C. Long	15	21	28	1892	B	80	12	68	SHp
436	Len Lhung	15	21	15	1899	B	90	15	75	
437	H. A. Ross	15	21	2	1898	B5	60	12	48	SG
438		15	21	2-3			(c)	(c)	(c)	

[a] Slough water 15 feet below.

[b] Swale water 10 feet below.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand		$4.00	Good	Dom; st	12
do	Wind	$40.00	150.00	do	do	13
do	8 wind	28.00	300.00	do	Dom	13
Hard	do	225.00	45.00	do	Dom; st	73
Soft	Hand	32.00	4.00	do	do	15
Hard		80.00		do	do	16
	Hand	52.00	4.00	do	do	9
Soft	Wind	94.00		do	do	18
Hard	Hand	90.00	4.00	do	do	15
Soft	do			do	do	12
do	do		4.00	do	do	21
Hard	Turbine			do	Dom	15
Soft	Hand	65.00	25.00	do	Dom; st	11
do	do	21.00	4.00	do	do	16
do	do		5.00	do	do	12
Hard	do			do	do	27
Soft	Wind	26.00	14.00	do	do	13
do	Hand		4.00	do	do	26
do	8 wind	27.00	40.00	do	do	11
do	Hand		12.00	do	do	
	do	40.00	12.00	do	do	11
Hard	do			do	do	24
do	do		4.00	do	do	23
	10 wind	50.00		do	Stock	21
Soft	Hand	18.00	4.00	do	Dom	9
Hard	do	36.00	4.00	do	Dom; st	
Soft; alk	do	35.00	4.00	do	do	10
Hard	do		4.00	do	Dom	23
Soft	do	37.00	5.00	do	Dom; st	30
do	do		4.00	do	Dom	8
Alk	do		4.00	Small	Dom; st	8
Soft	do		4.00	Good	do	8
do	do		4.00	do	do	14
do	do	30.00	4.00	do	do	14
Soft	Hand		4.00	Good	Dom; st	13
do	8 wind		58.00	do	do	9
do	do	90.00	60.00	do	do	10
do	Hand	51.00		do	Dom	9
do	do		4.00	do	Dom; st	13
do	do			do	do	16
do	do			do	do	19
do	do		4.00	do	do	12
do	do		4.00	do	do	
do	do		4.00	do	do	14
Hard	Wind			do	do	20
Soft	do	15.00	40.00	do	do	12
Soft	Wind			Good	Dom; st	15
do	Hand		4.00	do	do	8
do	do	19.00	80.00	do	do	11
do	Wind	65.00		do	do	9
do	Hand			do	Dom	12
do	do		6.00	do	Dom; st	12
do	Steam	206.00	1,300.00	1,292,633 gallons	Irr	9
do	Hand		5.00	Good	Dom; st	15
do	do	24.00	4.00	do	do	13
do	do	25.00	5.00	do	do	15
do	8 wind			do	do	16
do	Hand			do	do	12
Soft	Wind	30.00	4.00	Good	Dom; st	16
do	Hand	26.00	11.00	do	do	12
do	do	75.00	11.00	do	do	12
do	10 wind	75.00		do	do	9
do	8 wind	40.00	117.50	do	Dom	9
do	Hand	17.00	3.25	do	Dom; st	9
Hard	do		3.25	do	do	14
Soft	Wind			do	do	8
do	do	60.00	100.00	do	do	17
	do			do	Dom	12
Hard	Hand	45.00	4.00	do	Dom; st	29

[c] Swale water 15 feet below.

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
							Feet.	Feet.	Feet.	
439		14	21	35		B2	34	16	18	
440	M. Wash	14	21	27		B5		13		
441	M. J. Driver	14	20	22	1883	B7	40	15	25	LHpSC
442	E. F. Ball	14	20	14	1893	B6	85	13	62	
443	T. -I	14	20	14		B		12		
444	Mrs. F. C. Ketchum	14	20	13	1890	B2	60	12	48	
445	C. N. Brenenfeld	14	21	20	1895	B2	80	9	71	SCHp
446	Jas. Rutheford	14	21	21	1891	B2	100	9	91	CHpS
447	I. D. Garrison	14	21	29		B2		8		S
448	J. W. Scott	14	21	29	1897	B2	60	7	53	S
449	E. R. Bates	14	21	19	1890	B2	82	10	72	
450	J. H. La Ru	14	21	32	1886	B5	50	8	42	SC
451	John Oed	14	21	33	1885	B		10		
452	W. H. Martin	14	21	26	1890	B2		14		
453		14	21	36			(a)	(a)	(a)	
454	Mrs. J. J. Owen	14	22	31	1898	B5	48	13	35	SC
455	D. W. Butler	14	22	31	1898	B5	60	11½	48½	SHpC
456	Dr. A. D. Wilson	15	21	12		B5		11		
457	F. Lemon	15	21	13		B5		13		
458	Mr. Scott	15	21	13		B		15		
459	T. M. Boyd	15	22	17	1881	B5	60	13	47	LSC
460	Geo. West & Son	15	22	29	1900	B8	120	16	104	SCHp
461	Mrs. L. Vance	15	22	31	1885	B5	75	15½	59½	S
462	C. T. Pierson	16	22	6	1890	B2	80	12	68	
463	S. Y. Gordon	16	22	7	1882	B5	108	10	98	SHpC
464	J. C. Hinkle	16	21	11	1890	B5	40	8	32	SCHp
465	D. Shiflet	16	21	10	1890	B5		12		S
466	T. E. Finerty	16	21	4	1885	B5	80	16	64	SCHp
467	H. Craven	16	21	9	1894	B5	50	14	36	S
468		16	21	7–8			(b)	(b)	(b)	
469	Harry Weher	16	21	18		Dr1½	12	10	2	S
470	Sacramento Bank	16	21	18	1890	B6	30	10	20	S
471	H. Maguire	16	21	19		B5		8		S
472	David Heishie	16	21	20	1888	B5		8½		S
473	J. J. D. Barish	16	21	20	1894	Dr½	16	8	3	S
474	J. G. Burnett	16	21	30	1890	B4	25	7	13	SC
475		16	21	31		B5	20	15	5	S
476	Roza Breiza	16	21	29		B5		10		
477	Lee Burton	16	21	28	1880	B4	70	10	60	
478	Martin Elder	16	21	35	1898	B8	52	8	44	SCHp
479	T. G. Martin	16	21	26	1899	B10	50	8	42	LHpSC
480	Will Pickard	16	21	36	1892	B5		10		
481		16	21	24		B5		10		
482	C. S. Campbell	16	21	24	1882	B5	60	9	51	SCHp
483	Sacramento Bank	16	21	12	1880	B5	75	12	63	SCHp
484	Jno. H. Hoffman	16	21	1	1894	B5	35	12	23	S
485	C. E. Roberts	16	21	1	1888	B5	60	14	46	SCHp
486		15	21	35 / 36		⅓ by $\frac{1}{20}$ mi.	(c)	(c)	(c)	
487	Mr. Vogel	15	21	35		B2		15		
488	Edwin Bullock	14	20	25	1899	B	70	12	58	SCHp
489	F. G. J. Schmidt	14	20	23	1896	B2	40	10	30	
490		15	21	6			(d)	(d)	(d)	
491	F. H. Mills	15	21	5	1890	B5		13		
492		15	21	7			(a)	(a)	(a)	
493	J. V. Lamore	15	21	18	1885	B2	60	12	48	SHp
494	J. B. Perrin	15	20	12	1882	B5	22	13	9	SLHp
495	T. E. Elliott	15	21	18	1890	B2		12		
496	Chas. K. Kirby	15	21	18	1882	B5		12		
497	Mr. Madden	15	21	29	1885	B5	100	12	88	
498	Jno. K. Kennedy	15	21	30	1894	B5	96	13	83	SHp
499		15	21	30			(c)	(c)	(c)	
500	Harland & Stevens	15	21	31	1885	B5		14		
501		16	21	6			(d)	(d)	(d)	
502	Thos. Hansen	16	21	5	1893	B5		14		
503		15	21	32			(a)	(a)	(a)	
504	Robt. E. Hall	16	21	4	1890	B5	100	14	86	HpCS
505		16	21	4–5 W. ½			(c)	(c)	(c)	
506	Sacramento Bank	16	21	8	1892	B5		20		
507	Terry School	16	21	10		B5		10		
508	Mr. Johnson	16	21	10		B5		10		
509	Jno. Reynolds	16	21	14	1892	B5	60	9	51	SCHp

[a] Swale water 12 feet below.

[b] Swale water 15 feet below.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand			Good	Dom; st	
do	do		$4.00	do	do	12
do	do		12.00	do	do	13
do	Wind			do	do	13
do	Hand		4.00	do	do	12
do	do	$24.00	4.00	do	do	8
do	do	25.00	5.00	do	do	9
Hard	do	40.00	3.00	do	Dom	11
Soft	do		4.00	do	Dom; st	16
do	do	24.00	3.00	do	do	13
do	8 wind		250.00	do	do	16
do	10 wind	40.00	75.00	do	do	19
do				do	do	13
	Hand		3.25	do	do	15
Hard	Wind	26.00		Good	Dom; st	16
	Hand	23.00	3.25	do	do	21
Hard	Wind			do	do	24
Soft	Hand			do	do	10
do	do		4.00	do	do	15
do	do	60.00	11.00	do	do	
do	Steam	132.00		120,000 gallons	Winery	8
	Hand		3.25	Good	Dom; st	15
Hard	do		3.25	do	do	25
Soft	do	86.00	12.00	do	do	10
do				do	do	11
do	Hand			do	do	14
do	Hand	80.00	3.25	do	do	12
do	do	25.00	3.25	do	do	10
Soft; alk	Hand		3.25	Good	Dom; st	39
Hard	do		3.25		do	10
do	Horse		6.00	Good	do	26
Soft				Small	Dom	
Hard	Hand	4.00	3.25	Good	Dom; st	8
Soft	do		4.00	do	Dom	13
Hard	do		5.00	Small	Dom; st	16
Alk	Wind		3.25	Good	do	26
Soft	Hand	40.00	3.00	do	do	8
Hard	Steam	52.00	436.00	323,158 gallons	Irr	34
Soft	do	42.00	436.00	323,158 gallons	do	10
Hard	Hand		3.00	Small	Dom; st	12
Soft	Wind		4.00	Good	do	18
do	do			do	do	12
Soft; alk	Hand		3.50	do	do	10
Soft	do	20.00	4.00	do	do	15
do	do		3.50	do	do	18
Soft	Hand		3.25	Good	Dom; st	8
do	8 wind		35.00	do	do	11
do	Hand	20.00	3.25	do	do	15
Hard	Hand		3.25	Good	Dom; st	20
Soft	Hand	25.00	3.25	Good	Dom; st	12
do	8 wind		45.00	do	do	10
do	Hand		3.00	do	do	20
do	16 wind			do	do	15
do	Wind		70.00	do	do	14
Hard	Hand	57.00	3.25	do	do	28
Soft	Hand		4.00	Good	Dom; st	11
Soft	Hand		3.25	Good	Dom; st	4
Soft	8 wind		49.00	Good	Dom; st	11
Hard	Wind			Good	Dom; st	39
Soft	Hand		3.25	do	do	16
	do		3.00	do	do	14
Hard	do		3.25	do	do	24

c Swale water 14 feet below.

d Swale water 13 feet below.

Wells in Kings River delta—Fresno

No. of well.	Owner of well.	Location. T.	R.	S.	Year completed.	Class of well.	Depth of well. Feet.	Depth to water. Feet.	Depth of water. Feet.	Strata.
510		16	21	14			(a)	(a)	(a)	
511	J. D. Griffey	16	21	13		B5		12		
512	J. Hamilton	16	21	24	1899	Dr2	22	10	12	SHp
513		16	21	26			(b)	(b)	(b)	
514	Central School	16	21	26		B5		10		
515	Dick Butler	16	21	22	1888	B5	30	11	19	SHpC
516	E. R. Holton	16	21	28	1882	B5	30	7	23	
517	Mrs. M. L. Viere	16	21	15	1882	B5		9		
518	J. F. Crowder	16	21	24	1894	B5	94	10	84	S
519	D. Patton	16	22	9	1880	B5	100	11	89	LS
520	J. B. Fontaine	16	22	4	1896	B5	52	10	42	S
521		16	22	3-10			(c)	(c)	(c)	
522	Percy Fowler	16	22	3	1880	B5		14		
523	Sam. L. Hogue	16	22	12	1885	B5		11		HpCS
524	Prof. Heald	16	23	7	1880	B5		12		SHp
525		16	23	8		B5		12		
526	Prof Heald and Heley	16	23	6	1897	B5		14		SHp
527	Gust Almgren	15	23	33		B5		33		
528	Gust Stromberg	16	23	4	1899	B6	85	30	45	SHp
529	M. E. Stanton	15	23	32	1888	B5	62	40	22	HpS
530	Jno. Holnberg	15	23	33	1889	B6	93	50	43	HpCSG
531	T. L. Reed	15	23	22	1889	B5		60		LHpCSG
532	do	15	23	27	1889	B6	75	45	30	LHpCS
533	Burris Bros	15	23	26		B5	23	21	2	HpC
534	S. T. Curtes	15	23	35		B5		18		CHp
535	A. Winters	16	23	13	1898	D36	12	6	6	
536	Mrs. A. R. Orr	16	23	12	1890	B5	80	15	65	
537	Mr. Dittman	16	24	7		B		10		
538	J. W. Roberts	16	24	8	1900	B5	70	10	60	CSHp
539		16	24	5		B8	50	8	42	
540	Mrs. A. R. Orr	16	24	4		B		10		
541	K. Gregory	16	24	5	1887	B5	84	12	72	CHpS
542	L. Pederson	15	24	33	1900	B5	75	12	63	CHpS
543	Cal. F. & L. Co	15	24	29		B5	50	13	37	
544	J. S. Jones	15	24	19		B8		17		
545	R. M. Wilson	15	24	19	1891	B7	64	15	49	HpCS
546	J. T. Mance	15	24	18		B5	15	(d)	(d)	
547	Ger. L. & S. Bank	15	23	13	1886	B5	58	22	36	
548	A. L. Holmes	15	23	24		B5	38	29	9	
549	Purington	15	23	24	1890	B5		24		HpS
550	Joe Housley	15	23	27	1890	B6	71	35	36	HpSC
551	J. H. Harden	15	23	15	1885	B6	84	50	34	LHpS
552	P. Legure	15	23	15	1885	B5	85	40	45	HpCS
553	Fink School	15	23	10	1900	B5	100	42	58	HpCS
554	San Francisco Bank	15	23	11		B5		40		CHpS
555	Fisher	15	23	14		B5	80	35	45	
556	Frank South	15	23	14		B5	25	(d)	(d)	
557	F. Fisher	15	23	12		B8				
558	Victor Franzen	15	23	12	1881	B5	60	32	28	HpCS
559	Gosliner Bros	15	24	6		B				
560	do	15	24	7	1885	B7	80	25	55	HpSC
561	Sacramento Bank	15	24	6		B7	30	12	18	
562	Sweets Place	14	24	32		B6		13		CHpS
563	Mr. Martinez	14	24	33	1886	B5	97	12	85	
564	Mrs. Merrit	14	24	29	1885	B6	40	20	20	
565	Alta District	14	24	30		B5	100	20	80	
566	Jake Eppinger	14	23	26	1897	B6	90	27	63	HpCS
567	Mrs. J. D. Reese	14	23	9	1899	D	18	14		G
568	S. W. Lewis	14	22	14	1898	B12	48	18	30	LG
569	N. L. Durgin	14	22	22	1890	Dr2		20		
570	W. H. Spitler	14	22	22		B5	25	16	9	
571	C. Gravani	14	22	17	1898	B2		12		
572	Fruitvale estate	14	19	8	1894	B2	60			
573	I. C. Barman	14	19	18	1893	B1½	85	6	79	
574	Mat. Asmussen	14	18	12	1881	B2	70	8	62	
575	J. C. Appley	14	18	14	1894	B2		8		S
576	John Condon	14	18	26	1894	B2		8		S
577		14	18	26		B2	21	9	12	
578	Geo. P. Thornton	14	19	30	1893	B2	80	8	72	
579	Mrs. G. F. Thornton	14	19	29	1893	B2	90	10	80	HpSC
580	(On county road)	14	19	28		B7		7		
581	Burley Bros. & McNeil.	14	19	22		B2		5		S

[a] Lagoon water 11 feet below.

[b] Swale water 10 feet below.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand		$3.25	Good	Dom; st	12
do	do	$10.75	3.25	do	do	8
Soft	Hand		3.25	Good	Dom; st	13
	Wind		4.00	do	do	9
Soft	Hand			do	do	8
do	14 wind			do	do	15
do	8 wind		50.00	do	do	14
do	Hand			do	do	8
do	do		3.50	do	do	8
Soft	Hand		4.50	Good	Dom; st	8
do	do		3.50	do	do	17
do	Wind			do	do	24
do	Hand			do	do	17
do	do		12.00	Small	do	14
do	do			Good	do	16
Hard	do	67.00	11.00	do	do	14
Soft	Wind			do	do	12
Hard	Hand		100.00	do	do	15
Soft	do			do	do	12
Hard	Wind			do	do	26
do	Hand		4.25	do	do	12
Soft	do			do	do	11
	Rope			do	do	
Soft	Hand; horse	80.00		do	do	8
do	Hand			do	do	13
Hard	do	36.00	3.50	do	do	14
do	do		5.00	do	do	12
do	do		5.00	do	do	31
Soft	do	40.00	3.50	do	do	13
do	do	30.00	3.50	do	do	12
do	do		3.50	do	Dom	14
do	Wind			do	Dom; st	
do	do			do	do	12
do	Water; hand		6.00	do	do	12
do	12 wind			do	Stock	11
do	Hand		5.00	do	Dom; st	12
do	do			do	do	19
do	Wind			do	do	13
Hard	do	84.00	100.00	do	do	16
do	8 wind	80.00	70.00	do	do	14
do	Hand			do	do	10
do	do			do	do	14
do	14 wind			do	do	10
do	8 wind		47.00	do	do	11
do	Wind			do	Stock	8
do	do			do	Dom; st	12
do	Hand			do	do	10
do	12 wind	80.00		do	do	13
do	Hand		4.00	do	do	13
do	do		5.00	do	do	
Soft	do	97.00	3.25	do	do	13
Hard	8 wind			do	do	17
Soft	Hand		4.25	do	do	8
Hard	Wind			do	do	12
Soft	Hand		12.00	do	do	11
do	Wind			do	do	9
do	8 wind		47.00	do	do	18
do	Hand			do	do	11
	do		3.50	do	do	
Soft	Wind			do	do	8
do	Hand		3.50	do	do	13
Hard; alk	do	21.00	3.25	do	do	
Alk	do			do	do	19
Hard	do		5.00	do	do	20
				do	do	
Soft	Wind	24.00	47.00	do	do	16
do	do	25.00	89.00	do	do	21
Soft	Hand		3.25	Good	Dom; st	32

[c] Swale water 12 feet below.

[d] No water.

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			Feet.	Feet.	Feet.	
582	Mr. Harris	13	19	26		B5	17	14	3	
583	Lafayette Pearson	13	19	26	1892	B2		16		HpCS
584	Mr. Williams	13	19	29		B7	35	21	14	
585	S. H. Crane	13	19	30	1888	B7		16		SHp
586		13	18	25	1898	B2		19		
587	Kennedy & Owen	13	18	25		B5	40	16	24	
588	California Bank	13	18	23	1898	B5	100	22	78	
589	Mrs. Thornton	13	19	19	1888	B6	60	20	40	
590		13	19	17		B7				
591		13	19	17		B5				
592	Ed. Ferguson	14	21	12		B2		10		
593	Sierng Bros	14	21	13	1892	B5	90	10	80	LHpSC
594	P. M. Hart	14	22	19		B2		10		SGS
595	David Antres	14	22	19	1898	B5		10		
596	W. R. Wilson	14	22	21		B5		18		
597		14	22	29			(a)	(a)	(a)	
598		14	22	28			(a)	(a)	13	
599	Will McKenzie	14	22	28		Dr2	54	12	42	
600	Bethel schoolhouse	14	22	34	1888	B5		11		
601	J. A. Roberts	15	22	3	1892	B6	85	14	71	
602	M. A. Colton	14	22	35	1900	B5	58			CS
603	H. O. Marshall	15	22	11		B5		14		
604		15	22	3		Swale		13		
605	A. J. Wells	15	22	9	1883	B5	52	12	40	S
606	H. S. Hulbert	15	22	9	1879	B5	72	10	62	S
607	J. J. Wiley	15	22	15		B5		16		
608	Shafer Bros	15	22	14	1886	B5	70	16	54	S
609	D. C. McClarly	15	22	27	1881	B6	65	15	50	CHpS
610	H. White	14	22	27	1892	Dr2	32	10	22	S
611	G. L. Traber	15	22	26	1877	B5	60	15	45	
612	Mathias Thomson	15	22	35	1892	B5		14		
613	H. F. Graper	16	22	2	1888	B6	48	13	35	CS
614	Helge Lee	16	22	14	1896	B5		13		
615	Frank Hanson	16	22	13	1889	B5	40	15	25	S
616	W. H. Seward	16	22	13	1893	B5	45	15	30	LSHp
617	Charles Strid	16	22	23	1892	B5	30	12	18	GS
618	Wells Anderson	16	22	26	1888	B5	40	20	20	HpCS
619	E. S. Boot	16	23	30	1888	B5	52	25	27	CHpS
620	Mrs. A. Stober	16	23	19	1889	B5	67	17	50	LHpCS
621	A. B. Clark	16	23	19				22		
622	S. F. L. & S. Assn	16	23	18	1886	B5	70	15	55	HpCS
623	N. J. Shadle	16	23	18	1891	B5	60	20	40	HpCS
624	N. J. Layton	16	23	8	1884	B5	64	20	44	HpCS
625	G. Bordson	16	23	6	1888	B5	40	14	26	LHpSC
626	J. A. Beall	15	22	25	1900	B5		17		LHpSCHp
627	J. M. Marshall	15	23	29	1881	B6	116	30	86	HpCS
628	Martin Miller	15	23	30	1880	B5	70	20	50	LHpCS
629	J. A. Milton	15	23	20	1891	B5	68	28	40	LHpS
630	N. Boysen	15	23	20	1891	B8	55	25	30	HpS
631	Milton M. West	15	23	21	1891	B5	45	40	5	S
632	Sacramento Bank	15	23	19	1885	B5	53	30	23	HpS
633	C. O. Love	15	23	18	1885	B6	30	25	5	HpS
634	E. L. Jediker	15	22	13	1884	B5	59	25	34	HpCS
635		15	23	7		B6		45		
636	S. P. R. R. Co	15	23	8		B5		30		
637	Kimble estate	15	23	7		B6	60	35	25	SCHp
638	M. Bassett	18	21	14	1898	B5	44	10	34	SC
639	Aug. Weihe	14	20	5	1897	B2	35	7	28	LHpSC
640	O. J. Ransom	14	20	6		B		9		
641	Geo. Roeding	13	20	31	1900	B5	93	12	81	CHpS
642	Balfour, Guthrie & Co.	13	19	25	1888	B5		24		
643		13	19	35		B8		17		
644	Judson & Stutson	13	19	6	1883	B7	115	60	55	
645	California Bank	13	19	11	1897	B5	83	38	45	LHpSC
646	do	13	19	11	1882	B7	112	38	74	
647	J. E. Rawlins	19	21	1	1882	B6	42	10½	31½	HpS
648	Philips estate	19	22	7	1895	B5	40	10	30	S
649	R. S. Wait	19	21	13	1878	B6	40	10	30	CS
650	C. H. Watson	19	22	19	1893	B5	45	8	37	CHpS
651	Cal. S. & L. Assn	19	21	25	1880	B6	55	9	46	CS
652	A. P. Redding	19	21	36	1889	B10	783	(b)		SCCS
653	A. Onesti	18	21	36		B5		11		
654	A. L. Cressy	18	21	35	1884	B	25	10	15	

[a] Swale water 13 feet below.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand			Good	Dom; st	
do	do		$3.00	do	do	10
do	Lift			do	do	11
do	Hand		6.00	do	do	14
do	do		3.50	do	do	12
do	do		3.50	do	Stock	17
Hard	8 wind	$100.00	50.00	do	Dom; st	32
Soft	Wind			do	do	12
do	Hand		3.50	do	do	13
do	Wind			do	do	12
do	Hand		3.50	do	do	18
do	Wind	90.00	65.00	do	do	15
do	8 wind		56.00	do	do	14
do	Hand		3.50	do	do	16
do	do		3.25	do	do	19
Soft	Hand		3.00	Small	Dom; st	14
do	Lift			Good	Dom	14
do	Hand		3.00	do	Dom; st	8
do	do	30.00	3.50	do	do	10
do	do		3.50	do	do	12
Hard	Hand	30.00	3.00	Good	Dom; st	14
do	8 wind	79.00	200.00	do	do	11
Soft	Wind			do	do	8
Hard	Hand		3.50	do	Stock	19
Soft	do		3.25	do	Dom; st	8
Hard	do	4.50	3.50	do	do	8
Soft	do		3.50	do	do	13
do	do		3.50	do	do	18
Hard	do	36.00	3.50	do	do	32
Soft	do		3.50	do	do	9
Hard	do	30.00	3.50	do	do	31
	do	35.00	15.00	do	do	33
Hard	do	22.00	3.50	do	do	15
Soft	do	30.00		do	do	12
do	do		11.00	do	do	11
Hard	do	67.00	13.00	do	do	14
Soft	do		9.00	do	do	11
Hard	do	52.00	3.50	do	do	26
do	do	44.00	120.09	do	do	17
	Wind; hand			do	do	21
Soft	12 wind		200.00	do	do	29
do	Wind			do	Dom	15
Hard	12 wind	116.00	42.00	do	Dom; st	11
do	8 wind	70.00	46.00	do	do	13
do	do	48.00	55.00	do	do	17
Soft	Hand			do	do	29
Hard	do			do	do	11
Soft	do	53.00	11.00	do	do	11
do	do		5.00	do	do	11
Hard	Wind	59.00	158.00	do	do	16
do	8 wind		40.00	do	do	12
do	Hand			do	Stock	10
Soft	14 wind			do	Dom; st	8
Hard	Hand	22.00	4.00	do	do	9
Soft	do	8.80	3.50		do	12
do	14 wind; hand			Good	do	8
do	8 wind	73.00	50.00	do	do	12
do	16 wind			do	do	11
do	Hand		6.00	do	do	14
do	Wind			do	do	26
Hard	8 wind	58.00		do	do	38
Soft	do		53.00	do	do	16
do	12 wind	42.00	150.00	do	do	14
Hard	Hand		6.00	do	do	94
Soft	do			do	Dom	40
do	do			do	Dom; st	54
do	do	55.00	7.00	do	Dom	19
Soft; sul		2,600.00		488,920 gallons	Dom; irr	14
Soft	Hand		4.00	Good	Dom; st	12
do	8 wind	25.00	50.00	do	do	16

[b] Flows.

Wells in Kings River delta—Fresno

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			*Feet.*	*Feet.*	*Feet.*	
655		19	21	11		Dr1½		9		
656		19	21	14		B5		10		
657	Fred Ward	19	21	26		B5		9		
658	Silvan Fereira	19	21	26		B4		9		
659	Jno. Bowers	19	21	36	1894	B9	800	(a)		CS
660	W. S. Burr	20	21	2	1900	B5	44	16	28	CS
661	Mrs. J. Hide	20	21	12		B		15		CS
662	W. V. Walker	18	21	34	1890	B5	35	10	25	
663	Maria Reynolds	18	21	33	1885	B5	36	12	24	CS
664	S. Badger	18	21	32		B5		11		SC
665	Mrs. M. Camp	18	21	30	1880	B5	32	10	22	CS
666	W. J. Weir	18	20	36	1890	B5	40	10	30	SC
667	Mrs. H. Bryant	18	20	36	1880	B5	50	12	38	CS
668	T. L. Hanna	18	20	26	1900	Dr2	42	7	35	CS
669	M. P. Hatch	18	20	27	1882	B5	34	12	22	CSL
670	G. E. Lathan	18	20	33	1897	B5	132	1+	131	CS
671		18	20	33	1900	B5		3½		CS
672	R. M. Coon	19	20	4	1877	B8	52	8	44	SC
673	James Wright	19	20	10	1892	B6		8		SC
674	J. J. Moss	19	20	10	1888	B6	108	4	104	SC
675	Jno. Hunlen	19	20	16		B7	100+	(a)		SC
676	R. W. Dougherty	19	20	15	1892	B5	139	3½	135½	SL, SiltC
677	Mrs. E. Cory	19	20	14	1882	B6	33	8	25	SCS
678	Fred Jennings	19	20	13	1883	B6	36	10	26	CS
679	J. F. Florey	19	20	13	1885	B5	40	8	32	CS
680	G. E. Shore	19	21	18	1889	B7	40	10	30	SC
681	L. R. Love	19	21	20	1890	B5		12		S
682	W. W. Parlin	18	21	15	1880	B5		6		
683	Martin Roberts	19	21	22	1882	B5	25	12	13	SC
684	H. N. Hogle	18	21	25	1880	B4	75	10	65	CS
685	Wm. Hogle	18	21	23	1897	Dr2	100	8	92	CS
686	Mary White	18	21	22	1890	B5	57	8	49	CS.[b]
687	Mike Dutra	18	21	22	1889	B5	50	9		CS.[b]
688	Geo. I. Richie	18	21	21	1895	B5		10		CS.[b]
689	H. E. Ayers	18	21	30	1880	B5		8		CS.[b]
690	Mr. Page	18	20	24	1900	B5	24	8	16	CS
691	J. L. Kurtz	18	20	26	1896	B5	28	7	21	CS
692	J. D. Patterson	18	20	22	1892	B5	106	3	103	CS
693	J. Sutherland	18	20	28	1894	B2	530	(a)		CS.[b]
694	Frank Sharples	18	20	16	1898	B5	170	10	160	SC
695	R. H. Kearns	18	20	27	1894	B2	56	8	48	SC
696	J. Sutherland	18	20	15	1899	B5	96.5	3	93.5	CS.[b]
697		18	20	12		B5		12		
698	T. P. Sutherland	18	20	13		B5		10		
699	W. A. Long	18	21	18		B5	33	6	27	SC
700	C. Lathan	18	21	18	1890	B5	40	6	34	CS
701		18	21	17	1898	B.		8		SC
702	Kimball, trustee	18	21	9		B		8		SC
703	Mrs. M. A. Haws	18	21	9	1891	B5	50+	8	42+	SC
704	Jno. Wynrck	19	21	2	1884	B7	608	(a)		SC
705	Mrs. M. Andrews	19	21	10	1882	B5	60	10	50	SC
706	J. R. Mullinix	19	21	14	1880	B6	40	12	28	SC
707	W. S. Slavin	19	21	23	1895	B5	35	12	23	CS
708	Jno. Sigler	19	21	26	1892	B5	65	12	43	SC
709	M. P. Rose	19	21	26	1890	B4		10		
710	A. M. Stone	19	21	34		B5		14		
711	W. Burr	20	21	10		B7		13		
712	C. Paddock	20	21	4		B5	35	13	22	SC
713	M. F. Mines	20	21	4	1891	B5	83	14	69	SC
714	Mussel Slough C. and I. Co.	20	21	5		B5		21		
715	T. J. Smith	19	21	31	1899	B6	38	12	26	CS
716	E. G. Sellers	19	20	36	1895	B5	52	12	40	CS
717	E. Jacobs	20	20	2		B9		(a)		
718	W. Blevins	19	20	26	1892	B6	40	10	30	SC
719	John Hereford	19	20	22	1885	B5	40	11	29	
720	Joe Whiteside	19	20	26	1898	B6	114	8	106	CS
721		19	20	35		D48	10	7	3	CS
722	Judge Shores	19	20	25	1890	B6		10		
723	D. R. Nidiffer	19	21	19	1875	B5	37	10	27	SC
724	H. V. Woodgate	19	21	29		B5		10		
725	Geo. W. Houston	19	21	21	1890	B5	34	12	22	SLSC
726	P. C. Eccles	18	21	35	1891	B4	40	10	30	
727	F. E. Wood	19	21	3	1890	B5	50	8	42	

[a] Flows.

ulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand			Good	Dom	15
do	do		$3.25	do	Dom; st	15
do	12 turbine		130.00	do	do	31
Alk	Wind			do	do	23
Soft		$1,600.00		do	do	16
Hard	8 wind	22.00	31.50	do	do	92
Soft	Hand		5.00	do	do	12
do	do		3.25	do	do	14
do	do		6.00	do	Dom	9
do	do		3.00	do	do	11
do	8 wind	32.00	53.00	do	do	15
Hard	Hand			Small	do	13
do	do	50.00	4.00	Good	do	17
Soft	do	21.50	4.50	do	Dom; st	8
do	do	20.00	4.00	do	Dom	9
Soft; sul	do	69.00	4.00	do	Dom; st	15
Soft	do		4.00	do	do	23
Hard	Wind				do	24
do	Hand			Good	do	13
Soft	do			do	do	30
Soft; sul				5,789 gallons	Dom	72
Soft	Hand	108.00	4.00	Good	Dom; st	59
do	do	17.00	3.25	do	Dom	14
Alk	do	17.00	4.00	do	do	14
Soft	Wind; hand			do	do	19
Hard	do			do	Dom; st	32
	Force			do	do	10
Hard	Hand		3.00	do	Dom	17
do	do		3.00	do	do	59
do	do	30.00	4.00	do	Dom; st	11
Soft; sul	do	50.00	4.50	do	do	15
Hard		28.50		do	do	9
Soft	Hand		4.00	do	Dom	8
do	do		4.00	do	Dom; st	10
do	do		3.00	do	do	9
do	do		4.00	do	do	37
do	do			do	Dom	13
Soft; sul	do	99.00		do	do	14
do	Artesian			482 gallons	Dom; st	29
do	Hand		4.00	Good	do	13
Soft	do	28.00		do	do	10
Soft; sul	do	65.00	3.00	do	do	12
Soft	do		3.00	do	Dom	8
do	Wind; hand			do	Dom; st	13
Hard	Hand	16.00	4.00	do	do	12
do	12 wind	20.00	65.00	do	do	11
Hard	Hand		3.00	Good	Dom	11
Soft	do			do	do	11
do				do	do	9
Soft; sul		1,333.00		32,166 gallons	Dom; st	21
Soft	Hand		4.00	Small	Irr.; dom	12
do	do	41.00	4.00	Good	Dom	9
Hard	8 wind		4.00	do	Dom; st	75
Soft	Hand	33.00	3.00	do	Dom	13
do	do		4.00	do	do	11
do	do		6.00	do	Dom; st	12
	do		4.00	do	Dom	110
Soft	do		3.50	Small	Dom; st	34
do	do		3.00	Good	do	32
do	(c)					
Hard		18.00	4.00	Good	Dom; st	31
do	Hand		3.50	do	do	33
Sul				6,433 gallons	do	29
Hard	Hand	30.00	3.00	Small	do	22
do	do		3.00	do	Dom	41
Soft; sul		97.00	3.50	Good	Dom; st	37
Hard	Rope			do	do	33
	Hand		4.00	do	Dom	16
Soft	do		3.00	do	Dom; st	12
do	do			do	do	13
Hard	do		4.00	do	do	8
Soft	8 wind			do	do	9
do	Hand			Small	do	13

[b] Alternate layers.

[c] On high ground; 4 feet above average.

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			*Feet.*	*Feet.*	*Feet.*	
728	Mr. Stewart	19	21	3	1900	B5	24	8	16	SHp
729	Ben Scribner	19	21	4		B5	70	10	60	
730	W. W. Robinson	18	21	31	1888	B6	42	10	32	SC
731	Camp estate	19	20	1	1885	B		10		
732	Mrs. H. F. Bryant	18	20	35	1890	B6	60	8	52	
733	Mrs. Hunkey	18	20	34		B5		8		
734	Ger. S. and L. Bank	18	20	34	1891	B7	240		240	SC
735	W. H. Crowder	19	20	10	1900	B5	34	8	26	LCS
736	E. W. Clithero	19	20	14	1890	B5	60	6	54	CS
737	W. D. Runyon	19	20	12	1896	B5	122	7	115	CS
738	O. D. Brown	19	20	1	1883	B5	40	4	36	CS[a]
739	M. Keichert	19	21	7	1890	Dr1½		8		
740	R. P. Gray	19	21	18	1882	B6	20	7	13	LSC
741	Mrs. D. Copeland	19	21	17	1885	B5	35	7	28	
742	C. Manter	19	21	8	1879		50	8	42	G at bottom
743	S. J. White	19	21	5	1880	B5		7		
744	Chas. Feahill	19	21	9	1890	B5	46	8	38	SC
745	J. L. Walker	19	21	8	1897	B5	66	9	57	S
746	Geo. Rich	19	21	9	1889	B5	30	7	23	SC
747	R. Burton	19	21	32	1893	B5	28	12	16	SC
748	Marriott & Mathus	19	21	30	1898	B5	104	12	92	SC
749	Mrs. S. Wilson	19	21	28		B5		10		
750	Mr. Dunner	18	22	31	1888	B5	28	10	18	SC
751	J. O. Hickman	18	21	25	1890	B5	24	7	17	LS
752	J. C. Rice	18	22	18	1888	B5	54	6	48	CS
753	L. N. Gregory	18	21	13	1888	B5	82	7	75	CS
754	People's Ditch Co	18	21	1	1897	B5	46	7	39	CS
755	A. J. Cortner	18	21	1	1891	B5	38	12	26	CS
756	Boston Raisin Co	18	21	3	1896	B5	52	10	42	
757	C. J. McCullah	17	21	35	1890	B5	52	7	45	LS
758	Mrs. Sutherland	17	21	26	1893	B5	35	10	25	SC
759	P. C. Phillips	17	21	27		B8		10		CS
760	do	17	21	28	1899	B5	48	13½	34½	SC
761	Love & Chittenden	17	21	33	1900	B		8		
762	Timothy Page	18	21	4	1890	B5		8		
763	do	17	21	32		B5	30	8	22	
764	C. H. Smith	17	21	32	1897	B5	30	10	20	S
765	Timothy Page	17	21	31		Dr2		10		
766	Crocker estate	18	21	6		B5		10		
767		18	21	8		B5		10		
768	R. V. Daggett	18	21	4	1880	B6	40	10	30	
769	J. W. Lane	18	21	22		B5	61	9	52	
770	Banner Vineyard	18	21	14		B5		8		
771	Hanford Co. Nat. Bk	18	21	23		B5		8		
772	Wetmore Bros	18	22	29	1885	B7	35	8	27	CS
773	J. M. Fox	18	22	28		B5		8		
774	F. G. Ferreiro	18	22	22		B5	35	6		
775	Alex. Taylor	18	22	22	1894	B5	40	7	33	S
776	Willow Grove schoolhouse.	18	22	24		B5		8		
777[b]	E. Y. Bock	18	22	24	1878	B4	70	12	58	CS
778	M. D. Fierra	18	22	13		B5		9		
779	S. S. Cerderberg	18	22	11	1886	B5	54	8	46	SC
780	David Burris	18	22	12	1900	B5	58	8	50	CSHp
781	Sacramento Bank	18	22	11	1900	B5	32	9	23	
782	Pike Clough	17	23	30	1886	B5	40	10	30	LCS
783	Chas. Barlow	17	23	30	1885	B6	40	8	32	SC
784	E. Jacobs	17	22	25	1885	B8	60	9	51	CS
785	S. Sweet	17	22	25	1884	B5	35	8	27	
786	Silas Simons	17	22	24		B5		9		
787	David Burris	17	22	22	1900	B5	33	9	4	CS
788	do	17	22	27	1886	B5	40	12	28	S
789	J. W. Dawson	17	22	35		B5		8		
790	Excelsior schoolhouse.	17	22	34		B5		8		
791	J. R. High	18	22	20	1897	B5	25	6	19	
792	H. Marshall	18	22	17	1900	B5	92	7	85	
793	Eureka School	18	22	22	1893	B4		7		
794	R. W. Morgan	18	22	15	1888	B5	60	9	51	
795	S. A. Thompson	18	22	10	1889	B5	66	8	58	CS
796[b]	Mrs. J. M. Clark	18	22	3	1890	B5	62	12	50	CS
797	W. F. Farmer	18	22	9		B5		8		
798	E. Jacobs	17	22	33	1885	B6	44	8	36	CS
799	Cosmos L. and W. Co.	17	22	33	1874	B6	65	8	57	SCG

[a] Alternate layers.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Hard	Hand		$24.00	Good	Dom; st	9
Soft; sul	do		4.00	do	Dom	8
Soft	do	$21.00	3.50	do	do	12
do	do		4.00	do	do	11
do	Horse	60.00	6.00	do	Dom; st	11
do	Hand		4.00	do	do	
Sul; soft	do			do	do	19
Soft		16.00		do	do	19
do	Hand		6.00	do	do	29
do	do	61.00	3.50	do	do	18
do	do		3.00	do	do	10
Hard	do		3.50	do	Dom	11
Soft	do	12.00	3.00	do	Dom; st	12
Hard	do		3.00	Small	Dom	12
Soft	do		3.00	Good	Dom; st	12
do	Wind			do	do	11
do	Hand	23.50	3.50	do	Dom	12
Hard	do	33.00	4.00	do	Dom; st	12
Soft	do		4.00	do	do	13
Hard	do	14.00	3.50	do	do	18
do	do	54.00	3.50	do	do	35
Soft	do		3.00	do	do	14
Hard	do	14.00	3.00	do	do	10
do	do	18.00	4.00	do	do	11
Soft	8 wind	48.00	38.00	do	do	11
Hard	Hand	41.00	4.00	do	Dom	18
do	do	23.00	3.50	do	do	10
Soft	do	28.00	3.00	do	do	10
Hard	do	26.00	3.50	do	Dom; st	8
do	do	36.00	3.50	do	Stock	11
Soft	do	18.00	3.50	do	Dom; st	8
do	do		6.00	do	Dom	9
	do		6.00	do	do	8
	Wind		4.00	do	Stock	9
Soft	Hand		4.00	do	Dom; st	10
	do			do	do	9
Soft	do		4.50	do	do	10
Hard	Steam			do	do	8
Soft	Hand		3.50	do	do	11
Hard	do		2.75	do	Stock	10
Soft	do		2.75	do	Dom; st	19
	12 wind	31.00	30.00	do	Dom	8
Soft	Wind; hand			do	Dom; st	10
do	Hand		3.50	do	Dom	8
do	Wind; hand	27.00		Small	Dom; st	29
do	do		3.50	Good	do	14
Hard	Hand		4.00	do	Dom	22
Soft	do	20.00	4.00	do	Dom; st	40
Hard	do		3.00	do	Dom	34
do	do		350.00	do	Dom; st	150
Soft	do		3.00	do	do	141
Hard	do	39.00	3.50	Small	do	14
do	do	37.50	6.00	Good	do	30
do	do	20.00	3.50	do	do	14
Soft	do	30.00	3.00	do	Dom	16
do	do	40.00	3.50	do	do	12
Hard	Wind	45.00	6.00	do	Dom; st	12
Soft	Hand		3.50	Small	Dom	14
do	do		5.00	Good	Dom; st	14
	do	33.00	5.00	do	do	8
Soft	Wind; hand			do	Dom	12
	Hand		3.50	do	do	
Soft	do			do	do	13
Hard	do	13.00		do	do	24
Soft	do			do	Dom; st	12
do	do		3.00	do	Dom	10
do	do		5.00	do	Dom; st	12
Alk				do	Dom	21
Soft	14 wind	30.00		do	Dom; st	11
do	Hand		3.50	do	do	12
Hard	do	33.00	6.00	do	do	14
Soft	do	65.00	6.00	do	do	8

[b] On higher ground.

Wells in Kings River delta—Fresno,

No. of well.	Owner of well.	Location.			Year completed.	Class of well.	Depth of well.	Depth to water.	Depth of water.	Strata.
		T.	R.	S.			*Feet.*	*Feet.*	*Feet.*	
800[a]	Montgomery Bros	17	22	34	1900	B5	56	13	43	SCG
801	Mr. Jenkins	18	22	4		B5	30	8	22	
802	William A. French	17	22	32	1888	B6	35	8	27	SC
803	M. E. Templeton	18	22	5		B5		8		
804	M. B. V. Garcia	17	22	29	1899	B5		8		
805	Mr. Van Dorset	17	22	29	1900	B5	44	8	36	SC
806	C. W. Clark	17	21	36	1885	B5	60	11	49	SC
807	T. J. Alcorn	17	21	25	1900	B5	42	11	31	SC
808	R. H. G——	18	22	5		B5		9		
809	Frank Griffith	18	22	29	1894	B5	38	12	26	SC
810	Joe Rogers	18	22	28		B5		11		
811	S. B. Hicks	18	22	33	1880	B5		9		
812	Perry C. Phillips	18	22	35		B5		9		
813	do	18	22	25	1900	B5	138	12	126	SC
814	do	18	22	36		B5		16		
815	J. H. Murray	19	22	12	1892	B5	43	14	29	CS
816	W. Hampshire	19	22	11	1900	B5	30	8	22	LQsCS
817	R. Abbot	19	22	3	1899	B4	100	9	91	CS
818	P. Sweeney	19	22	14	1878	B5	40	8	32	SCSC
819[a]	Mrs. M. J. Covert	19	22	22	1878	B5	40	14	26	S
820	G. L. Fletcher	19	22	15	1889	B5	56	10	46	
821	Cal. S. and L. Soc	19	22	9	1880	B4	+22	10	+12	
822	Harry Peacock	19	22	3	1873	B5	75	9	66	
823	E. Pichett	18	22	35	1885	B5		9		
824	F. M. Hart	19	22	4		B5		9		
825	Cross Creek schoolhouse.	18	22	32		B5		9		
826	C. Waldorf	19	22	5		B4		8		
827	Fred Dunn	19	22	7		B5		12		
828	M. Braverman	19	22	9		B5		9		
829	Evelyn Davis	19	22	17		B5		9		
830	Robt. Dougherty	19	22	21		B5	15	8	7	
831	Eucalyptus schoolhouse.	19	22	21		B2		8		
832	S. L. Worley	19	22	28	1880	B5	30	13	17	
833	Robt. Dougherty	19	22	23		B5	30	14	16	SC
834	T. McCarthy	19	22	34	1876	B5	75	13	62	
835	Mrs. J. T. Hereford	19	22	34	1875	B6	40	11	29	
836	H. M. Richardson	19	22	34	1875	B5	30	10	20	
837	E. McCarthy	20	22	3		B5	64	14	50	
838	Wm. Rourke	20	22	3	1888	B5	30	17	13	SC
839	W. H. Heldebrand	20	22	10	1880	B5	34	16	18	
840	J. M. Moore	20	22	10	1900	B7		15		
841	Lakeside School	20	22	5		B5		14		
842	P. McCarthy	20	22	8	1886	B9	600	(b)		CS
843	F. E. Howe	20	22	8	1891	B8	750	(b)		
844	Lakeside Creamery Co.	19	22	33	1890	B5	60	15	45	SC
845	Geo. Clute	19	22	31	1885	B10	900	(b)		CS
846	J. H. Deardoeff	19	22	8		B5		10		
847	Susan Hill	19	22	20	1899	B5	30	10	20	
848	S. A. Brewer	19	22	20	1891	B5	54	12	42	SC
849	Sacramento Bank	19	22	29		B5		12		
850	A. & J. Toomey	19	22	32		B6		(b)		
851	Wm. Northup	19	22	31	1898	B5	30	12	18	CS
852	Mrs. C. Brown	18	22	15	1880	B5		12		
853	C. A. Roberts	18	22	16	1891	Dr1½		8		
854	E. Jacobs	18	22	17		B5		11		

[a] On higher ground.

[b] Flows.

Tulare, and Kings counties—Continued.

Quality of water.	Method of lift.	Cost of well.	Cost of machinery.	Supply.	Use of water.	Salts, parts per 100,000.
Soft	Hand	$28.00	$3.50	Good	Dom	10
do	do		3.00	do	Dom; st	8
Hard	do	17.00	3.50	do	do	13
Soft	8 wind		50.00	do	do	11
do	12 wind; hand			do	do	9
Hard	Hand	22.00	4.00	do	Dom	8
Soft	do	60.00	4.00	do	do	10
do	do	14.00	5.00	do	Dom; st	11
do	do			do	do	52
do	do	27.00		do	Dom	13
do	do		3.00	do	do	21
do	do		2.25	do	do	12
Hard	do		5.00	do	Dom; st	31
Soft	do			Small	Dom	50
do	do		4.00	Good	do	16
do	do	40.00	3.25	do	Dom; st	11
do	do	22.00	3.25	do	Dom	8
Hard	do	50.00	3.00	do	Dom; st	39
Soft	do	40.00	2.25	do	do	10
do	Hand; wind		3.25	do	do	10
do	Hand	56.00		Small	do	12
Hard	do		5.00	Good	do	48
Soft	14 wind; hand			do	Dom	16
	Hand		3.00	do	Dom; st	28
Hard; alk	8 wind		3.50	do	do	8
Soft	Hand		3.50	do	do	12
do	do		6.00	do	do	20
do	do		3.50	do	do	16
Hard; alk	do			do	do	46
Soft; alk	8 wind		41.00	do	do	128
Soft	Hand		5.00	Small	do	226
do	do		2.25	Good	Dom	9
Hard; alk	do		3.50	do	Dom; st	18
Hard				do	do	14
Soft	Hand		3.50	do	do	12
do	do	40.00	6.00	do	Dom	8
Hard	do		20.00	do	Dom; st	14
Soft	do	64.00	2.75	do	do	17
do	do	30.00	4.75	do	do	9
do	8 wind	34.00	114.00	do	do	12
Alk	do		50.00	do	Stock	......
Soft	Hand		3.50	do	Dom	11
Soft; sul		1,500.00			Dom; st; irr	13
do		1,250.00			do	12
Soft	Hand	45.00	12.00	Good	Dom	15
Soft; sul	Artesian	1,900.00			Dom; st; irr	15
Soft	Hand		2.25	Good	Dom	27
do	8 wind		35.00	do	Stock	17
do	Hand	30.00	2.50	do	Dom; st	29
do	14 wind; hand			do	do	18
Soft; sul					Stock	13
Soft	Hand	22.00	3.00	Good	Dom; st	19
Hard; alk	do		3.00	do	do	12
do	do			do	Dom	11
Soft	do		3.00	do	Dom; st	11

In 1882 Mr. C. E. Grunsky, then an assistant in the California State engineering department, made a careful study of the Kings River water supply. In 1898 he made a further study of the district for the hydrographic division of the United States Geological Survey, the results of which are published as Water-Supply and Irrigation Paper No. 18, which has previously been referred to and from which the following extracts regarding the ground water are made:

In no other irrigated region in California is the effect of irrigation on the elevation of the water table so plainly apparent as in the vicinity of Fresno. Here, notwithstanding the 6 feet per mile slope of the surface of the country, the subsoils have been and are being gradually saturated with water. When irrigation commenced the loss of water from canals in transit to lands to be irrigated was very great, and after reaching its destination it was found that frequently enough water was put upon the surface of individual small tracts of land to have covered them to an average depth of 15 to 20 feet in a season. Most of this water found its way into subsoils, together with the direct loss of water from the canals. When the first wells were dug at Centerville water was found at about 20 feet. It is now at 10 to 15 feet below the surface, and will probably not rise much higher on account of ample drainage of subsoils and a comparatively free subsurface flow toward the low river bottoms. [The same in 1900.]

Along Fancher Creek, where the creek is used as a canal, ground water was formerly at 50 to 75 feet below the surface; it is now at 12 to 20 feet along the upper portion of the creek, and still nearer the surface near the former sink of the creek, about 4 miles east of Fresno. In the Eisen vineyard, 5 miles east of Fresno, ground water is at 4 to 6 feet below the surface, and drain ditches have been constructed to prevent a further rise. Ground water is found at 4 feet below the surface in many parts of Temperance Colony, Nevada Colony, and Fresno and Central colonies. Throughout a considerable area near Fresno its surface is nowhere more than 16 feet below ground, though before irrigation commenced depth to water was 60 feet. Cellars which were in use until 1884 in Fresno have been condemned because ground water made its appearance in them. Near Selma and Kingsburg ground water was formerly found at about 30 feet. It is now at about 15 feet. [It was at 12 feet in 1900.] The so-called "Sand Hollow," which is a depression 100 yards to one-fourth of a mile wide, 12 miles long, and about 16 feet deep, having a southerly course, and passing about midway between Selma and Kingsburg, was formerly as dry as the surrounding plain. About 1880 the soil in its bed was found to require less moisture to produce crops than the adjacent plain; in 1885 water appeared at the lowest points of the bed, and in June of that year it had risen to the heads of ripening grain. Spots of black alkali now mar its bed and sides, which before were a light sand, apparently free from any excess of alkaline salts.

Near Sanders and at points eastward from there toward Kings River ground water was at 50 to 60 feet before irrigation commenced; it is now at 20 to 30 feet. Here, as in the case of Centerville, proximity to the river, which lies 60 feet below the surface of the plain, may interfere with a much greater rise of the ground-water plane.

In connection with this change in the elevation of the ground-water plane, it must be remembered that the effect of irrigation extends far beyond the points now under ditch. Owing to the slope of its surface and consequent hydrostatic pressure, ground water has a slow but certain motion westward through pervious subsoils of the Fresno region, and may therefore ultimately contribute more or less toward the flow of Fresno Slough and San Joaquin River.

At the time irrigation commenced near Fresno the soils and subsoils were dry; depth to ground water was 30 to 60 feet. The ground was porous, generally sandy, sometimes very hard on the surface. When wet it was converted into a bog.

Water passed through it readily into the lower strata. Thorough wetting compacted the soil and it was less liable to conversion into slush after the first and second wettings than before. It settled, as a result of the first wetting, about 8 inches to 1 foot, on an average. Sometimes the full supply of a ditch would flow for hours into a hole formed by the breaking in of the surface. Cavities 20 feet in diameter and 6 to 10 feet deep were occasionally formed in this way, and had to be refilled after the first wetting. The stability of buildings was in danger when water was first brought near them. It is not surprising, under these circumstances, that when irrigation commenced in this region sometimes enough water was run on small areas at one irrigation to have covered them 5 feet in depth, and that enough water was delivered to some of the 20-acre colony lots south of Fresno to have covered them to an average depth of 20 feet. After irrigation was practiced for a time the soils became more compact, absorbed water less rapidly, and a smaller amount of water passed into subsoils. At present the ground water near Fresno is so near the surface that the roots of alfalfa, vines, and trees readily penetrate to it and soils are kept moist by the water rising from below. Surface wetting has become unnecessary in many sections.

By the rising of the ground water plane near Fresno large tracts of land have been permanently moistened. Some are very thoroughly subirrigated, and in many instances injuriously so. Relief must be sought in some localities either by drainage or by proper regulation of the supply of water to the district whereby the elevation of the water table may be controlled.

Without attempting to express in detail the acreage irrigated per cubic foot per second of canal capacity or actual flow of water, it may be noted that the total volume of water brought to the vicinity of Fresno during the seventeen years 1879 to 1896 would at a very low estimate have covered to an average depth of about 0.8 foot per annum the entire 260,000 acres of the region through which the canals send their branches. It would have covered the 50,000 acres to whose surface water is actually applied to an average depth of 4½ feet per annum, or to a total depth of 75 feet. Some of this water has of course been consumed in sustaining plant life, more has been evaporated, but the most of it still permeates the subsoils of the irrigated region and of the lands to the west.

Pl. XXVI shows the regimen of the water plane near Hanford as determined by Mr. Grunsky.

A study has been made of the amount of water that has been used for irrigation on the Kings River delta during the last five years. It has been assumed that 4,000 second-feet of water (the aggregate discharge of the canals), when available from the river, were diverted between March and October, inclusive, and that during the remaining four winter months 2,000 second-feet, when available from the river, were diverted for irrigation. From the tables of daily flow the following results were obtained, on the foregoing basis:

Estimated seasonal diversion for irrigation from and seasonal flow of Kings River.

Season November 1 to October 31.	Seasonal irrigation diversion.	Total flow.
	Acre-feet.	*Acre-feet.*
1895-96	1,070,900	1,852,425
1896-97	1,198,691	2,088,924
1897-98	820,522	876,079
1898-99	996,307	1,227,217
1899-1900	1,032,158	1,281,051
Five-year mean	1,023,716	1,465,139

Probably one-fourth of the amount diverted is lost by seepage from the main canals and their laterals. Prof. L. G. Carpenter, of the Colorado Agricultural College, found that on Cache la Poudre River 30 per cent of the water that was applied for irrigation returned to the river below by seepage. Still larger percentages have been found in Utah, and the writer personally knows that similar conditions exist on Gila and Salt rivers in Arizona. If one-third of the remaining water applied on the fields for irrigation sinks to the water plane, we have a total seepage volume from losses in transit and from irrigation of 511,858 acre-feet annually. This great volume of ground water undoubtedly has a slow westerly movement in harmony with the surface slopes. This is indicated by the fact that there is a marked annual fluctuation in the elevation of the water plane, it being from 2 to 4 feet higher about July 1, after the heavy spring irrigation, than in October, at the end of the season's drought. If a pumping system were put in to draw upon this water plane for irrigation purposes, a portion of the water pumped would be lost by evaporation, but probably one-third would return to the water plane. Thus if 300,000 acre-feet of water were pumped the permanent withdrawal would be not more than 200,000 acre-feet, and the annual supply would be from two to three times that amount.

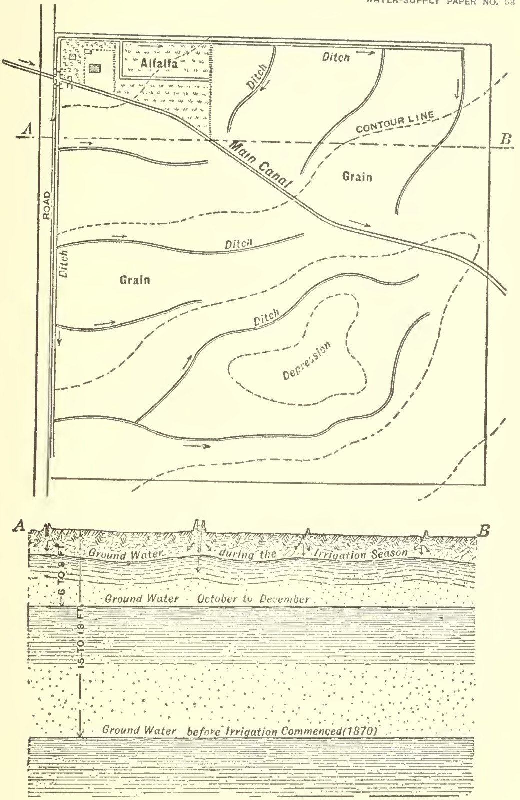
From the foregoing facts it is believed that a supply as great as 300,000 acre-feet can be obtained with certainty by pumping from the water plane of the Kings River delta.

The annual replenishment of the ground water is briefly discussed (pp. 87 to 88) in the accompanying report of Mr. Lewis A. Hicks on the generation and transmission of electric power and the installation of pumping plants.

As there is a heavy loss in the diversion canals, as this loss increases with their length, and as the general movement of the ground water is with the slope of the country in a southwesterly direction, it is believed that the best location for the pumping plants is near the lower ends of the canal lines and at the westerly portion of the irrigated lands. If located there a portion of the loss from the canals would be obviated, owing to their shorter length, and at the same time the pumping plants would have an ample water supply and the lift for the pumps would be slightly less. If the pumping plants were located near the upper end or the center of the canal lines they would probably draw directly from the canals water which otherwise would flow to its destination by gravity.

ALKALINE CONDITIONS.

The water of Kings River is almost chemically pure. Its alkalinity is negligible. The alkali encountered in the valley comes from the soil, largely from a calcareous hardpan which is found in some localities. In rising the water plane reaches the point where capillary action



PLAN AND GEOLOGIC SECTION SHOWING EFFECT OF IRRIGATION ON WATER PLANE IN THE HANFORD AREA OF THE MUSSEL SLOUGH COUNTRY, CALIFORNIA.

continually draws water from below and evaporating leaves practically all of the dissolved salt on the surface of the ground. Anything that will lower the water plane will tend to the reduction of surface alkali. If the voids in the soil be taken as one-third of the mass and 200,000 acre-feet of water are removed each year, then 600,000 acre-feet of soil are drained, equivalent to a depth of 2 feet over the entire irrigated area. It has previously been shown that this amount will be resupplied from the river. Nevertheless the tendency of the pumping plants would be to prevent the water-logging of the land and its alkalinity. As the amount of pure river water that is added to the water plane each year is greater than the amount of water that would be pumped and partially evaporated, the tendency would be to continually dilute the salt in the ground water. It is believed that the alkali is caused by the rising water plane, and it is likely that one of the principal provinces of the pump in the future will be to fight alkali by keeping down the water plane.

Mr. Thomas Means, of the Division of Soils of the United States Department of Agriculture, has personally made a study of alkaline conditions of the soil and water of the Kings River delta. He has devoted a great deal of time and thought to the general study of the alkali problem, and his views are very valuable in considering this subject. He has kindly furnished the following for use in this report:

The salt content of the waters near Fresno has been plotted. No marked lines of zones of underflow were found. The wells with the greatest amount of solids seem, however, to be in the alkali area and along the lower part of the valley. The wells in the portion of the valley north of Fresno are generally of lower salt content than the wells south of Fresno, yet an occasional well with a salt content as high as from 15 to 20 parts is found.

The water table under the Fresno Plains before irrigation was commenced averaged from 30 to 120 feet below the surface. At present the average depth to standing water in the Fresno area is about 10 feet, and during part of the year the level rises about 3 feet. Much of the area south and east from Fresno has the water table at about 6 feet, and during part of the year this level rises to within 2 or 3 feet of the surface. The Hanford area of Mussel Slough country has the level of standing water about 8 feet below the surface of the ground. [See Pl. XXVI.] During the winter the level of this standing water rises about 4 to 6 feet, so that over a great deal of the country the water table is within from 2 to 4 feet of the surface. Here the salt content of the water is greater than around Fresno, averaging about 20 parts per 100,000, while a few wells contain over 100 parts per 100,000.

The salt content of the water of Kings River is about 8 parts per 100,000, the most of which is lime carbonate. The scheme proposed for the irrigation of the desert lands of the area with the water pumped from below the land seems perfectly feasible to me and should, from the way I reason, lessen instead of increase the trouble with alkali. There is but one source of addition of alkali to the country, that is, the water which is taken out of Kings River for irrigation. This water is so pure and the salts which it does contain being lime salts are a benefit rather than a detriment to plant growth. For all practical purposes the only alkali with which we have to deal is the alkali which is at present in the soil.

Alkali salts to be harmful to vegetation must be concentrated within the top 2 feet of soil. Buried below this depth, or if evenly distributed through the soil in quantities not greater than 0.4 per cent of the dry weight of the soil, no trouble is ever experienced in raising ordinary farm crops (except in the case of the carbonate of soda or black alkali, which is harmful if present in quantities greater than 0.1 per cent). If the alkali be allowed to accumulate near the surface of the ground the roots of the plants are unable to perform their proper functions and the plant suffers, fails to ripen the fruit or dies.

There is a difference in the rate of upward and downward movement of the alkali salts. Experience has shown that the alkali salts move upward more readily than the same salts can be carried downward. This is because the upward movements are entirely capillary and the film around the soil moves, while the downward movement is largely gravitational and through the larger pores so that the film movement is small. This explains the reason why it is that even after large quantities of water are applied to a field of alkali salts may yet come to the surface.

Since alkali rises mainly by virtue of the capillary movements of the soil moisture, the capillary powers of the soil and the depth to standing water are the controlling factors of the rise of alkali. By the capillary power is meant the rapidity with which the moisture will rise within the soil. A heavy clay soil will raise water by capillarity much higher than a sand or silt soil, but the rate with which the water is raised is so slow that the soil is said to be of low capillary powers. In the same way a sandy soil, although the capillary rise is rapid, the height to which the water rises is not great, and the soils are said to be of low capillary powers. Silt soils, soils composed of very fine sand, and loam soils with a medium percentage of clay are generally classed as soils of great capillary power. The alkali soils of the San Joaquin Valley are almost without exception soils of great capillary power. Other soils of the same area which had all the conditions necessary for the accumulation of the alkali salts at the surface, except the fact that the soils were of low capillary power, are to-day free from accumulation of alkali. The Fresno sandy loam, or white ash land as it is locally known, is of great and rapid capillary power. The greater part of the land has been injured by the alkali which it contained. On the other hand the Fresno white sand, which is found typically developed on the plains around Caruthers and which is of low capillary power, although it originally contained within 10 feet of the surface as much alkali as did the white ash land, is very seldom found troubled with alkali.

The second factor in the accumulation of alkali is the depth to standing water. So long as the level of water does not come closer than 4 or 5 feet from the surface of the ground, practically none of the soils will become alkaline if cultivated. The reason for the accumulation of the alkali in the colony lands south of Fresno is that during part of the year the level of standing water comes so close to the surface as to permit continual upward movement and therefore rapid accumulation of the salts. White ash lands around Selma are found very fertile and give large returns where cultivated in fruit, yet an examination of these lands has shown that they contain within 10 feet of the surface as much alkali as do some of the alkali soils south of Fresno. The difference is this: the level of standing water at Selma never comes close enough to the surface (never closer than 6 feet) to permit rapid upward movement of the water. The consequence is that the salts either remain in the deeper subsoil or are distributed throughout the 10 feet. If ever the level of standing water around Selma is allowed to raise to within 3 or 4 feet of the surface, large areas of now fertile land will be rendered barren.

In this respect the scheme proposed for pumping promises to be of great assistance in the prevention of the further extension of the area of alkali land, but it promises also to be of great assistance in the reclamation of the lands already damaged. The pumps will be most active at the time the water table is ordinarily highest, and the amount of water taken from the soil will probably either prevent this rise or lessen its height. There is no question that if this annual rise of the water table could be prevented and the level of the water kept at its lower position the reclamation of all but the lowest of the alkali lands would be possible without a great and expensive system of drains.

Now the question is: Would the continued use of the water which lies below the land so concentrate the salt that it would in time contain too much salt for plant growth? My opinion is that it would not. You would be continually drawing the water from the depth of say 50 feet and applying the water to the surface of the ground. Part of this water would be evaporated, part used by the plant, and part would drain away to the rivers. The remainder would remain in the ground, but it would be continually diluted with the water which escapes from the irrigation canals and from irrigation and which now causes the annual rise of the water table. The absolute amount of alkali would diminish instead of increase, for the plants would take up some of the salts and another part would drain away into the country drainage. The concentration of the water would probably increase, but, as I have said before, I think the dilution of the irrigation water taken from the river would prevent this. If the water is drawn from a depth of 50 feet there are 15 feet in depth of water to be pumped before the same water is used the second time. Under ordinary pumping irrigation ten years would be required to effect this, and during these ten years sufficient water would have filtered in from the gravity irrigation around and above to dilute this salt. Moreover, at seasons of very high flood the soils could be irrigated with flood water at a slight expense, since the greater part of the country has been ditched.

Most of this applies directly to the Fresno country. Around Hanford the conditions would be slightly different, for here the rise in water table takes place in the winter; yet I can not see where this will affect the problem.

To sum the matter up, I think the result of pumping, if the pumping be carried on only to such an extent as to move the water which is now lost by seepage, would be to improve the conditions rather than to increase the trouble from alkali. The water table would be lowered sufficiently to permit the washing down of the alkali salts, and the salts, instead of being confined to the surface layers of the soil, would gradually be distributed throughout the 50 feet of soil, and by this dilution rendered harmless. The lowering of the water table would be of the greatest assistance to the reclamation of the lands already alkaline, and would probably permit this reclamation without extensive under-drains.

GENERATION AND TRANSMISSION OF ELECTRIC POWER AND INSTALLATION OF PUMPING PLANTS.[a]

INTRODUCTION.

The generation of power from the waterfalls of the high sierras flanking the wide expanse of unused yet fertile lands which form so large a part of the broad San Joaquin Valley, and its utilization, through electric transmission, for pumping the irrigating water supply in the valley, is a subject which fascinates the physicist as an example, on a large scale, of the conservation of energy, and it does not lose in attractiveness when considered as an engineering possibility quite within the range of known experimental results and susceptible of exact statement as to the cost of developing and producing continuously a unit quantity of water.

Several years ago the writer pointed out that the high load factor (the ratio of the average to the maximum load) which could be realized in the operation of a power plant handling a purely pumping load would reduce the cost of pumping sufficiently to make this method of water development economically possible, and as the result of the present investigation it is apparent that the required investment per acre-foot produced compares favorably with the cheapest surface-catchment projects, and that the annual cost of operating would be less than by any other method of extending the water supply, provided it is deemed advisable to operate the plant continuously throughout six or more months of the year. The very complete physical data which are available from the surveys, stream measurements, and photographs taken have made it possible to study the problem in detail. It falls naturally into three subdivisions: (1) The possibility of power development on Kings River depending on the fall and minimum run-off available within reasonable limits of conduit length; (2) the cost of generation, transmission, and application of sufficient power to pump 1,000 acre-feet of water daily for the irrigation of lands between Fresno and Hanford; and (3) the possibility of developing that amount of water continuously from the gravel storage of the alluvial cone of Kings River.

POWER AVAILABLE.

The site selected for the power house is at the junction of the South and Middle forks of Kings River, at an altitude of 1,980 feet. The diversion planned is from the Middle Fork, through 14,000 feet of continuous tunnel, with working adits at frequent intervals, delivering a maximum flow of 180 second-feet at the penstock, which is 68[illegible] feet above the water wheels.

[a] Report of Lewis A. Hicks.

The watershed tributary to this diversion contains an area of 325 square miles and rises to an altitude of 14,000 feet. The least mean monthly run-off during the last five years, which were years of drought, occurred in September, 1898, when the Red Mountain gaging records indicate an available mean flowage at the Middle Fork diversion of 85 second-feet. Following is the mean monthly minimum flow during these five years:

Mean monthly minimum flow of the Middle Fork of Kings River.

September—	Second-feet.
1896	206
1897	138
1898	85
1899	90
1900	126

In each year the minimum month was September. During the rest of the year the available flow was never less than 100 cubic feet per second, a quantity sufficient to generate the full load output contemplated. The recurrence of extremely dry seasons at more frequent intervals than ten or fifteen years is not probable and does not properly constitute a limitation of the plant to be installed.

ANNUAL REPLENISHMENT OF GROUND WATER.

A study of the water supply available for pumping, which has been fully considered by Mr. Lippincott, shows it to be ample to furnish the maximum of 328,500 acre-feet required annually by the pumping plants, and the supply will probably be much in excess of the demand.

Experience in Kern County, on a scale relatively as great, shows that the water plane is maintained, notwithstanding continuous pumping, where the wells are in proximity to gravity canals, and that while the plane of saturation is lowered during seasons when the canals are deprived of water it soon regains its former level when the use of the canals is resumed.

A careful study has been made of the data acquired by the extensive observations of the existing water plane in the Kings River delta, as revealed by more than 800 wells, supplemented by information given by well borers familiar with the district. The average wells for irrigating purposes have a log similar to the following:

Representative log of wells in Kings River delta.

	Feet.
Soil	7
Hardpan or clay	2 to 8
Coarse sand	10 to 50
Heavy clay	30 to 60
Coarse sand	4 to 6

The first layer of sand is generally found to be alkaline and is cased out, dependence being placed on the second stratum of sand, from which the supply is drawn through the open bottom of the casing. Under pumping such wells at first discharge considerable sand, creating around the casing a cavity of such dimensions that the entering velocity of the water is reduced to a point where its transporting power is lost. Where the clay roof is sufficiently thick to prevent caving these cavities may become very large and the capacity of the wells be proportionately increased. A formation of this character is therefore exceptionally favorable to the development of large quantities of water.

The storage capacity of the area affected by the annual infiltration above the level to which the water plane might be reduced by continuous pumping is not less than 2,000,000 acre-feet.

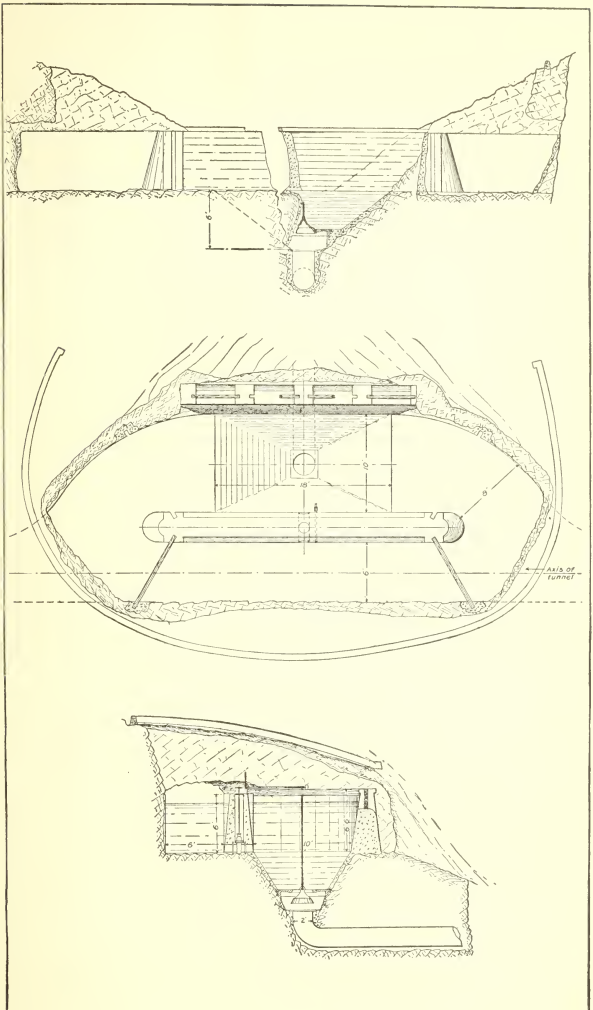
In the light of experience and of the data presented regarding storage capacity, rate of replenishment, favorable formations encountered, and the reabsorption of a part of the water pumped, the writer believes it entirely conservative to say that the quantity of water estimated upon in this report can be continuously developed from the gravel beds of the Kings River delta by the methods outlined.

PLANT PROPOSED.

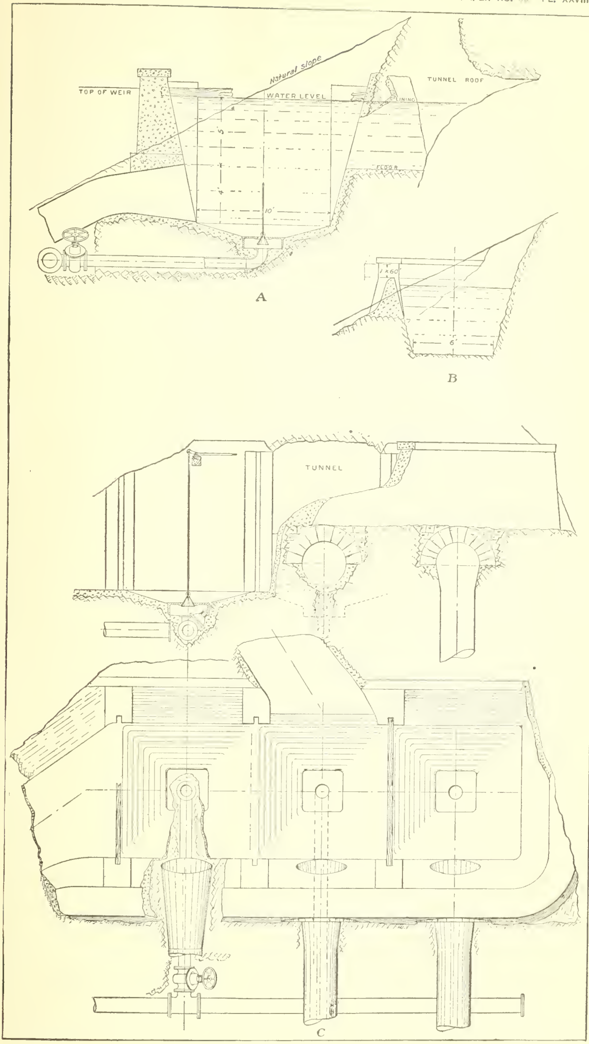
While the limits of this report make it necessary to omit many of the details, the general characteristics of the designs will be stated briefly before summarizing the estimates. The figures used for cost of intake, conduit, roads, bridges, and trails were prepared from preliminary surveys, and appear to the writer to be amply large to cover any probable modification of design or location. A description of the rest of the plant follows in order, from the intake to the pumps.

SAND TRAPS.

Ordinarily the water is very clear and carries but little silt. Provision has been made, however, for trapping the granitic sand which is present in all streams of the upper sierras during the spring freshets, while the snow is melting. The saving effected in the erosion of wheel buckets and nozzles justifies this expense. The normal conduit velocity through the traps for full-load conditions has been reduced to a little more than 1 foot per second, and at the penstock the transverse velocity will be less than 0.5 foot per second. This has been cheaply effected by locating the structure in one of the small lateral drainage lines intersected by the tunnel alignment at grade, and diverting the drainage around the open cut by means of a small training wall. Movable flashboard will make it possible to flush the settling chamber withou interferi wit the continuous flow of the conduit, and a by-pass wi equaliz the pressure on the flashboards. Flushing may be continuous when water is plentiful, and be intermittent or cease entirely when the flowage is less than required. A waste weir is provided for regulation and for use when



LONGITUDINAL SECTION, PLAN, AND TRANSVERSE SECTION OF SAND TRAP.



DETAILS OF PROPOSED POWER PLANT.

A, Section of tunnel; *B*, section of wasteway; *C*, plan of penstock.

it is desirable to shut off entirely the flow from the penstock. Pl. XXVII shows a longitudinal section, plan, and transverse section of the sand trap.

PENSTOCK.

As designed, this structure is divided into three bays, from each of which a pressure pipe is taken out. The bays can be separated by flashboards placed in grooves in vertical buttresses, and the pressure pipes can be shut off by stop boards between the buttresses. The tunnel enters the penstock in the center bay. The surface elevation of the water in the penstock can be regulated by stop boards between the portal buttresses. An overflow weir is provided to carry the maximum flow of the conduit when all outlets below are closed. Sections of the tunnel and wasteway and plan of the penstock are shown in Pl. XXVIII.

PRESSURE PIPES.

The three pipe lines are designed to be 30 inches in diameter, of steel plates riveted in place, with full-load velocities of 7 feet per second and an effective head of 660 feet, requiring a flow of 100 cubic feet per second to generate the rated output of the dynamos. Each pipe is equipped at frequent intervals with air valves of large area. The pipes are to be placed in a trench to a depth of half their diameter, anchored to rock in situ, and covered with rough rubble. A concrete thrust block is provided at the foot of each pipe, which tapers from a diameter of 30 inches at the thrust block to 18 inches at the gate valve (18-inch) in the power house immediately back of the nozzles. Each pipe feeds to a single generating unit, with practically no curvature in reaching the wheels. In case it is necessary, however, to feed two units from any one of the three pipe lines, this can be accomplished through a 30-inch by-pass connecting the three pipes back of the thrust blocks and not shown in the drawings.

POWER HOUSE.

In designing such a structure the endeavor should be to obtain, as cheaply as possible consistent with long life and utility, a safe and convenient assemblage of the necessary apparatus in such a manner that all working parts of the plant shall be easily accessible for repairs and that possible future extensions can be made in conformity to the same general plan, also to concentrate the machinery, so far as is consistent with safety, in order to minimize the expense of attendance. This has been the aim in planning these works.

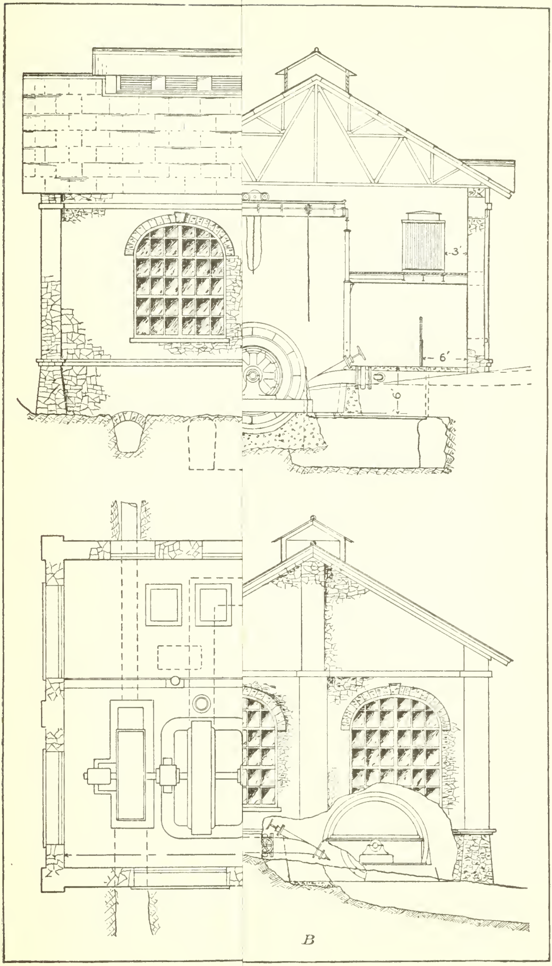
The power house, as designed, is shown in plan, side elevation, end elevation, and transverse section in Pl. XXIX. It is believed that the intense summer heat justifies the substantial character of the design and that the use of the granite country rock will be cheaper than any alternative material offering results equally satisfactory. Thorough ventilation will be obtained through louver openings in the roof ridge and by exhaust fans connected with the cool air in the wheel pits.

The pressure pipes and exciter branches are below the level of the switch-board floor, obviating the use of short goose necks on the main units. The tailraces provide a straight outlet for the waste water in direct line with the axis of the pressure pipes and offer head room for repair work under the wheel mounting. Work can be done on either unit without interference with the operation of the rest of the plant. Wire conduits for the leads from the generators to the low-tension busbars and exciter circuits are designed with ample working dimensions. The reasons for the arrangements adopted will be taken up in connection with the several classes of apparatus to which they appertain.

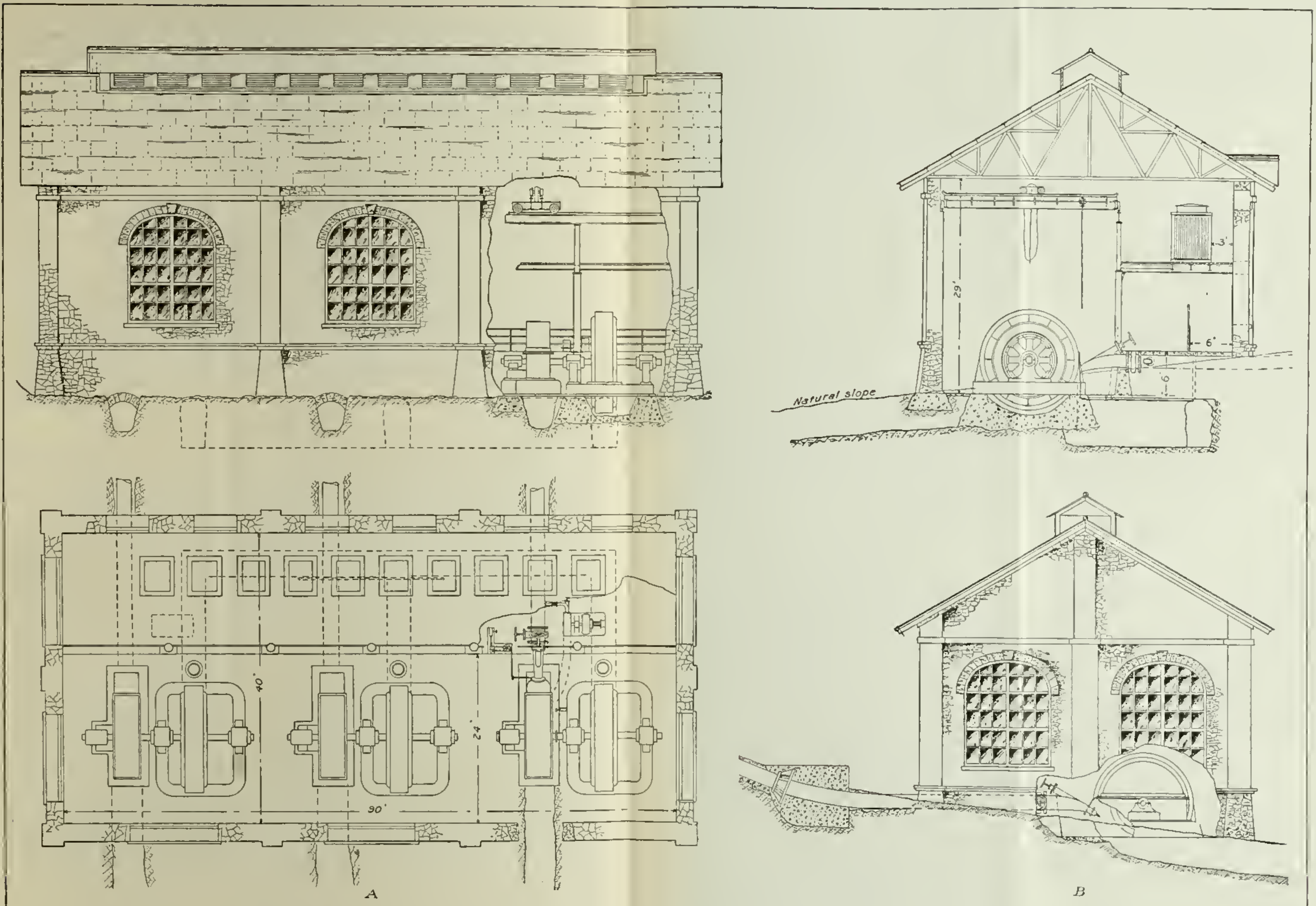
Hydraulic equipment.—As designed, the water-wheel centers are mounted on the shaft on which the revolving fields of the generators are carried, dispensing with an intermediate coupling, and are fitted with interchangeable single tangential buckets. The shaft is carried in three bearings of the usual ring-oiling type. The wheel housings part horizontally at the axis of the shaft, permitting easy access to the entire wheel. The nozzles are interchangeable, equipped with deflecting hood actuated by means of rocker shaft and links from a Lombard governor belted to the generator shaft. The nozzles are also provided with a needle valve for hand regulation if desired. The exciter units, two in number, are connected directly to their respective water wheels, either being of sufficient capacity to provide exciting current for two generators. The exciter tailwater will discharge into the main tailraces. The foundations for water wheels and generators to be excavated to solid rock, built up with concrete, and reenforced and tied together laterally with expanded metal and small I beams.

Generators.—The generators proposed, three in number, are of the 3-phase, 60-cycle, alternating-current, revolving-field type, with a normal capacity of 1,350 kilowatts, or 1,800 horsepower, at 2,200 volts, at a speed of 200 revolutions per minute, and are on the shaft with the water wheel. The stationary armature in this form of generator dispenses with any adjustment of moving parts on the generating element of the machine, as the leads simply connect to terminal blocks on the armature frame to which the ends of the 3-phase windings are brought. The elimination of collector rings, made possible in this way, tends to higher generating pressures, with resulting economy in transformers. Machines of this type of 12,000 volts capacity have already been developed and are in successful operation.

In designing these works moderate electric pressures have been adopted both for generation and transmission, with a view to keeping well within the limits of successful operation. As planned, the generating units are below the station floor, to permit the pressure pipes



B



PROPOSED POWER HOUSE.

A, Side elevation and plan; *B*, transverse section and end elevation.

to reach the wheels without unnecessary curvature, and plenty of working room has been provided around, under, and over the machines. A traveling crane provides means to lift and transport any part of the machines to any part of the building. The generator leads pass up from the subterranean working conduit behind the switch board to the busbars, where they are distributed to the transformers overhead. Wide passageways are provided around the switch board, which consists of a separate panel for each generator and one for the exciters, carrying the usual interconnecting switches, voltameters, ammeters, integrating wattmeters, fuse blocks, field rheostat, and synchronizing devices.

Transformers.—The floor or shelf on which the transformers are placed is of concrete and expanded metal, with working room between and around the transformers. The low-tension wires (2,200 volts potential) pass into the transformer coils on the rear, next to the wall of the building, and the high-tension wires (30,000 volts potential) are taken from the opposite side through a plug board equipped with long break switches, from which the wires pass back overhead, across the transformers, through glazed openings, to the external circuits.

POLE LINES.

The route selected for the pole lines follows in a general way the proposed wagon road from the power house to Millwood, and thence along the existing wagon roads to Centerville, in the valley below, for the purpose of insuring access to the lines during the winter, when the ground will be covered with snow. Beginning at an elevation of 2,000 feet the line attains an altitude of 5,500 feet at Millwood, and then descends to Centerville, 45 miles from the power house. Experience in Colorado and British Columbia demonstrates that if the lines are structurally strong no interruption of operation need occur by reason of snow. Interruption has invariably been due to weak mechanical construction and not to electrical causes. Two pole lines carrying four 3-phase circuits of No. 3 hard-drawn copper wire supported on suitable insulators to be built to Centerville, where a switch station will be located. The arrangement is such that each generator can be run separately on an independent circuit, or any number of circuits can be operated in multiple from a single generator, or all of the generators can be run parallel into any or all of the circuits by means of suitable connection at the busbars. From Centerville one line has been projected to Fresno and beyond and another to Hanford and the intervening lands.

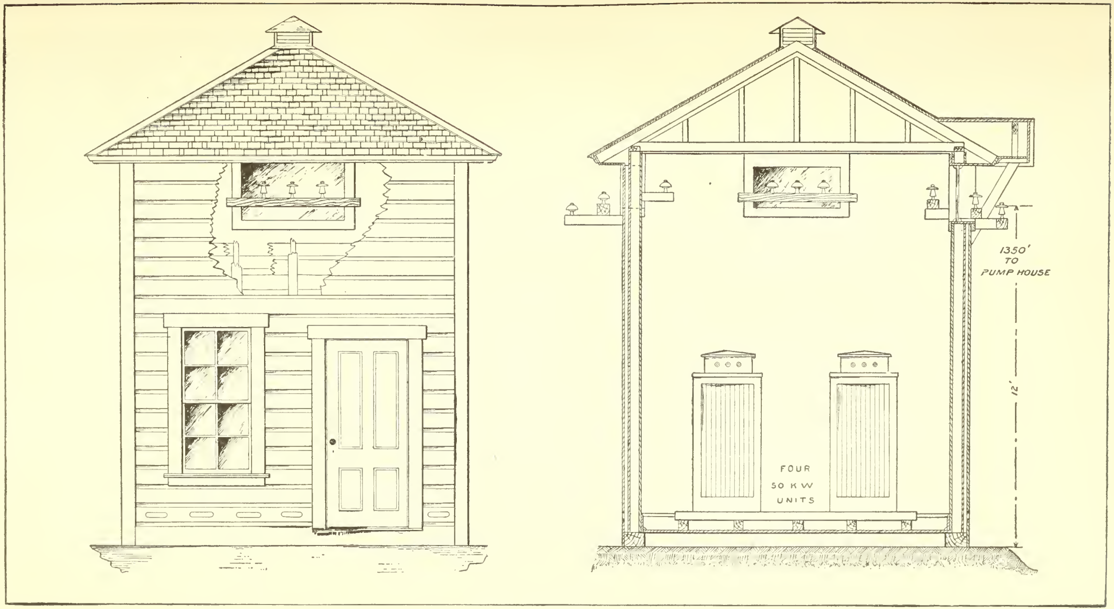
SUBSTATIONS.

The extraordinary yield of the developed wells around Fresno, considered in conjunction with the depth to the plane of saturation, the probable depth of exhaustion of the wells, and the economical output for each station, requires about 45 horsepower delivered to the motors, and the necessary size of the units suggests the use of 50-horsepower induction motors at 2,000 volts potential. The advantages of a large irrigating head have been obtained by grouping four pumping plants around a transformer station 800 to 1,200 feet distant. Each substation consists of a neat wooden building provided with a radiation wall so arranged that the heating of the air in the roof space creates a draft through the vent provided at the top, which establishes a circulation through the walls of the building and prevents the air within from attaining more than the normal temperature outside. The transformer house proposed is shown in elevation and section in Pl. XXX, and a section of its wall in Pl. XXXI, *B*.

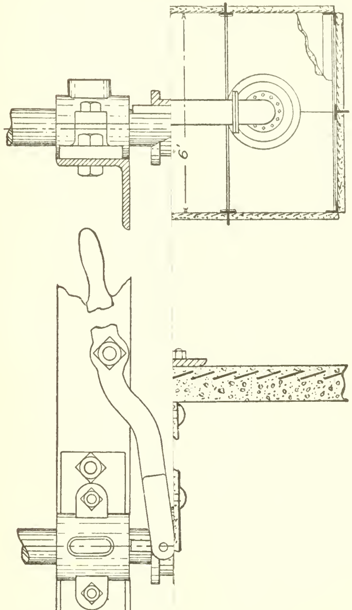
The equipment proposed consists of 200 kilowatts of self-cooling, oil-insulated transformers wound to convert the line pressure of 30,000 volts to a distribution potential of 2,000 volts, at which it is fed direct to the motors without further transformation. An outside high-potential, triple-pole, double, long-break switch provides means of cutting out the substations for adjustment.

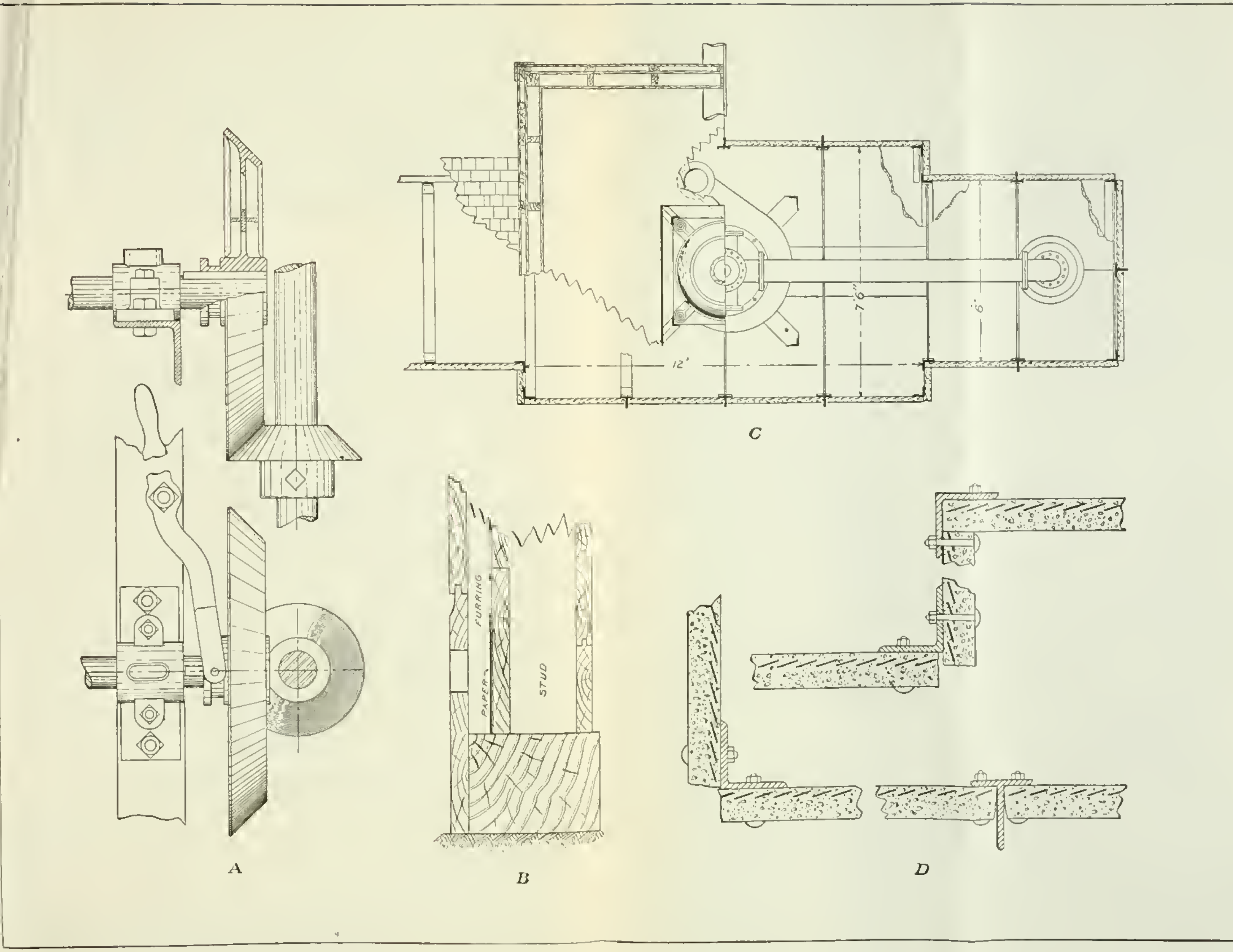
PUMPING STATIONS.

These buildings are of the same general construction as the transformer house (For elevation and section of proposed pump house see Pl. XXXII.) As designed, the equipment consists of a 10-inch centrifugal pump, with working vanes to suit the motor speed and height of lift, mounted in a steel frame, connected directly, with grip couplings, to the shaft of a vertical motor supported on the same frame above the level of the surrounding country, so that in case the pit is accidentally flooded the electric apparatus is safe from injury, and the plant suffers no damage. The pits are curbed with concrete and expanded metal panels set in steel T-beam frames and bolted in place, with diagonal bracing at the ends to prevent racking. (See Pl. XXXI, *D*.) The wells are 12 inches in diameter, sealed into the concrete floor, and will probably require sinking to an average depth of 100 feet. The suction pipes are 8 inches in diameter, of heavy galvanized iron, riveted and soldered. Suction inlet to the pumps is provided in the form of a cross, so that four wells, 90 degrees apart, can be connected. If the two wells shown in the section of the pit fail to develop sufficient water, another well will be sunk 30 or 40 feet away, laterally, and a fourth, on the opposite side, if it should prove necessary; these lateral wells to be connected by tunneling from the main pit, sinking a brick manhole over the well to the depth of the pit, and connecting the wall of the pit and the manhole by standard screw pipe surrounded by 6 inches of concrete, back-filled solidly and terminating at either end inside of the pits with a bolt flange from which connection can be made to the pump and vertical suction pipe. Priming is effected by closing the gate valve on the discharge pipe and exhausting the air from the suction pipes and pump with a mechanical primer operated with a taper friction from



ELEVATION AND SECTION OF PROPOSED TRANSFORMER HOUSE.


6'



DETAILS OF PROPOSED POWER PLANT.

A, Friction gear for priming pump; *B*, section of wall of transformer house; *C*, plan of pump pit; *D*, details of construction of pump pit.

the motor shaft. (See Pl. XXXI, *A*.) The motor starts idle, the weight of the motor and shaft being carried on a collar working on ball bearings on the pump head until the appearance of water at the discharge of the priming pump indicates the priming of the main pump. The opening of the gate valve on the discharge pipe permits discharge to begin, and the pump is so designed and adjusted that the static lift operates to balance the suspended parts. Each station is equipped with an automatic device for cutting out the motors in case of a disturbance of the line. Oilers are arranged to require attention once in twenty-four hours; more frequent inspection has been shown by experience to be unnecessary.

COST.

In the following estimate of cost wagon freight from Sanger to Millwood has been figured at $9 a ton, and from Millwood to the power house at $2 a ton. The figures used for the cost of the intake, conduit, roads, bridges, and trails were prepared from preliminary surveys, and appear to the writer to be ample to cover any probable modification of design or location. The delivery of construction material on the line of the tunnel and at the penstock requires the use of an inclined skidway and a small hoisting engine, which are included in the estimate. Several miles of difficult mountain wagon road and trails must be built, and a bridge be constructed across the South Fork at the power house. A screen of iron bars at the intake has been included in the estimate, also double screens at the penstock, to keep leaves and sticks from entering the pressure pipes. A telephone line of No. 12 wire, strung on the power line poles and equipped with instruments and cut-out switches at each of the substations, has been estimated upon, while a comfortable bunk house, with double roof and walls, library, dining room, kitchen, bathroom, and complete sanitary plumbing, which has been included, is regarded as a necessary adjunct, and a small ice-making plant and cold room piped for direct ammonia expansion, which have also been included, would add to the comfort of the employees.

Estimate of cost of power and pumping plants for generating and transmitting power from Kings River for the utilization of ground water in the valley.

Hydraulic works:		
Headworks and intake	$5,500	
Conduits	184,800	
Adits	7,700	
Sand traps	1,330	
Penstock and waste weir	3,478	
Pressure pipes (three steel pipes, each 30 inches in diameter, 3,200 feet in length, with gates and air valves)	59,691	
Hydraulic equipment (water wheels for the three generators and the two exciters, with governors, gates, and fittings)	27,000	
		$289,499

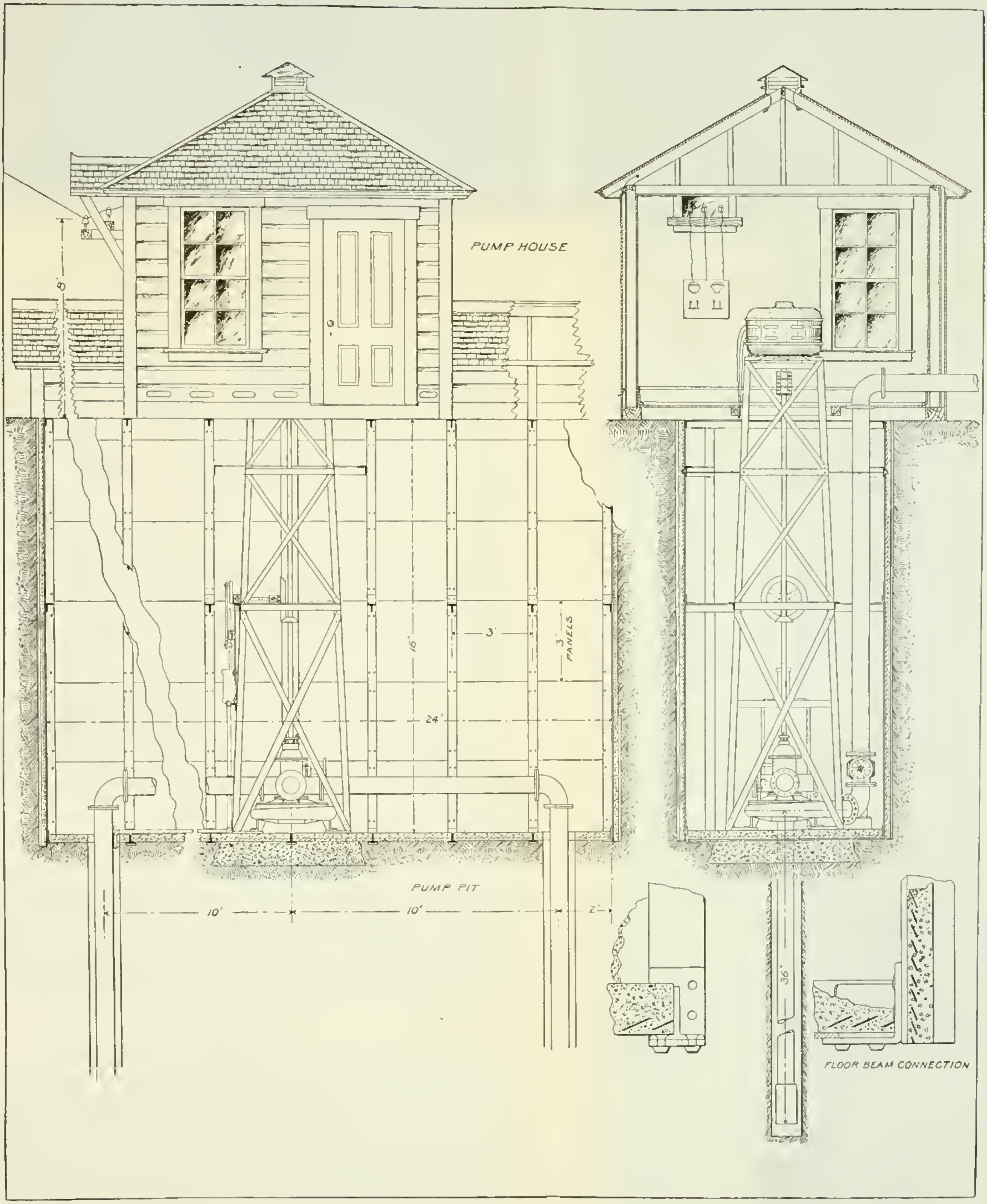
Buildings:		
Power house, foundations, and conduits	$15,738	
Mess and bunk house	3,600	
Refrigerating plant	1,500	
Stable, workshop, and tools	2,900	
		$23,738
Roads and bridges	58,850	
Trails	3,300	
		62,150
Electric generation and conversion:		
Generating equipment and control (three generators, 1,800 horsepower each, two exciters for same, switch board, instruments, and installation)	59,705	
Transformers (ten of 600 horsepower each, 30,000 volts, with switches, etc.)	33,000	
		92,705
Transmission:		
Pole lines (45 miles of double pole line, four circuits to Centerville, 45 miles distant, and 40 miles of distribution lines)	267,200	
Centerville switch house	3,000	
Substation transformation (25 substations, each containing four step-down transformers—one for reserve—total capacity 266 horsepower, with switches, etc., complete, each station designed to furnish the power for four pumping stations)	73,750	
		343,950
		812,042
Engineering and contingencies, 5 per cent		40,602
Total		852,644
Pumping stations, 100 at $4,057 (consisting of 50-horsepower motor, 10-inch centrifugal pump and attachments, cement-lined pump pit, four wells 90 feet deep, buildings, piping, etc.)		405,700
Engineering and contingencies, 5 per cent		20,285
Total		425,985
Recapitulation:		
Power generation and transmission		852,644
Water development, i. e., 100 pumping stations		425,985
Total		1,278,629

The estimate on pumping plants is for a capacity of 5 second-feet each, or a total of 500 second-feet, per 24 hours, being 1,000 acre-feet per 24 hours from an average depth of 45 feet, equivalent to 365,000 acre-feet per annum (365 days), making the cost of installation $3.50 per acre-foot of annual capacity.

The estimated cost of operating the plants is as follows:

Estimated cost of operating power and pumping plants.

Interest, 6 per cent on bonded indebtedness	$76,718
Taxes, 2 per cent on 60 per cent valuation	15,343
Depreciation and maintenance	25,550
	117,611



ELEVATION AND SECTION OF PROPOSED PUMP HOUSE

Power house:		
One superintendent	$1,400	
Three attendants at $1,000	3,000	
Three helpers at $800	2,400	
One laborer	750	
One watchman	750	
Horses and stable	1,300	
Oil, waste, and supplies	2,400	
		[a] $12,000
Pole line:		
Two linemen	1,800	
Teams and supplies	800	
		2,600
Pumping stations:		
Ten attendants at $800	8,000	
Two inspectors at $1,000	2,000	
Horses, 20 at $150	3,000	
Oil, waste, and supplies	2,400	
		15,400
Total operating expenses		30,000
Administration and local expenses:		
One general superintendent	2,400	
One bookkeeper	1,200	
Office rent and sundries	1,400	
		5,000
Insurance and contingencies		5,000
		10,000
Total		157,611

Considering the load factor of the pumping system, i. e., the ratio of the average load to the maximum load, to be 90 per cent, the annual pump output would be 328,500 acre-feet, on the basis of the use of the plant for 328½ days, and the total cost of operating would amount to, in round numbers, $0.50 per acre-foot produced per annum. If the plant were operated fewer days each year the cost per acre-foot produced would be much greater.

CONCLUSION.

In order to appreciate the magnitude of the proposed development it may be compared with what has already been achieved with the gravity flow of Kings River. The flow available during dry years is the measure of irrigated acreage on which stable values can be maintained, since land with an uncertain water supply must fluctuate in value as the seasons are favorable or otherwise. During 1898 the supply available was very deficient. Last year (1900) the profits from the raisin crop alone in the Fresno district are reported to have been more than $2,000,000, and this industry, as well as the fruit, stock, and general farming interests, is dependent on the river, not partially but absolutely, for its existence. Practically all created values within the area served by the water of Kings River are sustained by its

[a] Operatives to pay cost of board at mess house out of salaries.

flowage, and the aggregate of these values runs into millions of dollars. Plenty of additional land, of even better quality than that now under cultivation, is available if an assured water supply can be provided.

Making due allowance for seepage losses in conveying the pumped water, the annual amount available from the new supply would be 300,000 acre-feet, and the cost of supplying it would be only slightly in excess of the present charges for water from gravity canals in this locality.

The conditions described exist at many other places along the eastern slope of San Joaquin Valley, where there are many square miles of unused land, much of it possessing as great natural advantages as the tracts under cultivation at lower elevations, which a water supply would convert into a rich and productive country. Riverside is an example of what five years' development with water will accomplish. Notwithstanding the continued decreasing flow of the perennial supply due to the dry years 1895 to 1900, orange planting, which passed the natural limit of stream flow several years ago, has been steadily extended to outlying districts, and water development from well supplies has kept pace with the increasing requirements until the quantity available and the acreage served are much greater than ever before, and the best lands are now dependent on pump irrigation.

General attention now being directed toward the advantages possessed by California, it seems probable, under the pressure of increased population and the market demands which must follow, that another generation will witness the cultivation of every acre of land susceptible of irrigation in San Joaquin Valley, and in view of the possibilities herein suggested it does not appear unreasonable to believe that water will be provided for every acre that can be cultivated.

SUMMARY.

The important results of the investigations on Kings River are summarized in the following table:

Results of investigations for water development along Kings River.

Improvement.	Description.	Capacity, in acre-feet per annum.	Cost of installation.		Annual cost, per acre-foot, of interest and operation.
			Total.	Per acre-foot stored.	
Dusy Meadows reservoir.	125-foot dam	16,850	$538,860	$32.00	$3.10
Pine Flat reservoir	140-foot dam	78,197	1,750,000	22.38	2.06
Clarks Valley reservoir.	85-foot dam	120,499	1,331,025	11.05	1.04
Do	105-foot dam	217,196	2,206,822	10.15	.92
Long Meadow reservoir.	170-foot dam	25,334	713,715	28.00	2.64
Pumping plants	328½ days' operation per annum.	328,500	1,278,629	3.50	.50
Do	100 days' operation per annum.	100,000	1,278,629	12.78	1.43

The last column of the foregoing table gives the cost per acre-foot per annum of water delivered to the lands to be irrigated, a deduction of 20 per cent of the water stored being made for losses by evaporation and seepage in transit. The pumping plants being located where the water will be used, no such deductions are made for them.

The Dusy Meadows and Long Meadow reservoir sites are not of special value, as better reservoir sites are available. The Pine Flat and the Clarks Valley sites, however, are both of great value to the Kings River irrigation districts. The storage work should be begun by building the Clarks Valley reservoir with the 85-foot dam. This should be followed by the construction of the 140-foot dam at the Pine Flat site. The height of the dam at Clarks Valley can be increased to 105 feet or more in the future. Water from these reservoirs could most advantageously be applied to the foothill lands between elevations of 300 feet and 550 feet, where citrus fruits can be raised and where no water is now available.

The estimates show that the cheapest supply in the valley can be obtained by pumping with electric power generated by the river itself before it reaches points of diversion or storage, provided the pumping plants are operated at least half the time. This pumped water could be obtained most cheaply in the lower valley lands, where the water plane has now risen to near the surface and where the longest diversions are necessary under existing canals. While the pumping plants might be used near the foothills the water supply there would not be so large and the lifts would be greater, but the lands redeemed would be more valuable.

During the high-water stages of the river, which last from March until the middle of June or the first of July, an abundance of cheap water is now available by gravity for the irrigation of all of the lands within reasonable limits which are under Kings River. At present the use of the water is needlessly wasteful during that season of the year. It is believed that if, in addition to this spring irrigation, water to a depth of 1 foot could be furnished to the irrigated lands between the first of July and the end of November it would be sufficient to maintain them in a condition for the production of any crop. Assuming that the pumping plants will produce 200,000 acre-feet of water, there will be available from that source and from the Clarks Valley and Pine Flat reservoirs, with the lower dams, about 400,000 acre-feet of water. If all the water that is diverted by the pumping plants and the storage reservoirs should be put onto new areas it would mean the addition of 200,000 acres of irrigated land to the community.

In concluding it may be stated—

(1) The capacity of the canals diverting water from Kings River is approximately 4,000 cubic feet per second.

(2) Ten years' records of the river show that the average flow for the month of August is 603 cubic feet per second and for the month of September 389 cubic feet per second.

(3) The irrigable area is very great.

(4) Probably the most valuable areas in Fresno and Tulare counties are the foothill lands upon which citrus fruits can be grown between the 300-foot and the 600-foot contours of elevation. These lands are without water rights and can be irrigated from the reservoirs described herein.

(5) Pumping plants can be established and operated which will furnish 1,000 acre-feet of water per day at a cost not much greater than that now paid for gravity water from the canals, to supplement the present summer supply or to extend the irrigated areas.

(6) The operation of the pumping plants will partially if not wholly prevent the rising of alkali to the surface of irrigated lands.

(7) One hundred and ninety-eight thousand six hundred and ninety-six acre-feet of water now wasting annually can by storage be conserved at prices well within commercial limits.

(8) A good water right will add $50 per acre to the value of dry lands in the valley and $90 per acre to the value of lands in the foothills.

(9) All of the works included in the table on page 96 are feasible and safe from an engineering point of view.

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ADDENDA.

In the summer of 1901 a series of measurements of some of the canals taking water from the north bank of Kings River and east of Centerville were made for Mr. L. A. Nares, general agent of the Fresno canal. This is nineteen years subsequent to the measurements made by Mr. Grunsky, and the results are in marked contrast with those obtained by him. Evidently the continued irrigation practiced during the interval has raised the ground-water level so that it is largely supporting the water in transit in the canals. While in some instances gains in the volume of water are reported, it is believed by the writer that these must be the exception instead of the rule, for the canals are normally higher than the lands irrigated, and there can not be a gain unless the plane of saturation is higher than the surface of the flowing water.

These measurements are of interest, but owing to continued diurnal fluctuations in both the river and the canals absolute results can only be obtained by continuous records of water heights at rating stations.

Summary of measurements made in Kings River canals in August and September, 1901, to determine loss or gain by seepage and evaporation.

No. of measurement.	Name of canal.	Locality.	Distance.	Gain or loss.	
			Miles.	*Sec.-feet.*	*Per cent.*
1	Centerville and Kingsburg canal.	Centerville to Sanger	7	−20.00	− 5
2	Fowler Switch canal	Centerville to Collins Gate	9	+ 6.00	+ 2
3	do	Head gate to Centerville	2	+	+
4	do	Centerville to Collins Gate	9	− 9.57	− 8
5	Centerville and Kingsburg canal.	Centerville to Sanger	7	−33.00	−12
6	Gould canal	Holland Flume to Kutner Colony.	11	+ 2.25	+ 1
7	do	do	11	+ 1.50	+ 2
8	Main canal	Long Cut and Limbaugh Gate.	10	−27.65	− 7

NOTE.—All of the measurements except Nos. 4 and 5 were made with a current meter. Plus sign (+) indicates gain, and minus sign (−) indicates loss.

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