MORRIS BIEN.

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 19

IRRIGATION NEAR MERCED, CALIFORNIA.—GRUNSKY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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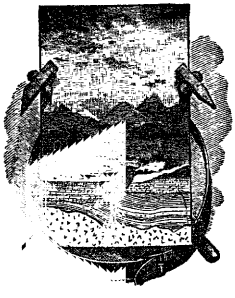
UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

IRRIGATION NEAR MERCED, CALIFORNIA

BY

CARL EWALD GRUNSKY



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GOVERNMENT PRINTING OFFICE

1899

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, July 15, 1898.

SIR: I have the honor to transmit herewith a manuscript entitled Irrigation near Merced, California, by Mr. C. E. Grunsky, and to recommend that it be published as one of the series of pamphlets on Water Supply and Irrigation. This is the third of three papers relating to irrigation in San Joaquin Valley, the other two being Nos. 17 and 18 of the series. This paper describes the irrigation systems deriving their water supply from San Joaquin, Chowchilla, Merced, Tuolumne, Stanislaus, and Mokelumne rivers.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

IRRIGATION NEAR MERCED, CALIFORNIA.[1]

By C. E. GRUNSKY.

SAN JOAQUIN RIVER.

HYDROGRAPHY.

San Joaquin River enters San Joaquin Valley from the east at a point about 20 miles northeast of Fresno, flows southwesterly 55 miles to the valley trough, and, entering the lowlands of the Fresno Slough country, turns at Las Juntas abruptly to the northwest and becomes the main drainage channel of the valley. For 40 miles below Hamptonville, the point at which the river enters the main valley, its course lies through narrow strips of bottom land hemmed in by bluffs rising to the plains above. These bluffs are generally one-half mile to a mile apart and descend abruptly toward the river from a very smooth-surfaced plain. They gradually decrease in height toward the west, their height being about 60 feet near the eastern edge of the valley and 40 feet near Herndon. Before the river reaches Las Juntas, 20 miles by river below Herndon, the bluffs have disappeared entirely, and the flood waters of the river sweep across country to the southwest into Fresno Swamp and to the northwest in a direction down the valley parallel with the river.

Bottom lands of small extent flank the river between its bluffs, but have remained unirrigated. The upland of the main valley plain is so high above the river near the eastern border of the valley that canals to command the upland would be very costly, and none have been constructed, though several have at various times been projected. The diversion of water for irrigation is confined to that portion of the river lying in or near the main valley trough.

The area of the river drainage basin above the point where it breaks from the Sierra Nevada is 1,637 square miles. This entire area is mountainous. It extends eastward to the summit of the Sierra Nevada, 70 miles of this summit, measured in a direct line, being the eastern limit of the river's drainage basin.

The river is ordinarily at its highest stage in the spring months, generally in May and June; but winter freshets are not uncommon, and extreme floods, such as those of 1861–62 and 1867–68, have occurred in winter. The flow of the river at Hamptonville, near the eastern border of San Joaquin Valley, was approximately determined by the State

[1] See introductory remarks in Water-Supply Paper No. 17, p. 13.

engineer of California for the years 1878 to 1884.[1] A mean monthly flow for November of 378 second-feet and a mean monthly flow for June of 10,150 second-feet were the extremes indicated by these measurements.

The river is ordinarily at a low stage from September to the end of December. It is at a medium stage, with a flow in excess of 1,000 second-feet, from January to March and in July and August. It is high from April to July. These periods are, however, to be taken only as a general guide, because the flow of this stream varies within wide limits, according to the varying conditions of rainfall and temperature of each season.

The Southern Pacific Company have maintained daily readings of gage height on this river since 1879 at their bridge half a mile north of Herndon and 12 miles north of Fresno. Since 1895 the United States Geological Survey has been taking measurements of discharge from the wagon bridge near by. The results of these measurements are published in various reports of the Survey.[2]

The following facts in regard to the flow of the river are brought out:

1895. Maximum discharge, May, 19,960 second-feet; minimum, September, October, November, and December, 260 second-feet; average for the year, 3,791 second-feet.

1896. Maximum discharge, May, 18,800 second-feet; minimum, September and October, 80 second-feet; average for the year, 2,756 second-feet.

1897. Maximum discharge, May 24, 18,600 second-feet; minimum, December 23, 60 second-feet; average, 3,105 second-feet.

Estimated monthly discharge of San Joaquin River at Herndon, California.[3]

[Drainage area, 1,637 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
January	11,225	1,260	2,881	177,102	2.029	1.760
February	8,500	909	2,568	142,590	1.634	1.569
March	9,318	1,554	2,779	170,840	1.957	1.697
April	9,863	3,354	5,834	316,600	3.626	3.564
May	19,960	5,100	13,124	807,000	9.243	8.017
June	14,565	7,250	10,674	599,404	6.866	6.520
July	8,000	2,148	4,528	278,410	3.189	2.766
August	2,301	793	1,417	87,104	.997	.866
September	8,500	260	1,085	64,567	.740	.663
October	1,260	260	420	25,846	.296	.257
November	426	260	362	25,562	.247	.221
December	677	260	373	22,905	.262	.228
The year	19,960	260	3,791	2,717,930	31.086	2.334

[1] See Physical Data and Statistics, Wm. Ham. Hall, State engineer of California, 1886, pp. 449, 476.

[2] Twelfth Ann. Rept., Part II, 1891, p. 321, Pl. LXXXIV; Bull. No. 131, 1895, p. 81; Bull. No. 140, 1896, p. 290; Eighteenth Ann. Rept., Part IV, 1897, p. 385; Water-Supply and Irrigation Paper No. 11, 1897, p. 91; Water-Supply and Irrigation Paper No. 16, 1898, p. 190.

[3] In using results shown in these tables of discharge, some allowance must be made for uncertainty as to the permanency of stream cross sections on which rating tables were based. A slight change in absolute elevation of river bed at the rating station, if known, would modify the rating table, particularly for low-water stages. Lack of information on this point may lead to erroneous conclusions. The flow of San Joaquin River at Herndon has probably never dropped to 60 cubic feet per second.

Estimated monthly discharge of San Joaquin River at Herndon, California—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
January	12,800	250	2,119	130,335	1.49	1.29
February	1,750	950	1,177	67,696	.77	.72
March	12,176	1,180	2,612	160,649	1.84	1.60
April	5,648	1,920	2,675	159,192	1.83	1.64
May	18,800	2,560	5,394	331,700	3.81	3.30
June	16,920	6,544	11,799	702,106	8.00	7.21
July	8,080	1,600	4,177	256,865	3.04	2.55
August	1,300	700	1,048	64,463	.74	.64
September	1,180	80	534	31,817	.37	.33
October	700	80	167	10,275	.12	.10
November	2,390	430	697	41,492	.48	.43
December	1,750	430	666	40,957	.47	.41
The year	18,800	80	2,756	1,997,547	22.96	1.69
1897.						
January	1,180	535	655	40,275	.46	.40
February	15,660	1,180	2,598	144,286	1.66	1.59
March	4,600	1,675	2,325	142,960	1.64	1.42
April	11,708	2,305	6,541	389,216	4.46	4.00
May	18,600	9,565	13,545	832,855	9.54	8.27
June	12,332	2,390	5,862	348,812	3.98	3.57
July	4,300	1,300	2,493	153,290	1.75	1.52
August	1,300	590	898	55,216	.63	.55
September	535	105	227	13,507	.16	.14
October	820	105	279	17,155	.20	.17
November	4,300	120	872	51,887	.59	.53
December	4,000	60	968	59,520	.68	.59
The year	18,600	60	3,105	2,248,979	25.75	1.90

For several miles below the western base of the Sierra Nevada foothills ledges of rotten granite appear in the bed of the river; these are often covered to considerable depth by sand and gravel bars. The river channel is here generally 300 to 500 feet wide. From Hamptonville to Herndon it falls 89 feet in 20 miles; thence to Las Juntas about 36 feet in a distance of about 36 miles. Below Herndon the low-water flow is between sandbars. After passing Las Juntas, where the river is joined by Fresno Slough, it becomes the main drainage line of San Joaquin Valley. It has not, however, been a rapid land builder, and the elevation of river banks is but slightly greater than that of the general surface of the submersible area which flanks the stream.

From Las Juntas to the head of Old River, where the river bifurcates, the distance in an air line is 87 miles. The river between these points has a length of 146 miles. Its average width is 400 feet, and the depth of its channel, from top of natural banks to river bed, is 12 to 18 feet. There is a slight slope of bank lands away from the river, except at a few points, where the river impinges upon spurs of upland that extend eastward from the Coast Range foothills, notably at Grayson and near San Joaquin. The river bottom is generally clean sand, but a firm clay is here and there exposed. River banks are of quite firm alluvial material, showing but little tendency to cave. They are lightly fringed with willows and cottonwoods and occasionally oaks.

The land upon either side of the river subject to periodical flooding

is generally open country, throughout which clumps of willows mark the alignment of sloughs, as the overflow channels from the river are called. Tule grows in spots where high bank lands along the sloughs or river have penned in water or sufficiently retarded drainage to keep the surface moist throughout the year. Oaks are dotted over some portions of this region, but rarely appear in dense groves. The main east-side and west-side plains have been described in Water-Supply Paper No. 17, on page 15.

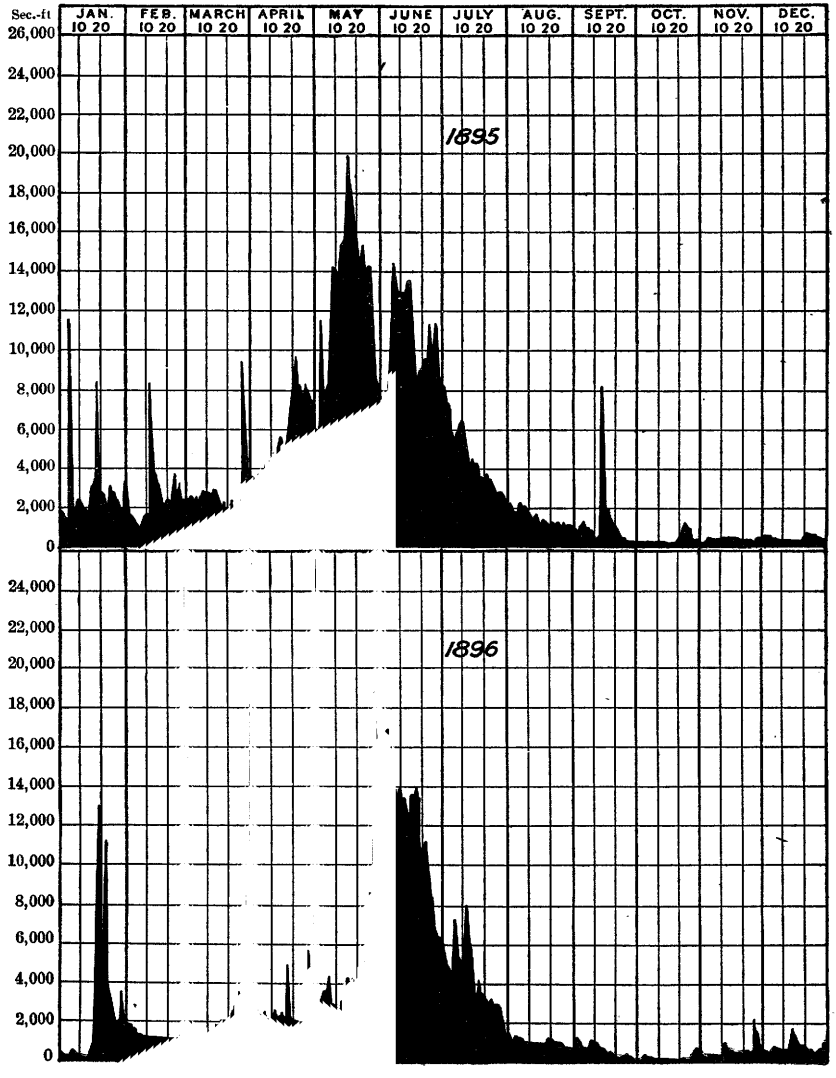


FIG. 1.—Discharge of San Joaquin River at Herndon, California, 1895–96.

CANALS AND DITCHES.

Upper San Joaquin River Canal.—This work has not been a success. The construction of the canal commenced in 1879. It was pushed for some time, until about $85,000 had been expended on it; several years then passed, during which little or no work was done. A new company finally took hold of the enterprise, expending about $300,000 on a dam at the head of the canal and on the main canal above Herndon. Their dam was completed in the fall of 1883 and was maintained

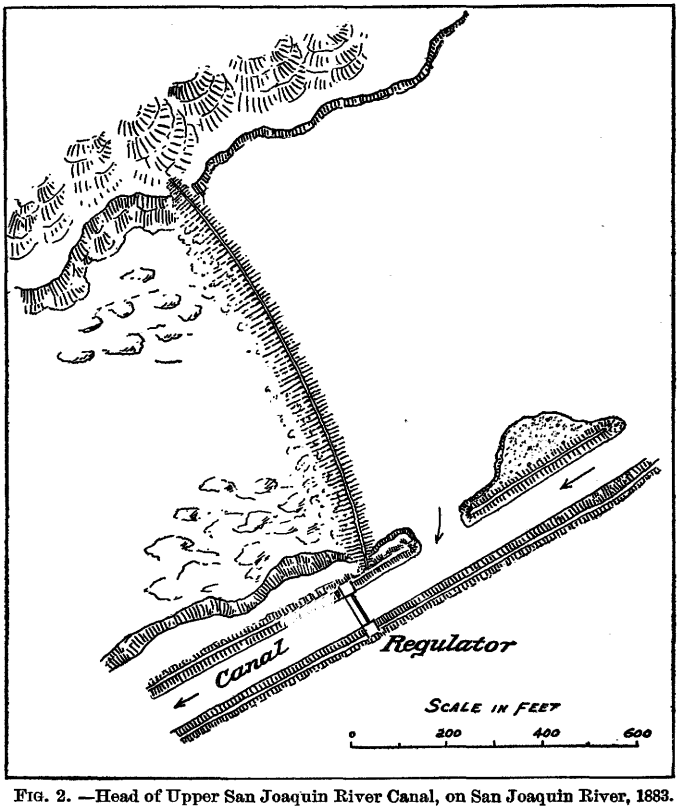


FIG. 2. —Head of Upper San Joaquin River Canal, on San Joaquin River, 1883.

with difficulty for several years, during which time a little water was forced through the canal and out upon the upland near Herndon. About 1887 the work was abandoned.

The head of the canal is about one-half mile below Hamptonville, at a point where the river is nearly 900 feet wide. The river bottom is sand, about 20 feet deep, resting upon a rotten granite formation. A loose-rock diverting dam was constructed at this point to a height of about 8 feet above low water. It was proposed to allow the river to flow over this from bank to bank. The material used for the dam was rock as quarried from a spur of granite, cobbles, and gravel. All material was

dumped into place from small cars. No attempt seems to have been made to secure large blocks of stone, and all rock fragments ordinarily classed as quarry waste went into the structure. The largest stone (maximum size about 1¼ cubic yards) was dumped downstream to form a face that should resist the force of overfalling water. As the lower face rock dropped into place the river cut out the sand in its bed, thus permitting at least the toe of the structure to find a solid formation. The upstream face was formed of fine quarry waste, cobbles, and gravel. Trestle piles which carried the car track were allowed to remain in place and the downstream crest edge of the structure was protected by three layers of planking. Other expedients, such as extending an iron plate over the upper portion of the downstream slope for its protection, were tried, but experience soon demonstrated the difficulty of maintaining a loose-stone dam in a river of considerable flow. Even the later reconstruction of the downstream face of the dam with large blocks of stone, hand laid, and its partial protection with fascines could not make the structure permanently secure and the river's freshets repeatedly cut out sections of it.

Experience with the canal itself was equally unfortunate. Its course for several miles is along and across the river bottoms, thence for 9 miles it hangs on the steep descent or bluff, from south-side upland to river, and finally cuts out to the higher level of the upland a few miles above Herndon. Near its head the canal has a bed width of 75 feet. Its total fall in the first 4 miles does not exceed 1 foot. Along the bluff it received somewhat irregular dimensions. It was intended to carry water 5 feet deep. Its bed width was generally 24 feet, side slopes 3 to 1, and its gradient one-quarter to 1 foot fall to the mile. It was endeavored to make sidehill cutting supply material for an outer levee, whose slope away from the canal was the natural slope of the material used in its construction, generally between 1½ to 1 and 2 to 1. Some of the excavated material was removed by blasting, being in firm layers of very hard clay or ashy sandstone. These firm materials, alternated with soft ashy deposits or a reddish loam material, did not make a safe levee, and great trouble was experienced in making this levee hold water.

Water was furnished through the canal long enough to encourage some tree planting and diversified farming, but not much progress had been made when the canal fell into disuse.

Madera irrigation district.—This irrigation district is located on the east-side plain of San Joaquin Valley, to the north of San Joaquin River. The district was organized in 1888 and was to be supplied with water from San Joaquin River. Notwithstanding active opposition, the necessary bonds were voted and the legality of the district organization was affirmed by the courts. It was proposed to take water from the north side of San Joaquin River near the point where it leaves the hills, but no construction work was done. Operations were blocked

by legal proceedings, and after many long delays it was decided to disorganize, which has been done. The district had an area of 305,000 acres, and the amount of bonds voted for construction of works was $850,000.

Chowchilla Canal.—This canal, which was constructed in 1872, has its head on the north side of San Joaquin River about 8 miles by river above Las Juntas. Its course is slightly west of north, almost parallel with the main drainage of the valley, and for a distance of over 20 miles it commands a strip of land averaging 5 miles in width, which is bordered on the west by San Joaquin River.

The river at the head of the canal lies in several channels, one of which sends off a branch toward the north, known as Lone Willow Slough. The river banks at the head of this slough rise about 15 feet above the low-water plane. By deepening the slough and constructing a gate in it, near its head, it was converted into a section of the canal, and from it, about 2 miles below, water was turned into the artificial canal. The canal was made 30 feet wide on the bottom and 2½ feet deep near the point where it leaves Lone Willow Slough. But these dimensions are maintained for 3 to 4 miles only. The width is then gradually reduced to 25, to 20, and finally to 15 feet. In its northerly course of nearly 30 miles the canal follows a grade line having a fall of 6 inches to the mile.

Mr. J. D. Schuyler, as assistant State engineer in 1879, describes the difficulties of canal construction and the canal head gate as follows:[1]

The total cost of the canal was, in round numbers, $100,000.[2] The tough character of the excavation, the greater portion of the distance rendering the free use of blasting powder necessary, greatly increased the cost over that of ordinary earthen channels of like dimensions.

The treacherous character of the quicksand bed at the head of the canal has made it an exceedingly difficult task to construct a head gate that would withstand the action of floods. For four successive seasons after the building of the canal the head gate was washed out, and as often replaced by a new structure on a different plan.

In the fall of 1877 the present structure, which has withstood severe tests, and gives every evidence of permanence, was built. As this structure has some novel features, and its plan is indorsed by its success, it deserves a brief description. The use of sheet piling, generally considered indispensable to the safety of structures of this kind, was in this instance abandoned. The foundation was prepared by spreading a layer of loose sandstone, one or two feet thick, evenly laid on the quicksand. Upon this a floor of 2-inch plank, without sills, was laid across the axis of the canal, to which was spiked another layer of plank laid lengthways. This floor was placed 6 feet below the level of the bed of the river, and upon it was built the structure of 10 by 10 timbers, having a length of 60 feet, a width of 13 feet, and a height of 10 feet of clear waterway. The whole was weighted with an embankment of earth, 10 feet high, placed on top of the structure, the weight exceeding 500 tons. The sluiceways or regulating gates were placed 5 feet from the upper end of the floor, the space of 5 feet in front being occupied by a box of heavy timbers filled with rock and floored over, the top being 1 foot below the bed of the

[1] See Report of State Engineer, 1880, Wm. Ham. Hall, Part IV, Appendix, p. 176.

[2] This is believed to be an over estimate. The original total cost of the main canal was probably nearer $50,000 than $100,000.

river. The water comes into the canal therefore with a free overfall of 5 feet. In lieu of heavy solid regulating gates which are difficult to raise and lower, loose planks 5 feet long placed in grooves in the vertical posts are used. They are removed by a double hook which engages on an iron pin passing through the planks and projecting two or three inches on each side. A rope and windlass assists in raising the planks to the top. The cost of this structure was $3,200, of which $2,000 was expended in laying the foundation.

There is no weir or dam in the river to aid in accomplishing diversion of water into the canal, but the canal bed is below the low-water plane of the river (reported to be 6 feet below), affording a fall from river to canal which insures it a full supply of water.

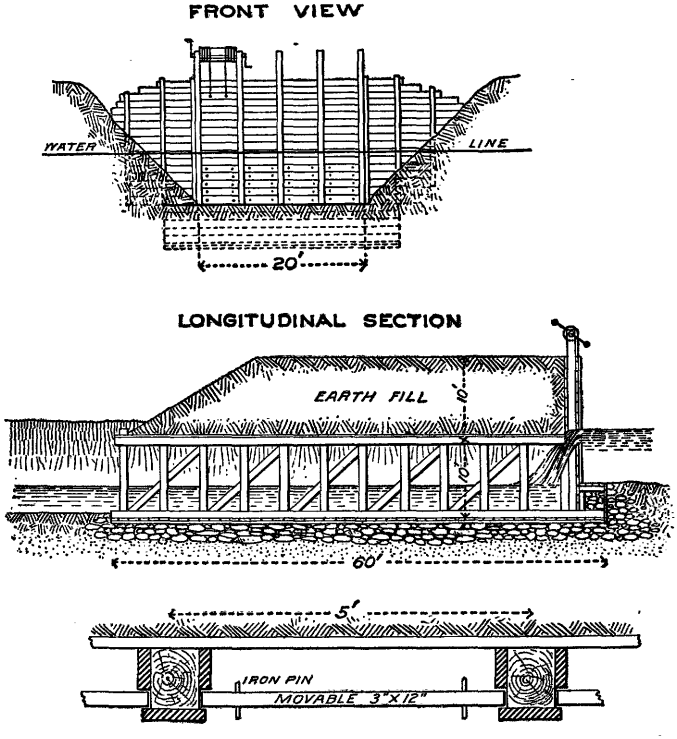


FIG. 3.—Plan and section of Chowchilla Canal regulator.

The head gate above described is located in Lone Willow Slough, about 100 feet from the river bank. A second regulator is maintained in the head of the artificial canal, and the lower portion of Lone Willow Slough is used as a channel for waste water.

The canal crosses the natural drainage of the east-side plain, a location which has at times made maintenance and repair expensive, owing to the frequent destruction of canal banks by the water reaching the canal from the east. At the crossings of Cottonwood Creek, Fresno River, Berenda Slough, and Ash Slough the canal is left open toward

the east, and an outlet gate in its west or lower bank permits the passage of the creek waters when they are swollen by freshets.

The canal is owned jointly by the Miller & Lux Company and the California Agricultural and Pastoral Association. The interests of the two concerns are equal to the point where the canal leaves the lands owned by the former; below that point the latter is sole owner.

The canal capacity near its head is from 100 to 200 second-feet. Its water is now used largely for the irrigation of alfalfa, although when first undertaken the work was intended principally for stock purposes. The place of use is on the Riverside and Columbia ranches of the Miller & Lux Company and on the Chowchilla Ranch of the California Pastoral and Agricultural Association. No water is sold from this canal, it being all required for use on the three tracts named.

The total area of alfalfa land now under irrigation is about 7,000 acres, nearly equally distributed to the three tracts named. On the Chowchilla Ranch works have recently been constructed for extensive irrigation of grass lands. These consist of high well-built levees extending from the high bank land of San Joaquin River eastward far out upon the plain. These levees, six in all, are about a mile apart, and each is equipped with a large so-called "stop gate." These gates are similar to the check weirs in ordinary use on large canals. The largest are 40 feet wide, and some of these are reported to have cost $1,500 each. Each of these gate structures supports a bridge. They are used to restrain water until the submersible area above each is covered with water, which then flows through the gate to the next tract to be inundated. For this grass-land irrigation the flow of the canal and the natural flow of the streams intercepted by it supplement the flow of the Blyth Canal, hereinafter referred to.

The method of irrigating alfalfa lands is by flooding in contour checks. The check levees on the Chowchilla Ranch were originally made high and had exceptionally steep side slopes. The areas of the compartments or checks ranged from 20 to 100 acres. They were altogether too large for the available water supply. It was at first attempted to make the gates through the check levees serve as roadways for teams and farming implements, but this idea soon proved impracticable. The advantage of reducing check areas and of making low flat levees has long been recognized by the managers of the property, and the original defects in the irrigation system have in a measure been remedied.[1] The Riverside Ranch receives its water through a branch canal which was constructed in 1884. This branch is taken out of Lone Tree Slough about 1½ miles below its head and closely follows the river. It has a length of about 8 miles. The soil on the Riverside and Columbia ranches is a heavy black loam. The original practice was to subdivide into irregular checks of 10 to 50 acres by means of high, steep levees. It was found necessary to make use of natural sloughs and waterways to carry off

[1] See Report of State Engineer, Wm. Ham. Hall, 1880, Part IV, Appendix, p. 177.

surplus waters from the many low spots, which, on account of the light slope of this section of the valley, could not otherwise readily be relieved of standing water. The gates in use in the irrigating ditches and to control the flow of water from one check into another are somewhat peculiar. They are built without the use of sheet piling or its equivalent and without wings, but seem to stand well in the firm soil.

After a number of years of experience the management of the Riverside and Columbia ranches has learned its lesson and the large checks are being subdivided. A few acres in each compartment are preferred, and levees are made low and broad, generally 18 inches high on a 12-foot base.

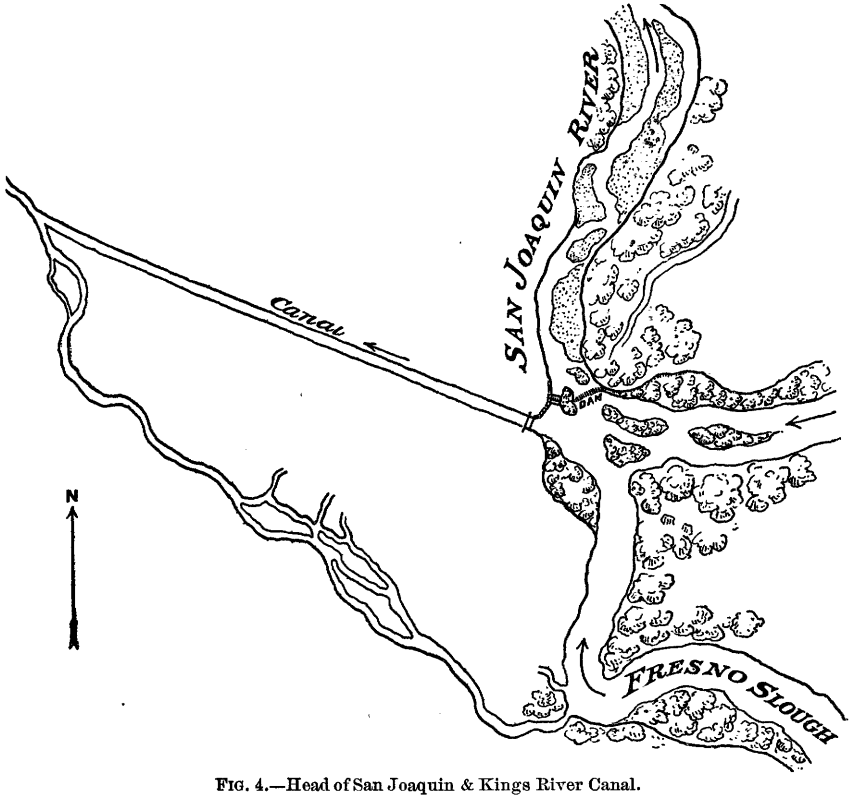


FIG. 4.—Head of San Joaquin & Kings River Canal.

The lands adjacent to this canal for about 15 miles of its length, intermediate between the Columbia and the Chowchilla properties, are practically worthless for agricultural purposes. The soil is shallow; it lies on a sandstone-like hardpan and can produce but a scant growth of grass.

San Joaquin & Kings River Canal.—This is one of the most important of the canals in San Joaquin Valley. It commands a large portion of the west-side plain. Its head is just below Las Juntas, the point where Fresno Slough unites with San Joaquin River, about 9½ miles above Firebaugh. At that point a small island divides the river into

two channels, of which the lesser one, about 50 feet wide, lies at the west. Into this lesser channel a structure with falling dam, 47 feet between side walls, has been built to facilitate the passage of steamboats. (See Pl. I.) In the other channel a brush diverting dam about 350 feet long is maintained, which holds water at all stages about 6 to 8 feet above the river's natural low-water plane. The inflow into the canal is controlled by means of a gate 47½ feet between walls, which is bridged over. The space between walls is subdivided by gate and bridge posts into six divisions, each of which can be closed by means of drop timbers. (See Pl. II.)

This regulating gate and the steamboat chute required much pile work and sheet piling to afford them support and protection. The

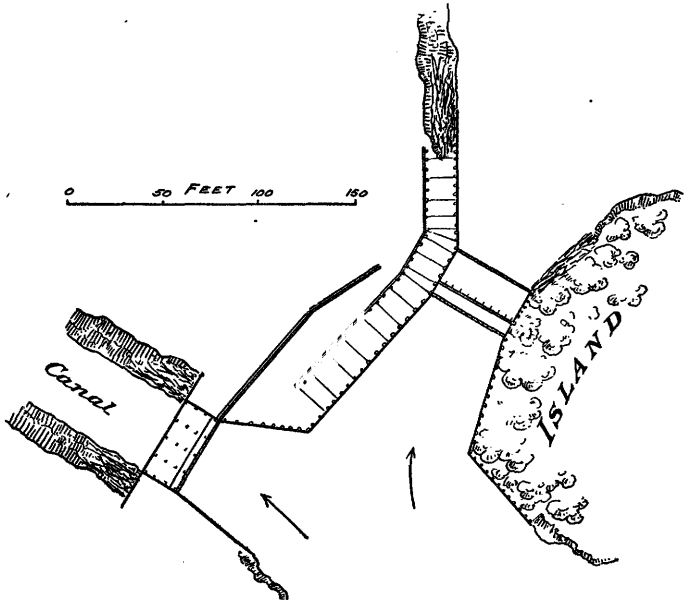


FIG. 5.—Details of head works of San Joaquin & Kings River Canal.

brush dam, as is the case with all structures of its type, must be repaired and raised annually after the spring high waters. It will thus appear that, notwithstanding the apparent simplicity of arrangement of head works, their construction and maintenance have been expensive.

The construction of this irrigation work commenced in 1871, and in that year the canal was excavated to Los Baños Creek, a distance of 38 miles. It was extended in 1877 and 1878 to Orestimba Creek, and its present terminus is but a few miles farther south. Canal construction was undertaken by a corporation which proposed not only to supply water to irrigators, but also to make a practical demonstration of the advantages of irrigation by operating a farm of its own. The land selected for farming purposes was very carefully prepared for irrigation, and the water was to be brought to the soil from irrigating

ditches in a system of cross furrows. The experiment, involving the introduction of methods that may be successful in India, where labor is abundant and cheap, proved a complete failure, and seems to have brought the entire canal project into temporary bad repute. While the affairs of the canal company were thus in a deplorable condition it was easy for the firm of Miller & Lux to acquire a controlling interest in the canal stock, and to become in time practically the sole owners of the canal. This firm had already made special contracts for water for their extensive holdings at rates below those to be established for other water takers, granted in return for right-of-way concessions, and it was soon apparent that the successful operation of the canal would depend upon them alone.

Although the general demand for water did not increase rapidly, and although comparatively few of the renters of land from Messrs. Miller &

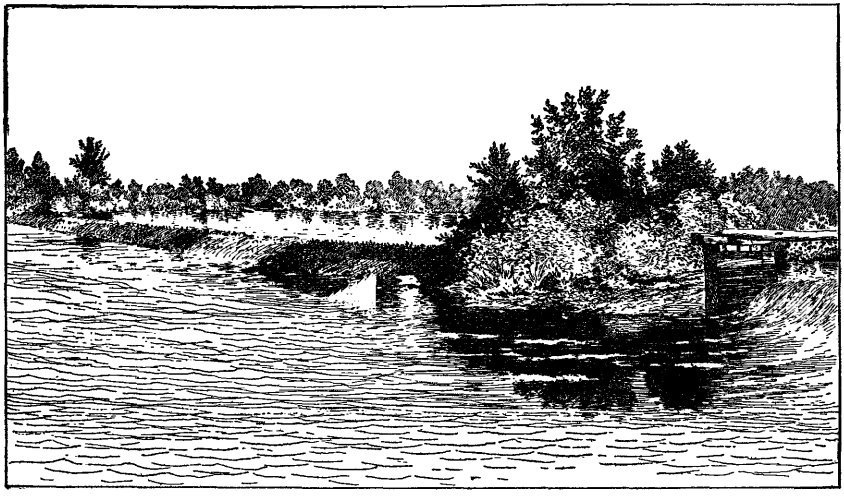
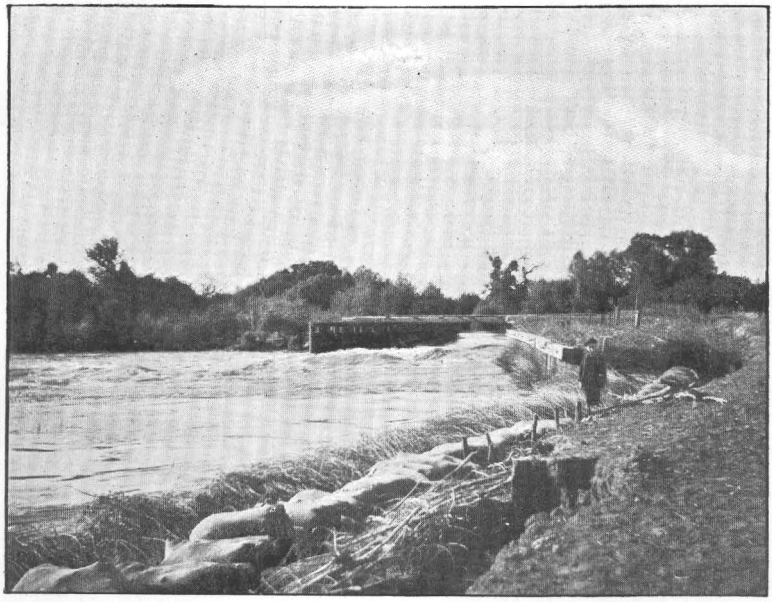


FIG. 6.—Brush dam across San Joaquin River at head of San Joaquin & Kings River Canal.

Lux succeeded in making sufficient profit to purchase the lands farmed, the consumption of water from the canal gradually increased, the increase being notably due to its extensive use on alfalfa and pasture lands of the big cattle firm, and reached about 34,000 acres in 1882 and 1883. The area to which water is actually applied varies, according to the character of the season, within wide limits. It was only 14,000 acres in 1886 and 12,300 acres in 1890, because the preceding winters were wet. It reached 38,600 acres in 1894, and may be rated at about 27,000 acres on an average.

The system of water distributed to irrigators has not been calculated to increase the duty of water, and will account in large measure for the relatively small area actually irrigated by a work of such great extent as this canal.

It has been the practice not to limit irrigators in the amount of water



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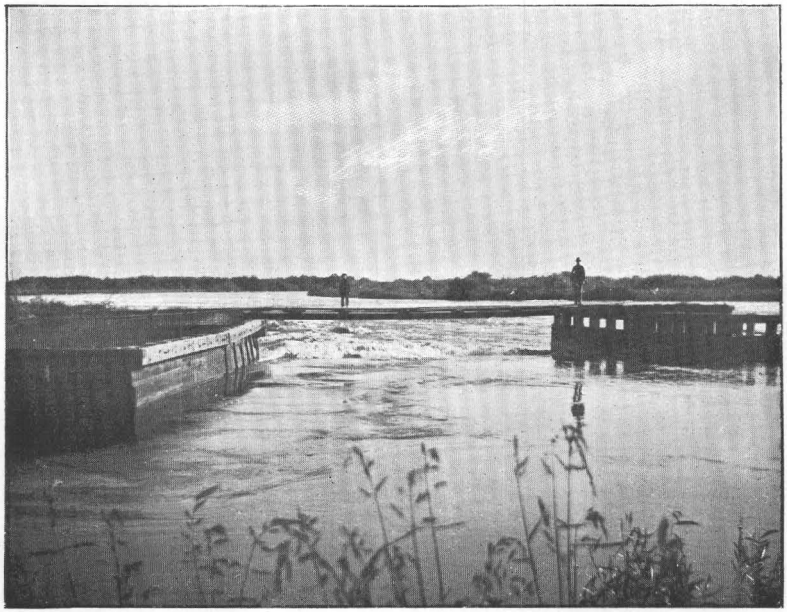


B.

STEAMBOAT CHUTE, SAN JOAQUIN RIVER, AT HEAD OF SAN JOAQUIN & KINGS RIVER CANAL.

A, As seen from below; *B*, As seen from above.

to be used. They pay for water by the acre irrigated. The canal company reserves the right to charge for water wasted, when such waste can be ascertained. When there is a shortage of supply, the canal superintendent distributes water to the irrigators in proportion to the acreage for which water is required. If an insufficient quantity of water is delivered to effect the proposed irrigation, a corresponding reduction in the water bill is made. Charges for water are made by the acre, according to character of crop irrigated. The rates in force preceding 1880 were about as follows:[1]

For cereals during any part of the season from July 1 of one year to the same date the following year, $2.50 per acre.

For alfalfa, $3 per acre per year.

For market gardens, $5 per acre per year.

For wild-grass lands, 75 cents per acre per year.

For the irrigation of a second crop during the season, $1.

For the fall irrigation of lands, from July 1 to January 1, the charge for a single application is $1.50 per acre. After January 1, any number of waterings necessary to mature a crop of cereals is given for $1.

These rates have at various times been modified somewhat. The rate for alfalfa has recently been $2.50 per acre per year, and, under agreement to take water for the season, application being made before October 1, $2 per acre. No charge is made for the irrigation of small gardens of those irrigating large tracts of grain or alfalfa. The special contract made with Messrs. Miller & Lux gave them water at about one-half of the above rates.

The distribution of water from the canal to irrigators is in charge of a canal superintendent. Those requiring water must give ten days' notice and must specify the number of acres for which water is wanted, as well as the particular tract of land to be irrigated.

The soils to which water is applied from this canal are thus described by Mr. James D. Schuyler:[2]

The lands irrigated by the San Joaquin and Kings River Canal vary so greatly in character that the practice of irrigation is not uniform. From the point where irrigation first begins, near Firebaugh's, 8 miles below the head of the canal, to its terminus at Orestimba Creek, there is a gradual change in the quality, depth, and texture of the soil, from the minimum of absorbtiveness and the consequent maximum number of irrigations required to produce crops, to the maximum of absorbtiveness and the minimum of applications necessary. The soils which retain moisture longest are those which absorb most water and are consequently best adapted for irrigation. In no irrigated section of the State are the extremes in quality of soil more marked. The adobe soils do not extend the entire distance from the canal to the river, but seem to be principally limited to a strip 2 to 5 miles wide from Firebaugh's to Los Baños Creek. They are shallow—from 1 to 2 feet deep—and underlaid with yellow clay hardpan. East of this strip to the river the soil is generally of an alluvial character, highly susceptible of profitable irrigation, but not heretofore provided with facilities for irrigation, the land being devoted exclusively to grazing purposes. On either side of Los Baños Creek the soil is a

[1] Report of State Engineer, 1880, Part IV, Appendix, J. D. Schuyler.
[2] Idem, p. 166.

compact sandy loam for a mile or two in width, very fertile, and well adapted to irrigation. With the exception of 3 or 4 miles along the canal where San Luis Creek spreads out upon the plains, the soil for the remaining distance to the terminus is a light-brown argillaceous loam, with an occasional admixture of sand. It is 30 to 40 feet in depth, compact, fertile, and highly retentive of moisture.

The shallow soils referred to in this description are those at, or but slightly elevated above, the western limit of the submersible portion of the valley. The soils to the east of this strip of inferior land are within the flood limits, and those traversed by the lower sections of the canal are of the general type of the high west-side plain.

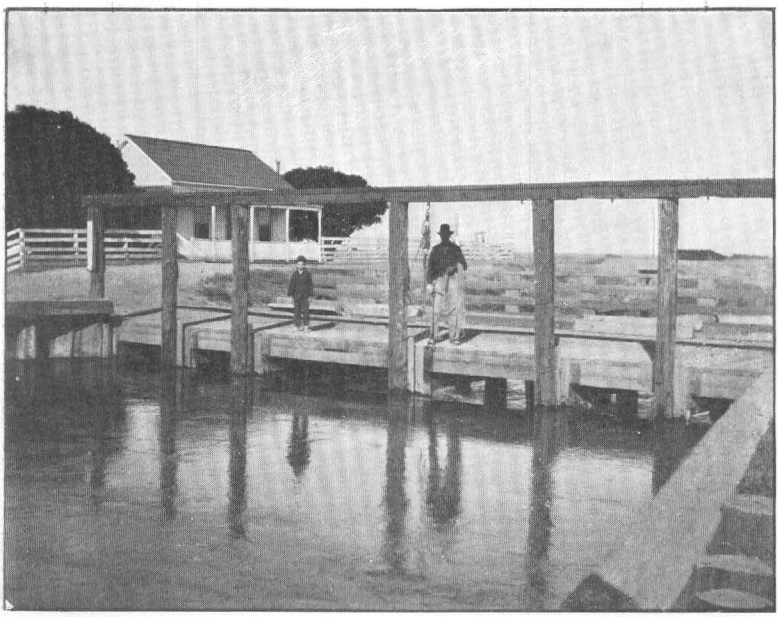
The method of irrigation generally practiced from this canal is that of flooding in contour checks of large area. The irrigation of grain lands has been found profitable, but opinions of irrigators differ as to the best time of applying water. Near the upper end of the canal the practice of applying water to the growing crop is preferred, each crop receiving two to five waterings, according to character of soil. Along its lower portion the method of wetting the ground in the fall before plowing seems to be the most satisfactory. In this case the rainfall, generally 8 to 12 inches, is relied on to mature the crop. Orchards and vineyards are irrigated by the furrow method.

The surface of the lands irrigated is remarkably smooth, and its slope toward the trough of the valley is generally 5 to 10 feet to the mile, thus adapting it admirably for irrigation. The system of check-levee building does not, however, conform with the most advanced practice. These check levees are usually made too steep to permit of their being crossed at random by farming implements. A little is thus saved in first cost, but often at considerable sacrifice in convenience of tillage.

The cost of preparing the ground with ditches and check levees is stated by Mr. Schuyler at $1.50 per acre for the large farms owned by Messrs. Miller & Lux. He gives the cost of the check levees at $12 per mile. They are built with a V scraper.

The main canal was originally constructed with a bed width of 28 feet, a depth of 4 feet, and side slopes of 2 to 1. Its gradient was fixed at 1 foot to the mile. It was soon found that these dimensions gave the water greater velocity than the light soil of the banks could stand, and to prevent erosion their slopes were reduced to 5 to 1. The disadvantage of this very flat slope manifested itself some years later, when reeds, weeds, and mosses took root in the shallow water at the edge of the water surface and gradually encroached upon the deeper water, rendering it necessary to keep men at work during the summer cutting out the rank plant growth, and making it very difficult to force a full supply of water to the lower canal sections. Among the appliances used to cut the weeds, particularly one trailing species, the most successful was a long chain dragged upstream by means of horses, generally one on each bank.

About ten years ago it was finally decided to clean out the canal thoroughly and at the same time to cut its banks as nearly vertical as



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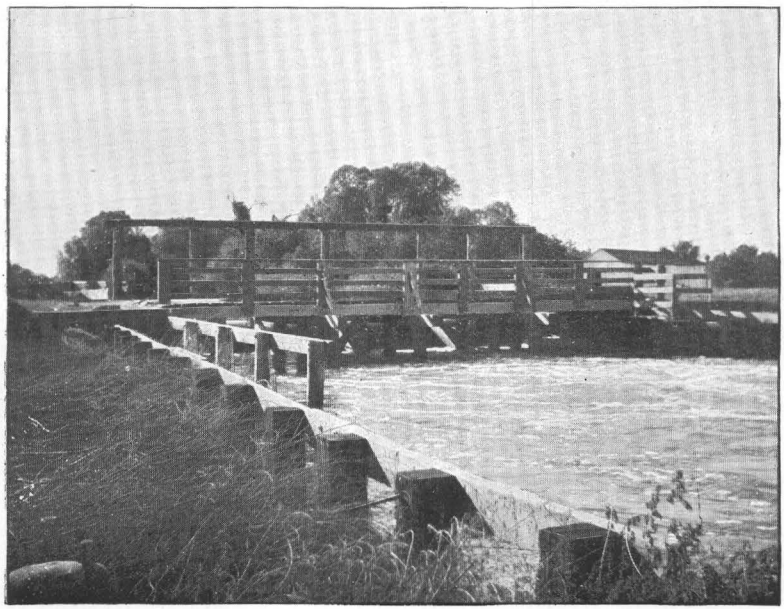


B.

REGULATOR IN SAN JOAQUIN & KINGS RIVER CANAL.

A, As seen from above; *B*, As seen from below.

possible. This was done with excellent success. The canal bed was made 45 feet wide, with its sides practically vertical, and the water depth was increased to 6 feet. The soil of the banks, impregnated with the mud deposits from the canal water and rendered resistant by the roots of plants which had penetrated it in all directions, showed no further tendency to erosion, and the great inshore depth of water, as well as its velocity, retarded the growth of plants.

Below Los Baños Creek the fall of the canal was made only 6 inches to the mile. This 6-inch fall practically commences 2 miles above Los Baños Creek, as for some reason the grade line of the canal bed was raised 1 foot at that point. Experience on this canal seems to justify the conclusion that for a canal of its size a slope as light as 6 inches to the mile may safely be adopted.

This canal crosses the natural drainage lines of the west-side plain at right angles. The water courses are torrential in character. They have no flow in years of scant rainfall, and in the occasional wet winters they respond quickly to the local storms, but do not maintain their flow long. Where crossed by the canal the arrangement of the crossing is extremely simple. A check weir is put into the canal just above and just below the creek channel, and an embankment, usually of gravel, is carried across the creek channel just below the canal and connected with the canal levee. When the creek rises and overtops this barrier, it is quickly cut out by the water, in whole or in part, and upon subsidence of the freshet is replaced. The flow of the creek, if there be any after the freshet, is received into the canal.

The San Joaquin & Kings River Canal was intended to be used for navigation as well as irrigation purposes, and in accordance with that idea the structures originally planned for it included arrangements for passing canal boats. They were all timber structures of unnecessarily heavy and cumbersome design and correspondingly expensive. The more modern structures on the canal are of the usual light inexpensive type so common on the canals of the West.

The distributing ditches, which usually lead off from the main canal nearly at right angles, are generally 8 to 12 feet wide on the bottom and carry water 2 to 3 feet deep. Their aggregate length is estimated at about 200 miles.

The cost of the canal and works connected therewith has been about $1,000,000, not including about $300,000 expended in maintenance and repairs. The dividends paid have probably not exceeded $250,000. At the time of this writing there is a supplementary high-line canal being constructed which will greatly increase the capacity and efficiency of this canal system. This new canal leaves the original canal about 3 miles below its head and gradually separates from it, being carried on a grade of only 6 inches to the mile. It has a bed width of about 45 feet and is generally about 1 mile distant from the main canal, with which it is connected by means of a number of short branch ditches.

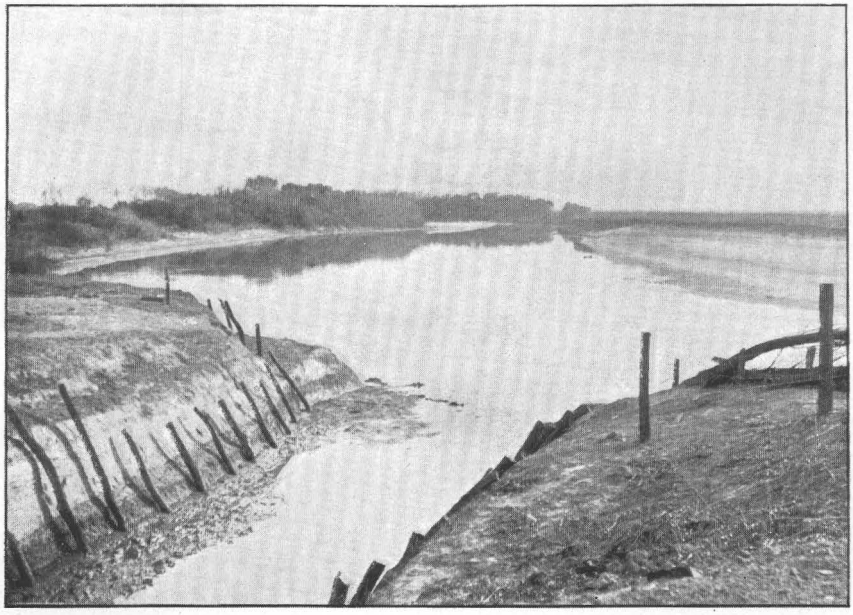
Posey Slough or Dos Palos Canal.—This is a work which hardly deserves enumeration among irrigation canals, as it amounts to but little more than a control of the inflow into a natural high-water channel which breaks out of San Joaquin River about 8 miles below Firebaugh's. It was necessary in protecting west-side lands against overflow to either close the slough with an embankment connected with the west side or to put a gate into it. The latter arrangement was preferred, and the water now admitted to the slough under control is utilized in flooding considerable areas of grazing lands. The gate has a clear opening of 24 feet, divided by means of gate and bridge posts into four spaces, each of which can be closed by means of light drop timbers. The top of the gate is provided with a bridge floor, affording a crossing for the river road.

The slough continues inland for some distance as a well-defined channel through which water is led into a series of broad swales or gentle depressions. Across these depressions embankments of earth have been erected to a maximum height of 4 or 5 feet, by means of which the water is checked and made to inundate considerable areas. One embankment after another is cut for the passage of the water to the next, or the water breaks a passage of its own, and by this crude system of irrigation considerable areas of grazing land are wet during the spring rise of San Joaquin River.

It is hardly necessary to say that this method of wetting lands can be practiced only on large holdings, such as those of the Miller & Lux Company.

Temple Slough.—This is a slough of the same type as Posey Slough, though somewhat smaller. It has been similarly treated. It breaks out of the west side of the river about 3 miles below Posey Slough. Its head gate is also in use as a bridge, but the head gate is of the culvert type and is loaded on top with an earth fill. It is 16 feet wide, being divided by posts into four spaces. The bottom of the gate is at or slightly above the low-water plane of the river. The water admitted to the slough is used for irrigation in the same crude way as that of Posey Slough.

Sanjon de Santa Rita.—This is a third slough which breaks out through the west river bank, but, unlike Posey and Temple sloughs, it has a comparatively direct northwesterly course to a reunion with the main channel of San Joaquin River, about 12 miles below its head. There is no gate at its head for the control of inflowing water, but by means of temporary spur dikes or dams of sand and brush built into the main stream its period of flow is prolonged somewhat beyond what it would otherwise be. Water is diverted from the slough into a short ditch for the irrigation of several hundred acres of land at the Miller & Lux home place, the Santa Rita Ranch. The head of this ditch is about 3½ miles below the head of the slough, on its west bank. The flow of the water into the ditch, which has a width of 10 to 12 feet, is controlled by means of a light gate.



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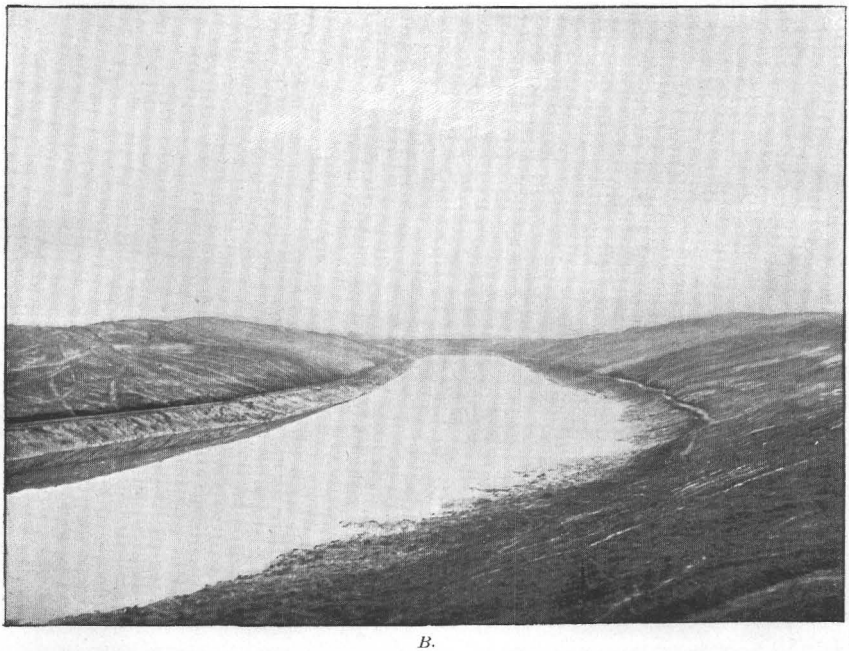


B.

BLYTH CANAL.

A, Head at San Joaquin River; *B*, Nine-foot cut.

Blyth Canal.—The main supply of water for the grassland irrigation on the Chowchilla Ranch—already referred to in describing the Chowchilla Canal—is obtained from the San Joaquin River through the Blyth Canal. (See Pl. III.) This is an east-side canal from San Joaquin River, the head of which is some miles below Las Juntas. The canal is cut boldly into the river bank, with a bottom width of 20 feet. It receives water from the river only at high stages. Its flow is controlled by a well-constructed regulator or head gate of the culvert type. It supports a 5-foot fill of earth, which serves as a roadway across the canal. The entrance to the culvert is divided into five 4-foot spaces by vertical posts, which afford support to vertically sliding flashboards, 3 by 12 inches, raised by means of two double hooks engaging on iron pins, to which power is applied by a winch. The canal discharges into the east-side flat valley trough, where its flow is intercepted by a series of cross levees, each extending from comparatively high ground at the river eastward across the depression. These cross levees, five or six in all, are about a mile apart and are all equipped with stop gates, for the discharge of surplus water to lower levels. The basin above the uppermost one is first filled, then water is allowed to flow through its stop gate to the second, and so on to the last, thus effecting wholesale and very economical grass-land irrigation.

East Side or Stevenson-Mitchell Canal.—This canal, as its name implies, is an east-side diversion. The head of the canal is at a point on San Joaquin River about 14 miles southwest of Merced. It has a northwesterly course from this point for a distance of 20 miles, to near Merced River, and commands a strip of land intermediate between the canal and San Joaquin River, 2 to 4 miles in width. (See Pl. IV.) The first few miles of its course are over heavy clayey soils within the limits of the river's flood plain; the rest of its course is out upon the sandy plain which skirts the southern bank of Merced River. It commands about 50,000 acres of land.

The canal was constructed in 1887 by Messrs. J. J. Stevenson and the late John Mitchell, who were the principal owners of the lands commanded. It is 42 feet wide on the bottom and has side slopes of 1 to 1 to the natural surface of the ground, generally at 4 feet above the bottom. The fall is 6 inches to the mile. The canal levees rise about 3 feet above natural ground and are set back 10 feet from the edge of the excavation. The proposed maximum water depth is 6 feet and width on water surface 74 feet. The steep sides of the canal excavation were adopted as a result of the experience on the San Joaquin and Kings River Canal—to prevent the growth of weeds and aquatic plants, which take root readily on flat slopes.

All structures on the canal are of a simple flashboard type. There is provided a regulator or head gate, and the flow of water in the canal is further controlled by means of six check weirs, locally called stop gates. The canal crosses the natural drainage of the country. At each water course thus crossed an inlet gate is put into the upper or

east-side canal levee and an outlet gate into the lower levee. These gates, 36 in all, range in width from 12 to 64 feet. All of them, as well as the check weirs in the canal, are bridged over. During winter the canal is out of service, and all of the gates are left open, to admit of the free passage of drainage waters across the line of the canal. The first cost of the canal work was about $80,000, which has been increased by subsequent expenditures, principally on the construction of branches, to about $125,000.

Water is sold from this canal by the acre irrigated, the charge being $2 per acre if application be made for water before the 1st of January, and $2.50 per acre if applied for later. This difference in the rate per acre is intended to induce irrigators to make application before it is known whether rainfall alone will prove sufficient to produce a grain crop.

The water distributed is under control of a canal superintendent. The canal company furnishes the gates for water delivery to irrigators. All lateral or branch canals are constructed by the irrigators and at their expense.

FRESNO RIVER.

HYDROGRAPHY.

Fresno River is a small torrential stream which drains the western slope of outlying spurs of the Sierra Nevada and which debouches upon the plains of San Joaquin Valley about 15 miles to the north of San Joaquin River. The river is dry in summer, but ordinarily has a considerable winter and spring flow. Its drainage basin above the point where it leaves the hills has an area of 272 square miles. Its flow usually commences in December and gradually increases till March. It ceases to flow in June, July, or August. During the rainy season it is subject to sudden rises of short duration. The maximum monthly average for the period 1878 to 1884, as approximated by the State engineer, is given as 568 second-feet for the month of March.

This stream soon after leaving the foothills proper bifurcates, sending off several lesser southerly branches, among which are Adobe and Cottonwood sloughs. A branch of the former reunites with the main stream some miles above Madera.

The bed of the river is a broad sandy depression, having comparatively high banks, near the eastern edge of San Joaquin Valley, where it is here and there flanked by small tracts of bottom land. At Madera the river banks are quite low, and a few miles farther west the freshet waters of the stream spread and are carried on toward San Joaquin River in several small channels.

CANALS AND DITCHES.

The water brought down to Madera in the flume of the Madera Lumber Company is used for irrigation at and to the west of Madera. This water is in large part a diversion from a tributary of San Joaquin River. It was necessary to make this diversion high up in the mountains and to carry the water from the one watershed across the dividing ridge into the other stream, on account of the small summer flow of Fresno River.

The lumber flume is of the ordinary V-shaped type, serving to float lumber a distance of about 35 miles, from the sawmill to Madera. The waste water from the flume flows into branches of the Madera Canal.

Madera Canal (Fresno River Dam and Canal Company's Canal).—This is a work of some magnitude which is interesting, in part, at least, on

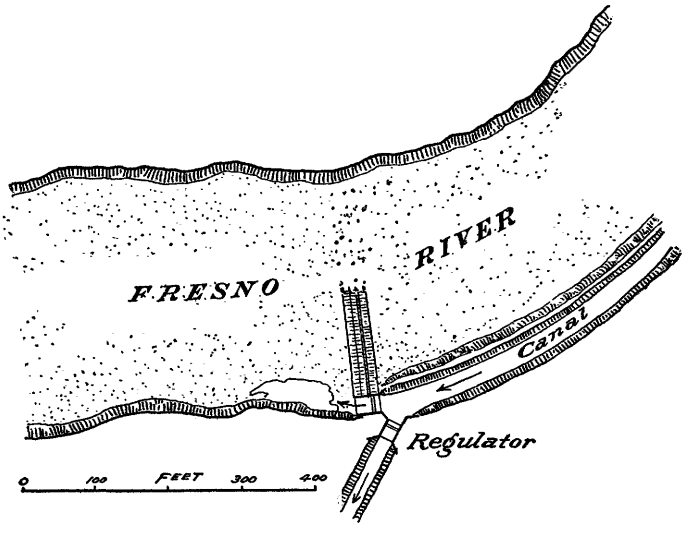


FIG. 7.—Head of Fresno River Canal.

account of the failures in which the first effort to secure water resulted. At great expense a dam was constructed across Fresno River about 2 miles above Madera, and from it a deep cut was excavated through the river bank, which there rises about 15 feet above the river bed. The dam consisted in the main of three rows of double sheet piling, reenforced by numerous ordinary piles, and a timber top work, forming a substantial sill across the stream that was intended to raise water 4 or 5 feet above the ordinary low-water plane. It was 311 feet long, and raised the water surface of the river 6 feet. It was intended also to intercept a subsurface flow supposed to exist in the sands of the river bed, but failed to develop any water from this source. A head gate and waste gate at the south end of this structure afforded control of the inflow into the canal, which was made 20 feet wide on the bottom,

with side slopes of 1 on 2. The depth of the cut through the river bank became less as distance from the river increased, and within a mile the canal was at the general surface level of the valley plain. From this point special effort was made to hold the main canal on the top of flat sand ridges, which position it was thought would afford the best possible command of the lands to be irrigated. Not only was the canal located on the highest available ground, but it was endeavored to hold the water surface in the canal and distributing ditches well above the natural surface of the ground. Material for canal banks was taken largely from the outside. After the expenditure of about $60,000 on the dam and canal it was found that breaks in the canal banks were of so frequent occurrence, and loss of water was so great, that it would be unwise to perfect or further extend the system. It was found, too, that the dam was a failure, particularly owing to the loss of water in the porous creek channel for miles above it. It was then found that by turning a portion of the river's flow into Adobe Slough, some miles farther upstream, and putting an inexpensive regulator in its head, water could be brought into the head of the canal and thence into a water course passing directly through the lands already prepared to receive it. This was done, and a few dams in the slough lower down, with regulating gates in each, completed a main canal system that has been comparatively inexpensive and has served its purpose well. About $20,000 was the first cost of this supplemental work.

It is understood that the water supply of the canal is further reenforced by the Adobe Ranch Ditch, which diverts water from the river at a point known as "Chinee Store," located in the foothills about 19 miles above Madera. This ditch is 10 feet wide on the bottom, carries water 4 feet deep, and at the Adobe Ranch, about 7 miles above Madera, is connected with, and adds in a measure to the supply of, the lower works. The canal company proposes soon to construct storage works in the mountains in order to secure a continuous flow of water for its canal system.

The lands prepared for irrigation with water from this canal have an area of about 16,000 acres. They lie in a compact body to the southward, beyond Cottonwood Slough. The surface of the lands irrigated is very smooth and has an almost imperceptible slope of 7 to 8 feet per mile toward the southwest, adapting them admirably for irrigation. The soil is a sandy loam, rather heavy in the eastern portion of the irrigated region, and very sandy near its western limit. The heavier soils are underlain by a shaly hardpan a few feet below the surface. This is deeper below the surface of the sands or is entirely wanting.

Water is ordinarily available for irrigation from some time in December to May. Occasionally there is a good flow in the canal during June. It is diverted from the slough above referred to into branch ditches, which leave the slough just above the dams that have been built into it.

The method of irrigation is that of flooding in contour checks. The check levees are almost invariably constructed on contour lines, each being 1 foot lower than the next one above. The space between levees is divided by cross levees into compartments or checks whose area varies between wide limits, reaching as high as 40 acres. The ordinary check has an area of about 4 to 12 acres.

A good head of water for irrigation in this section is from 20 to 25 second-feet, but irrigators are frequently compelled to be content with only 10 to 15 second-feet. Irrigation is always commenced on the highest ground; the upper check is filled, and when full, the water is turned into the next lower check, while at the same time the surplus water of the upper check is also turned into the second check through a cut or gate in the contour levee between the two checks. Irrigation progresses night and day, and two men are constantly on duty for each irrigating head of water.

Both alfalfa and grain are generally irrigated but once each season. Grain as a rule is irrigated only when long-continued drought makes irrigation necessary to save the crop. Alfalfa receives more than one irrigation when water is available long enough.

The main canal of this system was until February of this year (1897) owned by a company or association of farmers which made no agreements for the delivery of water to irrigators for longer periods than one season. The distribution of water from the canal was in charge of a superintendent, to whom application for water had to be made before the irrigating season commenced. To these parties, who were required to specify the acreage which they purposed to irrigate and the time when water was required, the water was apportioned. When there was more water in the canal than was required by them, this was available for those parties who neglected to put in application for water before the date fixed as the commencement of the irrigating season. All parties applying for water were required to pay for it whether they used it or not. If water was insufficient to meet the demands of all applicants, it was apportioned by the superintendent according to his judgment, and was paid for by the acre of land actually irrigated. The charge for water was originally $1 per acre for grain and $2 for alfalfa. Subsequently the rate was raised to $1.50 for grain, and since 1885 it has been made $2, which is the charge per acre regardless of the nature of the crop. This rate remained the same no matter how often water was applied.

Of the 16,000 acres of land prepared for irrigation, it is reported that as much as 12,000 acres have been irrigated in one season. Ordinarily, however, the area irrigated is 5,000 to 6,000 acres.

The cost of land preparation for irrigation, covering the construction of small irrigating ditches and check levees, is estimated at $2 per acre, and the cost of each application of water at about 25 cents per acre.

The canal property has recently passed into the hands of a new corporation and will be managed on lines similar to those of the Fresno Canal from Kings River, except that in addition to selling water to lands covered by water rights water will also be furnished at an increased annual rate to lands not so covered. The new company is known as the "Madera Canal and Irrigating Company." It is capitalized at $400,000, in shares of $10 each.

The water rights are at present sold at $5 per acre. The annual water rate to be paid for each acre covered by the right is $1. The canal company places the gate in the canal bank for the delivery of the water; it reserves the right to convert the irrigator's private ditch into a branch ditch under the company's control, provided such use shall not interfere with the delivery of water to the owner of the water right; it makes the water right an appurtenance of the land on which it is located; it reserves the right to shut off water for repairs, and does not hold itself responsible for deficiency of water caused by drought, insufficient water in river, hostile diversion or obstruction, forcible entry, or temporary damage by flood or other accidents, but agrees to use at all times due diligence in restoring and protecting the flow of water in the canals. The canal company also reserves the right to sell 250 water rights of 1 second-foot of water each (1 second-foot to each 160 acres), and it is to be understood that each water right sold shall, whenever the canals flow less than 250 second-feet, represent the two hundred and fiftieth part of the available supply. The purchaser of the water right makes the water rights a lien upon the land covered; he agrees not to use water wastefully, and he grants to the canal company the right of way for canals and ditches over all land owned by him and located in the same township as the specific tract covered by the so-called water right.

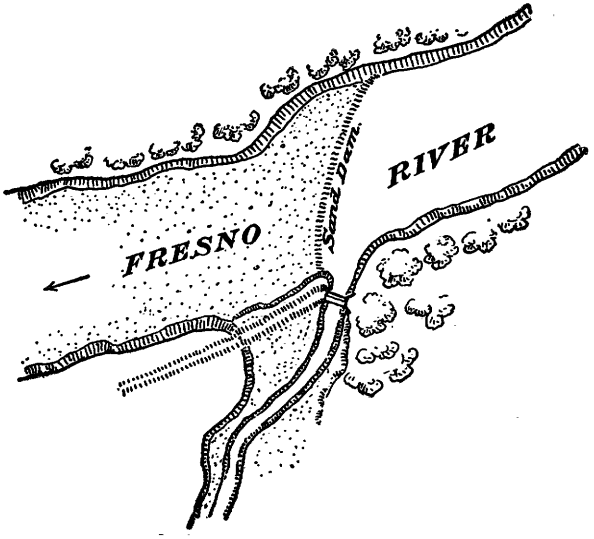


FIG. 8.—Head of Adobe Slough.

Water is delivered for $2 per acre per year to parties whose lands are not covered with water rights. The charge for grain land is $1 per acre for one wetting. The charge for garden irrigation is $5 per acre per year.

Adobe Ranch Ditch.—About 12 miles above Madera, on Fresno River, between low outlying foothills, lies the Adobe Ranch, on which between 300 and 400 acres of bottom lands are cultivated in alfalfa. Water for use on this land was made available by means of a small ditch constructed about fifteen years ago, the head of which is about 7 miles farther upstream, on the south side of the river. The water of this ditch was originally delivered into a small reservoir lying between low hills on the south side of Fresno River close by the tract to be irrigated, and water was drawn from the reservoir as required. The method of irrigation is by flooding in checks, each several acres in area. The cost of applying water is given at 65 cents per acre per irrigation.

The ditch is now said to be a feeder of the Madera Canal and is reported to have a bed width of 10 feet and to carry water 4 feet deep.

CHOWCHILLA RIVER.

HYDROGRAPHY.

The same description given for Fresno River will answer for the Chowchilla, except that its bank lands are even lower and the separation of its water into several channels soon after its debouchment on the valley plain is still more pronounced. The river's drainage basin is 268 square miles. Its flow and period of flow are about the same as noted for Fresno River.

Two channels break out from the south side of the river near the eastern margin of the valley plain. These are Berenda and Ash sloughs, both of which have a very direct southwesterly course, being respectively 4 and 2 miles from the main stream at Minturn. All of these channels across the east-side plain of San Joaquin Valley have shallow beds of sand and banks rather low, but still somewhat higher than the general surface of the plain. Their flow spreads over large areas near San Joaquin River, and there is no pronounced junction of Chowchilla River with the main drainage way of the valley.

CANALS.

Kohler, West & Minturn canal system.—The use of water from Chowchilla River for irrigation has been confined to several thousand acres of land at and near Minturn. (See map, Pl. IV.) The main river channel has been converted into a supply canal by the construction of several dams. The uppermost of these dams is just below the head of Ash Slough. It is in the nature of an earth or sand embankment carried across the river channel and equipped with a large regulating gate in its center. The gate is of the ordinary flashboard type, with a light bridge over its top. It is protected against undermining by sheet piling, and the water required for irrigation below is allowed to pass through it. Any excess flow of the river is turned down Ash and Berenda sloughs. About a mile north of Minturn and about 10 miles below the dam just referred to, a second dam of similar character is

maintained. This structure converts a section of the river into a reservoir which overflows through a gate in the dam to the lower portion of the river, and through gates in river-bank levees sends water toward the north and south.

The water diverted at this point is used principally on the vineyard lands of Messrs. Kohler, West & Minturn. Some of it is passed on to other irrigators. The irrigation ditches are small, 8 to 12 feet wide, carrying water about 2 feet deep, and terminate within a few miles of the river.

A third dam is maintained in the river about 2 miles below the second, and water is taken from above it for the irrigation of the Minturn farm.

These dams are 8 to 14 feet high, built of such material as the river bed affords, and have stood remarkably well. The success of this system of handling the water of the river, which is 200 to 300 feet

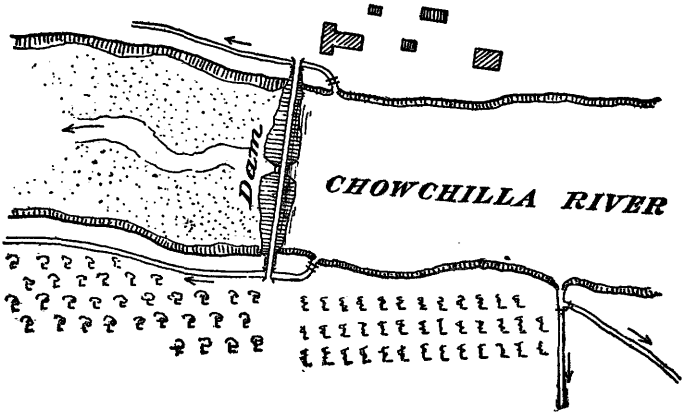


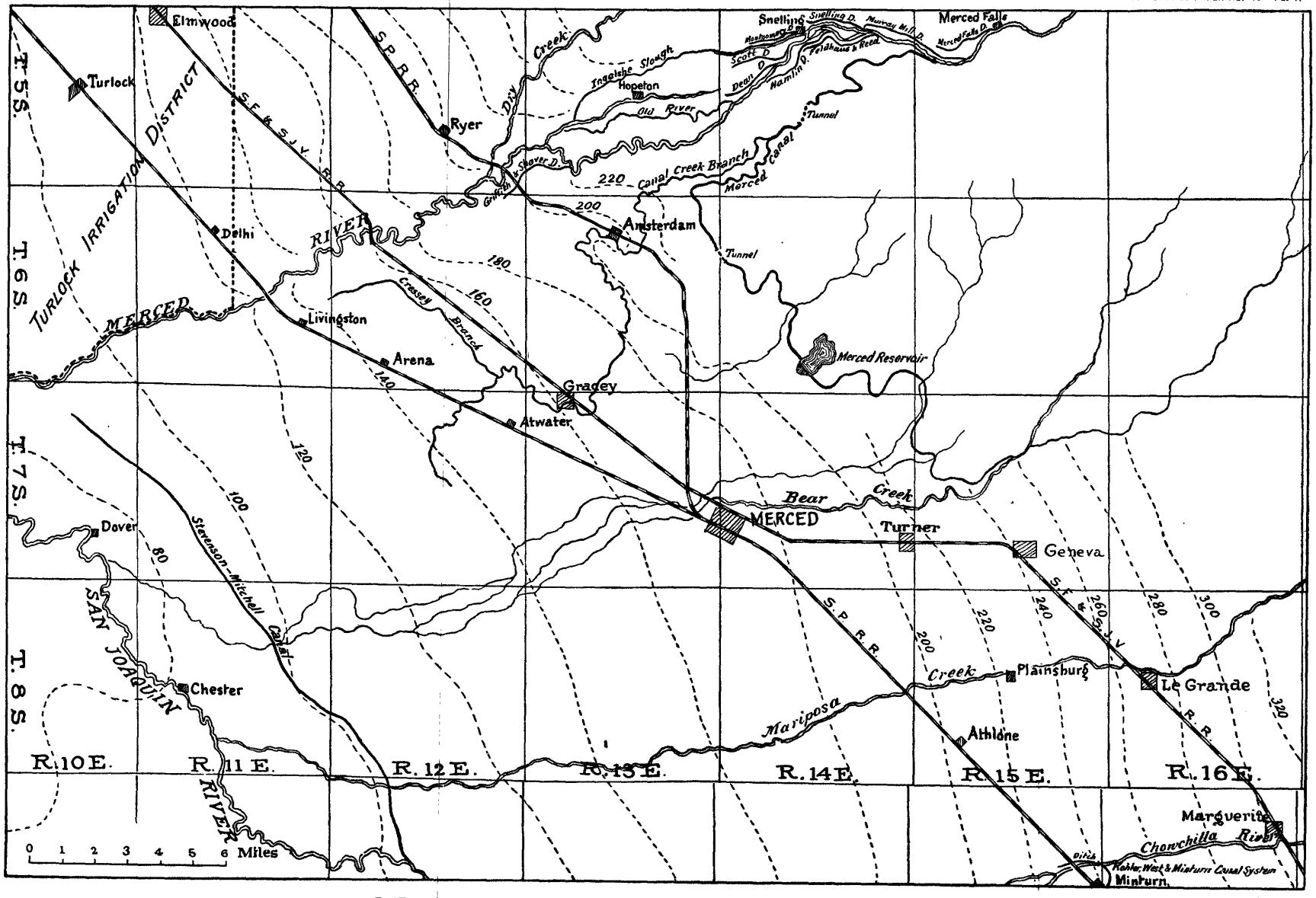
FIG. 9.—Water diversion by Kohler, West & Minturn Canal.

wide, depends, of course, upon the possibility of forcing practically the entire freshet flow into the other channels.

The method of vineyard irrigation practiced at Minturn is that of flooding in small checks, some of which have been laid out rectilinearly, while others are fitted to the contours of the ground. The soils irrigated are sandy loams, very retentive of moisture, which with water have proved very productive and well adapted to the culture of the grape.

Surplus waters—that is, water in excess of that required for the irrigation of the lands belonging to the firm owning the canal—have been held for sale. The rate which prevailed several years ago was $1.50 per acre of land actually irrigated.

Buchanan Reservoir project.—A work of considerable magnitude proposed for Chowchilla River is the construction of a reservoir of great capacity several miles above Buchanan. This work is to be carried out to secure an adequate water supply for the 30,000 acres of land of


Elmwood
Turlock
Delhi
Livingston
Arena
Gregory
Atwater
MERCED
Turner
Geneva
Dover
Chester
Ryer
Hopeton
Amsterdam
Snelling
Merced Falls
Plainsburg
Le Grande
Athlone
Marguerite
Minturn
Merced Reservoir
Tunnel
Tunnel
Creek
Creek
Creek

the Berenda-Chowchilla tract owned by the Sharon estate. The dam as proposed is to be built of uncoursed rubble. It is to have a height of 100 feet and will store 42,400 acre-feet of water.[1]

MERCED RIVER.

HYDROGRAPHY.

Merced River is to be classed among the principal streams which flow down the western slope of the Sierra Nevada into San Joaquin Valley. It has a perennial flow, its low-water discharge being about the same as that of Tuolumne, Stanislaus, and Mokelumne rivers, nearly 200 second-feet. The river has a high mountain and foothill watershed of 1,076 square miles. Its bed where it enters the valley is considerably depressed below the general surface of the plain. It is flanked by low bottom lands, which extend with irregular width to the base of the bluffs rising to the higher land of the main valley. The bottom lands near Snelling expand to a width of several miles, forming a secondary valley of no small importance. Westward from Livingston the main plain gradually drops to the level of the river lands, and long before a junction with San Joaquin River is effected the Merced is flanked by large areas subject to periodical inundation.

The flow of the river approximated by the State engineer for the years 1878 to 1884 indicates an average monthly rate of 1,500 second-feet for February, over 1,700 second-feet for March, 3,000 to 5,000 second-feet from April to June, 1,900 second-feet in July, 400 to 600 second-feet in August, December, and January, and a low-water flow of about 200 second-feet during the months of September, October, and November.[2]

These figures, indicating as they do a very considerable flow in the spring and early summer, show the importance of this stream as a possible source of water supply for large irrigation canals. Although the value of this stream for irrigation has long been recognized, as well as that of the other rivers of the same class—the Tuolumne, Stanislaus, and Mokelumne—the construction of irrigation works on a large scale has progressed but slowly. This is due, first, to the fact that the position of these streams, depressed as they are from 40 to 80 feet below the general surface of the east-side plain, makes a diversion of water upon the higher surface of this plain very expensive; and, secondly, to the fact that the lands commanded are sufficiently favored with natural advantages to render them available, in a measure at least, for farming without rrigation.

The only canal from Merced River which carries water out upon the east-side plain of San Joaquin Valley is the Merced or Crocker-Huffman Canal. All other irrigation works are comparatively small ditches in use for the irrigation of the limited bottom lands.

[1] See American irrigation engineering, by H. M. Wilson: Thirteenth Ann. Rept. U. S. Geol. Survey, Part III, 1893, p. 314.

[2] Physical Data and Statistics, W. H. Hall, State engineer of California, 1886, pp. 434, 476.

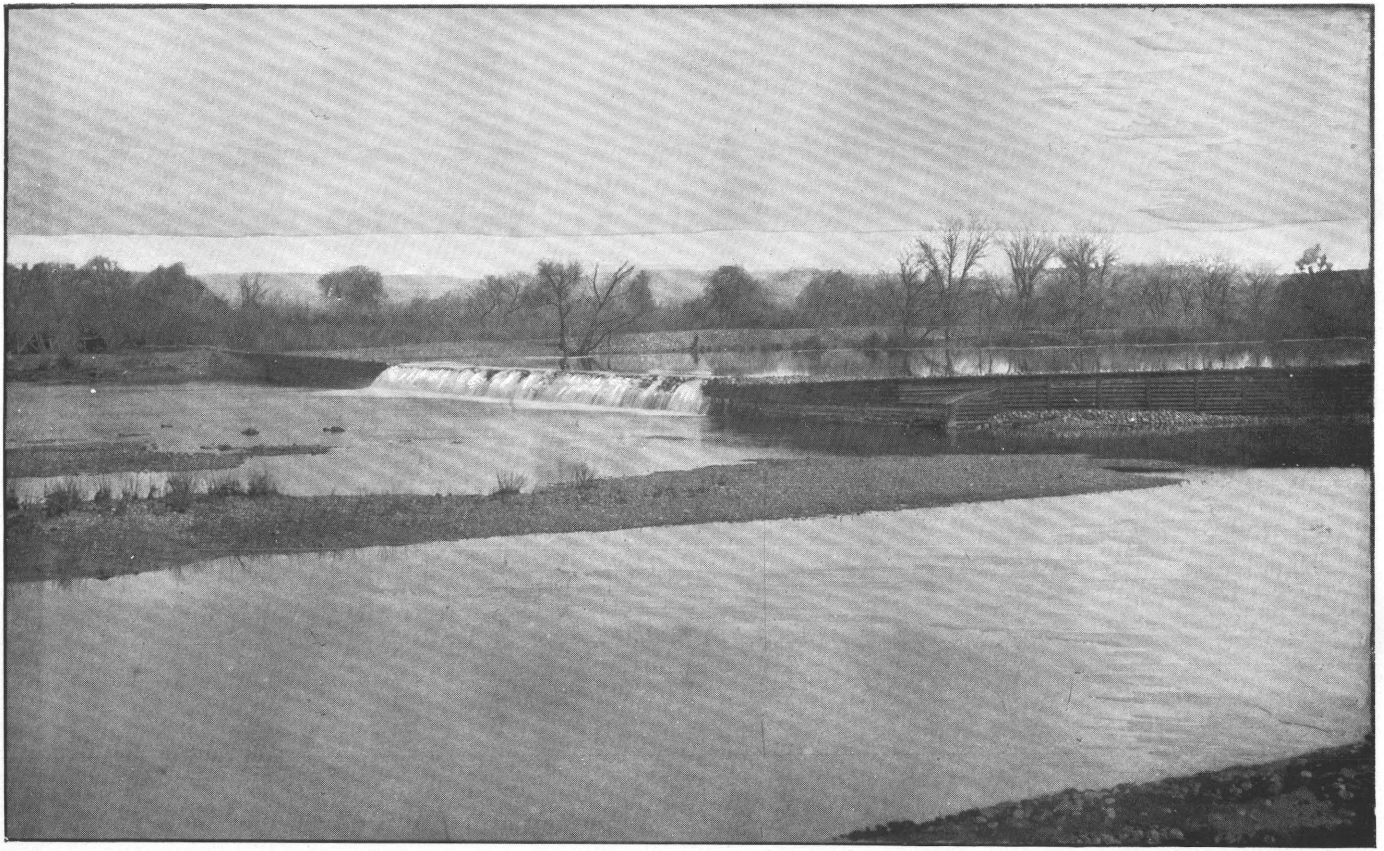
CANALS AND DITCHES.

Merced or Crocker-Huffman Canal.—This work is the extension and enlargement of an older ditch known as the Farmers Canal. It has its head on the south side of Merced River, about 2 miles below Merced Falls. (See map, Pl. IV.) Skirting the base of the bluffs to the south of the bottom lands, it reaches the upland and, penetrating several foothill spurs, attains a position which commands the east-side plain of San Joaquin Valley to and beyond Bear Creek. (See Pl. VIII.)

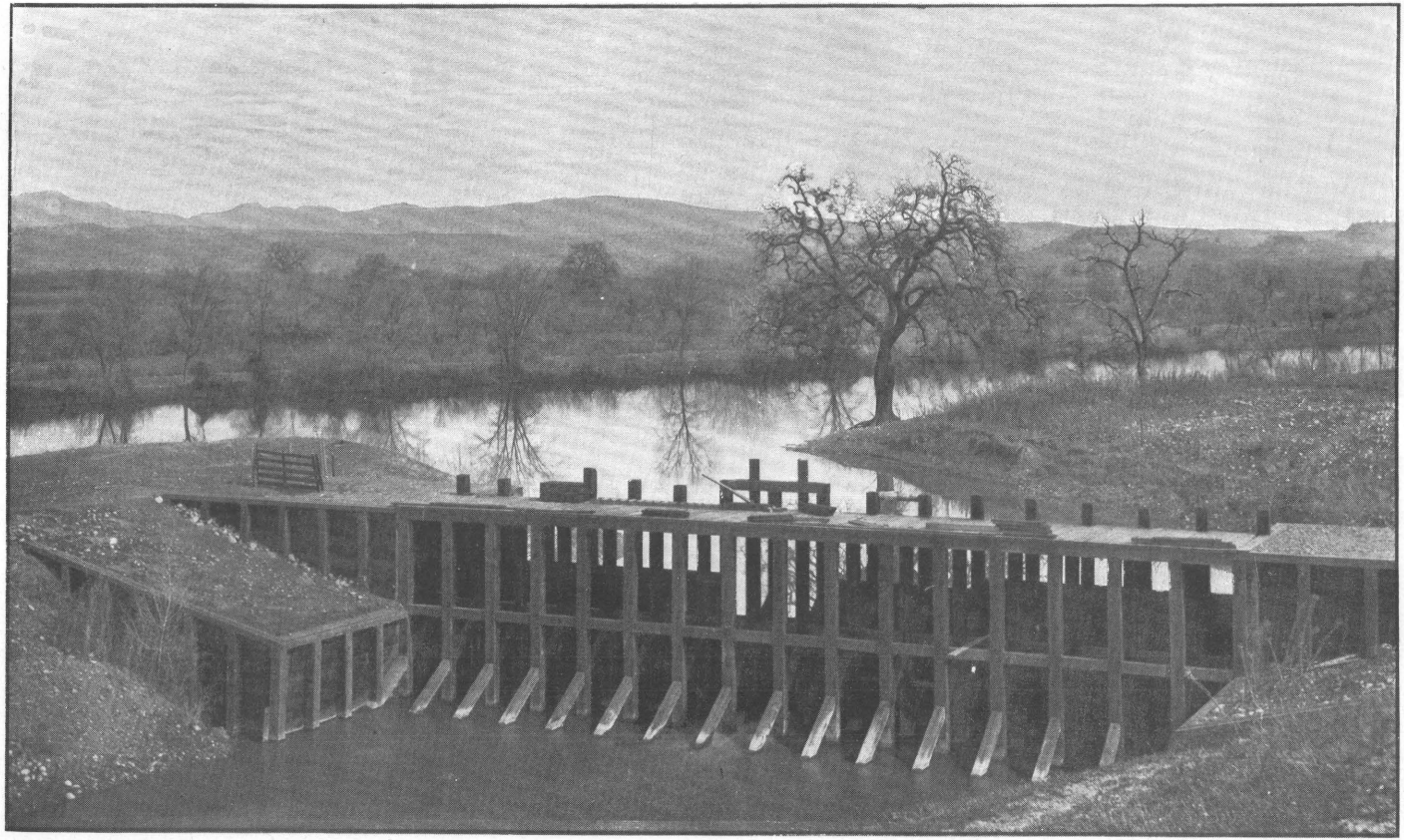
The enterprise was conceived by the late William G. Collier, a surveyor and civil engineer, who had already had some experience in constructing irrigation ditches from Bear Creek. An organization of farmers was formed, which incorporated in 1873 under the name of the Farmers Canal Company, and work on the canal was pushed forward as rapidly as the available means would permit. Unforeseen difficulties, notably due to lack of funds occasioned by excessive cost of excavation, prevented the plans from being fully carried out as originally proposed. However, by March, 1876, the canal reached Canal Creek, and water was, through it, made available for irrigation. The length of the canal to this point was about 8 miles. For most of the way it had been cut into a hard gravelly soil, which cost to excavate about 20 cents per cubic yard, instead of 10 cents, as had been estimated. It penetrated a ridge by a tunnel 1,600 feet long, 11½ feet wide by 9 feet high, which cost about $20,000. This tunnel is in soft sandstone and firm cemented gravel, and did not require lining. The canal as constructed had a bed width of 20 feet, and was 4 feet deep. It followed, in a southwesterly direction, a grade line having a fall of 1 foot to the mile, except at the tunnel approaches and in the tunnel itself, where the fall was increased to 10 feet to the mile.

The Farmers Canal Company could not succeed in making arrangements for the extension of the canal beyond Canal Creek, and finally sold out to Messrs. Charles Crocker and C. H. Huffman in 1882. The enlargement of the canal was commenced at once. Except one change of location near the head of the canal, the original alignment of the old ditch was all too carefully adhered to. In making the enlargement to a bed width of 60 feet, the material handled, including original levees and spoil banks, was fully as great as it would have been on a new route adapted to the increased canal dimensions, and it is questionable whether a complete change of alignment for some of the canal sections would not have been advisable. The tunnel, too, was enlarged to a width of 22 feet, while it might well have served for many years without enlargement.

Near its head the new canal was made 80 feet wide on the bottom. It was planned to have a depth of 10 feet throughout. Its extension beyond Canal Creek was rapidly pushed. The creek channel was enlarged, and for about a mile became a section of the canal. From



DAM ACROSS MERCED RIVER FOR CROCKER-HUFFMAN CANAL.



REGULATOR IN CROCKER-HUFFMAN CANAL.

that point the main canal was given a more southerly course, skirting the western base of a number of foothill spurs and finally penetrating one at a point about 8 miles north of Merced, in a timber-lined tunnel 20 feet wide, 13 feet high, and 2,100 feet long, with a total fall of about 5 feet. Tunnel frames are constructed of timbers, 12 by 14 inches, 4 feet apart. Lagging and flooring are 3 inches thick, all redwood. Tunnel lining required over 1,000,000 feet of timber, and it alone is said to have cost about $30,000. It is extremely doubtful whether the reduction of a few miles in the length of the canal could justify its construction, even if it had been found to require no lining. The total cost of the tunnel was about $70,000. Work on it progressed night and day, and it was completed in about six months. (See Pl. VII.)

About 6 miles below the tunnel just described, and about 12 miles by canal from Canal Creek, the canal delivers its water into a reservoir, the primary purpose of which is to afford a reliable supply of water to the city of Merced, lying about 6 miles farther to the southwest. This reservoir has a surface area of about 600 acres. It lies between two low foothill spurs, the gap between which was closed by means of an earth dam having a crest length of 2,200 feet and a maximum height of 50 feet. The dam rests on a very firm foundation of cemented gravel, into which a wide, deep puddle trench was cut. Much of the material of which it is constructed had to be loosened by blasting. All material was wet when put into place, and was firmly trampled by horses. There was enough clay in the material used throughout the structure to make it a very compact bank.

A masonry conduit, brick laid in cement mortar, has been carried through the natural foundation under the dam, and in this the delivery pipe and the sluice pipe have been placed. (See Pl. IX.) The main canal is continued southward, or rather southeastward, from the reservoir on a continuation of the grade line entering the reservoir from the north. This arrangement cuts the canal extension out of a supply when the reservoir is not full. Water was turned into the reservoir through the completed main canal on February 1, 1888.

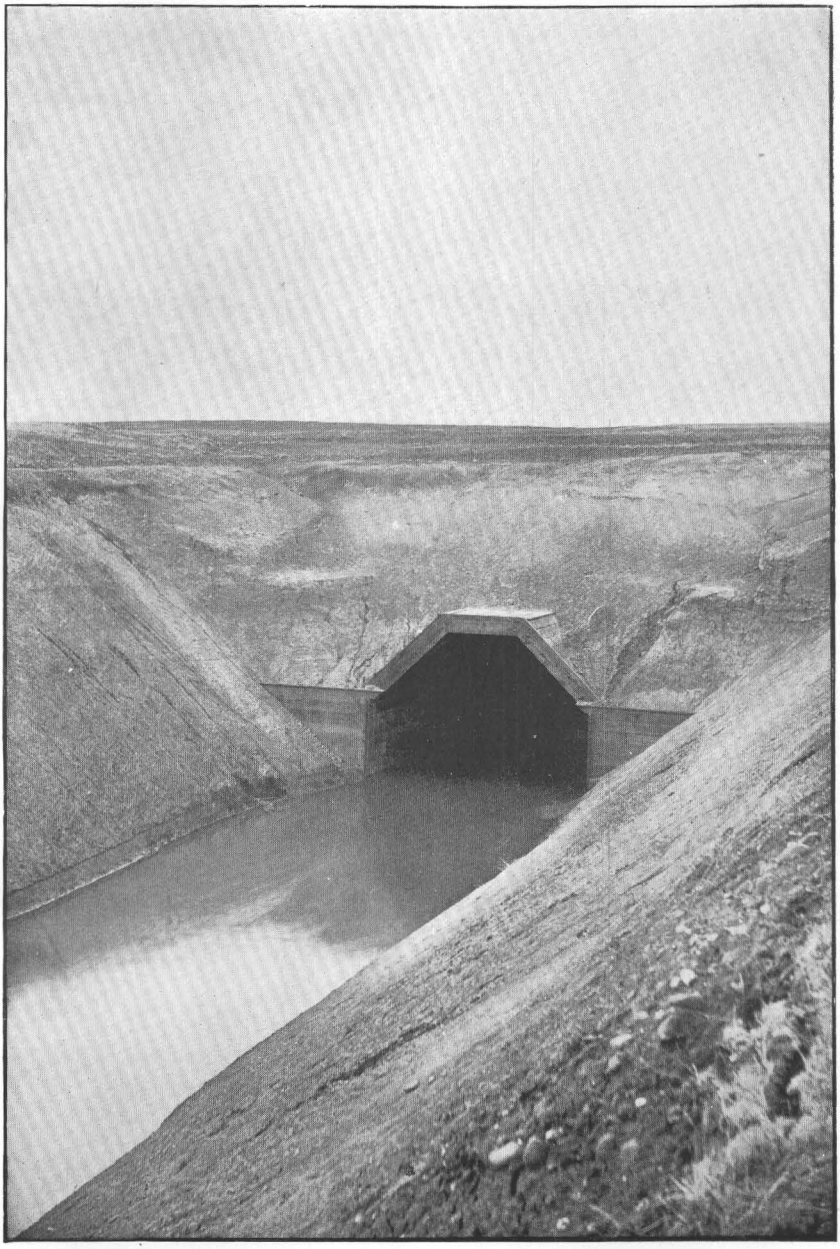
The diversion from the river is made at a point where Merced River leaves the base of a vertical cliff which rises to the south. The canal head gate or regulator is constructed between two rock-filled timber piers or bulkheads, of which the southernmost rests against the foot of this cliff. The regulator has a width of 80 feet, divided into a number of small spaces between vertical posts, all of which are controlled by means of vertically sliding gates. (See Pl. VI.) From this gate a timber dam, raising the water surface about 8 feet, extends, with a broad downstream sweep, across the river to a connection with the bottom land on the north side of the river. (See Pl. V.) The dam proper rests on a timber platform or sill, which, extending downstream 10 or 12 feet below the lower face of the dam, forms an apron, on which the overfalling water is received. Considerable trouble has been experienced in repairing cuts which the river has made through the bottom lands around

the north end of the dam. The cost of this entire work, including the distributing system of pipes in Merced, is given at about $1,500,000.

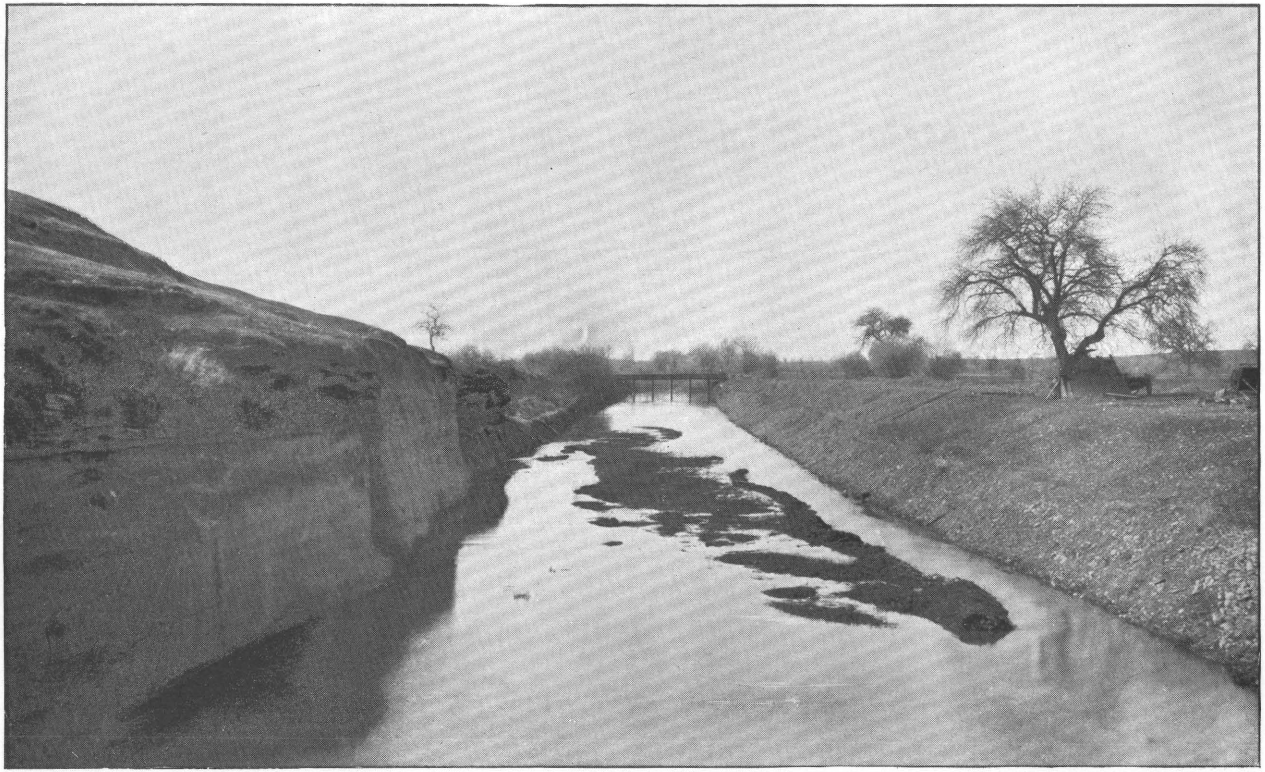
In April, 1888, the owners of the canal incorporated under the name of the Crocker-Huffman Land and Water Company and declared themselves ready to furnish water for irrigation. The canal company sells so-called water rights, which are very similar to those issued by the Fresno Canal and Irrigation Company. The purchaser of a right pays for it at the rate of $10 per acre. He designates the particular tract of land for which the right is purchased, and the rights acquired by the purchase become appurtenances of the land. He agrees to construct the necessary ditch or ditches for the conveyance of the water to his land, and grants to the water company the right to assume control of such branch ditches at any time and to use them for the delivery of water to other purchasers, provided that such use and control shall not interfere with the delivery of water to him. He agrees not to use the water on any land other than that described, and not to permit it to run to waste. He grants to the canal company the right of way for canals, flumes, and pipes across land belonging to him, or that may hereafter come into his possession, in the same township as that in which the specified tract is located. He also binds himself to pay a fixed sum annually, generally $1 per acre, on the first Monday of September, and in case of a violation on his part of the water-right agreement the contract, except in so far as it relates to a right-of-way grant and to the making of the water right an appurtenance of the land, may, at the option of the water company, be declared forfeited. On the other hand, the water company grants a water right in perpetuity, agreeing to furnish water at the rate of 1 second-foot for each tract of 160 acres; it agrees to construct the necessary gate in the canal bank for the delivery of the water and to use reasonable diligence in maintaining its works, reserving the right to sell water on similar terms "to the full capacity of its canal," which is not otherwise defined. When the supply is insufficient to afford to each taker the full amount of water to which he is entitled, a delivery of a proportional amount shall fully satisfy the covenants entered into. All of the work done in connection with this irrigation system was carried out on a broad scale. The entire system is of magnificent proportions, and can not fail to become in time one of the most reliable and important in San Joaquin Valley.

It is unfortunate that the first projects for the establishment of colonies dependent on this canal for water resulted disastrously, because the district which the canal commands is, as a whole, well adapted for irrigation, and a successful colony enterprise would have gone far toward demonstrating possibilities of development with irrigation.

Among the first lands sold in small subdivisions was a tract of about 4,000 acres, located in the bad-land strip on the base of the hills about



TUNNEL NO. 2 ON CROCKER-HUFFMAN CANAL.



CROCKER-HUFFMAN CANAL NEAR HEAD, LOOKING DOWN.

6 miles north of Merced. These lands were sold to a colony of Hollanders, who failed to achieve the results anticipated. They experienced great difficulty in preparing and cultivating the shallow, coarse, gravelly, hogwallow soil, which, unlike the black soil of the Bear Creek country nearer Merced, or the sandy loams of Atwater and Livingston, had before canal construction been considered worthless, except for grazing purposes. The efforts of the colonists proved unavailing, and after a time it was realized that the cultivation of the selected tract in small areas of fruits, truck gardens, and the like, could not be made profitable, and the colony project was abandoned.

This unsatisfactory experience, together with the general business depression of the last few years, will account in large measure for the comparatively small demand that has been made for water from the Merced Canal. The area actually irrigated in a season has probably not exceeded 12,000 acres.

MERCED RIVER BOTTOM CANALS.

The bottom lands flanking Merced River, extending downstream from Merced Falls to near Livingston, are in large part irrigated by a number of small ditches, chiefly interesting from the fact that some of them are among the oldest irrigation works in San Joaquin Valley.

Merced Falls mills.—Power is supplied to a flour mill and to a woolen mill at Merced Falls by water from Merced River, which there crosses a ledge of slate. The natural fall of the rapids at that point is increased by means of a light dam, about 800 feet long, which follows the crest line of the slate reef from bank to bank. This dam is of the lightest possible type, being constructed of a series of inclined timbers, usually 4 by 6 inches, loosely resting upon the rock and supported from below by means of shores, irregularly spaced according to facility of support afforded by the uneven surface of the rock. The spaces between timbers are closed with 1-inch boards. The maximum height of the structure is about 8 feet. Power has been developed at the falls since about 1856.

Merced Falls Ditch.—The water from this ditch is taken from the north side of Merced River above the dam at Merced Falls, but the rights of this ditch are subject to the prior rights of the mills. The ditch was constructed in 1857 and has been in use to some extent ever since. It is about 2 miles long, 4½ feet wide on the bottom, 1½ feet deep, and has a fall of about 2 feet to the mile. The area irrigated by it is 300 to 400 acres. Like all the ditches in Merced Bottoms, it is a private ditch, supplying water only to lands of its owners.

Murray Mill Ditch.—This is another small north-side ditch, which has its head about 1½ miles below Merced Falls. A low dam of cobbles and brush is annually thrown across the river to force water into the ditch, which is about 3 miles long. The ditch has a width of about 10 feet, carrying water 1 to 1½ feet deep, and supplies water to about 100 acres

of land. It also furnishes power for a small gristmill located about a mile below its head. The ditch was constructed about 1858, in which year rights of way for it were secured, but it fell into disuse and was reconstructed or enlarged in 1862. The dimensions originally intended, and which were probably given the earlier ditch, were described as follows: 5 feet wide on bottom, 7 feet on top, and deep enough to carry 2 feet of water.

Snelling Ditch.—The Snelling Ditch was constructed in 1860, or about that time, for the irrigation of lands near Snelling. A company was formed composed of interested landowners, and ownership in the ditch was represented by shares of stock. The head of the ditch is on the north side of the river, about 2 miles above Snelling, which was at the time of the ditch construction a prosperous town and the first county seat of Merced County. A temporary dam of cobbles and brush is annually constructed at the head of the ditch. The ditch is about 4 miles long, 6 feet wide on the bottom, and carries water from 1 to 2 feet in depth on a grade of about 2 feet to the mile. The irrigation is confined principally to orchards, vegetables, and alfalfa, Chinese being the renters of most of the land irrigated.

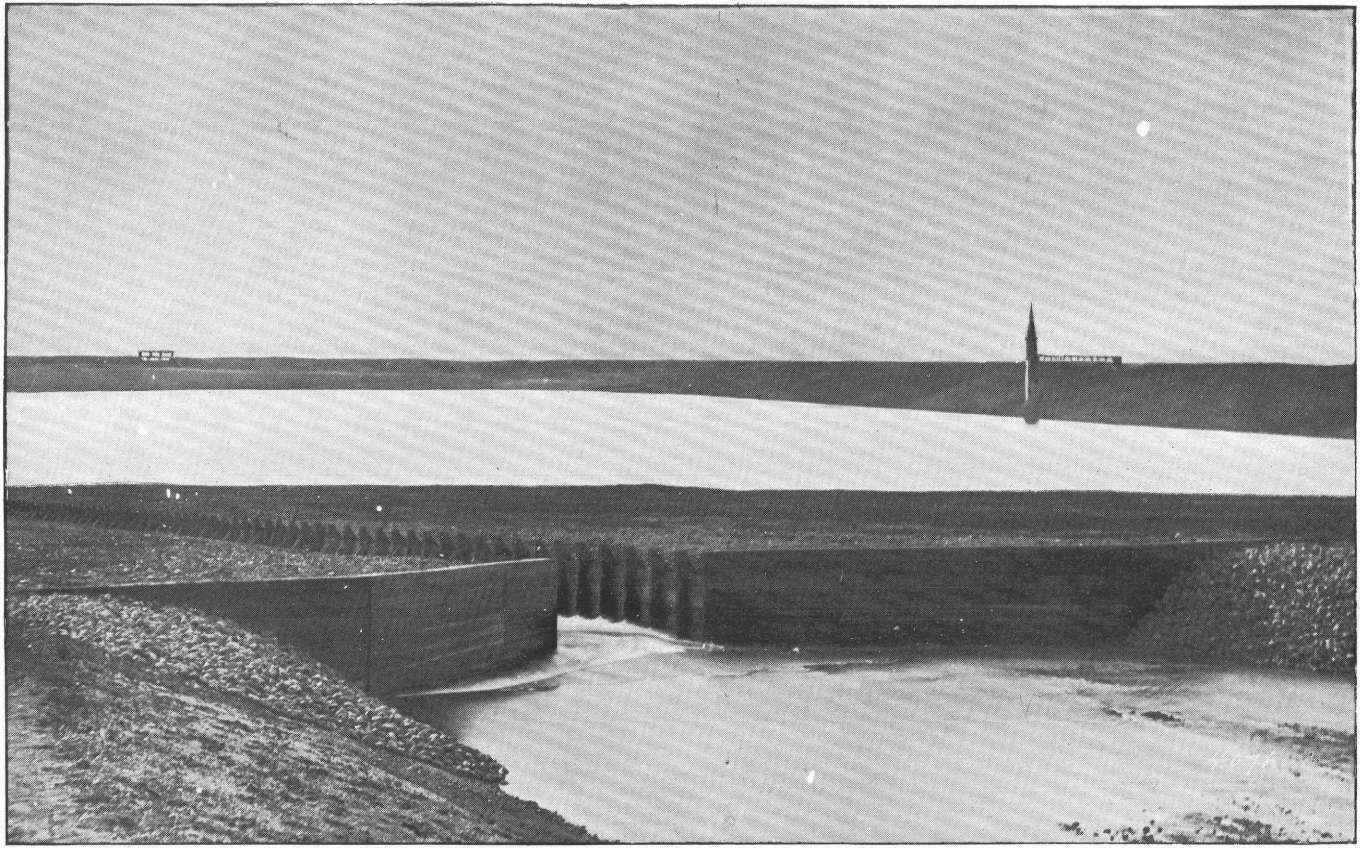
Montgomery & Anderson Ditch.—This is another old-time ditch of small capacity. Its head is on the north side of Merced River, at the ford, about a mile above Snelling. It is about 1½ miles long, and supplies water to a few acres of alfalfa, orchard, and gardens near Snelling. Its bed width is only about 4 feet, and the depth of water carried is about 1 foot.

Ingalsbe Slough.—This is a natural high-water channel, which breaks out through the north bank of Merced River just above Snelling. It has a westerly course along or near the northern margin of the bottom lands for about 8 miles, and supplies water to several small ditches, notably the Ruddle ditches, besides wetting considerable areas by infiltration of water from the slough into the porous subsoils. A barrier has been erected across the head of the slough, and in this a regulating gate is maintained.

Scott Ditch.—The head of this ditch is on the north side of Merced River, about a mile below Snelling. It was constructed in 1857, has a bottom width of about 3 feet, and is about 2 miles long.

Dean Ditch.—This is still another small ditch, on the north side of the river. It takes water about 1½ miles below Snelling, is about 3 miles long, 5 feet wide on the bottom, and 1 to 2 feet deep. Some of its water is dropped into Hopeton Slough.

Old River.—This is an old channel about 3 miles below Snelling. During the freshets of 1861–62 Merced River cut a new channel near the southern margin of its bottom lands, abandoning about 3 to 4 miles of its old channel. This is now known as Old River, and a cut has been made at its head to increase its flow and to make it serve as a source of supply for the irrigation of a number of farms. A little over



INLET TO MERCED RESERVOIR, CROCKER-HUFFMAN CANAL.

2 miles below its head water is diverted from it into the Sillman & Ruddle Ditch, in which it is carried westerly about 3 miles. This ditch has a bed width of 7 feet, and carries water 1 to 2 feet deep. It has a fall of about 7 feet to the mile. Half a mile below the head of the Sillman & Ruddle Ditch is the Means or Montgomery Ditch, which irrigates a few acres of land lying between Old River and the present channel of Merced River.

Feldhaus & Reed Ditch.—This is a south-side ditch, having its head about 2 miles above Snelling, just below the head of the Snelling Ditch. It is between 2 and 3 miles long, and supplies water for the irrigation of several hundred acres of bottom land on the south side of the river, opposite Snelling. The ditch penetrates the point of a hill in a tunnel about 400 feet long, 3 feet wide, and 5½ feet high. The ditch was constructed in 1865, and was made 6 feet wide on the bottom, 1½ feet deep, and has a fall of nearly 5 feet to the mile. All parties interested in this ditch contributed toward the construction of that part of it located above the point where it leaves the land of each, in proportion to individual interests. The expense of maintenance is apportioned in the same way. No water is sold.

Hamlin or Millrace Ditch.—Water is diverted from the south side of Merced River into this ditch about a mile above Snelling. It has a course parallel with the lower portion of the Feldhaus & Reed Ditch, but extends beyond it, being about 2½ miles long. It is 7 feet wide on the bottom, carries nearly 2 feet of water, and has a fall of between 4 and 5 feet to the mile. The ditch was constructed for irrigation purposes. Its owners were subsequently interested in the erection of the Merced flour mill, and the ditch became a part of the mill property. Some concessions to the use of its water were made for right-of-way privileges. Irrigators use the waters of the ditch on Sundays, at night, and at other times when the mill is not running. Several hundred acres of alfalfa and orchard are dependent on it for a water supply.

Griffith & Shaver Ditch.—This is a ditch on the south side of Merced River, about 10 miles by river below Snelling. It is a small ditch, about 2½ miles long and 3 to 4 feet wide. It has been poorly maintained, and has been out of service at various times.

Other small ditches, besides those enumerated, have been in service in Merced Bottoms; but it is impossible to obtain full and accurate data relating to them or to many of those mentioned, for the reason that official records disclose nothing more, as a rule, than a claim to water antedating ditch construction or possibly a right-of-way grant, and all other facts relating to the history of irrigation must be compiled from the recollections of the oldest inhabitants.

METHODS OF WATER DIVERSION AND USE.

Except in the case of the Crocker-Huffman Canal and the Merced Falls Ditch, the diversion of water from Merced River is accomplished by means of temporary dams constructed of brush and cobbles. These

are, as a rule, renewed after the high waters of each season, though occasionally they serve through several years. The inflow of water into the ditches is generally regulated by means of primitive wooden gates. In some cases overfalls or escape ways near the heads of the ditches reduce the amount of water to ditch capacity.

Before the flood year of 1861–62 Merced River had a well-defined channel, with high banks, from Merced Falls to near Livingston. The high water of that year, however, washed away large tracts of the alluvial soil of the bottoms, leaving in their stead great cobble beds; it caused a general silting up and widening of the river channel and a consequent rise of the plane of the water surface, as well in the river as in the adjacent soils of the bottom lands. Since that time it has been an easy matter to accomplish a diversion of water for use on the bottom lands of the river.

On these lands the crops generally irrigated are fruits, grapes, hops, alfalfa, and vegetables. Many of the orchards are not well cared for, being leased to Chinese from year to year. Alfalfa is irrigated by flooding in small checks; orchards and vineyards in furrows. Irrigations are frequent. They commence with the cessation of rains and continue at intervals of three or four weeks for orchards, vineyards, etc., until their product is matured. Each new growth of alfalfa receives at least one wetting. Ground in which grain is to be planted is sometimes wet before plowing. To some extent lands are moistened by the rise of water in the porous subsoils, caused by infiltration from the irrigation ditches and water courses. The ditches are owned by the landowners, and the cost of water from each is a proportional part of the cost of maintaining the works. Water is generally used in turn by those irrigators dependent upon the same ditch for their water.

TUOLUMNE RIVER.

HYDROGRAPHY.

The description written for Merced River applies also to this stream. Its mountain drainage basin is, however, somewhat larger, covering 1,635 square miles, and the extent of its bottom lands is considerably less than those of Merced River.

Its low-water flow at the mouth of its canyon above Lagrange ordinarily covers the period August to December. The winter rise of the stream, due to rainfall in the foothills and low mountain spurs within its watershed area, is immediately followed by the spring rise, due to the melting of snow in the higher mountains. The flow of the stream gradually increases till May or June, and falls rapidly in the latter part of June and in July. The maximum average monthly flow, based upon the approximations of the State engineer department, for the six years 1878 to 1884, has been noted at 4,500 second-feet for May.[1]

[1] Physical Data and Statistics, W. H. Hall, State engineer of California, 1886, pp. 431, 476.

The extensive freshet flow, which occurs in winter, when warm rains fall upon snow, may reach 120,000 second-feet.

There has been but little use made of water from this stream for irrigation, but works on a large scale have been commenced which are quite in keeping with its importance as a source of supply.

Two gaging stations have been maintained on this river by the United States Geological Survey, one at Lagrange, near where the river issues from the foothills, and the other at Modesto, farther down the valley.[1] Gage readings at the lower station have been maintained by the Southern Pacific Company for a number of years, and an attempt was made to rate the station, but owing to its proximity to San Joaquin River, whose back flow in times of high water affected the height at Modesto, the work was not so satisfactory as it might be.

For this reason the other station at Lagrange was established August 30, 1895. Its location is at the highway bridge in the town. The following facts in regard to the discharge of the river are brought out:

At Modesto:

1895. Maximum discharge, February, 19,650 second-feet; minimum, October, 120 second-feet; average for the year, 3,719 second-feet.

1896. Maximum discharge, April, 14,873 second-feet; minimum, October, 180 second-feet; average for the year, 2,927 second-feet.

Estimated monthly discharge of Tuolumne River at Modesto, California.

[Drainage area, 1,501 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
January	16,130	1,398	4,828	296,900	3.700	3.220
February	19,650	1,322	3,915	217,430	2.720	2.610
March	10,785	1,710	3,165	194,610	2.430	2.110
April	10,012	3,255	5,824	346,570	4.330	3.880
May	16,000	6,097	11,798	725,400	9.065	7.870
June	12,530	5,616	9,163	545,110	6.815	6.110
July	6,692	1,550	3,831	235,540	2.944	2.554
August	1,550	285	848	52,125	0.652	0.565
September	5,616	200	615	36,600	0.457	0.410
October	200	120	152	9,346	0.117	0.101
November	500	210	255	14,985	0.187	0.170
December	730	180	283	17,405	0.217	0.189
The year	19,650	120	3,719	2,692,021	33.634	2.45
1896.						
January	13,686	246	3,080	189,370	2.37	2.05
February	1,880	950	1,182	68,007	0.86	0.79
March	11,798	1,006	2,725	167,578	2.10	1.82
April	14,873	1,970	3,577	212,828	2.66	2.38
May	14,754	2,550	5,180	318,500	3.98	3.45
June	14,754	6,990	11,648	693,104	7.87	7.09
July	8,735	1,306	4,121	253,408	3.17	2.75
August	1,118	300	575	35,392	0.44	0.38
September	2,918	220	574	34,191	0.43	0.38
October	474	180	224	13,797	0.17	0.15
November	7,802	273	1,210	72,012	0.90	0.81
December	3,560	516	1,028	63,247	0.79	0.69
The year	14,873	180	2,927	2,121,434	25.74	1.90

[1] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, 1891, p. 322; Bull. No. 131, 1895, p. 83; Bul. No. 140, 1896, pp. 298-304; Eighteenth Ann. Rept., Part IV, 1897, pp. 378-385; Water-Supply and Irrigation Paper No. 11, 1897, p. 90; Water-Supply and Irrigation Paper No. 16, 1898, pp. 188-189.

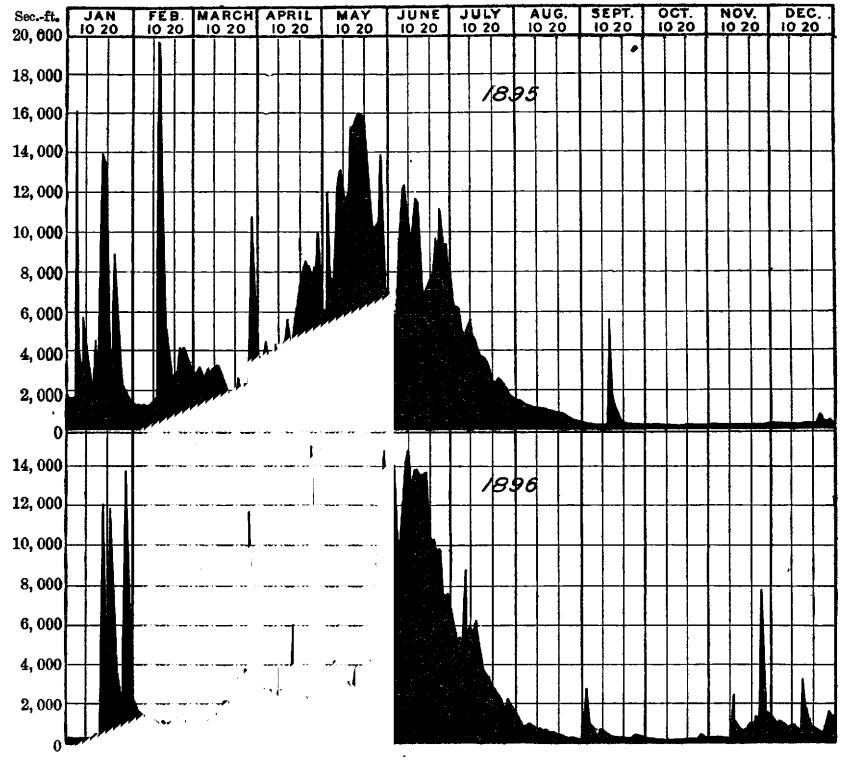


FIG. 10—Discharge of Tuolumne River at Modesto, California, 1895–96.

Estimated monthly discharge of Tuolumne River at Lagrange, California.

[Drainage area, 1,501 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
September	2,182	78	263	15,635	0.195	0.175
October	299	78	134	8,231	0.103	0.089
November	129	112	113	6,698	0.084	0.075
December	1,004	129	270	16,614	0.208	0.180
1896.						
January	7,610	350	2,312	142,159	1.78	1.54
February	1,780	1,080	1,164	66,954	0.84	0.78
March	11,798	1,006	2,725	167,578	2.10	1.82
April	7,990	2,670	3,522	209,574	2.60	2.34
May	10,100	2,670	4,429	272,371	3.40	2.95
June	9,320	5,140	7,692	457,705	5.74	5.13
July	5,330	960	3,003	184,677	2.31	2.00
August	3,050	227	485	29,828	0.37	0.32
September	1,620	132	432	25,742	0.32	0.29
October	350	75	19	7,366	0.09	0.08
November	5,710	227	1,135	67,543	0.83	0.75
December	3,620	670	1,083	66,603	0.83	0.72
The year	11,798	75	2,342	1,698,100	21.21	1.56

Estimated monthly discharge of Tuolumne River at Lagrange, California—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	3,930	660	1,231	75,692	0.94	0.82
February	13,200	1,840	5,172	287,238	3.59	3.45
March	10,800	2,500	4,032	247,920	3.10	2.69
April	13,500	3,280	7,735	460,263	5.75	5.15
May	14,700	9,600	11,923	733,121	9.15	7.94
June	9,300	2,500	5,673	337,566	4.22	3.78
July	4,840	480	2,181	134,105	1.67	1.45
August	570	76	237	14,573	0.18	0.16
September	140	28	86	5,117	0.07	0.06
October	750	76	222	13,650	0.17	0.15
November	3,540	260	768	45,699	0.57	0.51
December	4,060	570	1,104	67,883	0.85	0.74
The year	14,700	28	3,364	2,422,827	30.26	2.24

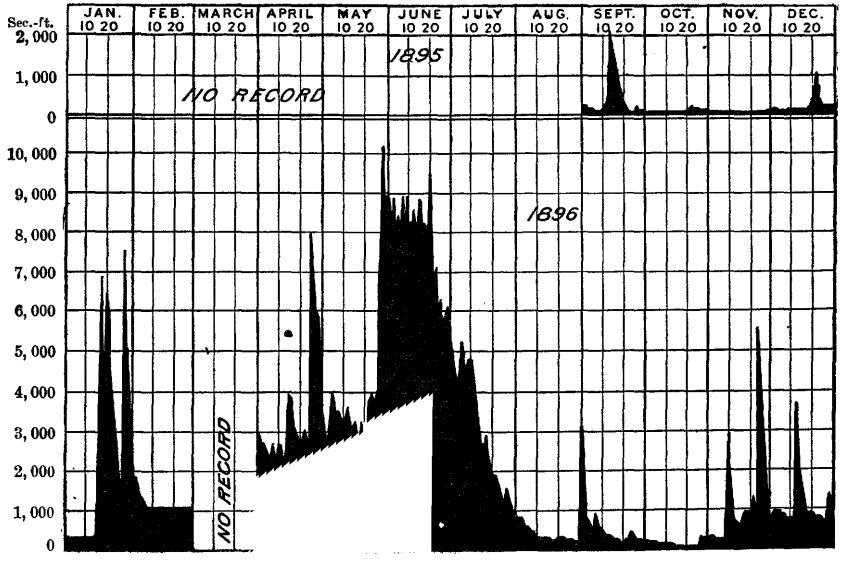


FIG. 11.—Discharge of Tuolumne River at Lagrange, California, 1895–96.

At Lagrange:

1896. Maximum discharge, March, 11,798 second-feet; minimum, October, 75 second-feet; average for the year, 2,342 second-feet.

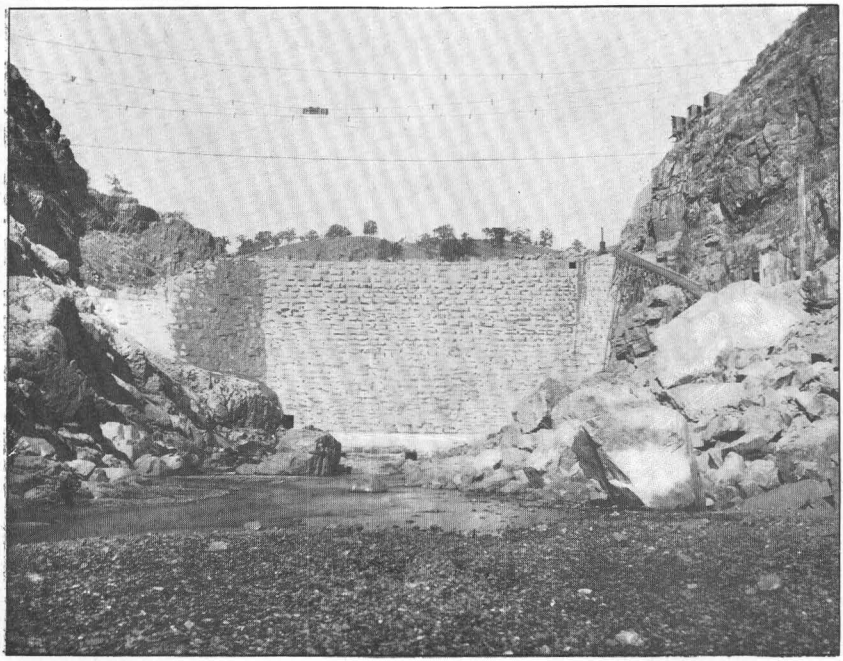
1897. Maximum discharge, May 25, 14,700 second-feet; minimum, September 21, 28 second-feet; average for the year, 3,364 second-feet.

CANALS AND DITCHES.

Lagrange Ditch.—In 1871 this ditch was constructed by the Lagrange Ditch and Hydraulic Mining Company, from the upper end of Indian Bar to French Hill, at Lagrange, for mining purposes, and has been in constant use, supplying water to the gravel mines near Lagrange and to those at Patricksville, about 4 miles southwest from Lagrange. Very

little of its water has been used for any other purpose. The ditch may ultimately, however, come into service as an irrigation ditch as the demand for water for hydraulic mining decreases. The ditch is carried under the gravel deposit of Indian Bar in a box culvert; thence follows the south side canyon wall for 14 miles, being always within one-half mile of the river, and reaching the vicinity of Lagrange at an elevation of 250 to 300 feet above the water surface of the river. There are many and long flumes in use where the canyon walls are too steep and rocky to permit of open-ditch construction. The ditch has an average bottom width of about 6 feet and carries water 3 to 3½ feet deep. Its grade is 7 to 8 feet to the mile and its capacity 50 to 60 second-feet. The cost of this ditch was about $300,000. The total expenditure on the ditch property is, however, reported to have been $800,000. The annual cost of repair and maintenance is $3,000 to $4,000. The ditch drops its water into the Patricksville Reservoir about 3 miles south of Lagrange. The reservoir is formed by means of two earth dams. It has a surface area of 132 acres and a capacity of about 57,500,000 cubic feet, or 1,320 acre-feet, its average depth being about 10 feet.

Wheaton Ditch.—This ditch has gone out of service. It was a small ditch on the south side of the river, having its head at the Wheaton Dam, which was maintained in the mouth of the Tuolumne River Canyon, about 1½ miles above Lagrange, until replaced in 1891–1893 by the massive masonry structure of the Turlock and Modesto irrigation districts. Several water companies were early interested in diverting water for mining purposes from the river at or near the Wheaton Dam site, just above French Bar. Of these, the Franklin Water Company was incorporated in 1854. It and the French Bar Mining Company both sold out to the Stanislaus County Water Company in 1855. The purpose of the new company was to supply water to Lagrange and vicinity by means of ditches on each side of the river. Water was diverted from the river on the south side at a point about 500 feet above the falls or rapids, the latter being the point subsequently selected as the site for the dam. This water company sold out to the Tuolumne Water Company in 1871. The latter company at once constructed a dam, a substantial cribwork structure of sawed lumber. Its height ranged from 16 to 30 feet. Its lower face was nearly vertical. Its upstream face was covered with a timber skin, which was renewed but once during the entire life of the structure. The upstream face was but little flatter than 1 to 1. The crest length of the dam, not including the overfall wall forming the outer ditch bank at its head, was 125 feet. About 250,000 feet of lumber were used in its construction. It is reported to have cost about $24,000. Several years after the construction of this dam the entire property of the water company was sold to Mr. M. A. Wheaton, one of the stockholders, and a small ditch about 2 miles long was kept in service. Its duty gradually dwindled to the irrigation of a few acres of orchard and vegetable land (not exceeding 50 acres) in the river bottoms just below Lagrange.



A.

B.

LAGRANGE DAM DURING CONSTRUCTION.

A, As seen from front; *B*, Abutment.

Lagrange Dam.—The structure which replaced the Wheaton Dam is generally known as the Lagrange Dam. It was built by the Turlock and Modesto irrigation districts. It is noteworthy as the highest overfall dam ever built on a large river. For the irrigation of the Turlock irrigation district, on the south side of Tuolumne River, which was organized in 1887, it was necessary to construct a high-line canal. A high dam at or near the Wheaton Dam site was decided upon. After long deliberation the Modesto irrigation district, on the north side of the river, determined to join in the construction of the dam, as it appeared desirable to have joint control of the diverting works with the other district and because it afforded the best command of canal routes westward to the district lands. (See Pls. X and XI and fig. 12.)

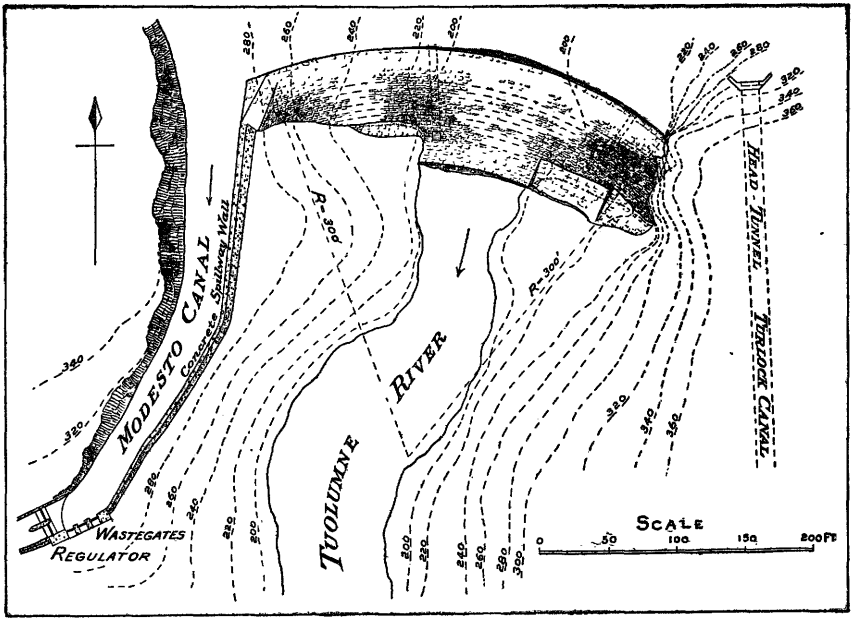


FIG. 12.—Plan of Lagrange Dam.

The engineers of the two districts were required to prepare plans for the structure, from which those submitted by Mr. Luther Wagoner were adopted; but as Mr. Wagoner soon afterwards resigned his position as engineer for the Modesto district, Mr. E. H. Barton, the Turlock district engineer, was placed in charge of construction. The dam from lowest point of its foundation surface to its crest line has a height of 125 feet. It raises the surface of the river 100 feet. It is arched upstream, its upstream face being curved to a radius of 301 feet. Its crest length from the retaining wall built for the outside bank of the Modesto canal to the cliff on the south side of the river is 310 feet. The upstream face of the dam is vertical from its top downward for 70 feet, thence to the foundation surface it has a batter of 1 in 20. The

top edges of the dam are rounded off toward the upstream face on a radius of 3 feet; toward the inclined downstream face on a radius of 17½ feet. The level portion of the top has a width of 6 feet. At 6 feet below its crest line the dam is 24.13 feet thick; at 69 feet below its top it is 52 feet thick; at 89 feet it is 66.25 feet; and at 97 feet, the top of the foundation masonry, it is 84 feet thick. The extreme bottom width at the highest point of the dam is 90 feet. The downstream face has a pitch of 1 on ½ (about 25°) down to 70 feet below the crest height of the structure, where a compound curve 64 and 23 feet radii commences, which carries the face to its intersection with the downstream face of the foundation masonry, about 3 feet above low water.

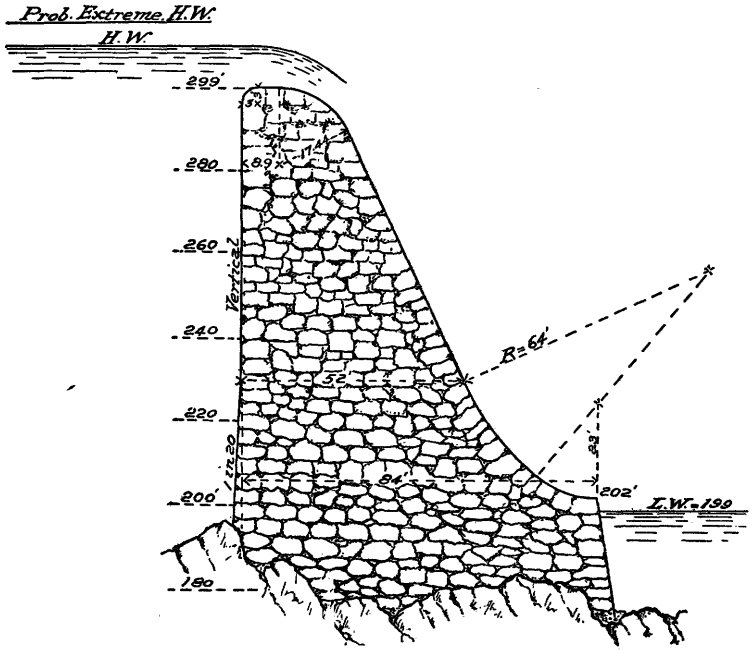
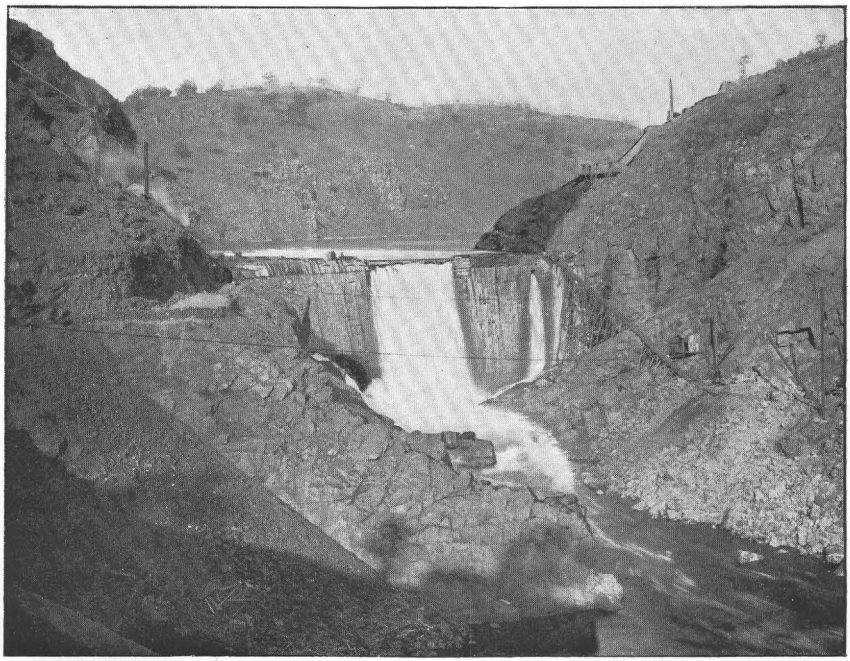


FIG. 13.—Section of Lagrange Dam.

From this line down to bed rock the masonry has a batter of 1 in 7. The dam thus affords a smooth support for the overfalling waters, which shoot off from the almost horizontal surface at the termination of the downstream face with great force against the river below. The original design contemplated the use of a second or subsidiary dam below the first, to create a pool of dead water, or water cushion, against which the force of the overfalling stream might be expended, but this has not been carried out. As the low-water width of the river—or rather its width at the height of top of the foundation—is only 80 feet, to be compared with 310, the crest length of the dam, it is apparent that during high stages of the river there must be a considerable crowding of the water from both sides toward the center of



A.

B.

LAGRANGE DAM.

A, Nearing completion; *B*, At time of high water.

the stream. What effect this will have upon the solid rock walls of the canyon is not yet known; but if these show any tendency to break away on crevice and cleavage lines recourse will be had to a reenforcement with cement mortar and concrete. The dam is constructed throughout of uncoursed rubble laid in cement concrete. The cement used in the structure was furnished by the irrigation districts. The work of stripping and cleaning the foundation and putting masonry in place was all covered by the price of $10.39 per cubic yard of masonry, at which construction was contracted for. The amount of masonry in the dam is about 39,500 cubic yards. Nearly 30,000 barrels of Portland cement were used in its construction. The total cost of the dam, not including canal head works, was about $550,000. This great cost of work executed under comparatively favorable conditions must be ascribed largely to the lack of active competition among bidders for the work. There was doubt concerning the ability of the two districts to meet their obligations in coin at the time of the letting, because bonds were not selling readily at the prescribed limit of 90 per cent, and the contractors were compelled to make arangements to receive at least a portion of their pay in district bonds. During construction of the foundation masonry in 1891 the river was carried past the work in a flume. Two openings or culverts were left through the masonry at the elevation of low water and one about 10 feet above low water. These were 4 feet wide and 6 feet high, and easily passed the low-water flow of the river in the following seasons. The two lower ones were closed when the masonry had reached sufficient heigth to force the full low-water flow through the upper culvert. The upper culvert remained open long after the completion of the dam. It was closed in 1896. Water went over the top of the finished dam for the first time on the morning of December 23, 1893.

TURLOCK IRRIGATION DISTRICT.

This irrigation district was organized in April, 1887, under favorable auspices. There was but little opposition. Mr. George Manuel was made district engineer and estimated the cost of the necessary works at $467,545. Bonds were issued in the amount of $600,000, and when it became apparent that this sum would not cover the cost of the works an additional issue of $600,000 was made. Pending protracted litigation and the negotiations with the Modesto irrigation district relating to its participation in the construction of a high dam above Lagrange, the work on the main canal was pushed as rapidly as possible; but it is not even yet completed.

This district lies on the south side of Tuolumne River, extending southward to near Merced River and from the western edge of the Sierra Nevada foothills westward to near San Joaquin River. It has an area of 176,210 acres, of which about 30,000 are in Merced County, and the remainder in Stanislaus County. The land in the district is generally

held in tracts of less than 1,000 acres, practically all of which are grain farms. The soil is generally a sandy loam, fertile with moisture, producing fair crops of cereals when the rainfall reaches 10 inches, favorably distributed through the season; but on the whole there has been little profit in wheat farming.

Water is to be taken from above the Lagrange Dam by a tunnel 560 feet long, 12 feet wide, and 11 feet high, with vertical sides, and a radius of arch of 6 feet. It was originally proposed to place the regulator and a waste gate at the lower end of this tunnel, but this idea was abandoned and a regulating gate has been constructed at its inlet. For over a mile below the head-works tunnel the canal winds along a slaty hillside. The canal has there been constructed with a bed width of 20 feet and a proposed water depth of 10 feet. The outside canal bank is constructed of dry-laid rock retaining walls with clay puddle core. At the lower end of this hillside work the canal crosses Snake Ravine, which was closed by a dam and up which the canal water is to be turned for about 1,000 feet. The earth dam has been washed out, and the pond which it was to form is to be replaced by a flume. Thence the course of the canal leads through a cut about 800 feet long, made by the hydraulic process, and its water is dropped into old mining pits, in which it is held for a distance of about 2,000 feet. This canal section is followed by a rock cut 860 feet long, leading into Dry Creek. The channel of Dry Creek is utilized for 1¼ miles, and this creek section of the canal is followed by a flume. In its course farther westward the canal pierces three foothill spurs in tunnels, none of which are lined. Below the last of these tunnels the canal crosses a gulch, which is to be closed with a concrete dam 40 feet high, and the canal then enters another cut 3,300 feet long. It will cross Peasley Creek in a flume 20 feet wide and 7 feet deep.

The canal below Peasley Creek is generally 45 feet wide on the bottom and 7½ feet deep, and has a fall of 1 foot to the mile; but dimensions are not uniform, being varied to suit the character of material into which the canal is cut. The canal capacity as reported by the district engineer is 1,500 second-feet. Great care has been taken to keep canal dimensions uniform and to bring the canal bed to grade, often necessitating the taking of material from borrow pits at the outer levee base, thereby increasing the apparent height of canal levees and greatly increasing the danger of breaks in these embankments. There would have been no objection, so far as simple inspection discloses, to deepening the canal below grade where necessary to secure material, and the cause for adopting the above type of cross section has not been made apparent. Drops or check gates have been constructed where material is liable to erosion and the natural fall exceeds that prescribed for the canal. The canal approaches some of these between high levees and leaves them in moderate cut—a questionable arrangement. It might even be better to bring the canal into service without the use of drops

and to place these later where required. The main canal is 18 miles long and will supply water to five principal laterals, which are to have an aggregate length of 80 miles. These are to be 30 feet wide on the bottom and 5 feet deep, and are to have an effective fall of 2 feet to the mile. Other branch ditches of smaller dimensions, to the extent of 180 miles in aggregate length, are also to be constructed by the district. As the surface of the district is very smooth and the fall quite uniform from northeast to southwest, most of the branch canals will be constructed on land lines from north to south and from east to west. It is understood that a contract for the completion of this entire system of ditches, including the main canal, has been let, and that work is to be actively pushed under this contract.[1]

MODESTO IRRIGATION DISTRICT.

Soon after the project of organizing the Turlock district had taken definite shape, the farmers on the north side of Tuolumne River resolved upon the formation of a second district to be dependent on that stream for its water. Although considerable opposition was encountered, the result of their action was the formation of the Modesto irrigation district, which was consummated in July, 1887. The district extended northward from Tuolumne River to Stanislaus River, and from the foothills westward into the trough of the valley to near San Joaquin River. It had an area of about 108,000 acres. The preliminary study indicated conclusively that the expense of constructing a canal from Tuolumne River to command the entire district would be prohibitory, and that either the high southeastern portion of the original district must be excluded or that water must be taken from Stanislaus River at an estimated cost of over $700,000. Before further steps were taken bonds to the amount of $800,000 were voted, and a reduction of the area of the district to 81,500 acres soon followed. The project for the irrigation of the district lands did not assume its final definite shape until an arrangement was entered into with the Turlock irrigation district, according to which the two districts were to unite in constructing a great diverting dam in Tuolumne River about 1½ miles above Lagrange, and agreed to contribute equally toward its construction.

The canal has an inlet capacity of about 750 second-feet. Now hanging on hillsides, now following table-lands or mesas, or penetrating low spurs of the foothills in tunnels, it reaches a point near Waterford, with a total length of 23 miles. The canal regulator or head gate is in place and main canal excavation is reported finished, but other structures are incomplete or wanting, such as check weirs, flumes along steep hillsides and over creeks and gulches, and road bridges. This, including one-half the cost of the Lagrange Dam, has been accom-

[1] For further description of this canal, see American irrigation engineering, by H. M. Wilson: Thirteenth Ann. Rept. U. S. Geol. Survey, Part III, 1893, pp. 203, 232.

plished, under district management, with an expenditure, expressed in bonds sold, of the entire first issue of $800,000. The result is hardly more satisfactory than in many other of the irrigation districts. The district is not yet in position to furnish water to any of its lands; the cost of the work has been excessive, owing largely to the uncertainty of pay on completion, which deterred contractors in the case of nearly all district work in this and other irrigation districts from making low bids. Several years ago additional bonds to the amount of $350,000 were voted by the district, but these are to be withheld from sale pending final settlement of matters that have involved the district in litigation.

The surface of the district is admirably adapted for cultivation by irrigation. The soils are sands and sandy loams, and the ground has a slope from east to west of 5 to 10 feet to the mile. The entire area of this district, as well as of the Turlock district, was originally a treeless plain. For many years past it has been a vast wheat field.

STANISLAUS RIVER.

HYDROGRAPHY.

Stanislaus River is of the same type as the Merced and the Tuolumne, and of equal rank as a source of supply for large irrigation canals. Its mountain watershed has an area of 1,051 square miles, the run-off from which is ordinarily greatest in May, when snows are melting. The stream is at a low stage from August to December. During the winter months its flow is variable, being greatly influenced by rainfall and temperature. Its mean monthly discharge increases rapidly from January to April. From April to June is the period of its spring rise. The low-water flow is ordinarily from 100 to 200 second-feet, and the mean flow during the spring rise is 3,000 to 5,000 second-feet.[1] At Oakdale, where the river enters San Joaquin Valley, its bed is depressed about 80 feet below the general surface of the main valley plain. The river's low banks are flanked on either side by narrow strips of bottom land, which extend from river to base of the slope rising to the higher level of the upland. For over 40 miles below Oakdale the river surface is thus depressed below the level of the valley lands, but the difference in level gradually decreases, and near the trough of the valley the bottom lands of the river are merged into the submersible portion of the east-side plain.

Irrigation from this river has been confined to the foothill region until the enlargement and extension of an old ditch within the last two years has made water available on the north-side upland.

The United States Geological Survey has maintained a gaging station on this river since June, 1895. It is located at the highway bridge

[1] See Physical Data and Statistics, W. H. Hall, State engineer of California, 1886, pp. 428, 476.

just above the bridge of the Southern Pacific Company at the town of Oakdale.[1]

The following facts are brought out from this record:

The low-water flow for 1895, occurring in August, September, and October, was 145 second-feet.

1896. Maximum discharge, May, 13,050 second-feet; minimum, January, 150 second-feet; average for the year, 1,935 second-feet.

1897. Maximum discharge, February 4, 10,580 second-feet; minimum, September and October, 140 second-feet; average for the year, 1,835 second-feet.

Estimated monthly discharge of Stanislaus River at Oakdale, California.

[Drainage area, 1,051 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
June	8,510	3,842	5,686	338,340	6.038	5.410
July	3,842	550	1,778	109,330	1.950	1.692
August	550	145	330	20,304	.362	0.314
September	3,161	145	638	37,970	.677	0.607
October	246	145	176	10,802	.193	0.167
November	179	179	179	10,651	.190	0.170
December	414	145	198	12,208	.218	0.189
1896.						
January	6,956	150	1,806	111,058	1.98	1.72
February	1,208	632	782	45,038	0.80	0.75
March	12,000	694	2,464	151,505	2.70	2.35
April	9,050	1,966	3,274	194,870	3.48	3.11
May	13,050	2,290	4,717	290,092	5.17	4.57
June	11,000	2,656	6,541	389,247	6.97	6.22
July	3,156	470	1,293	79,503	1.42	1.23
August	2,412	218	385	23,703	0.42	0.37
September	962	252	332	19,761	0.35	0.32
October	370	218	239	14,695	0.26	0.22
November	4,514	252	705	41,968	0.75	0.67
December	1,750	470	681	41,904	0.75	0.65
The year	13,050	150	1,935	1,403,344	25.05	1.85
1897.						
January	2,251	410	609	37,446	0.67	0.58
February	10,580	1,264	3,252	180,607	3.23	3.10
March	5,062	1,264	1,915	117,750	2.10	1.82
April	9,234	1,880	5,064	301,328	5.37	4.81
May	9,980	5,480	7,324	450,338	8.04	6.97
June	3,974	860	2,077	123,590	2.21	1.98
July	1,180	250	582	35,786	0.63	0.55
August	230	170	198	12,175	0.22	0.19
September	190	140	152	9,045	0.16	0.14
October	250	140	176	10,822	0.20	0.17
November	780	170	255	15,174	0.27	0.24
December	1,516	210	411	25,272	0.45	0.39
The year	10,580	140	1,835	1,319,333	23.55	1.74

[1] Bull. U. S. Geol. Survey No. 140, 1896, p. 305; Eighteenth Ann. Rept., Part IV, 1897, p. 371; Water-Supply and Irrigation Paper No. 11, 1897, p. 90; Water-Supply and Irrigation Paper No. 16, 1898, p. 187.

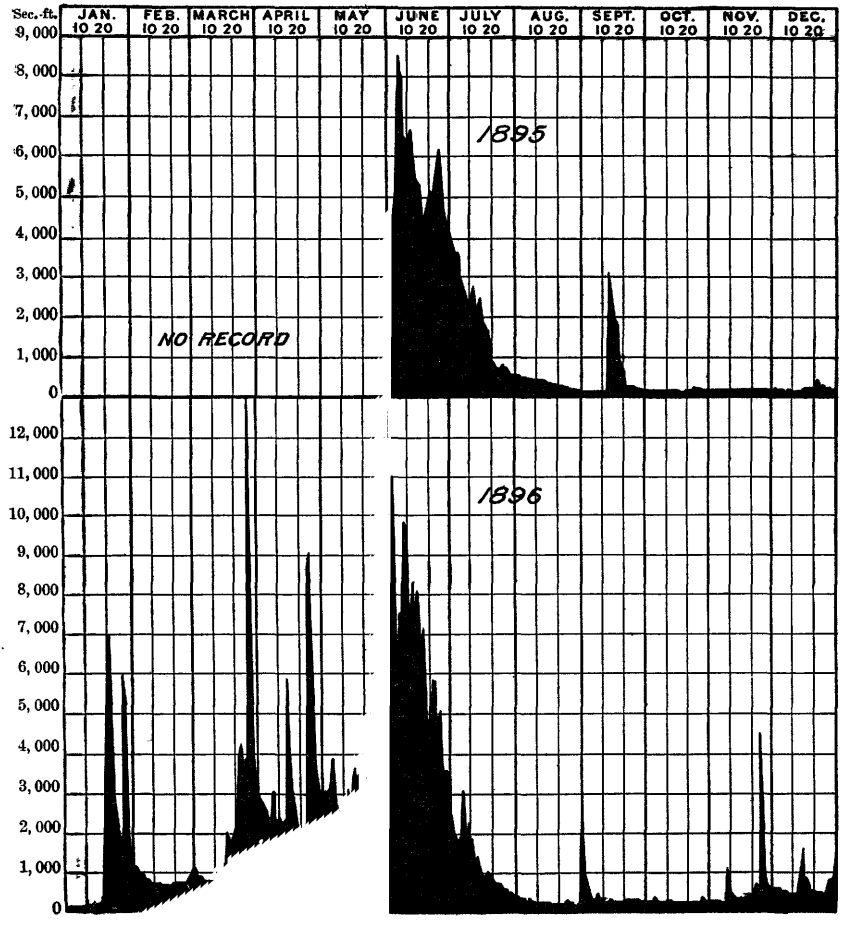


FIG. 14.—Discharge of Stanislaus River at Oakdale, California, 1895–96.

CANALS AND DITCHES.

Stanislaus & San Joaquin Canal.—Among the ditches constructed as aids to placer and river-bed mining over forty years ago was one on the north side of Stanislaus River, constructed by the San Joaquin County Water Company. Water was diverted from the river about 7 miles above Knights Ferry and was carried in ditch and flumes along the broken northern wall of the river canyon to points at and near Knights Ferry, where the ditch water had attained an elevation of 150 feet above the river surface. The ditch constructed by this company in 1854 to 1856 has remained in service ever since. As the demand for water from miners decreased, the demand from irrigators increased. Many projects for the diversion of a greater quantity of water than that represented by the old ditch capacity were proposed, but none

were pushed to completion, until finally, under new management, an enlargement and extension of the old work was successfully accomplished within the last few years, and is now known as the Stanislaus & San Joaquin Canal.

The old ditch before enlargement had somewhat irregular dimensions. It was generally 4 feet wide on the bottom, about 5 feet at the top, and carried water 2 feet deep. Its fall was not uniform, generally about 5 feet to the mile. Its capacity was about 15 second-feet. A dam was constructed across Stanislaus River at its head in several sections, closing the spaces between high projecting points of bed rock. The spaces into which these divided the river bed were closed by means of timber crib work having a crest length of about 300 feet and an average height of about 16 feet. It raises the water surface of the river 12 to 14 feet. A portion of this dam was renewed in the years 1877 to 1880.

The north-bank end of the dam rests against a high timber crib filled with rock, which is perforated for the ditch. The inflow into the ditch is controlled by means of a gate operated with a winch. When it was decided to increase the capacity of the original ditch, about 1888, work was commenced by a new organization, known as the San Joaquin Land and Water Company, on a masonry dam 4,300 feet below the present head of the ditch, but the structure has not been completed.

The old ditch for nearly a mile below its head had a position below the extreme limit of the river's flood plane. It has therefore frequently been cut out or filled with sand during the river's high stages, and its owners have been put to much trouble in keeping this upper section open. At 3 or 4 miles below its head the ditch was carried for over 1,000 feet along a smooth-surfaced vertical cliff in a hanging flume, whose iron supports were firmly anchored to the solid rock. The ditch at Knights Landing was at such elevation that but a short tunnel was necessary to carry a branch northward through the divide into Little Creek Valley. Its water was there used in one of the pioneer vineyards of the State, the property of Judge Schell. The original cost of the old ditch was $80,000. At the time it was superseded by the new work its waters were being used on 200 to 300 acres of orchard, vineyard, and garden land.

As a matter of history, reference may be made in this connection to the Farmington Water Company, whose works were intended to supplant those of the older ditch. This company, with Colonel Bulkley as chief engineer, proposed to construct a loose-rock dam across Stanislaus River one-quarter mile above the head of the San Joaquin County ditch and to turn the river through a rock cut past the south end of the dam. The location selected as a dam site was a favorable one, but the route from the dam for a large canal for 2 or 3 miles to the point where it was proposed to construct a tunnel through the ridge between the river and Little John Creek was not favorable. The construction of the

tunnel was, however, commenced, and it was driven into the mountain 700 feet from its south end and 200 feet from its north end. The length of the finished tunnel would have been 1,940 feet. This work was done in 1874 and 1875, but was not carried to completion, because the necessary financial arrangements could not be made.

The successive failures to accomplish a diversion of Stanislaus River water in a large north-side ditch, including a number that did not progress far beyond the recording of a claim to water, did not deter the Stanislaus and San Joaquin Water Company from undertaking the work.

The canal as it came into service in 1896 received water through an upper ditch extending from the diverting dam to the proposed new dam, 8 feet wide on the bottom, sides nearly vertical, water depth 5 feet, and a fall of a little over 4 feet to the mile. Below the partially built new dam the ditch for a distance of 900 feet is 9 feet wide on the bottom and its water depth was increased to 6 feet. The canal then enters a flume 1,112 feet long, thence flows through a tunnel 1,047 feet long, thence for 1,520 feet in another flume, from which it is delivered into a second tunnel 1,037 feet in length, and thence by ditch and flumes to a point to the north of Knights Ferry, where the Farmington Branch is sent off practically on the line of the old Schell Ditch to Little John Creek.

The main ditch is carried from there in a flume half a mile long across the depression to the north of Knights Ferry, thence by short ditch into a natural channel, in which it flows westward several miles, thence again in ditch and flumes alternately to a point about 11 miles west of Knights Ferry, where a distribution of its water is to be made to three branch ditches or laterals; of these one, the Escalon lateral, is to supply water to the uplands near Stanislaus River; a second, occupying the natural channel known as Lone Tree Slough and continued as Lathrop lateral, will command the main body of land intermediate between French Camp Creek and Stanislaus River; and the third, taking a northwesterly course, is to skirt the foothill base. From the main ditch a flume, in part supported by a bridge, has been carried across Stanislaus River for the delivery to Oakdale of 80 second-feet of water.

The Farmington Branch flows in Little John Creek about 11 miles, thence in a ditch on the north side of the creek 12 miles, reaching and extending upon the valley plain to the northwest of Farmington. It is 8 feet wide on the bottom, will carry water 2 feet deep, and has a fall of 1½ feet to the mile. The Escalon and Lathrop laterals are 14 and 24 feet wide, respectively. They were not complete in 1896, neither had the proposed Clyde lateral been constructed.

The upper two flumes on the main canal are 10 feet wide by 6 feet deep. These are followed by three flumes 8 feet wide by 8 feet deep. The gradient of main flumes varies from 1.9 to nearly 2.5 feet in 1,000.

The flumes below Knights Ferry generally are 8 feet wide and 6 feet deep, on a grade of 1.6 feet in 1,000; but the long flume is an exception; it is 6 feet wide, 5 feet deep, and has a fall of 11.4 feet in 1,000. The upper tunnel is 12 feet wide, planned to carry water 6 feet deep, on a grade of 1.5 in 1,000. The second tunnel is 14 feet wide, but has a grade of only 1.1 in 1,000. Where the upper portion of the main ditch is in excavation it is an enlargement of the old ditch. The outer bank of the old ditch was not disturbed, the entire enlargement having been effected by deepening and by cutting into the hillside. The new ditch is 9 feet wide on the bottom; it is to carry a maximum depth of 6 feet of water, and its fall is 0.9 foot in 1,000.

The great variability in capacity which the above dimensions indicate is to be accounted for in a measure by the fact that further enlargement is contemplated and that the new work was fitted to the old, as circumstances permitted. The total expense of canal enlargement, not including engineering nor rights of way, was about $150,000.[1]

Water is being furnished to irrigators very nearly on the same plan as that adopted by the Fresno and Crocker-Huffman companies, and long before water was available for delivery contracts were entered into between farmers and the canal company according to which the landowner pledged himself to take water for a specified tract of land as soon as water was available, and to pay therefor a bonus of $10 per acre, in deferred payments, at the rate of 50 cents per acre per annum, with interest at 6 per cent per annum on the amount remaining unpaid. The takers of water rights, in addition to the payment of this bonus, also obligate themselves to pay an annual water rental at the rate of $1.50 per acre. But the rate per acre is to become due during the first four years on only so much of the land as is actually irrigated; on not less, however, than one-fourth of the entire area the first year after water is available, on one-half the second year, on three-fourths the third year, and on the full acreage the fourth year and thereafter. The water rights issued at the beginning of 1896 covered about 14,000 acres. No information is available as to extent of irrigation during the first season.

Knights Ferry & Table Mountain Ditch (also known as *Pentland Ditch*).—This ditch, which has been out of service since 1881, is mentioned because before its final abandonment it supplied water to a few acres of orchard, vineyard, and garden land on the south side of Stanislaus River, opposite Knights Ferry. This ditch was constructed for mining purposes in 1855, at a reported cost of $210,000. Its head was at Sixmile Bar, about a mile below the head of the San Joaquin County Ditch. At that point a log dam, 30 feet in maximum height, enabled diversion into the ditch, which was cut into the south canyon wall. The location was not favorable for a ditch; flumes had to be used at a number of points, and at others the ditch was supported by

[1] The above facts relative to the work done by the new water company are largely from the published report on the work by Prof. George Davidson.

a high outside wall of dry rubble. The flumes were 4½ feet wide and 2 feet deep. The ditch was about 8 miles long; it had a fall of about 8 feet to the mile. Its capacity was about 20 second-feet.

Oakdale Canal.—From a point on the south side of Stanislaus River about a mile below Knights Ferry, a canal has been constructed to Oakdale. It has a total length of about 12 miles, and commands the low mesa, or second bottom, on which the town of Oakdale is situated. The construction of this canal was commenced about 1888, but much difficulty was experienced in making the diversion. At its head a loose-rock dam was to be maintained in the river. This was constructed of large blocks of rock, which were abundant near the dam site, and it was expected that, if piled into the river in sufficient quantity, they would form a riffle or sill above which water would be at sufficient elevation to be forced into the canal. The low-water plane of the river was to be raised by the structure about 8 feet. Seven years after the first construction of this dam the river was still annually breaking through it, and arrangements were then made with the Stanislaus and San Joaquin Water Company to take water to the extent of 80 second-feet from the canal of that company. This water is delivered to the Oakdale Canal at a point some distance above Oakdale, through a flume which spans the river.

MOKELUMNE RIVER.

HYDROGRAPHY.

Mokelumne River is the most northerly of the Sierra Nevada streams which are directly tributary to San Joaquin River. Its mountain drainage basin has an area of 657 square miles. In character it does not differ materially from the Stanislaus, the Tuolumne, and the Merced. Its bottom lands are nearly as extensive as those of Merced River, but do not lie in so compact a body. They extend well into the foothill region and westward to near Woodbridge. At that point there is a gradual merging of the upland and river bottom, this point being at the eastern limit of lands naturally subject to inundation.

The river is subject to the usual freshet flow of all Sierra Nevada rivers in winter, and has a pronounced high stage late in spring, due to the melting of snow. Its flow in April, May, and June is generally 3,000 to 4,000 second-feet. At its lowest stage, in the fall of the year, it brings less than 100 second-feet of water into the main valley.[1] The lesser drainage area of this river when compared with the others of its class is offset in a measure by greater rainfall throughout its watershed.

The Southern Pacific Company commenced observations of gage heights on this river in 1879 at their bridge at Lodi. The United States Geological Survey made a number of measurements of discharge

[1] See Physical Data and Statistics, W. H. Hall, State engineer of California, pp. 422, 476.

at that point, but, owing to the poor character of the section, results were not altogether satisfactory and the station was discontinued. For results of the work at this point see various reports of the Survey.[1]

CANALS AND PROJECTS.

As most of the water of this river flows idly to the sea, it is not without interest to inquire why the water is not utilized, particularly as the upland on both sides of the stream is a friable sandy loam of excellent quality, well adapted for irrigation.

The rainfall of this portion of San Joaquin Valley is about 15 to 20 inches per annum, enough to permit cultivation of cereals by methods of dry farming, and even to make orchards and vineyards yield a fair return. The demand for water has never, therefore, been very imperative. On the other hand, many projects have been discussed or partially executed, but, on account of engineering and financial difficulties, have met with entire or partial failure. The most notable project was that of the Mokelumne Ditch and Irrigation Company, which, under its original organization, commenced but did not finish the construction of a high masonry overfall dam or weir at the Westmoreland bridge near Lancha Plana. After many years of inaction work was again undertaken in 1887. The dam was then raised and repaired and work on the canal was commenced. It was proposed to carry water in a large canal on the south side of the river along and through the hills into Bear Creek, and thence to the eastern border of the valley lands, where it was to be put into a system of branch ditches or canals. The project failed for lack of funds.

A few years later the farmers living near the eastern margin of the flood limit of the valley, between Stockton and Mokelumne River, gave sufficient encouragement to the Woodbridge Canal Company to warrant the construction of their proposed canal. The river was brought under control and raised at Woodbridge by a series of gates, equivalent to a movable dam, from above which a canal was cut toward the south. The canal came into use in 1891, but the demand for water was not so great as had been anticipated. Financial difficulties increased from year to year, and accidents happened to the head works, so that this canal also is again out of service. The irrigation with water from the river, therefore, is practically confined to a few acres of bottom land served by small neighborhood ditches, such as the Bahmert Ditch, on the north side of the river some miles above Clement. The principal mountain ditches which are fed by the river and its tributaries are still in service for mining and domestic use rather than for irrigation.

[1] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, 1891, p. 323, Pl. LXXXVII; Bull. No. 131, 1895, p. 86; Bull. No. 140, 1896, p. 308.

WEST-SIDE CREEKS AND OTHER STREAMS OF SAN JOAQUIN VALLEY.

From this account of irrigation in San Joaquin Valley it will appear that here, as well as in the State at large, irrigation is a local rather than a general aid to farming operations, and that ample opportunity remains for further development. This is particularly true of the most northerly portion of the valley, and applies with increasing force to Sacramento Valley, where irrigation has thus far barely secured a foothold. It remains to be said, however, that the foregoing chapters are not to be considered exhaustive, because neither time nor means at command permitted a revisit to the entire field, and little or no attention has been given to the lesser irrigation work from small creeks intermediate between the more important streams.

On the west side of the valley are a number of small irrigation works which draw their supply from the creeks of the Coast Range. These streams are torrential in character. Their flow is occasionally considerable during severe storms, but it is of brief duration. Ordinarily the run-off is very slight, and in many winters the streams remain almost unaffected by the light fall of rain on the eastern slopes of the Coast Range. This uncertainty of supply interferes with attempts to bring them under control for irrigation purposes. Here and there, however, some success has been had, particularly on those creeks having the largest drainage basins. This has been the case on Los Gatos Creek just above Huron, which has a drainage area of 441 square miles. The bed of this creek some miles above Huron remains moist during summer, and diverting works there constructed (in part at least of sheet piling, nearly equivalent to a submerged dam) have developed a flow of 6 to 8 second-feet for the Pleasant Valley Ditch, which is a private ditch in use for the irrigation of a tract of alfalfa.

The favorable indications near the head of this ditch for the development of a larger water supply encouraged the farmers to the east of Huron to form an irrigation district, which was organized in 1891. It is known as the Huron irrigation district, and has an area of about 20,000 acres. A plan of works was adopted, but no bonds were sold and no construction work has been done.

Notable among great works projected but not carried out was the west-side canal, which was to have been fed with water from Tulare Lake, it having been assumed at the time the project was under discussion, in 1876 and 1877, that the lake could be relied on to overflow annually. As there has been no such overflow for about twenty years, it appears fortunate that the project was not undertaken.

The subject of irrigation and water development from artesian wells should not be entirely neglected in treating of irrigation in San Joaquin Valley, but space will not permit of its consideration in this paper. For information on the subject reference may be made to the special bulletin of the Eleventh Census, Report on Agriculture by Irrigation in the Western Part of the United States, by F. H. Newell, page 50.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett, and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton, and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1898," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton, and "A preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Water-Supply and Irrigation Papers, 1896–1898.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas, by W. F. Hutson, 1898.
14. New tests of certain pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.

In press:

20. Experiments with windmills, by Thomas O. Perry.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This quantity falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules or who have furnished data. Requests made for a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent indiscriminately.

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