DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 59

DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON, AND RIVERSIDE CAL., PART I.—LIPPINCOTT.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1902

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

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, in two parts; 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

DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON AND RIVERSIDE, CAL

PART I

By JOSEPH BARLOW LIPPINCOTT

WASHINGTON

GOVERNMENT PRINTING OFFICE

1902

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 29, 1901.

SIR: I have the honor to transmit herewith a manuscript concerning the development and application of water in southern California, prepared by Mr. J. B. Lippincott, resident hydrographer for this Survey in California. This paper describes the general conditions of water supply in an important and densely populated agricultural area, where water has probably the greatest value for irrigation of any part of the United States. The data are of particular interest because of the development made during the series of dry years which culminated in 1890. Every possible expedient was resorted to for economizing or increasing the supply of water; tunnels were driven into the hills, dams were built to bed rock in the canyons, and wells were dug or drilled throughout the valleys. Almost every conceivable device for pumping water has been employed and great ingenuity displayed in bringing water to the orchards and more valuable crops.

The details of some of the works and wells have been brought together by Mr. Lippincott and form an exhibit of results accomplished under conditions where water has great value. The results are instructive, as showing what may be done in other parts of the United States under favorable conditions of climate and soil, and have peculiar interest in any consideration of the extent to which the Arid Lands can ultimately be redeemed by irrigation.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

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

JULIUS BIEN & CO. LITH. N.Y.

DEVELOPMENT AND APPLICATION OF WATER NEAR SAN BERNARDINO, COLTON, AND RIVERSIDE, CAL.

PART I.

By JOSEPH BARLOW LIPPINCOTT.

GENERAL LOCATION AND TOPOGRAPHY.

Owing to the uniformity and mildness of its climate, the grandeur and diversity of its scenery, and the great variety and vigor of its vegetation when furnished with moisture by irrigation, southern California has become the pleasure ground of the United States. In its semitropical valleys, lying between snow-capped mountains and a mild sea, art, refinement, and wealth have combined to make beautiful homes. The narrow strip of land lying between the mountains and the sea is fast becoming the Riviera of America. San Bernardino Valley is its garden, furnishing many varieties of deciduous and semitropical fruits for Eastern and domestic markets. Riverside and Redlands are the two principal centers of fruit production.

This valley is protected from the cold winds off the desert on the north and east by the Sierra Madre and San Bernardino Range, the elevations of the crests of which vary from 5,000 to 10,000 feet. To the south and west the valley is inclosed by low mountains, which form a secondary coast range, the highest peaks of which are in the Temescal Range to the south, the lowest in the San Jose and Puente hills to the west. The latter separate San Bernardino Valley from San Gabriel Valley and the Santa Ana coastal plain. San Bernardino Valley somewhat resembles a right-angled triangle, the apex being at the point where Santa Ana River leaves the mountain range, the base extending from Corona to Lordsburg, 24 miles distant, the right angle being at Corona, and the height 32 miles. The area of the valley is 563 square miles. The streams enter it from the north and east, coming from the Sierra Madre and the San Bernardino Mountains, with the exception of San Timoteo Creek, which discharges about 1 second-foot in summer, and Temescal Creek, which irrigates 3,600 acres.

The Riverside district is on the south side of the valley and is irrigated from return water, from pumping plants, and from artesian wells. The city of San Bernardino and its surrounding neighborhood are similarly supplied, supplemented also by Lytle Creek. Corona is irrigated from Temescal Creek and from local wells, supplemented by a pumping plant and pipe line from the water-bearing lands of San Jacinto Valley. All of the remaining orchards and gardens of San Bernardino Valley are on the northern and eastern edge of the valley and are supplied from local mountain drainage basins.

During years of average stream flow the duty of water for citrus fruits may be taken at from 5 to 8 acres to the miners' inch (0.02 second-foot), continuous flow, when good service is rendered, and double that area when used for deciduous trees.

All of the streams issuing from the north side of the valley have assisted in building up a bench-like mesa of débris cones of granite material, which varies in elevation from 800 to 1,200 feet above the thalweg of the valley. The northern rim of the valley at the foothills is at an elevation about 2,000 feet above sea level and the southern rim at an elevation of approximately 1,200 feet. On the southern side of the valley the mesa which lies next to the foothills is formed to a large extent from disintegrated granite mingled with red clays from San Timoteo Canyon and adjoining hills. Upon this bench are Riverside and Redlands, and it is from the red soil that the latter district derives its name. The Riverside bench is from 100 to 300 feet above the river bed and from 850 to 1,000 feet above sea level. It is 20 miles long and about 5 miles wide.

Water is the life blood of the land. Without it there can be no substantial growth, except occasional crops of grain, and this region would become a semidesert. We therefore find (see map, Pl. I) the towns and orchards clustered around the mountain edges, the canyons from which the streams issue, or in the lower depressions of the valley toward which the underground and return water from irrigation gravitate, to appear again for use on the surface, as at Colton and Rincon. The intermediate lands remain mostly unused and uncultivated, a few cattle to the section or an occasional crop of grain being all they will support. The highly productive portion of the valley is limited by the amount of water that is available for irrigation. All of the summer and much of the normal winter flow of the streams has now been appropriated and diverted, and it would seem that the valley had reached its limit of irrigated land from that source. However, in the lower valley lands the extensive saturated gravel beds will be drawn upon to supplement the surface supply, especially during dry years. The precipitation occurs almost entirely between November and April, and in normal years varies from 10 inches in the valley to 50 inches on high mountains. The minimum is as low as 33 per cent and the maximum as high as 200 per cent of the mean. The discharge of the streams is relatively large in winter and low in summer. The increase of the summer water supply is dependent upon the construction of reservoirs in the mountains, to store the winter storm water, or upon the development of water by wells or excavations in the valley lands.

The map accompanying this report (Pl. I) shows, by shaded areas, the land actually under irrigation and supplied or partially supplied with water during the summer of 1900. No effort has been made to distinguish between good and poor water supplies. The irrigated areas were determined by actual field observations, those in the Redlands quadrangle by Mr. Louis Mesmer, and those in the San Bernardino quadrangle by Mr. C. J. Roney, both of Los Angeles. The various irrigation canals and the principal distribution lines are also indicated on the map, as well as the locations of the power plants on Santa Ana River and Mill Creek, the approximate location of the water plane for the summer of 1900, and the locations of the wells. The numbers on the map correspond with the numbers of the wells in the table on pages 115 to 134 (Part II). Where isolated wells occur and the information is not sufficient to contour the water plane, its elevation is given (black figures) on the map.

SOIL.

The soil of the valley is of two distinct classes, the bench or delta-like lands around the rim of the valley and the moist bottom lands. The former merge from mere piles of rocky bowlders and sand containing little humus or soluble matter but which are capable of growing orchards, to sandy loams such as are found around Riverside. They are very deep and apparently of the same chemical composition in the lower strata as at the surface. They are warm and porous, and on such surface gradients that they are well drained, so that there is no danger to either the crops or the health of the cultivator from a rising and stagnant water plane with its accompanying alkali. Prof. E. W. Hilgard, professor of agriculture at the University of California, furnishes the following analyses of the Riverside soil and subsoil:

Analyses of soil and subsoil at Riverside.

	Soil, depth 12 inches.	Subsoil, depth 9 to 10 feet.		Soil, depth 12 inches.	Subsoil, depth 9 to 10 feet.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Coarse materials	20.000	23.000	Alumina	5.296	5.078
Fine earth	80.000	77.000	Phosphoric acid	.141	.159
			Sulphuric acid	.001	.001
Insoluble matter	76.410	75.445	Water and organic matter	1.600	1.440
Soluble silica	8.204	8.066			
Potash	.869	.928	Total	99 947	100.172
Soda	.293	.360	Humus	20.000	
Lime	1.568	1.727	Available inorganic matter	64.000	
Magnesia	1.325	1.581	Available phosphoric acid	.015	
Brown oxide manganese	.040	.041	Hygroscopic moisture absorbed at 16°C		
Peroxide iron	4.200	5.338		1.77	2.160

In the lower portions of the valley, where the water comes to the surface, the land is moist enough for cultivation without irrigation. Fields of alfalfa are thus grown around San Bernardino, Colton, and Rincon, and it is upon land of this character that the Chino beets are raised. Where the subdrainage is poor the continuous evaporation from the surface of the soil of water that is but slightly charged with sodium, carbonate, and sulphate will ultimately produce an alkali soil. This has occurred frequently in these localities. It is claimed, however, that the sugar beet will thrive on land somewhat alkaline, and this is said to have been demonstrated at Chino. In these bottom lands some adobe is found, but it does not cover extensive areas. The remedy for this alkali condition will probably be found in drainage and in the use of gypsum.

CLIMATE.

It has been said of southern California that every township has a distinct climate. It has taken years of time and the expenditure of thousands of dollars to determine the frost line. There is no protracted cold weather in San Bernardino Valley. A temperature of 26° F. maintained for several hours will freeze and ruin an orange or lemon crop, a temperature of 18° will kill young trees, and a temperature of 14° maintained over night is sufficient to kill old trees. These low temperatures are reached only during the night. The isotherms follow topographic contours within certain limits. The frost and cold settle into the relatively low lands, but other local conditions tend to modify this physical phenomenon.

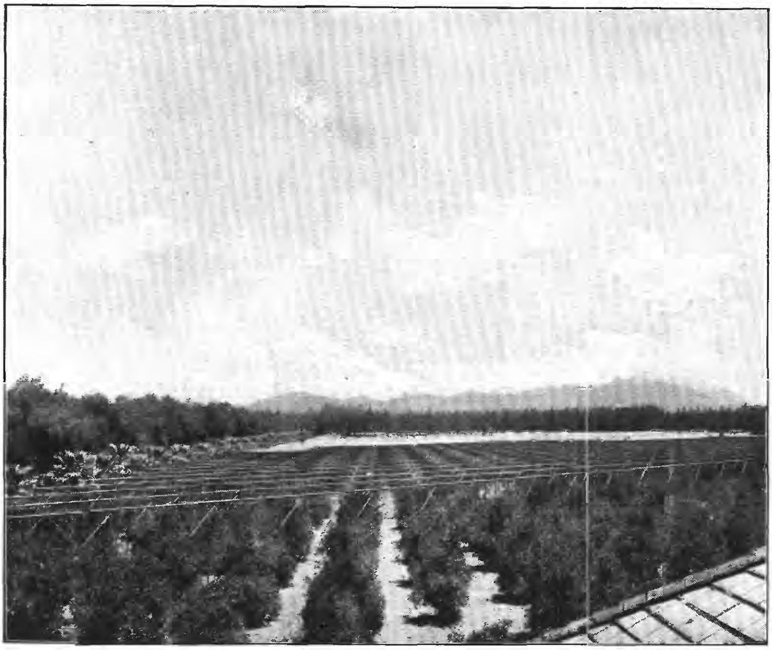
The air over the desert east of the mountains is raised to a relatively high temperature during the daytime and is forced upward. In the citrus belts frost usually occurs when a high barometric pressure exists over the desert, producing winds away from that locality. The air currents that are forced over the higher mountains are chilled and frost is found along the depressions of the canyons leading from their crests, while the drafts of desert air passing through the low passes are warmer. The areas affected by frost vary from year to year and no exact isotherms can be drawn for all years. After entering the valley the cold air, being relatively heavier, gravitates to the lower levels. The north wind from the Cajon Pass, which protects Rialto, Riverside, and Bloomington, seems to force the colder air which gravitates toward the lower portions of the valley around Colton into the extreme lower portion of Santa Ana Valley.

Up to elevations of 2,000 feet the relatively high lands are free from frosts and the relatively low lands are subject to it. For instance, in the Del Rosa and West Highlands districts the lands south of the track of the Southern California Railroad are considered unsafe for oranges while those above it are relatively free from frost. The neighborhood of the town of San Bernardino has been largely abandoned as a citrus district and converted into dairy, vegetable, and deciduous-fruit farms. This determination of the frost line is a subject of vital importance to those intending to cultivate citrus fruits, and can not be studied with too much care. After orchards have been developed it has often been found that they are not within the thermal belt, and vigorous efforts have been made to remedy the evil. Thermometers which ring alarms when the mercury drops below 32° have been constructed and placed in the orchards. A common practice is to burn brush or coke, or otherwise produce a smoke, so as to raise the temperature a few degrees and prevent freezing. Wind, if there be any, tends to mitigate the frost. In some localities ignited jets of crude oil or distillate, 15 to the acre, have been tried and have raised the local temperature 3°, but even this is uncertain, for the wind blows away the warmer air and the burning oil smuts the trees. When this method is adopted oil tanks are placed in the orchard and distribution pipes are laid to the jets throughout the groves. A unit of water in freezing gives off sufficient latent heat to raise the temperature of an equal unit of water 142° F. In order to use the latent heat thrown off in freezing, Mr. A. J. Everett, of Riverside, tried discharging sprays of water above the trees when the temperature of the atmosphere fell below 32°. The result, however, was a failure, the trees becoming coated with ice and the limbs being broken, with no resultant benefit.

The most successful efforts in the protection of orchards from frosts have been those of Mr. Everett, who covered 15 acres of orchard with lath fencing, half the space being open, as shown in Pl. II. The day temperature under the screen is found to be as high as that outside. The theory is to hold the day temperature of the earth under the screen as long as possible at night, or in other words to impede radiation. The shade afforded by the screen also tends to prevent rapid thawing of the fruit and the expansion of the liquid in the fruit cells at sunrise, which bursts the cells and spoils the fruit. Without fires under the screen the night temperature is held 6° above that of the outside atmosphere. In one instance, with an outside temperature of 19° and with ten coke fires to the acre distributed under the screen in wire pots holding about 1 cubic foot each, the temperature under the screen was kept at 29° during the night, and it is said that it could have been kept at 32° except for carelessness. In the fall of 1897, 75 trees in the coldest portion of an orchard were covered and the crop was saved. Part of the trees were covered with canvas over the lath and part with lath only, the results being equally beneficial. Outside the screen both crop and trees were frozen and in some instances the trees were killed. Inside the screen the St. Michael oranges, the most delicate, were saved. The crop, however, does not ripen as quickly under the screen as outside. With lumber at $20 a thousand the cost of building the screen is approximately $425 to the acre. The uprights are 3 inches by 4 inches by 15 feet high, and are set 21.2 feet apart. The top members are two 1-inch by 4-inch boards edged in T shape. The top of the screen is of lath commonly used for chicken-yard fences, openings the width of the lath being left between them. The high cost of this cover has prevented its being generally used.

A more even temperature exists nearer the seacoast than in San Bernardino Valley, and for winter vegetables and deciduous fruits that may be the better location, but not for citrus fruits. In the interior valley the temperature during the summer rises from 30° to 40° higher than on the coast, and high temperatures are necessary for the production of a sweet fruit. The cooler coast temperatures and fogs also tend to cause the citrus fruits to grow a thick-skinned, pulpy-celled lining. The higher temperatures are also unfavorable to the scale pest, which is the insect enemy to citrus fruits. The black scale exudes a sticky substance, which falling on the leaves and fruit retains the dust and gives the trees and fruit a dirty appearance. In the interior valleys the scale is not found. Generally speaking, in southern California the best citrus fruit is grown 30 or more miles from the coast, on the western slope of the mountains, and at elevations from 600 to 1,800 feet above sea. The conditions mentioned have greatly restricted the area where citrus fruits can be grown at a profit, and this area may be said to be decreasing rather than increasing. The general development of the country and improved transportation facilities are tending to enhance the value of really first-class citrus lands. It must be remembered that the determination of the frost line has been a slow process, but it is gradually being located, and the newer groves are planted in more propitious places. The groves located within the frost belt are chiefly old seedlings, now in full bearing, so that the loss from freezing is relatively much larger now than it will be ten years hence, for the old orchard lands that have been found frosty will be put into different crops or their water rights be transferred to other and better located lands. It is safe to say that throughout San Bernardino Valley much more land will be found adapted to this class of horticulture than the water supply will serve.

From the following tables of rainfall and temperature it will be seen that during the summer, or growing season, there is an absence of rain. In fact, from April 1 to November 1 there is practically continuous sunshine. The atmosphere also is very dry. These two conditions produce a rapid plant growth when water is abundantly supplied by irrigation. Vegetation develops with much greater rapidity under these conditions than at similar latitudes in the Eastern States.



A. GENERAL VIEW OF FRAMEWORK OF SCREEN FOR PROTECTING ORCHARDS FROM FROST AT RIVERSIDE.

B. FROST SCREEN AS SEEN FROM BENEATH.

Table of temperatures, in degrees Fahrenheit, at Riverside.[a]

Year.	Jan.		Feb.		Mar.		Apr.		May.		June.	
	Maximum.	Minimum.	Maximum	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1890	66	26	82	28	83	32	93	36	96	38	108	44
1891, mean	49.3		48.0		53.8		57.8		60.3		67.6	
1892, mean	53.4		53.8		56.6		59.8		64.9		68.2	
1893, mean	52.5		50.4		51.5		60.7		64.9		70.8	
1894, mean	47.3		48.4		54.2		60.3		62.4		63.8	
1895, mean	49.8		50.8		56.7		60.6		67.7		71.4	
1896	65.47	41.67	71.81	43.22	70.10	46.10	69.20	41.70	79.75	50.37	90.39	56.40
1897	75	35	76	31	80	28	93	36	93	44	100	48
1898	83	30	86	36	83	31	104	36	73.2	47.6	99	46
1899	65	40	86	28	88	32	96	36	90	38	102	46
1900	69	45	73	42	75	47	69.59	43.37	......	......	......	......

Year.	July.		Aug.		Sept.		Oct.		Nov.		Dec.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
1890	109	50	105	52	104	49	97	38	95	36	78	34
1891, mean	78.2		77.8		70.0		66.6		58.4		48.3	
1892, mean	73.1		74.3		70.4		62.0		59.5		51.0	
1893, mean	74.8		75.7		65.5		62.0		54.0		54.0	
1894, mean	75.2		74.4		71.6		64.8		61.5		53.2	
1895, mean	74.8		75.2		71.6		66.0		56.6		51.4	
1896	91.65	76.02	89.60	57.90	87.64	54.58	83.03	52.23	70.03	54.57	68.57	43.47
1897	102	50	108	52	100	46	84	42	89	35	86	27
1898	108	52	111	51	112	47	100	41	93	36	80	31
1899	103	49	103	49	107	52	94	40	84	38	84	35
1900	......	......	......	......	......	......	......	......	......	......	......	......

[a] Authority, Weather Bureau.

Record of precipitation, in inches, at Riverside.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1880-81	0.00	0.00	0.20	2.26	0.48	0.25	1.30	0.74	0.03	0.00	0.00	0.00	5.26
1881-82	.10	.40	.25	.40	1.70	1.40	1.08	.72	.08	.18	.00	.00	6.31
1882-83	.00	.13	.29	.20	.09	.83	.89	.26	.25	.00	.00	.00	2.94
1883-84	.00	.97	.00	2.25	.84	7.94	6.56	1.67	1.99	.52	.00	[a]3.00	25.74
1884-85	.00	.12	.12	2.56	.77	.00	.01	2.15	.24	.00	.00	.00	5.97
1885-86	.00	.02	1.34	.62	2.68	1.38	1.95	1.43	.00	.00	.00	.00	9.42
1886-87	.00	.00	.54	.04	.13	3.30	.02	1.70	.17	.02	.00	.00	5.92
1887-88	.00	.75	.87	.85	4.17	1.05	3.84	.18	.05	.00	.00	.00	11.75
1888-89	.00	.00	2.83	3.37	.87	1.30	5.10	1.83	.25	.00	.00	.00	15.55
1889-90	.09	1.35	1.82	7.10	4.44	1.96	.60	.06	.09	.00	.00	.05	18.26
1890-91	.79	.13	.32	3.21	.13	6.36	.40	1.04	.46	.00	.00	.00	12.84
1891-92	.13	.03	.00	1.29	.00	2.60	1.07	.00	1.32	.00	.00	.00	6.44
1892-93	.00	.29	.28	.94	3.01	1.95	5.71	.29	.04	.00	.33	.00	12.79
1893-94	1.27	1.08	.67	2.05	.69	.33	.70	.00	.00	.00	.00	.26	7.05
1894-95	.20	.05	.00	5.22	6.48	1.09	2.54	.29	.26	.00	.00	.00	16.13
1895-96	.00	.00	1.25	.24	1.72	1.00	3.16	.56	.58	.00	.01	.02	7.54
1896-97	.00	2.07	1.48	.92	3.38	3.07	1.62	.03	.03	.00	.00	.04	12.64
1897-98	.09	1.67	.02	.95	1.41	.16	.62	.24	.30	.00	.00	.00	5.46
1898-99	.03	.00	.00	.62	1.81	.52	1.13	.10	.08	.53	.00	.00	5.00
1899-1900	.00	1.05	.68	.58	1.11	.00	1.11	1.32	1.04	.00	.00	.00	6.89
Mean	......	......	......	......	......	......	......	......	......	......	......	......	10.00

[a] Hail.

Record of precipitation, in inches, at San Bernardino.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1885-86	0.00	0.39	4.36	1.20	6.34	2.52	4.18	2.36	0.32	0.16	0.00	0.00	21.83
1886-87	.00	.00	.11	.61	.39	6.44	4.41	1.90	.42	.22	.11	.04	14.50
1887-88	.09	1.17	2.29	1.91	4.01	3.60	3.41	.58	.52	.03	.00	.00	17.76
1888-89	.00	.05	4.12	4.64	.93	1.50	6.55	2.05	1.13	.00	.17	.63	20.97
1889-90	.11	2.30	2.23	10.85	5.44	2.52	.89	.00	.31	.00	.13	2.16	25.45
1890-91	.88	.58	1.27	3.02	.00	7.78	.06	.53	1.67	.00	.00	.91	18.08
1891-92	.93	T.	T.	1.67	3.24	3.30	1.75	.37	2.10	.08	.00	.00	14.35
1892-93	.00	.16	1.02	2.23	4.53	5.37	8.00	.48	.03	.00	.20	.00	19.82
1893-94	.05	1.05	.30	2.28	1.26	.88	1.15	.40	.56	.00	.00	.16	8.13
1894-95	.37	.15	.00	7.25	7.39	1.14	3.44	.64	.44	.00	.00	.00	20.98
1895-96	.00	.00	1.14	.66	2.02	.00	2.92	.37	1.00	.00	T.	.17	8.11
1896-97	.00	2.10	.98	1.09	3.40	5.40	3.41	.08	.01	.00	T.	.00	16.74
1897-98	.13	2.10	.21	.57	2.10	.60	.97	.48	1.08	.00	.00	.00	8.24
1898-99	.00	.03	.05	.44	2.03	.51	3.22	.07	.19	.95	.00	T.	7.49
1899-1900	.01	.81	1.47	.84	.92	.00	.12	.02	.00	.00	.50	.00	4.69
Mean													15.14

Record of precipitation, in inches, at Colton.

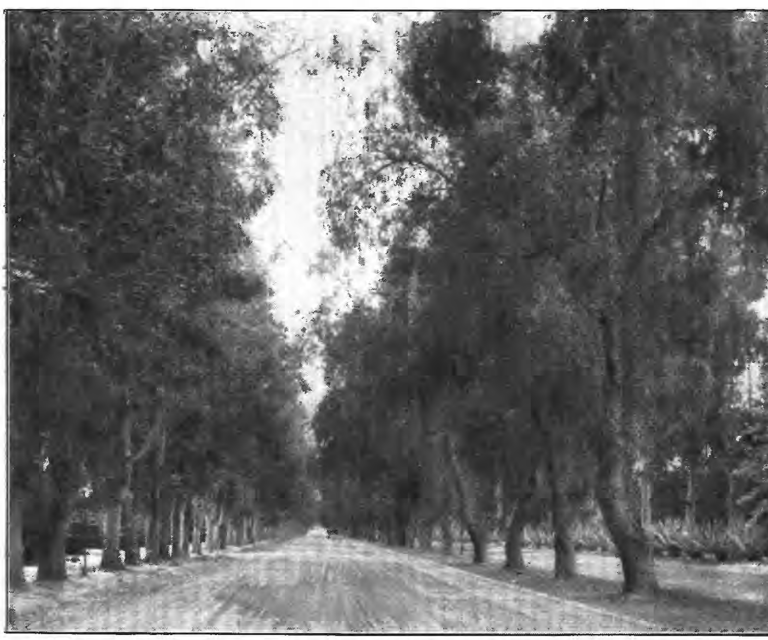
Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1885-86	0.00	0.00	1.92	0.52	2.78	0.40	3.54	0.50	0.00	0.00	0.00	0.00	9.66
1886-87	.00	00	.80	.00	.21	3.64	.00	1.94	T.	.00	.00	.00	6.59
1887-88	.00	.00	.70	.80	1.43	2.15	3.68	.43	.00	.00	.00	.00	9.19
1888-89	.00	.00	2.37	3.26	.86	.88	4.47	1.02	.60	.00	.00	T.	13.46
1889-90	.04	1.59	1.26	7.41	.94	1.15	.50	.00	.00	.00	.00	.06	14.95
1890-91	.67	.00	.19	2.45	.00	6.48	.25	.80	.90	.00	.00	.00	11.74
1891-92	.00	.00	.00	.87	2.27	3.36	.80	.24	1.44	.00	.00	.00	8.98
1892-93	.00		.90	1.45	2.40	2.91	6.64	.16	.00	.00	.30	.00	14.76
1893-94	.00	1.18	.22	1.93	.20	.55	2.00	.10	.50	.00	.00	.00	6.68
1894-95	.45	.15	.00	5.70	2.88	1.00	2.94	1.08	1.05	.00	.00	.00	20.26
1895-96	.00	.00	1.16	.00	.10	.00	2.91	.25	.38	.00	.00	.10	5.90
1896-97	(?)	2.28	.94	1.11	3.52	3.96	2.70	.00	.15	.85	.00	.00	15.51
1897-98	.00	2.20	(?)	.30	1.48	.23	.80	.10	.34	.00	.00	.00	5.45
1898-99	.00	T.	T.	.45	1.57	.45	1.55	.00	.00	T.	.00	.00	4.02
1899-1900	.00	.00	1.96	.55	1.06	.00							
Mean													10.51

T indicates trace.

CROPS.

The distinctive crop of San Bernardino Valley is citrus fruits. Oranges predominate, followed next by lemons, and of late years the grape fruit has become a popular product. The favorite variety of orange is the navel, a seedless fruit which has been highly developed at Riverside. Other varieties are the Mediterranean Sweet, the St. Michael, and the Malta Blood. These all are budded fruits on seedling roots. Pl. III, *A*, shows a bearing grove of navel oranges at Riverside. The seedling orange that was at first planted extensively is not now popular. Its value is less than half that of the budded fruit. The seedling tree is larger and longer lived than the budded varieties, but the fruit is not so sweet nor so highly flavored. The Eureka and Lisbon are the favorite varieties of lemon. The orange trees bloom in March and the crop ripens from December 1 to May 1. Some varieties of lemon trees are constantly ripening fruit, a heavier crop being borne in the winter. Olives, almonds, prunes, apricots, peaches, pears, and wine, raisin, and table grapes are all grown in this

A. NAVEL ORANGE GROVE AT RIVERSIDE, SAN BERNARDINO VALLEY.



B. MAGNOLIA AVENUE, RIVERSIDE.

district to perfection and in large quantities. Generally speaking, these are planted where the frost line debars the growth of citrus fruits. The citrus trees being constantly in fruit or blossom require more water than deciduous trees; therefore where the water supply is limited deciduous fruits are the more popular crop.

In the moist lands of the river bottoms near San Bernardino dairy farming is generally practiced, the products being disposed of to the orchardists and the local towns. In the moist lands near the lower narrows of the river beets are grown without irrigation, and at Chino there is a beet-sugar factory. The beets grown here contain from 16 to 18 per cent of saccharine matter, which is very high compared with those grown in Eastern localities.

An interesting feature of this district is the care that is taken of the orchards. No weeds are permitted to grow, and the lands are evenly sloped to true grades. Efforts are made to carry out artistic and neat effects in the homes, the streets, the canals, and the groves, as will be seen in Pls. III, *B*, and IV.

In the eleven years prior to 1898 Riverside shipped nearly 7,000,000 boxes of oranges, which at fair figures means an average income of $1,000,000 a year. With the present condition of the orchards an income twice as large may fairly be expected. There were 4,000 carloads of citrus fruits shipped from Riverside during the season of 1897–98. The annual yield there in 1899 is said to be about one-third of the entire output of the State. Navel oranges during the last ten years (1890–1900) have averaged at Riverside $1.50 a box,[a] and Mediterranean Sweets $1.25 to $1.50 a box; Malta Bloods and St. Michaels have brought somewhat higher prices. The production of the lemon has not been very popular in the past, as the method of curing it was not well understood. This problem has now been mastered, however, and the well-cured California lemon ranks with the best Sicilian product. The United States imports $5,000,000 worth of lemons yearly, and California is after the market. Lemons are worth about $1 a box, and the yield of trees fifteen years old is from five to eight boxes each.

It is difficult to say what the profits of citrus fruit culture are. It is a question of the survival of the fittest. The man whose crop is frozen every third year, or who has but half a water supply in dry years, or whose trees are of a low grade, is not among the fittest. For financial success these conditions must be relatively perfect. With these conditions satisfactory he should average 10 per cent net on his investment at the end of fifteen years. In the past, when prices were higher and competition less severe, there doubtless have been many cases where as much as $500 or $1,000 per acre per season has been produced from an orchard, and it is possible that these figures may again be reached, but they are not a proper basis for estimates. It costs in the neighborhood of $900 an acre to get a citrus orchard in bearing condition, including land, water, and interest on the invest-

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[a] Prices are f. o. b. cars.

ment. Under favorable conditions a ten-year-old orchard should produce $200 gross and $100 net per acre. Almost without exception the policy of living in the Eastern States and paying kind friends or parental corporations to attend to an orchard results in the loss of money and mutual respect. Under the best conditions it takes five or more years of hard, patient, and intelligent work to get an orange orchard on a paying basis. It is not a poor man's business. When success comes it is an ideal life to spend one's days among the golden fruit in a pleasant land. It is a country life surrounded by cultivated neighbors and with most of the conveniences of the city.

In the Eleventh Census (1890), under Agriculture by Irrigation, page 33, is the following statement:

> In average value on June 1st, 1890, of farm land irrigated, $150 per acre, California leads the list, Utah coming second, with $84.25 per acre. This figure exhibits perhaps better than any other the extraordinary values of land in California arising from its utilization for orchards and vineyards. The value of these ranges from $300 to $500 and upward per acre, thus greatly raising the average value of irrigated land, which of course also includes the great areas devoted to the raising of hay crops. The same fact is exhibited, though perhaps not as clearly, in the high average value of products per acre in 1889 and in the large average first cost of water rights, $12.95 per acre, and average value of these in 1890, $39.28 per acre, a high cost and value being justified by the enormous profits resulting from successful fruit culture. In short, it may be said that the conditions in California, although by no means perfect, have produced such results that they have served to stimulate development in all parts of western United States. Much is still to be accomplished by the subdivision of the great irrigated holdings, this state standing first in the aggregate area and average size of irrigated holdings of over 160 acres in area. These, although embracing 61.88 per cent of the total area irrigated are not of as great relative importance as in Nevada and Wyoming, where the large farms are devoted mainly to the forage crops.

What is true of the State as a whole is doubly true of San Bernardino Valley. There irrigation and horticulture have probably reached higher planes of development than in any other irrigation district.

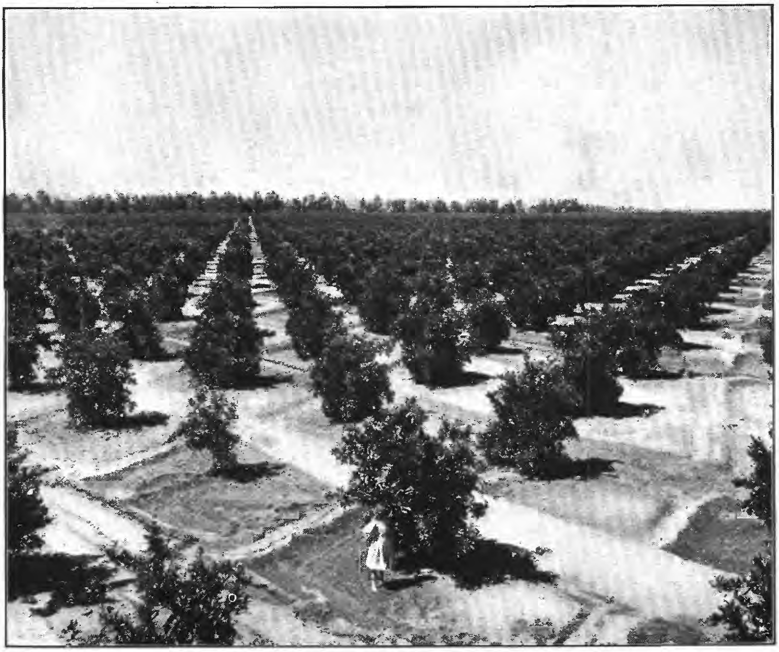
During the season of 1900–1901 southern California shipped 7,664,626 boxes of oranges and 908,856 boxes of lemons, worth to the growers $5,750,000.

Pl. IV, *A*, is a view of an orange grove in San Bernardino, showing a method of irrigating by throwing up the earth so as to construct around each tree a basin in which water is turned and allowed to stand until absorbed. Pl. IV, *B*, shows an irrigation canal of the Riverside Water Company near Riverside.

WATER SUPPLY.

The rain clouds from the Pacific Ocean, passing in large part over the lower intervening foothills and valleys, are condensed on being forced up and over the high crest of the Sierra Madre and the San Bernardino Mountains, which are from 6,000 to 11,000 feet in elevation.

The precipitation in the mountains occurring in the winter months



A. ORANGE GROVE, SHOWING METHOD OF BASIN IRRIGATION.

B. CANAL OF RIVERSIDE WATER COMPANY NEAR RIVERSIDE.

is largely in the form of snow, part of which does not melt until the spring months, thus maintaining the flow of the streams up to the first of May at a relatively large volume. Occasional thunderstorms visit the higher mountains in the summer. They are very violent and cause a sudden rise of the streams, which is not maintained. The rainfall of the valleys is about 15 inches annually, occurring in nongrowing months, there being little or no precipitation from April 1 to November 1. The grades of the drainage lines in the mountains are very steep, affording little opportunity for storage reservoirs. This is particularly unfortunate, as more than three-fifths of the stream flow occurs during the winter months. The Bear Valley reservoir is the one exception. It has a capacity at the 60-foot contour of 40,476 acre-feet, or 5,590 miners' inches (111.8 second-feet), flowing for six months. This water is taken to the Redlands and Highlands districts. The works are described in the Nineteenth Annual Report of the United States Geological Survey, Part IV, pages 584 to 598.

With the exception of San Timoteo and Temescal creeks all of the valley streams rise in the Sierra Madre and supply more than 90 per cent of the water used in the valley. There are three classes of water supply available, viz, surface streams, underground water, and water held in storage reservoirs. The principal stream of southern California is Santa Ana River. From the mouth of its mountain canyon to a point 4 miles east of Colton it has a grade of 100 feet to the mile, while below that point, to the lower narrows, the grade is but 27 feet to the mile. City Creek has a grade for the first 5 miles below its canyon of 100 feet to the mile, Lytle Creek a grade of 150 feet, and San Antonio and Cucamonga creeks a grade of 200 feet. The grades of these streams are still heavier in their granitic mountain canyons, and during flood stages they have carried down masses of sand and bowlders and built delta-like benches or mesas far out into the center of the valley, the finer material being conveyed farthest. In this way the valley has been filled to a depth of several hundred feet. In their course over these deltas the winter floods largely disappear in the detritus near the rim and penetrate in part under these layers of clay, thus forming reservoirs of ground water of unknown but great capacity. The water diverted for irrigation at the mouths of the canyons is also distributed upon porous soils, on steep grades, and with other underground bodies of water gravitates on the heavy prevailing slopes toward the center of the valley. One and a half miles northeast of Colton is an outcropping of clay known as Bunker Hill. This is a point on a low clay ridge bearing approximately S. 40° E., connecting with the foothills on the south side of the valley east of and near the mouth of Reche Canyon and extending northwest along the west bank of Lytle Creek. This ridge is the lower limit of the upper Santa Ana artesian belt. It also serves to force to the surface the return waters from irrigation that are flowing or percolating westward above the clay cap. Six-sevenths of the water of Riverside is obtained from underground sources above this range of clay hills. This ridge was probably formed by the folding of the floor of the valley.

A somewhat similar condition is repeated south of Chino, at Rincon, where Santa Ana River has cut its way through the lower Coast Range. At this point the underground waters from Cucamonga, San Antonio, and Temescal creeks as well as the return waters from irrigation near Pomona, Ontario, Corona, and Riverside are forced to the surface, creating wet lands and rendering a water supply available for Anaheim, Santa Ana, and Fullerton. Beyond these lower narrows there is an open plain to the sea, and the Santa Ana makes no further reappearance, except in an artesian district below the 100-foot contour. A view of the river below Rincon is shown in Pl. V, *A*, and a view of the division box of the Santa Ana and Anaheim canals, which divert water from the river below Rincon, in Pl. V, *B*.

This artesian and percolating water yields a very uniform flow. The development works near Colton and San Bernardino draw from this reservoir as a spigot draws from a tank. The flow is relatively uniform, and the tank is filled by winter floods and by seepage. The greater portion of the hydrostatic pressure is exhausted in overcoming the large amount of friction expended by the water in passing through the sand, and its flow comes largely under the law of hydraulics. The capping or uncapping of numerous wells in a neighborhood has little immediate effect on the flow of any well until the full discharge capacity of the underground conduit is approached. When that occurs the water in all of the wells is lowered and pumping must be resorted to. Pl. VI (*A* and *B*) shows a group of artesian wells of the Riverside Water Company near Colton, in the Santa Ana River bottoms. In the foreground of Pl. VI, *B*, is shown an aerating basin.

The velocity of underground flow is extremely difficult to compute. It has been discussed at length by Professor King and Professor Slichter, of Madison, Wis.,[a] and by Prof. L. G. Carpenter, of Fort Collins, Colo.[b] A great deal depends upon the size of the particles composing the soil and the way in which they are mixed. Cobbles, coarse sand, and sandy soil mixed in equal parts is more impervious than any one of the materials singly. Water percolating under ground for long periods often establishes underground channels from an eighth of an inch to 10 inches in diameter, then ceases to percolate and begins to flow through them. These conditions tend to confuse, because most of the formulas that have been presented are based on soil grains of distinct sizes.

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[a] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II.

[b] Bulletin No. 33 of Colorado experiment station, Fort Collins, Colo.

A SANTA ANA RIVER BELOW RINCON.

B. DIVISION BOX OF SANTA ANA AND ANAHEIM CANALS BELOW RINCON.

A. ARTESIAN WELLS OF RIVERSIDE WATER COMPANY.

B. ARTESIAN WELLS AND AERATING BASIN OF RIVERSIDE WATER COMPANY.

The flat valley area above Colton comprises 132 square miles, and it is reasonable to estimate that 100 square miles of this consists of gravel deposits eroded from the mountains. These gravels are of unknown but great depths. Numerous wells have been put down to a depth of 900 feet, and the writer does not know of bed rock being encountered. If this gravel bed is considered to have an average depth of 300 feet and the voids or interstices therein are taken at 33 per cent, the aggregate storage capacity would be 6,400,000 acre-feet. It is believed to be greater instead of less than this amount. As the water plane is drawn down throughout this mass its capacity to absorb subsequent floods at its rim, where the mountain streams debouch, is increased. It is a great regulating reservoir, sufficient in capacity to carry the irrigation communities through cycles of dry years, to be recharged during those of copious rainfall. The observations of the elevation of this water plane will be of value in making comparisons at a later date to determine whether the present rate of withdrawal is permanently lowering it or if in wet years the rainfall is sufficient to recharge the reservoir and restore it to its former level. This subject is of vital interest to the irrigators of the valley. From data now available a continuous withdrawal of 140 second-feet is believed to be reasonably safe.

The water of Warm Creek and of the artesian wells of the Gage system has been analyzed by Prof. E. W. Hilgard, of the University of California, with the following results:

Analyses of waters from artesian wells of the Gage system and from Warm Creek.

[Composition in 10,000 parts.]

	Artesian wells.		Warm Creek at mill.		Artesian wells.		Warm Creek at mill.
	Group D, No. 5.	Group A. No. 2.			Group D, No. 5.	Group A, No. 2.	
	Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
Total residue	1.911	2.266	2.604	Calcium carbonate	1.017	1.212	0.762
Soluble part	.418	.418	1.119	Magnesium carbonate	.232	.249	.253
Sodium chloride (common salt)	.063	.091	.257	Silica	.244	.239	.324
Sodium sulphate (glauber salt)	.193	.313	.582	Summary, in grains per gallon:			
Sodium carbonate (soda)	.102	.021	.200	Total residue	11.16	13.23	15.21
Potassium sulphate	.060	.068	.080	Soluble part	2.44	2.84	6.53
Insoluble after evaporation	1.493	1.778	1.485	Insoluble after evaporation	8.72	10.38	9.67
Calcium sulphate	....	.078	.146				

In total solids this water compares favorably with that of Los Angeles and Kern rivers, and is much purer than the water of the coast streams. It carries large quantities of potash salts, and not enough calcium carbonate to injure the well-drained lands of the Riverside mesa.

SMALL CANALS NEAR COLTON AND SAN BERNARDINO.[a]

DESCRIPTIONS.

Haws & Talmage ditch.—This ditch receives its supply from the rising water of Warm Creek, and is the first diversion on that stream between Harlem and Rabel Springs. It is a small earthen ditch, and takes water from the south side or left bank of the creek, and distributes it southwest of Harlem Springs. The diversion is by means of a dam. The ditch is three-fourths of a mile long. It is owned and maintained by local ranchers, and is entitled to 50 miners' inches (1 second-foot) of water. Usually the ditch is cleaned each spring, or whenever it becomes so foul that some irrigator can not get as much water as he requires. The water is used for alfalfa and other dairy products. The cost of maintenance of ditches of this class is from 50 cents to $1 per acre per year. The supply is relatively constant. The ditch was built in 1857, separating its water right from that of the Rabel Dam ditch. During the years 1898 and 1899 this ditch was practically dry, the only water it received being that pumped from the Harlem swimming pool, which is cleaned about twice a week. In June and August, 1899, and in March, 1900 and 1901, the ditch was dry.

Rabel Dam ditch diverts its water by means of an earthen dam at lot 2, block 60, San Bernardino Rancho, on Warm Creek. It is the second ditch on that stream. As is the case with all of these rising waters, the supply is practically constant throughout the year. An agreement, made in October, 1895, between the Riverside Water Company and the owners of the ditch provided for the natural flow of water in Warm Creek at the head of the ditch to the amount of 250 miners' inches, and in the agreement it was stipulated that the Riverside Water Company should at its own expense build at the head of the ditch an iron weir embedded in a cement foundation, to measure the water. This was done. The canal is an earthen ditch 4.2 miles in length, and has a capacity of 250 miners' inches (5.0 second-feet). It takes its water from the south side of Warm Creek and carries it to the southwest of Harlem Springs, irrigating 400 acres of alfalfa, vegetables, and garden produce. It is owned and operated by local ranchers. It was built in 1854 by the Mormon settlers, and is the oldest water right on Warm Creek. On June 20, 1898, it was discharging 5.37 second-feet. During the summer of 1899 the iron weir at the head of the ditch was removed by the owners of the ditch, with the consent of the Riverside Water Company. The upper part of the ditch was lowered by running it on a flatter gradient to the headworks, with the idea of diverting Warm Creek at a lower level. This plan increased the flow of water for a time, but it soon dropped to less than the original flow.

Shay or Stout Dam ditch.—The headworks of this ditch are in the west half of lot 4, block 60, San Bernardino Rancho, 1 mile north and 3 miles east of the city of San Bernardino. The diversion is by means of an earthen dam. The supply is relatively constant. The canal is 1½ miles in length; it runs west on the north side of the San Bernardino base line and Warm Creek, and irrigates those lands. The ditch is used the year round, and is cleaned twice a year. The cost of maintenance to consumers is less that $1 per acre per year. It served 210 acres in 1885 and 150 acres in 1898. It was built in 1857, and ranks third in its order of water rights to Warm Creek. By a compromise made with the Riverside Water Company in 1895 this ditch is entitled to 112.5 miners' inches of water (2.25 second-feet), provided there is that amount in Warm Creek at the headworks. During the years 1899 and 1900, however, the supply fell considerably below that quantity.

McKenzie ditch.—The headworks, consisting of a wooden dam, are on Warm Creek, the center of lot 8, block 51, San Bernardino Rancho, 2 miles east of the city of San Bernardino. The supply is relatively constant. The ditch was built

[a]The writer is indebted to Mr. Kingsbury Sanborn for most of the data regarding these canals.

in 1862. It irrigates lands immediately east of San Bernardino, between City and Warm creeks, and 85 acres on the south side of City Creek. The canal is about 1.3 miles in length. It is an earthen ditch built in sandy loam, with a flat grade, and is owned and operated by local ranchers. It is said to lose 33 per cent of its volume by seepage. The owners claim all of the water of Warm Creek at the point of diversion, but the Riverside Water Company claims that their right is limited to the original capacity of the ditch, which was 100 miners' inches (2.0 second-feet). The ditch is still in litigation. It has lately been enlarged. Three hundred acres of alfalfa and gardens are irrigated. Cost of maintenance is prorated and amounts to about 50 cents per acre per year. On June 20, 1898, it was discharging 127 miners' inches (2.54 second-feet).

Meeks & Daley ditch.—This ditch originally diverted its water from the lower part of Warm Creek, and the Agua Mansa, Juaramillo, and San Salvador canals took water from Santa Ana River, southeast of Colton. The owners of these four canals, in cleaning them out each year, gradually enlarged their sections, to the detriment of the Riverside Water Company, which company instituted suit against them to restrict their diversion. To avoid a protracted lawsuit and excessive loss of water by seepage in sandy channels, a compromise was arranged in 1885 by which the Riverside Water Company agreed to build and deliver to the owners of these ditches a cement-lined canal, estimated to cost $30,000, which should deliver from this conduit, at certain stated points, the following amounts of water:

Ditches to be supplied by cement-lined canal.

Name of ditch.	Original source of supply.	Water guaranteed.
		Miners' inches.
Meeks & Daley	Warm Creek	400
Juaramillo	Santa Ana River	50
Agua Mansa	do	250
San Salvador	do	125
Loss by evaporation (estimated)		25
Total		850

This canal was built by the Riverside Water Company at a cost of $37,281. All water remaining available from the sources of these canals belongs to that company. In 1885 the Meeks & Daley Water Company was incorporated, with a capital stock of $78,000 divided into 780 shares, to handle these combined waters.

The headworks of the new canal were located 1½ miles northeast of the town of Colton and a half mile east of Bunker Hill. The headworks of the Meeks & Daley ditch consist of a well-constructed brush dam across Warm Creek, which diverts the water to a weir at the head of the ditch. At the weir the ditch is 10 feet wide on the bottom and 1½ feet deep, with side slopes of 1½ to 1, gradually contracting to its normal size at station 28, which is 3 feet wide on the bottom, 5 feet wide across the top, and 2 feet deep. The sides are of rubble masonry, with a 3-inch concrete bottom, and the whole inside is plastered with cement mortar a half inch thick. The supply is from Warm Creek and is very constant in volume. Under this contract the Riverside Water Company made a saving of from 100 to 200 miners' inches (2 to 4 second-feet). The canal built by them is about 3½ miles in length. It runs through the southern side of the town of Colton and around the south side of Slover Mountain, being on the north or right bank of Warm Creek and Santa Ana River. It is owned by a stock company of local ranchers, each share of the stock carrying with it a water right to some certain piece of land to which it is appurtenant. The water is used largely for the irrigation of citrus fruits.

The Agua Mansa ditch is an extension of the Meeks & Daley ditch through the Agua Mansa and San Salvador districts. It is of the same construction as the Meeks & Daley ditch, but is smaller, being 2 feet on the bottom and from 1 foot to 1½ feet deep, according to the grade, with side slopes of ½ to 1. Very little of the original Agua Mansa land is now irrigated, as the irrigation on the mesa has converted the land into a bog hole, unfit for cultivation, and many shares of water have been sold to ranchers in West Riverside, who now own the controlling interest and are using the water on their lands.

Beam ditch derives its water from a cienaga tributary of Warm Creek in lot 14, block 43, San Bernardino Rancho. The ditch is about a mile in length. The water is diverted by means of a brush dam, and flows in a southwesterly direction, irrigating the land lying west of Warm Creek, in blocks 43 and 44 of the San Bernardino Rancho. The ditch has an apparent capacity of 45 miners' inches, and irrigates about 100 acres of land. On June 20, 1898, it was flowing 0.67 second-foot in the flume near the headworks.

Timber ditch.—This was one of the first canals constructed in San Bernardino Valley. It diverted its water from Santa Ana River near the center of sec. 8, T. 1 S., R. 3 W. The water rights of this canal were transferred by individual owners to the North and South Fork canals of Highlands and Redlands, and at the present time it is practically abandoned. The water was applied to the lands between the city of San Bernardino and Santa Ana River. It was entirely dry during the summers of 1898 and 1899. At its headworks there is a flume intake 4.3 feet wide and 2 feet deep, also a crib diversion dam. This ditch is described in the Nineteenth Annual Report of the United States Geological Survey, Part IV.

Logsdon & Farrell or Waterman ditch.—The Logsdon & Farrell ditch makes its diversion from the south side of City Creek, a mile east of the city of San Bernardino, by means of a flume 2 feet wide and 1 foot deep and a rough sheet-pile dam. The canal is three-fourths of a mile in length, and its water is used southeast of the city. About 80 acres of gardens are irrigated. On June 29, 1898, there was flowing in this ditch 36 miners' inches (0.72 second-foot) of water. This ditch is a combination of the Waterman, Logsdon-Farrell, and Brooks ditches.

Whitlock ditch.—This ditch takes its water from the north bank of City Creek 2 miles east of the business portion of the city of San Bernardino, and is about a half mile in length. At the place of measurement it is a flume 1.5 feet wide and 0.8 foot deep, and on June 29, 1898, it was discharging 12 miners' inches, or 0.24 second-foot. Its water is used to wash vegetables, and it is mingled with the waters of the McKenzie ditch and used on Chinese vegetable gardens.

Daley ditch.—This ditch diverts water three-fourths of a mile east of the business portion of the city of San Bernardino and about one-fourth of a mile east of the junction of Warm and City creeks, from the north side of the latter creek, crosses to the south side of that creek, and distributes its water on 40 acres of block 6 of the San Bernardino Rancho. It is about a half mile in length. The flume crossing City Creek is 1 foot wide and 1 foot deep. On June 29, 1898, it was carrying 31 miners' inches (0.62 second-foot).

McIntyre ditch.—This canal makes its diversion from the south or right bank of Lytle Creek, near the southwest corner of the city of San Bernardino, and receives its supply from the return water of that creek. It is approximately 1 mile in length, and distributes its water on the south side of Lytle Creek, between Colton avenue and Mount Vernon avenue. It is an eight-day ditch, and is owned by local ranchers, who maintain it for about 70 cents per acre per year. About 30 acres are irrigated for alfalfa. During the years 1898, 1899, 1900, and 1901 the ditch was dry.

Whiting ditch also derives its supply from the return water of Lytle Creek, and distributes it on the adjoining lands of D. G. Whiting, who owns the ditch. On June 27, 1898, it was carrying 15 miners' inches (0.30 second-foot). Twenty-five acres of pasture are irrigated.

Furguson water.—This is a $2\frac{1}{2}$-miners' inch right in Ranchero ditch, which comes from Raynor Springs. The water is used around Bloomington.

Ward & Warren ditch.—This is one of the oldest ditches on Santa Ana River, and is the outgrowth of the Warren-Warner ditch, the Jansen ditch, and the waste water from the Hunt & Cooley ditch. The ditch originally took its water from Santa Ana River near the east end of the Southern Pacific Railway bridge, in lot 8, block 64, San Bernardino Rancho, but during the flood of 1892 the main channel of Santa Ana River was changed to a point about a half mile to the north, and the following spring the Ward & Warren ditch was extended to the new channel of the river. The water is now diverted by means of a rough sand and brush dam in the westerly part of lot 2, block 64, San Bernardino Rancho.

During the years 1888 and 1889 this ditch was considerably enlarged and the water spread over a greater area. The Riverside Water Company, which had been using the water of Santa Ana River for years, brought suit against the owners of the ditch, to restrain them from using all the water in Santa Ana River at their headworks, claiming that they were entitled to only the original capacity of the ditch.

The case came to trial February 26, 1890, the decision being that the owners of the ditch are entitled to the water flowing from Santa Ana River at the head of the Ward & Warren ditch to the extent of 309 miners' inches (6.18 second-feet), measured under a 4-inch pressure, the measurement to be made from the center of the orifice, and that the Riverside Water Company is the owner and entitled to the use of the remainder of the water flowing in Santa Ana River at the head of the Ward & Warren ditch. The court further decreed that the owners of the Ward & Warren ditch are entitled to have from the Rice & Thorne tracts (which are owned by the Riverside Water Company) on Santa Ana River water to the amount of 78.18 miners' inches (1.56 second-feet), measured under a 4-inch pressure from the center of the orifice, when necessary to make up the 309 miners' inches. This 78.18 miners' inches was the overflow from the fish pond of a cienaga located on their lands, the stream of which is one of the natural tributaries of Santa Ana River. This pond, owing to the dry season and the development of artesian water in that neighborhood, is now almost dry, and the 78.18 miners' inches delivered to the Ward & Warren ditch is now practically all artesian water. The line of the ditch is located through the dry and sandy bed of Santa Ana River and loses a large percentage of its water before reaching the first point of distribution. In June, 1898, this ditch was receiving from the Rice-Thorne canal 1.60 second-feet of water and from Santa Ana River 0.72 second-foot.

North Riverside or Jurupa canal.—The Jurupa canal, sometimes called the North Riverside, derives its water from different sources: (1) From a covered flume in the Santa Ana River bottom, in lot 3, block 88, San Bernardino Rancho, above Colton avenue crossing; (2) from surface development in two cienagas in lot 2, block 88, San Bernardino Rancho; and (3) from the Salazar water. The Salazar water was originally diverted from the bed of Santa Ana River.

The Riverside Water Company agreed, because of the priority of the Salazar right, to permit the water for this ditch, to the extent of 75 to 100 miners' inches (1.5 to 2 second-feet), to pass its headworks and be conveyed by a sandy river bed to the Salazar headworks. In order to prevent the loss by seepage and evaporation in the river bed, the Riverside Water Company now delivers into the Jurupa flume 75 miners' inches (1.5 second-feet), in consideration for which it diverts all of the water at the headworks of its canal. All of these developments occur east of the Colton avenue crossing of Santa Ana River. The ditch which is now called the Rubidoux ditch is generally known as the Jurupa ditch, and diverts its water from Santa Ana River just north of the point where the county line between Riverside and San Bernardino crosses the lands of the Rubidoux ranch. The ditch now known as the Jurupa, belonging to the North Riverside Land

and Water Company, diverts a portion of its water from an underground flume in the bed of Santa Ana River a short distance east of the Colton avenue bridge. On July 1, 1898, the canal was flowing 7.11 second-feet at the Colton avenue crossing. This includes the 75 miners' inches (1.50 second-feet) of Salazar water. The main canal is 17 miles in length. The company owns the land upon which the water is distributed, and claims the right to develop all the water available at its headworks. The first 350 miners' inches (7 second-feet) belong to settlers to whom the company had sold water and land. The Jurupa ditch carries 75 miners' inches from the Riverside Water Company's flume, and this water is known as the Salazar right. It is measured at the junction of the Riverside Water Company's flume with the North Riverside and Jurupa canal. Agua Mansa water enters the Jurupa canal from the Meeks & Daley ditch 1 mile southwest of Slover Mountain, and is carried by it to the San Salvador district. The Temescal tin mine syndicate has a run of 200 miners' inches (4 second-feet) for twenty-four hours every eighth day through the Jurupa ditch. Ordinarily the Jurupa ditch contains—

	Miners' inches.	Second-feet.
Agua Mansa water	350	(7.0)
Salazar water	75	(1.5)
Santa Ana River water	350	(7.0)
Total	775	(15.5)

The following measurements have been made:

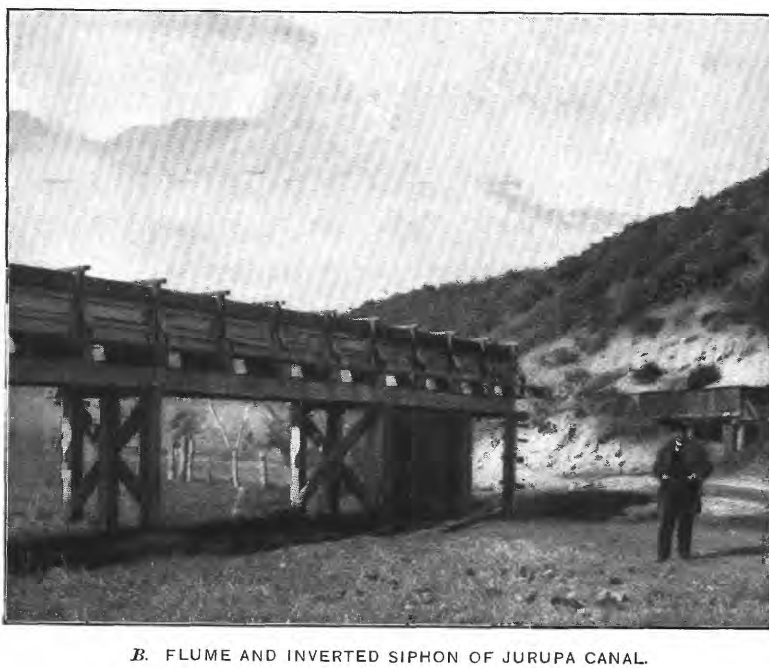
	Miners' inches.	Second-feet.
July 1, 1898, Jurupa flume at Colton avenue	355	(7.11)
June 18, 1898, Jurupa flume below Agua Mansa junction, including Agua Mansa water	691	(13.83)
August 27, 1898, Jurupa flume at Colton avenue, below Agua Mansa junction, including Agua Mansa water	509	(10.18)

During the year 1897 the assessments to the owners of the Jurupa ditch amounted to $9.54 per miners' inch. They charge $3.27 per inch per year for carrying Agua Mansa and other water.

The canal is located around a rock hill immediately above the old upper canal of the Riverside Water Company and crosses the river in a flume on a trestle 2,460 feet in length, shown in Pl. VII, *B*. Then for 2 miles the water is flumed along a bluff on the north bank of the river, after which it passes through a tunnel 4,000 feet long into an open ditch 3 miles long, and thence to the Jurupa mesa lands. The Jurupa Land and Water Company was incorporated in May, 1888, with a capital stock of $3,500,000, divided into $100 shares.

Hunt & Cooley or Camp Carlton ditch.—This was originally one of the oldest diversions on middle Santa Ana River. It was taken out in 1859, and had several headings in the river, which were washed out by floods, until the final one was made at about the point where the Gage canal started to divert its water, and it remained there until the year 1887, when the managers of the Gage canal agreed with the owners of the ditch to bore wells and develop for them 130 miners' inches of water, and to receive in return what they thought to be the right to all the water flowing in Santa Ana River at the headworks of this ditch. This led to a long and expensive lawsuit with the Riverside Water Company, who contended that the Gage canal was entitled to only an amount of water equal to the original capacity of the canal, which was 200 miners' inches. It resulted, however, in the courts allowing the Gage canal the right to 298.5 miners' inches of the flow of Santa Ana River at the headworks of their canal.

A. FLOWING WELLS OF GAGE CANAL SYSTEM, VALLEY OF SANTA ANA RIVER.



B. FLUME AND INVERTED SIPHON OF JURUPA CANAL.

DISCHARGE MEASUREMENTS.[a]

Haws & Talmage ditch.—On June 7, 1898, 0.84 second-foot was flowing in this ditch near the headworks. The area of the water section was 0.9 square foot, the surface velocity 1.33 feet per second. Measurements were made by floats. Coefficient 70 per cent.

September 14, 1898, all of the water in Warm Creek at the head of the ditch was passed through the waste gate; by weir it measured 0.43 second-foot. The weir was 4.6 feet long, the head 0.094 foot, two full contractions, velocity of approach less than 0.5 foot per second.

March 2, 1899, a weir was put in near the head of the ditch, and the discharge measured 0.28 second-foot; length of weir 1 foot, head 0.2 foot, velocity of approach less than 0.5 foot per second, two full contractions.

In June and August, 1899, and in March and on June 12, 1900, the ditch was dry.

Rabel Dam ditch.—September 14, 1898, at 2.10 p. m., this ditch was diverting 3.07 second-feet over the iron weir at the headworks, which was all of the water in Warm Creek at that point. The weir is 4 feet long, the head was 0.38 foot, two full contractions, velocity of approach less than 1 foot per second.

March 2, 1899, the ditch was discharging 2.36 second-feet at the head; length of weir 4 feet, head 0.31 foot, velocity of approach less than 1 foot per second, two full end contractions. This was all of the water in Warm Creek at the point of diversion.

June 16, 1899, at 1.45 p. m., this ditch was discharging 1.54 second-feet; head 0.24 foot, length of weir 4 feet, two full end contractions, velocity of approach less than 0.5 foot per second.

During the summer of 1899 the iron weir at the head of the ditch was removed by the owners of the ditch, with the consent of the Riverside Water Company. The upper part of the ditch was lowered by running on a flatter gradient to the headworks, with the idea of diverting Warm Creek at a lower level. This plan increased the flow of water for a time, but it soon dropped to less than the original flow.

August 25, 1899, the discharge measured 0.94 second-foot; the water area was 0.9 square foot, the surface velocity 1.5 feet per second.

March 15, 1900, the 4-foot iron weir was again in place; the discharge measured 0.54 second-foot, the head was 0.12 foot, and there was no perceptible velocity of approach.

June 12, 1900, at 12 m., the discharge measured 0.35 second-foot at the headworks weir; length of weir 4 feet, head 0.09 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Shay or Stout Dam ditch.—On June 20, 1898, the volume in this canal measured 2.30 second-feet; length of weir 2 feet, head 0.502 foot, velocity of approach 0.7 foot per second, two end contractions.

September 14, 1898, at 1.55 p. m., the discharge over the same weir was 2.08 second-feet. Being at the end of the irrigating season the ditch had not been cleaned and was very foul. The tail water was higher than the crest of the weir by 0.193 foot, causing the weir to be submerged. Head 0.5 foot, two end contractions, velocity of approach less than 0.5 foot per second. Fteley and Stearns's formula was used.

March 2, 1899, the discharge over the same weir was 2.23 second-feet; head 0.5 foot, two end contractions, velocity of approach less than 0.5 foot per second.

June 16, 1899, at 2.10 p. m., the discharge was 1.13 second-feet. The ditch was again foul, and the weir was submerged 0.320 foot; head 0.406 foot, velocity of approach less than 1 foot per second.

[a] All measurements were made by Mr. Kingsbury Sanborn, of Riverside, except where stated to the contrary.

August 25, 1899, at 2.15 p. m., the discharge measured 0.9 second-foot, head 0.27 foot, two end contractions, velocity of approach less than 0.5 foot per second.

A few months previous to March 15, 1900, when a measurement was made, the owners of the Shay ditch relocated the ditch, starting from the headworks and taking it to higher grounds, which caused the water to back entirely over the weir, so that it became necessary to make a float measurement. The water area was 1.45 square feet, surface velocity 0.5 foot per second, discharge 0.507 second-foot, coefficient 70 per cent.

On June 19, 1900, at 1.10 p. m., the discharge was 0.4 second-foot about 200 feet below the dam across Warm Creek; sectional area 1.7 square feet, surface velocity 0.34 foot per second, coefficient 70 per cent.

McKenzie ditch.—On June 20, 1898, a float measurement was made. The area of the section was 2.90 square feet, surface velocity 1.25 feet per second, coefficient 70 per cent, discharge 2.54 second-feet.

September 12, 1898, at 2.30 p. m., the discharge a half mile below the headworks measured 2.08 second-feet. The sectional area was 5.2 square feet, the velocity of approach 0.64 foot per second, coefficient 70 per cent.

March 2, 1899, the discharge measured 9.4 second-feet at the same point as the last measurement; the sectional area was 4.9 square feet, surface velocity 2.77 feet per second, coefficient 70 per cent.

June 16, 1899, at 2.45 p. m., the discharge measured 3.86 second-feet about 150 feet below the headworks on Warm Creek; the sectional area was 1.9 square feet, surface velocity 2 feet per second, coefficient 70 per cent.

August 22, 1899, there was flowing in the ditch at the same point as the last measurement 2 second-feet; the sectional area was 4.1 square feet, the surface velocity 0.7 foot per second, coefficient 70 per cent.

March 16, 1900, the discharge measured 2.3 second-feet about 250 feet below the headworks on Warm Creek; the sectional area was 3.3 square feet, the surface velocity 1 foot per second, coefficient 70 per cent.

June 19, 1900, at 1.10 p. m., the discharge measured 1.57 second-feet about 150 feet below the headworks dam; the sectional area was 2.2 square feet, the surface velocity 1 foot per second, coefficient 70 per cent.

Meeks & Daley ditch.—Measured on June 20, 1898, the discharge at the headworks weir was 8.42 second-feet (421 miners' inches); length of weir 6 feet, head 0.525 foot, two end contractions, velocity of approach less than 0.5 foot per second.

Measured on March 2, 1899, at the headworks weir the discharge was 17 second-feet; length of weir 6 feet, head 0.917 foot, two end contractions, velocity of approach less than 1 foot per second.

June 26, 1899, the discharge at the headworks weir was 15.48 second-feet, the head 0.845 foot, two end contractions.

August 25, 1899, the discharge at the headworks weir was 10.45 second-feet, head 0.659 foot.

March 1, 1900, the weir was submerged 0.28 foot; the discharge was 13.94 second-feet; length of weir 6 feet, head 0.84 foot, velocity of approach less than 1 foot per second.

June 19, 1900, at 4 p. m., the discharge measured 13.78 second-feet at the headworks weir, which was submerged 0.415 foot; the velocity of approach was less than 1 foot per second, length of weir 6 feet, head 0.875 foot, two end contractions.

Logsdon & Farrell ditch.—Measured near headworks on June 29, 1898, by J. B. Lippincott and K. Sanborn. Area of section 0.878 square foot, mean velocity 0.824 foot per second, coefficient 80 per cent, discharge 0.72 second-foot.

In September, 1898, the discharge was 0.63 second-foot at the same place.

March 1, 1899, 1.61 second-feet of water was in the flume near the headworks. This ditch is flat, and it is impossible to put in a weir without losing a large percentage of the water, so that it became necessary to make float measurements. The width of the flume is 2 feet, the depth of the water 0.7 foot, sectional area

1.41 square feet, surface velocity 1.43 feet per second, coefficient 80 per cent. The flume was in fair condition.

June 27, 1899, the discharge measured 1.15 second-feet at the same place; depth of water 0.71 foot, surface velocity 1 foot per second, sectional area 1.44 square feet, coefficient 80 per cent.

August 25, 1899, the discharge measured 0.54 second-foot in the flume near the headworks, which was in fair condition. The depth of water was 0.56 foot, surface velocity 0.6 foot per second, sectional area 1.12 square feet, coefficient 80 per cent.

March 15, 1900, the discharge measured 1.26 second-feet at the same place. There was a deposit of sand in the bottom of the flume, and the depth of water was as follows: Side 0.82 foot, center 0.86 foot, and opposite side of flume 0.84 foot. The surface velocity was 1 foot per second, coefficient 75 per cent.

June 23, 1900, the discharge measured 0.49 second-foot in the ditch near the headworks dam; sectional area 0.9 square foot, surface velocity 0.77 foot per second, coefficient 70 per cent.

Beam ditch.—Measured June 30, 1898, 300 feet below headworks, by floats. Area of section 1.08 square feet, mean velocity 0.63 foot per second, discharge 0.67 second-foot.

March 2, 1899, discharge measured 0.72 second-foot in the flume near the headworks. This ditch is very flat, and it is impossible to put in a weir and get satisfactory results; for that reason float measurement was made. The water area was 1.5 square feet, the surface velocity 0.6 foot per second. The flume was in fairly good condition. Coefficient 80 per cent.

June 27, 1899, measured in the same flume as the last measurement. Discharge 0.52 second-foot, width of flume 1.38 feet, depth of water 0.95 foot, surface velocity 0.5 foot per second, coefficient 80 per cent.

August 25, 1899, the discharge at the same place measured 0.4 second-foot, the depth of water was 0.84 foot, surface velocity 0.5 foot per second. Flume in fairly good condition. Coefficient 80 per cent.

March 15, 1900, the discharge measured 0.68 second-foot, same place, same conditions. The depth of water was 0.62 foot, the surface velocity 1 foot per second, coefficient 80 per cent.

June 14, 1900, at 2 p. m., the discharge measured 0.5 second-foot at the same place; the sectional area was 1.14 square feet, the surface velocity 0.59 foot per second, coefficient 75 per cent.

Upper canal of Riverside Water Company.—On June 30, 1898, the discharge over the headworks weir (see Pl. IX) was 59.04 second-feet. There are three weirs, with end contractions, each 9½ feet long. Head equals 0.677 foot, velocity of approach 1.12, 2.18, and 1.94 feet per second, respectively.

February 28, 1899, the discharge was 60.53 second-feet, the head 0.843 foot.

June 26, 1899, the discharge was 53.92 second-feet, the head 0.686 foot.

August 31, 1899, there were 52.04 second-feet of water flowing over the headworks weir, and the head was 0.67 foot.

March 21, 1900, there were 61.94 second-feet flowing. Head 0.755 foot.

June 23, 1900, at 3 p. m., the discharge at the headworks weir measured 52.94 second-feet; the head was 0.68 foot, average velocity of approach 0.77 foot per second, full contractions.

Lower canal of Riverside Water Company.—Meter measurement on June 17, 1898, at 4 p. m., as determined by Mr. F. H. Olmsted, was 9.27 second-feet.

June 18, 1898, at 10 a. m., Mr. Olmsted made a meter measurement and found a discharge of 11.27 second-feet.

June 27, 1898, there were 10.83 second-feet of water flowing in the flume just below the intake at Santa Ana River. The sectional area was 4.18 square feet, the velocity 3.24 feet per second, coefficient 80 per cent.

September 2, 1898, there were 7.7 second-feet of water flowing at the same place. The water area was 3.84 square feet, the velocity 2.5 feet per second, coefficient 80 per cent.

March 10, 1899, there were 16.20 second-feet flowing over the weir at the end of the flume. Length of weir 5 feet, head 1.01 feet, two full end contractions, velocity of approach less than 1 foot per second.

June 28, 1899, the discharge at the same place measured 9.09 second-feet, the water area was 3.63 square feet, the surface velocity 3.12 feet per second, coefficient 80 per cent.

September 1, 1899, the discharge in the flume measured 7.38 second-feet, the water area was 3.33 square feet, the surface velocity 2.77 feet per second, coefficient 80 per cent.

June 23, 1900, at 9.05 a. m., the discharge measured 7.16 second-feet in the flume; sectional area 3.4 square feet, surface velocity 2.63 feet per second, coefficient 80 per cent.

Gage canal.—On June 29, 1898, this canal was measured at its intake from Santa Ana River. The discharge was 1.16 second-feet over a weir 5 feet long, head 0.17 foot, velocity of approach 0.5 foot per second, no end contractions.

March 7, 1899, the discharge measured 0.72 second-foot, length of weir 5 feet, head 0.125 foot, velocity of approach less than 1 foot per second, no end contractions.

June 20, 1899, the discharge over the same weir measured 0.24 second-foot, head 0.06 foot.

August 25, 1899, the discharge over a weir 1 foot in length measured 0.64 second-foot, head 0.35 foot, velocity of approach less than 1 foot per second, two full contractions.

March 1, 1900, the discharge over the same weir measured 0.395 second-foot, head 0.25 foot.

June 7, 1900, the discharge measured 0.29 second-foot over same weir, head 0.2 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Gage canal at Palm avenue weir.—June 30, 1898, Mr. K. Sanborn and Mr. J. B. Lippincott measured the flow over the weir, and obtained a discharge of 27.42 second-feet. The weir was 13.34 feet in length, with a head of 0.7 foot. There were two contractions. The velocity of approach was 1.4 feet per second. The level of the water below the weir was the same as the elevation of the crest, or knife edge.

September 21, 1898, there were 26.238 second-feet of water flowing over this weir. The head was 0.709 foot, the velocity of approach 1 foot per second, two full contractions.

March 7, 1899, the discharge over the weir measured 27.4 second-feet, head 0.73 foot, velocity of approach less than 1 foot per second.

June 26, 1899, the discharge measured 25.46 second-feet, head 0.69 foot.

August 15, 1899, the discharge measured 24.11 second-feet, head 0.67 foot.

March 21, 1900, the discharge measured 22.36 second-feet, head 0.639 foot.

June 7, 1900, the discharge measured 22.52 second-feet, head 0.64 foot, velocity of approach less than 1 foot per second.

Daley ditch.—Measured at 5.15 p. m. on June 29, 1898, by J. B. Lippincott and K. Sanborn. Discharge in flume across City Creek was 0.63 second-foot, water area 0.4 square foot, surface velocity 1.95 feet per second, coefficient 80 per cent.

September 12, 1898, at 11.30 a. m., the discharge measured 0.67 second-foot; water area 0.42 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

March 1, 1899, the discharge measured 0.71 second-foot, the water area 0.354 square foot, surface velocity 2.5 feet per second, coefficient 80 per cent.

June 27, 1899, the discharge measured 0.51 second-foot, water area 0.32 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

August 28, 1899, the discharge measured the same as on June 27, 1899.

March 15, 1900, the discharge measured 0.72 second-foot, water area 0.45 square foot, surface velocity 2 feet per second, coefficient 80 per cent.

June 23, 1900, at 12 m., the discharge measured 1.12 second-feet, the sectional area 0.28 square foot, the surface velocity 5 feet per second, coefficient 80 per cent.

McIntyre ditch.—June 12, 1898, at 4.25 p. m., the discharge measured 0.37 second-foot in flume near the head; the water area was 1.48 square feet, surface velocity 2.5 feet per second, coefficient 80 per cent.

September 14, 1898, the discharge measured 0.038 second-foot over a weir near the headworks, which was 0.5 foot in length; head 0.083 foot, no velocity of approach, two full end contractions.

March 1, 1899, the discharge measured 0.82 second-foot over a weir 1 foot in length; head 0.45 foot.

June 23, 1899, the discharge over the same weir measured 0.149 second-foot; head 0.13 foot.

August 26, 1899, there was no water flowing.

March 16, 1900, the discharge over the same weir measured 0.143 second-foot; head 0.126 foot.

June 12, 1900, the discharge over the same weir measured 0.01 second-foot; head 0.026 foot, two full contractions, velocity of approach less than 0.5 foot per second.

Whiting ditch.—June 27, 1898, the discharge measured 0.26 second-foot over a weir 1 foot in length near the headworks; head 0.19 foot, velocity of approach less than 0. 5 foot per second, two full end contractions.

September 14, 1898, the discharge measured 0.01 second-foot over a weir 0.5 foot in length; head 0.036 foot, velocity of approach less than 0.05 foot per second, two full end contractions.

March 1, 1899, the discharge measured 0.76 second-foot over a weir 1 foot in length; head 0.395 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 27, 1899, the discharge over the same weir measured 0.246 second-foot; head 0.182 foot.

August 26, 1899, the discharge over the same weir measured 0.009 second-foot; head 0.02 foot.

March 1, 1900, the discharge over the same weir measured 1.12 second-feet; head 0.522 foot.

June 12, 1900, the discharge measured 0.13 second-foot over the same weir; head 0.12 foot, velocity of approach less than 0.25 foot per second, two full end contractions.

Swamp ditch.—September 1, 1898, there were 1.02 second-feet flowing in flume to the Riverside Water Company's Rice-Thorne flume; the water area was 0.32 square foot, the surface velocity 3.5 feet per second, coefficient 80 per cent.

February 28, 1899, the discharge measured 0.85 second-foot over a weir at the first distributing box; length of weir 1 foot, head 0.427 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 20, 1899, the discharge over the same weir measured 0.77 second-foot; head 0.4 foot.

August 30, 1899, the discharge over the same weir measured 0.69 second-foot; head 0.37 foot.

March 21, 1900, the discharge over the same weir measured 0.7 second-foot; head 0.374 foot.

June 7, 1900, the discharge over the same weir measured 0.89 second-foot; head 0.44 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

Ranchero ditch.—September 22, 1898, at 1 p. m., the discharge measured 1.64 second-feet over a weir in the cement ditch on the Raynor ranch; length of weir 4 feet, head 0.25 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

March 13, 1899, the discharge measured the same over the same weir.

June 23, 1899, at 4.30 p. m., the discharge over the same weir measured 1 second-foot; head 0.18 foot.

August 26, 1899, the discharge over the same weir measured 0.41 second-foot; head 0.1 foot.

March 17, 1900, the discharge over the same weir measured 0.24 second-foot; head 0.07 foot.

June 12, 1900, the discharge measured 0.55 second-foot in the ditch; sectional area 0.74 square foot, surface velocity 1 foot per second, coefficient 75 per cent.

Ward & Warren ditch.—In June, 1898, this ditch was receiving from the Rice-Thorne canal 1.60 second-feet of water and from the river 0.72 second-foot.

March 10, 1899, there were 3.09 second-feet flowing over a weir 3.33 feet in length near the head of the ditch; head 0.434 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 20, 1899, the discharge measured 0.615 second-foot over a weir 1 foot in length near the headworks; head 0.34 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

August 30, 1899, the discharge measured 1.56 second-feet over a weir 2 feet in length near the headworks; head 0.38 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

March 19, 1900, the discharge measured 2.55 second-feet over a weir 3 feet in length at the head of the ditch; head 0.41 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

June 23, 1900, the discharge measured 1.7 second-feet in the ditch just below the dam across Santa Ana River; sectional area 1.95 square feet, surface velocity 1.25 feet per second, coefficient 70 per cent.

Mill flume of Riverside Water Company.—June 15, 1898, there were 3.12 second-feet flowing at the end of the flume near the old Colton mill; water area 1.76 square feet, surface velocity 2.22 feet per second, coefficient 80 per cent.

September 12, 1898, at 3.35 p. m., there were 3.36 second-feet at the same place; water area 1.68 square feet, surface velocity 2.5 feet per second.

February 28, 1899, there were 5.3 second-feet at the same place; water area 2.208 square feet, surface velocity 3 feet per second, coefficient 80 per cent.

June 26, 1899, the discharge measured 7.29 second-feet at the same place; water area 3.04 square feet, surface velocity 3 feet per second, coefficient 80 per cent.

August 30, 1899, the discharge measured 2.56 second-feet at the same place; water area 1.6 square feet, surface velocity 2 feet per second, coefficient 80 per cent.

March 9, 1900, the discharge measured 2.67 second-feet; water area 1.52 square feet, surface velocity 2.2 feet per second, coefficient 80 per cent.

June 7, 1900, the discharge measured 2.17 second-feet; sectional area 1.36 square feet, surface velocity 2 feet per second, coefficient 80 per cent.

Colton mill pump of Riverside Water Company.—June 15, 1898, there were 1.94 second-feet flowing over the weir at the old Colton mill; length of weir 4.015 feet, head 0.276 foot, no end contractions, velocity of approach less than 1 foot per second.

September 1, 1898, there were 2.04 second-feet flowing over the same weir; head 0.286 foot.

June 26, 1899, 1.77 second-feet were flowing over the weir; head 0.26 foot.

August 31, 1899, 1.67 second-feet were flowing over the weir; head 0.25 foot.

June 7, 1900, the discharge over the weir measured 1.88 second-feet; head 0.27 foot, velocity of approach less than 1 foot per second, no end contractions.

Camp Carlton ditch.—June 30, 1898, at 4.30 p. m., 0.61 second-foot was flowing over the weir at the Waterman avenue crossing; length of weir 3.33 feet, head 0.146 foot, velocity of approach less than 0.5 foot per second, two full end contractions.

September 12, 1898, at 9.30 a. m., there were 1.2 second-feet flowing over the same weir; head 0.229 foot.

March 7, 1899, there were 2.13 second-feet flowing over the weir; head 0.333 foot.

June 20, 1899, 1.62 second-feet were flowing over the weir; head 0.28 foot.

August 27, 1899, 1.02 second-feet were flowing over the weir; head 0.25 foot.

March 21, 1900, 2.55 second-feet were flowing over the weir; head 0.38 foot.

June 7, 1900, the discharge over the weir measured 2.6 second-feet, head 0.385 foot, velocity of approach less than 1 foot per second, two full end contractions.

East Riverside irrigation district.—It is stated that on June 10, 1898, 4.4 second-feet were being pumped for this district at the head of the Vivienda pipe line.

September 17, 1898, at 4 p. m., measurement showed that 4.43 second-feet were flowing over a weir 3.33 feet in length at the reservoir at the head of the Vivienda pipe line, which runs to East Riverside. Head 0.55 foot, two full end contractions, velocity of approach less than 1 foot per second.

March 13, 1899, 4.25 second-feet were flowing over the same weir; head 0.54 foot.

June 23, 1899, at 4 p. m., there were 2.08 second-feet flowing over the same weir; head 0.33 foot.

March 1, 1900, there were 6.59 second-feet flowing over a weir 4.16 feet long in the tunnel pipe line; head 0.6 foot, no velocity of approach, two full contractions.

June 12, 1900, the discharge over the foregoing weir measured 5.38 second-feet; head 0.542 foot, two full end contractions, velocity of approach less than 1 foot per second.

Colton Terrace Water Company.—June 30, 1898, 1.97 second-feet were flowing over a weir 2 feet in length at Reservoir Hill; head 0.456 foot.

September 22, 1898, 1.61 second-feet were flowing over a weir at the head of the pipe line above First street in San Bernardino; head 0.3 foot, length of weir 3 feet.

March 13, 1899, 1.69 second-feet were flowing over the same weir; head 0.31 foot.

June 26, 1899, 1.3 second-feet were flowing over the same weir; head 0.26 foot.

August 26, 1899, the discharge measured the same as on June 26.

March 17, 1900, the discharge over the same weir measured 1.69 second-feet; head 0.31 foot.

June 12, 1900, the discharge over the same weir measured 1.54 second-feet; head 0.292 foot, velocity of approach less than 1 foot per second, two end contractions.

City of Colton pumping plants.—June 26, 1899, 2.09 second-feet were flowing over a weir 4.17 feet in length at the head of the pipe line of the First street reservoir in San Bernardino; crest of weir 18 inches wide, head 0.29 foot.

August 26, 1899, 1.52 second-feet were flowing over the same weir.

August 26, 1899, the pumping plant west of Mount Vernon avenue was discharging 2.37 second-feet over a weir 2 feet long in the pipe line; head 0.52 foot, two full contractions, velocity of approach less than 0.5 foot per second.

March 17, 1900, the First street pumps were discharging 2.57 second-feet over a weir 4.15 feet long, crest 18 inches wide, head 0.33 foot, two full contractions, velocity of approach less than 0.5 foot per second.

June 12, 1900, the discharge of the two pumping plants measured 3.21 second-feet. The First street pump was discharging 1.23 second-feet over a weir 4.15 feet long at the head of the pipe line; head 0.23 foot, velocity of approach less than 0.5 foot per second, two full contractions. The Mount Vernon avenue pumps were discharging 1.98 second-feet over a weir 2 feet long in the reservoir; head 0.46 foot, two end contractions, velocity of approach less than 0.5 foot per second.

Whitlock ditch.—June 29, 1898, at 5 p. m., the discharge measured 0.34 second-foot in the flume on Styles street across the McKenzie ditch; the water area was 2.65 square feet, surface velocity 1.6 feet per second, coefficient 80 per cent.

October 6, 1898, the discharge in the flume measured 0.38 second-foot, water area 0.338 square foot, velocity of approach 1.42 feet per second, coefficient 80 per cent.

March 1, 1899, the discharge in the flume measured 0.47 second-foot, water area 0.59 square foot, velocity of approach 1 foot per second, coefficient 80 per cent.

June 27, 1899, the discharge in the flume measured 0.277 second-foot, water area 0.6 square foot, velocity of approach 0.66 foot per second, coefficient 80 per cent.

August 28, 1899, the discharge in the flume measured 0.094 second-foot, water area 0.147 square foot, surface velocity 0.8 foot per second.

March 15, 1900, the discharge in the same flume measured 0.232 second-foot, water area 0.145 square foot, surface velocity 1 foot per second.

June 23, 1900, the ditch at this point was dry.

Bloomington flume.—September 17, 1898, at 4.00 p. m., the Bloomington flume was discharging 5.49 second-feet of water over a weir 2 feet in length at the upper end of the flume. That weir was submerged 0.41 foot; the head was 0.96 foot, velocity of approach less than 0.5 foot per second, two end contractions.

June 23, 1899, 5.930 second-feet were flowing over the same weir. The weir was submerged 0.19 foot, the head was 0.95 foot, velocity of approach 2 feet per second, two end contractions.

August 26, 1899, 3.05 second-feet were flowing over the same weir, which was not submerged. The head was 0.62 foot.

March 16, 1900, the weir at the upper end of the flume was found to be destroyed; 3.8 second-feet were measured by floats at the lower end of the flume; the water area was 3.05 square feet, surface velocity 1.66 feet per second, coefficient 80 per cent.

June 12, 1900, the discharge near the end of the flume measured 3.68 second-feet, sectional area 3.93 square feet, surface velocity 1.25 feet per second, coefficient 75 per cent.

Johnson & Hubbard pumping plant.—March 16, 1900, 1.26 second-feet were flowing in the flume at the lower end of the pipe line just east of Colton. The water area was 1.1 square feet, surface velocity 1.43 feet per second, coefficient 80 per cent.

Comparative amounts of water, in second-feet, flowing in canals above Colton.

Name of ditch.	June, 1898.	Sept., 1898.	Mar., 1899.	June, 1899.	Aug., 1899.	Mar., 1900.	June, 1900.	Sept., 1900.
Haws & Talmage	0.84	0.00	0.28	0.00	0.00	0.00	0.00	0.00
Rabel Dam	5.37	3.07	2.36	1.54	.94	.54	.35	.07
Shay or Stout Dam	2.30	2.08	2.23	1.13	.90	.507	.40	.16
McKenzie	2.54	2.08	9.40	3.86	2.00	2.30	1.57	1.69
Meeks & Daley	8.42	[b] 17.00	17.00	15.48	10.45	13.94	13.78	14.68
Beam	.67	[b] .65	.72	.52	.40	.68	.50	.33
Riverside Water Co., upper canal[a]	59.04	61.34	60.53	53.92	52.04	61.94	52.94	61.02
Timber	.00	.00	.00	.00	.00	.00	.00	.00
Gage canal, Santa Ana River	1.16	1.16	.72	.24	.64	.395	.29	.17
Gage canal, Palm avenue	[c] 26.26	[c] 25.07	[c] 26.68	[c] 25.22	[c] 23.47	[c] 21.96	[c] 22.23	[c] 27.85
Logsdon & Farrel	.72	.63	1.61	1.15	.54	1.26	.49	.20
Whitlock	.34	.38	.47	.28	.094	.23	.00	.00
Daley	.63	.67	.71	.51	.51	.72	1.12	.54
McIntyre	.37	.038	.82	.15	.00	.14	.01	.00
Whiting	.26	.01	.76	.246	.01	1.12	.13	.00
Swamp	1.00	1.02	.85	.77	.69	.70	.89	.86
Ranchero	[b] 1.75	1.64	1.64	1.00	.41	.24	.55	1.33
Ward & Warren	2.32	[b] 2.32	3.09	.615	1.56	2.55	1.70	.53
Mill flume, Riverside Water Co.	3.12	3.36	5.30	7.29	2.56	2.67	2.17	.94
Mill pump, Riverside Water Co.	1.94	2.04	(d)	1.77	1.67	(d)	1.88	1.52
Camp Carlton	.61	1.20	2.13	1.62	1.02	2.55	2.60	1.67
East Riverside	4.40	4.43	4.25	2.08	2.00	6.59	5.38	3.70
Colton Terrace Water Co	1.97	1.61	1.69	1.30	1.30	1.69	1.54	1.53
City of Colton	6.82	7.40	3.20	5.49	3.89	4.94	3.21	3.54
Bloomington flume	5.26	5.49	(d)	5.93	3.05	3.80	3.68	3.28
Total	138.11	144.69	146.44	132.11	110.14	131.46	117.41	125.61

[a] Above Slover Mountain. [b] Interpolated. [c] River water not included. [d] Pumps not run.

Return water, natural flow in second-feet, compared with developed water in San Bernardino Valley above Colton.

Name of ditch.	June, 1898.		September, 1898.		March, 1899.		June, 1899.	
	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.
Haws & Talmage		0.84		0.00		0.28		0.00
Rabel Dam		5.37		3.07		2.36		1.54
Shay or Stout Dam		2.30		2.08		2.23		1.13
McKenzie		2.54		2.08		9.40		3.86
Beam		.67		.65		.72		.52
Riverside Water Co., upper canal	18.00	41.04	17.54	43.80	18.04	42.49	17.50	36.42
Gage canal, Santa Ana River		1.16		1.16		.72		.24
Gage canal, Palm avenue weir	26.26		25.07		26.68		25.22	
Logsdon & Farrell		.72		.63		1.61		1.15
Whitlock		.34		.38		.47		.28
Daley		.63		.67		.71		.51
McIntyre		.37		.038		.82		.15
Whiting		.26		.010		.76		.246
Swamp		1.00		1.020		.85		.77
Ranchero		[a]1.75		1.640		1.64		1.00
Ward & Warren	1.60	.72	1.60	.720	1.60	1.49	.615	
Mill flume of Riverside Water Co.		3.12		3.360		5.30		7.29
Mill pump of Riverside Water Co.	1.94		2.04		Not run.		1.77	
Camp Carlton ditch	.61		1.20		2.13		1.62	
East Riverside district, or Riverside Highland Water Co	4.40		4.43		4.25		2.08	
Colton Terrace Water Co.	1.97		1.61		1.69		1.30	
City of Colton pumping plant	6.82		7.40		3.20		5.49	
Bloomington flume	5.26		5.49		.00		5.93	
Meeks & Daley ditch		8.42		[a]17.00		17.00		15.48
Total	66.86	71.25	66.38	78.31	57.59	88.85	61.525	70.59

Name of ditch.	August, 1899.		March, 1900.		June, 1900.		September, 1900.	
	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.	Developed.	Natural.
Haws & Talmage		0.00		0.000	0.00	0.00		0.00
Rabel Dam		.94		.540		.35		.07
Shay or Stout Dam		.90		.507		.40		.16
McKenzie		2.00		2.300		1.57		1.69
Beam		.40		.680		.50		.33
Riverside Water Co., upper canal	27.50	24.54	24.54	37.40	32.36	20.58	27.00	34.02
Gage canal, Santa Ana River		.64		.395		.29		.17
Gage canal, Palm avenue weir	23.47		21.96		22.23		27.85	
Logsdon & Farrell		.54		1.26		.49		.20
Whitlock		.09		.23		.00		.00
Daley		.51		.72		1.12		.54
McIntyre		.00		.14		.01		.00
Whiting		.01		1.12		.13		.00
Swamp		.69		.70		.89		.86
Ranchero		.41		.24		.55	.80	.53
Ward & Warren	1.56		1.60	.95	1.60	.10	.53	
Mill flume of Riverside Water Co		2.56		2.67		2.17		.94
Mill pump of Riverside Water Co	1.67			Not run.	1.88		1.52	
Camp Carlton ditch	1.02		2.55		2.60		1.67	
East Riverside district, or Riverside Highland Water Co	2.00		6.59		5.38		3.70	
Colton Terrace Water Co.	1.30		1.69		1.54		1.53	
City of Colton pumping plant	3.89		4.94		3.21		3.54	
Bloomington flume	3.05		3.80		3.68		3.28	
Meeks & Daley ditch		10.45		13.94		13.78		14.68
Total	65.46	44.68	67.67	63.79	74.48	42.93	71.42	54.18

[a] Interpolated.

From the two preceding tables it will be noted that despite severe droughts which existed from 1898 to 1900, inclusive, the output of water from the gravel beds above Colton has but slightly diminished, the total being 144.69 second-feet in September, 1898, as compared with 125.61 second-feet in September, 1900. The amount of developed water in September, 1898, was 66.38 second-feet and in September, 1900, 71.42 second-feet, while the natural return water between the same dates decreased from 78.31 second-feet to 54.18 second-feet. During this period much development work was done, and while these new supplies do not mean an absolute addition to the output from the district, the fact that the total supply was maintained notwithstanding the drought is a decided achievement.

The most important question in considering this underground water supply is the rate at which the gravel beds will be recharged during wet years. This underground reservoir is of such magnitude, however, that it will require a term of years to demonstrate what these conditions are. Certainly more water can not be permanently pumped from a reservoir than its mean inflow. During this investigation an effort has been made to determine the elevation of the water plane throughout the valley above Colton, as shown on Pl. I. During the last four years the plane of saturation has been lowered. After a cycle of rainy years observations of these same wells should be taken to determine what the rise, if any, in the water plane has been. Not until this has been done will it be possible to state whether the supply is of a permanent nature. The data now at hand, though meager, indicate that 140 second-feet can with safety be continuously withdrawn, but this amount should not be greatly increased.

WELLS.

There are a large number of artesian wells near San Bernardino and Colton, in the basins of Santa Ana River, Lytle Creek, and Warm Creek. On page 530 of Physical Data and Statistics of California, published by the State engineering department in 1886, is given a list of 408 artesian wells above Colton, 208 of which were measured and found to be discharging 20.11 second-feet. Nearly all of these wells must have been near San Bernardino and Colton, and all of them must have been in San Bernardino Valley. In 1898 the wells in Santa Ana River Basin proper that supply irrigation water were all flowing wells. In the basin of Lytle Creek the wells are more numerous, and are owned either by individuals or by small corporations. In the town of San Bernardino many artesian wells have been bored for domestic purposes during the last twenty years, which when properly capped furnished water under pressure to many houses. These wells are from 200 to 400 feet deep, and all are driven through layers of clay and gravel. They cost (in 1898), cased, from $1 per lineal foot for 4-inch wells to $2 per lineal foot for 10-inch wells. Some of them furnished as much as 50 miners' inches of water; many of the smaller wells flowed only 3 to 5 miners' inches. During the last four years many of these wells in the city of San Bernardino have ceased to flow, and the discharge of all of them has greatly decreased. These wells afford a very cheap water supply in a locality where the large irrigation companies charge from 5 to 20 cents for a run of 1 miners' inch for twenty-four hours. The area of artesian lands in this basin was 32 square miles in 1897 and 15 square miles in 1900. The irrigation companies have purchased these water-bearing lands. About fifty wells have been sunk in the Lytle Creek Basin. The prices at which the lands are sold vary widely. In August, 1888, the Riverside Water Company paid $25,000 for 40 acres of artesian land in the Warm Creek bottoms. In 1898 the same company bought the water right to 72 acres of excellent artesian lands in the Warm Creek Basin for $50 an acre. The latter price has also been paid in several localities northwest of San Bernardino, between the Lytle Creek Wash and the mesa to the west, which seems to be an extension of the Bunker Hill dike. Pumping plants have been placed in many of the wells, and the supply has thus been increased. The result has been to very largely exhaust the small domestic wells in the city of San Bernardino, and it would now appear that it has become a contest between the owners of the pumping plants as to which shall control the water. It probably is largely a question of pumping out an underground reservoir, and the man who taps it lowest down and has the strongest pump will get the most water. The results of a series of interesting experiments made by Prof. E. W. Hilgard on the wells at the head of the Gage system are given under the description of the water supply of that system. These experiments show that in April, 1889, capping and uncapping 27 adjoining flowing wells did not produce an immediate effect upon the surrounding wells.

The table on pages 84 and 85, showing the effect of opening and closing neighboring artesian wells of the Gage canal system, is also of interest in considering this matter. Observations of 55 wells were made in October, 1892, and while the volume of water increased as more wells were sunk, the aggregate flow is not so great, by 52 per cent, as the sum of the flow of the individual wells when all of the wells except one were closed.

The question whether the water supply in the aggregate can permanently be increased by digging larger wells and pumping is of course a vital one in this connection. An artesian basin is practically an underground reservoir. In this case it is probably refilled during wet years, principally by the winter floods from the surrounding mountain drainage basins and from the return water from irrigation. When the reservoir is filled the basin runs over at its rim and permits larger surface flow. The wells tapping this basin at its lowest depression probably occupy the most favored positions, and those at the upper rim the poorest positions. All draw from the same source, and it is exceedingly difficult to tell which wells are responsible for the draining of those that have failed. It is claimed by the owners of the newer pumping plants that the failure of the wells that ceased to flow in 1898 is due to the series of dry years that preceded.

During the winter of 1897–98 there were very few floods, and even the normal winter flow of the streams was diverted for irrigation purposes. The same condition prevailed in the winters of 1898–99 and 1899–1900. The points of diversion on some of the surrounding streams have been moved higher up into the canyons and tunnels run under the stream beds to bed rock, which tends to decrease the supply of artesian water. While the wells near San Bernardino have failed and the wells in the Lytle Creek Basin have fallen from 19.12 second-feet in June to 13.94 second-feet in September, those in the lower central portion of the main valley have held their own. There is apparently no redress at law for those whose wells have failed, because it is difficult to show any direct stream relation between given groups, and at present the law does not take cognizance of so complex conditions.

The more an artesian basin is drawn upon the greater will be its storage capacity in unfilled voids during the following season; consequently it is possible that the total output from this basin may be permanently increased by tapping it more extensively in the lower levels. As a water supply is controlled absolutely by its minimum production, and as many of the artesian wells about San Bernardino failed during the summer of 1898, it is clear that the limit of artesian supply near the 1,100-foot contour has been reached. The limit of maximum available supply entering the artesian reservoir is governed by the area of the intake, the velocity of the entering water through the intake, and the length of time during which the entering water is available. These conditions are manifestly difficult of determination.

The large number and the great capacity of wells that have been bored in the lower regions of the artesian belt have so nearly approached the carrying capacity of the gravel and have so diminished the pressure at the lower wells that it is difficult to obtain a definite idea of the elevation at which water may be found in the upper regions of the artesian belt. A distinct grade is very noticeable in the crest of all wells when their pressure is considered. The flowing of water from these wells is changed from a condition of hydrostatics to one of hydraulics. It is of interest to note that when a well has an even flow over its casing, so that the height of rising water in the center of the well above the casing can be accurately measured, this height may be considered as the head on a weir, the length being the circumference of the pipe, end contractions being eliminated. The probable error in this computation ordinarily will not exceed 4 per cent.

All of the wells in San Bernardino Valley in the Redlands and San Bernardino quadrangles, irrespective of their size or producing capacities, were visited by the representatives of the Geological Survey during the summer of 1900. The 412 wells in the Redlands quadrangle were inspected by Mr. Louis Mesmer, of Los Angeles, Cal., and the 478 wells in the San Bernardino quadrangle were inspected by Mr. C. J. Roney, observer. The results of their observations are contained in Part II of this report—Water-Supply and Irrigation Paper No. 60.

Artesian wells of the Riverside Water Company.—During the last thirteen years the Riverside Water Company has sunk 70 artesian wells in the Warm Creek Basin east of Colton and San Bernardino, varying in depth from 60 feet to 590 feet and in diameter from 6 inches to 10 inches. The largest well developed by the company previous to 1898 was in the bottom land of Santa Ana River, in lot 2, block 54, San Bernardino Rancho, about 2 miles east of the town of Colton. In the spring of 1898 the managers of the Riverside Water Company decided to increase this development by sinking numerous shallow wells 8 or 9 inches in diameter about 300 feet apart, and close enough to discharge their waters directly into the company's main conduit leading to Warm Creek. For this purpose two hand rigs were procured and 13 wells were sunk, at an average cost of $1.75 per foot, the result being an increase of 282 miners' inches (5.64 second-feet). These wells were bored through alternate layers of sand and clay to water-bearing gravel and bowlders by means of derricks and sand pumps.

The total output of this tract, as measured June 30, 1898, was 554 miners' inches (11.09 second-feet), 79 miners' inches (1.58 second-feet) of which goes to the Ward & Warren ditch, the remaining 445 miners' inches (9.51 second-feet) being delivered into Warm Creek just above the Riverside Water Company's upper canal diversion.

One of the largest wells was sunk on the south side of Warm Creek in lot 11, block 51, San Bernardino Rancho. It was commenced in January, 1898, and was completed in February, 1898, the total cost being $1,100. It is 590 feet deep, has a 10-inch casing of No. 10 iron, B. W. G. The water all comes from the bottom, and when completed the well flowed 120 miners' inches (2.4 second-feet). During the summer of 1898 a basin was placed around this well and connected by a pipe to the main channel of Warm Creek. Twelve feet of pipe was cut off from the top of the well to make it correspond with the bed of Warm Creek. This increased the flow to 150 miners' inches (3.0 second-feet). The cost of water from this well was $7.33 per miners' inch. There are seven wells on this tract, the aggregate flow of which in August, 1898, was 340 miners' inches (6.8 second-feet). This water is carried in a vitrified clay pipe direct to the natural channel of Warm Creek, with whose waters it mingles, and on its course toward Riverside is allowed to pass through the various head gates of the irrigating ditches and is not deducted from the other stream measured at the Riverside Water Company's upper canal.

During the months of March and April, 1900, the Riverside Water Company sunk three wells, to an average depth of 552 feet, in block 44 of the San Bernardino Rancho. The water all comes from the extreme bottom of these wells. The pipes are 10 inches in diameter, of No. 12 iron, B.W.G. On May 19, 1900, the total flow of these three wells was 420 miners' inches (8.40 second-feet).

Martius well.—The Martius well, at Tippecanoe station, on the Riverside Motor Railroad, may be taken as a type of numerous pumped dug wells. It was excavated in 1893, is 20 feet deep and 12 feet in diameter. The wall is of dried brick laid on a wooden toe of crib work. Mr. Martius says that at first he used a steam engine to run the pump, but the cost was $3 for a day of ten hours. He now (1900) uses a 9-horsepower Webber gasoline engine, and the cost of pumping is $1.30 a day, or at the rate of 1.44 cents per horsepower per hour. A centrifugal pump is used, and 15 miners' inches (0.30 second-foot) of water are raised. This water is used for irrigation and street sprinkling. Ordinarily the cost of gasoline for power is about 33 per cent less than this amount.

PUMPING PLANTS.

One feature of special interest in the pumping plants in this valley is the use of electric motors for developing power. The mountain streams enter the valley on very heavy grades, and when diverted from their canyons into canals they obtain as much as 400 or 500 feet head in 4 or 5 miles length of conduit. The water is then dropped through large steel pressure pipes to nozzles which play on impulse water wheels of the Pelton, Knight, or Tuthill make.[a] These wheels have velocities so high that they can be coupled on the same shaft with the dynamos, thus eliminating loss by gearing. By means of transformers the voltage of the current to be transmitted is "stepped up" to from 20,000 to 40,000 volts, i. e., it is driven over the transmission line under very heavy pressure to the point where it is intended to be used. It is then "stepped down" to a low voltage for the motor which drives the pump. The 3-phase motor is the machine usually employed for this work. Numerous plants of this class have been in service in this locality for the last two years. They give little or no trouble, and are easily started under a load. One attendant can watch three or four of these plants when they are situated within distances of

[a] For description of some of these power plants, see Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. IV.

from a half to a fourth of a mile of one another. The 20-horsepower motor and the centrifugal pump is the most popular plant. The motor is spherical in shape and only 4 feet in diameter. The amount of current used for power is metered and paid for at meter rates. Single or 2-phase motors have been tried for this work, but difficulty is found in starting them under a load. A secondary small machine called an "exciter" has been used in starting them, but even then trouble is experienced. The method of obtaining power by the simple turning of a switch, without the usual accompaniments of dirt and heat and with the little attendance that is required by a plant of this character, is ideal. It is a great improvement over the gas engine. Motors running horizontally, attached to the vertical shaft of the centrifugal pump, are now (1900) made, and give increased efficiency.

Descriptions of the pumping plants located east of Mount Vernon avenue, San Bernardino, in the Lytle Creek bottom, are given below. It is difficult to determine the volume of water pumped, as the pumps do not run with uniform speed and usually discharge into pipe lines. The statements of owners as to volumes discharged have usually been accepted, and while the amounts they give are probably somewhat in excess of the average flow, this will tend to compensate for a number of minor flowing wells or windmill plants not visited or considered in this connection.

East Riverside Pumping Company, Raynor ranch.—In June, 1898, the East Riverside Pumping Company was using at one of its wells a General Electric 20-horsepower 3-phase motor under 550 volts pressure. The power is measured by meter and costs (1898) 1 cent per hour per horsepower for 20-hour days, or $6 a month. The power is furnished by the Redlands Electric Light and Power Company and is developed at the drop in the Mill Creek Canyon. In 1898 the electric motor was consuming 16 horsepower and was lifting 85 miners' inches of water (1.7 second-feet) 28 feet high with a Byron-Jackson No. 6 centrifugal pump discharging through a 6-inch pipe. The total output from the plant of this company is 221 miners' inches (4.43 second-feet), as determined by weir measurement in September, 1898. The water is carried through the Vivienda pipe line to the East Riverside irrigation district.

City of Colton pumping plant.—The pumping plant of the city of Colton furnishes water for irrigation and domestic use at and near that city. Two of the wells (Nos. 2 and 3) are located on what is known as the Barnhill and Lamb tract, block 25, San Bernardino Rancho. The third well is on the south line of First street. All are in the Lytle Creek Basin. These wells are locally known by numbers.

Well No. 1 has a General Electric 20-horsepower 3-phase motor applying 14 horsepower in running a No. 6 Byron-Jackson vertical centrifugal pump, and on June 27, 1898, it was lifting 121 miners' inches (2.42 second-feet) 35 feet high per day of 20 hours, which is equivalent to 101 miners' inches (2.02 second-feet) for a 24-hour day. This is a cased well.

Well No. 2 is a 10-inch cased well. A General Electric 20-horsepower 3-phase motor of 550 volts capacity is running a No. 10 Byron-Jackson horizontal centrifugal pump, and in June, 1898, was said to be lifting 60 miners' inches (1.2 second-feet) of water 34 feet high per day of 20 hours, equivalent to 50 miners' inches (1 second-foot) for a 24-hour day. On September 22, 1898, this plant was furnishing 31 miners' inches (0.62 second-foot), weir measurement.

Well No. 3 is a 10-inch cased well on the Lamb tract. A 10-horsepower 3-phase electric motor with a capacity of 550 volts is running a Byron-Jackson horizontal centrifugal pump which on June 27, 1898, was raising 50 miners' inches (1 second-foot) of water 35 feet high per day of 20 hours, equivalent to 42 miners' inches (0.83 second-foot) for a 24-hour day. This plant is running with remarkable smoothness, there being no jar and scarcely any appreciable sound from either pump or motor.

Well No. 4 supplies the domestic service of Colton. It is of special interest owing to the grouping of the wells that are operated from one centrifugal pump. The pump is 16 feet below the surface of the ground, in a pit. The suction pipe from the pump is

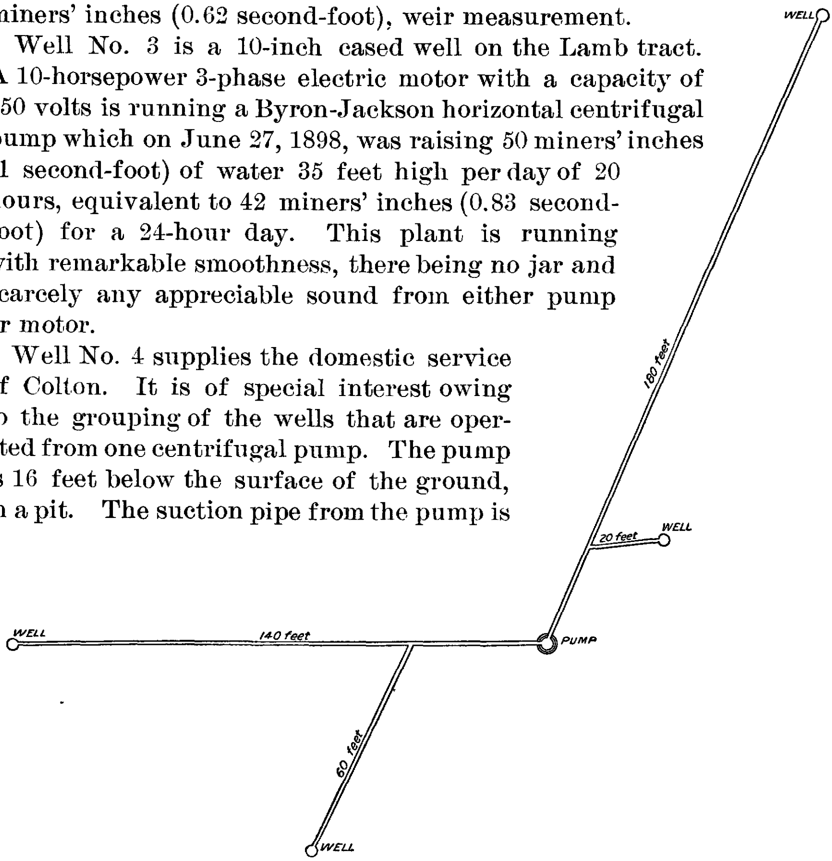
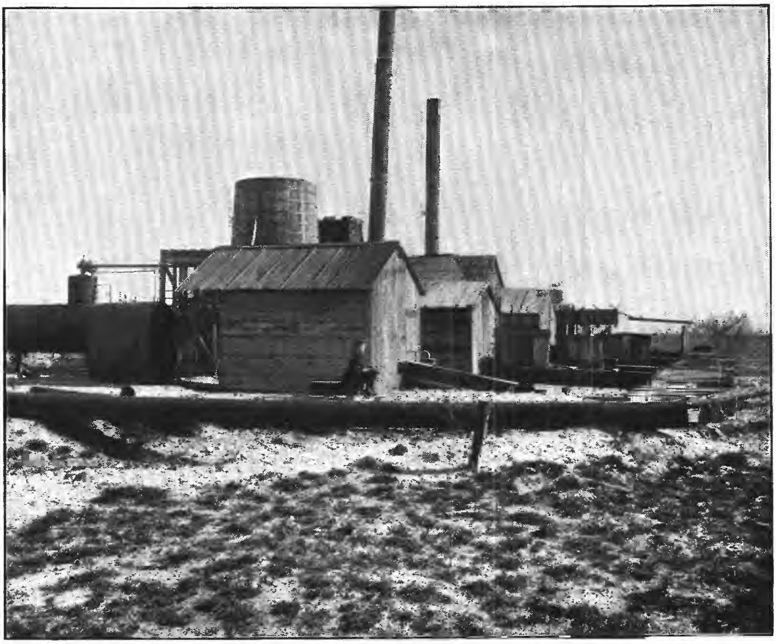


FIG. 1.—Plan of city of Colton pumping plant, showing group of wells operated by one centrifugal pump.

led to four cased wells. A deep trench was dug for these pipes. Fig. 1 shows the location of the wells and pump. This plant is located northwest of the Santa Fe Railroad, at the crossing of Lytle Creek. The pump was originally situated on the surface of the ground, but during the summer of 1898 it was lowered 16 feet, all of the connections of the wells being lowered also. The pump is a No. 8 Byron-Jackson vertical centrifugal, and is operated by a General Electric 20-horsepower 3-phase motor, which is developing 24 horsepower. On June 27, 1898,



A. PUMPING PLANT NEAR EL MONTE.

B. AIR-PUMPING PLANT NEAR COLTON.

110 miners' inches (2.2 second-feet) of water were being pumped, and on September 22, 1898, 150 miners' inches (3 second-feet), per day of 20 hours. The wells are all 10-inch cased wells. The pumps were lowered because of the falling of the water plane. The plant is entirely successful. A plant of similar design is located near Exeter, Cal., in the bottoms of Kaweah River.

Pomeroy & Marble wells.—The pumping plant of the Colton Terrace Citrus Land Company is at the corner of Mount Vernon avenue and Mill street, San Bernardino. A No. 4 Byron-Jackson horizontal centrifugal pump is run by an 8-horsepower gasoline engine. There is one well (cased) 100 feet deep, from which on June 18, 1898, 40 miners' inches (0.80 second-foot) were being lifted 32 feet. On that date there was also an artesian well furnishing water to this system from this locality. The latter well was flowing 40 miners' inches (0.8 second-foot).

Colton Terrace Orange Land and Water Company.—The wells of this company are four in number and are from 200 to 300 feet deep. They are 7-inch cased wells and are about 150 feet apart. This plant is of special interest, as the water is lifted by an air system. A 20-horsepower single-phase electric motor costing $700 was originally used to operate a Stillwell-Bierce air compressor. The electric motor was a failure and it was replaced by steam. From the air compressor the air is conveyed through a reservoir to a distributing pipe system. Thirteen horsepower is now being expended; but it is proposed to increase the number of wells, when more power will be required. The wells are bored and cased and a ¾-inch air pipe is run down to almost the bottom of each well. A stopcock is placed near each well to regulate the volume of air entering it. (See Pl. VIII, *B*.) The water is raised by the expansion of the air in the lower portion of the well pipe. The feature of special value in the system is that the lifting force can be indefinitely distributed to the numerous wells in the various localities. The illustration (Pl. VIII, *B*) shows a well into which an excessive amount of air has been admitted. Ordinarily just enough air is passed to produce a flow about 2 or 3 inches above the top of the well. The water stands naturally at a level of 20 feet below the surface. On June 30, 1898, the wells were producing 98.5 miners' inches (1.97 second-feet). This system of pumping does not as a rule give a working efficiency of more than 35 per cent and is proving a disappointment in several localities. In 1900 this method of pumping had been discontinued at this plant.

In Pl. VIII, *A*, is shown a pumping plant near El Monte. The water supply is from five cased wells in the gravel beds below the mouth of San Gabriel Canyon. The output is approximately 500 miners' inches.

Bloomington pumping plants.—The water flowing in the Bloomington flume is a combination of 100 miners' inches (2 second-feet) of

Lytle Creek water for the domestic supply of the city of San Bernardino and the output of three pumping plants in the Lytle Creek Basin. The irrigation water is being used near Bloomington, on the Citrus Belt irrigation district. The pumping plants are—

No. 1: A 20-horsepower gasoline engine expending three-fifths of its indicated power is pumping from a 10-inch cased well 400 feet deep. A No. 5 Byron-Jackson centrifugal pump is used, which on September 12, 1898, was lifting 56 miners' inches (1.12 second-feet).

No. 2: A 20-horsepower Daniel Best gasoline engine using 16 horsepower is running a Byron-Jackson centrifugal pump which lifts from a 10-inch cased well 469 feet deep 100 miners' inches (2 second-feet) of water. The water is raised 22 feet. On June 18, 1898, the plant was pumping 115 miners' inches (2.3 second-feet) and on September 12, 1898, it was pumping 100 miners' inches (2 second-feet).

A Pelton wheel is run from 100 miners' inches of water, which is dropped 80 feet from the Lytle Creek Improvement Company's canal, about 1½ miles north of the base line at the west bank of the Lytle Creek Wash, and develops 24 horsepower. On June 18, 1898, 110 miners' inches (2.2 second-feet) of water were being raised 46 feet from two wells and conveyed to the Citrus Belt irrigation district, near Bloomington.

Minor pumping plants.—Johnson & Hubbard have two 10-inch cased wells, one 190 and the other 260 feet deep. In June, 1898, a 3-phase electric motor developing 26 horsepower and a Byron-Jackson centrifugal pump were used to lift 120 miners' inches (2.4 second-feet) of water 40 feet high. The well furnishing the supply is located near the corner of Mill street and Mount Vernon avenue, San Bernardino. This water irrigates orange land north of Colton. The plant is used at intervals of a few days.

A well 2 miles northeast of San Bernardino is operated by an electric motor and a centrifugal pump. On September 9, 1898, it was discharging 25 miners' inches (0.50 second-foot). The water is being used on the Chinese gardens at the point of development. This well is pumped from only at intervals of about ten days. It is at the corner of the base line and Waterman avenue.

There are several other small pumping plants using water a few days each month which are not described here, because they are of relatively small importance.

STREAMS TRIBUTARY TO SAN BERNARDINO VALLEY ABOVE AND BELOW SLOVER MOUNTAIN.

For the purpose of making comparisons between the surface waters entering San Bernardino Valley above and below Slover Mountain, the following table of discharge measurements made in the summer of 1898 is introduced. It must be remembered that the summer of 1898 was preceded by a series of unusually dry years, and that the streams of the State were then at an extremely low stage. Mill Creek and Santa Ana River were visited by local storms during the latter part of August, and the flow from the Santa Ana had been specially reenforced by the water discharged from the Bear Valley reservoir, which regulates the flow from 54 out of 188 square miles of its drainage basin. The flow of Plunge Creek has been reenforced by development works in the bed of its canyon.

Discharge measurements of mountain streams in San Bernardino Valley above Slover Mountain, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
San Timoteo Creek	Above Brookside[a]	June 12	1.00	September 8	0.50
Mill Creek	Crafton divide	do	18.10	do	13.07
Do	MacIntosh development.	do	.28	do	.28
Santa Ana River	At Warmsprings (including Bolen tunnel, 1.24).	do	40.30	do	37.91
Plunge Creek	At headworks	do	2.26	September 9	.20
City Creek	do	June 11	3.03	do	.07
East Twin Creek	Canal and development water.	do	2.05	do	.73
West Twin Creek	Headworks and Hot Springs.	do	2.13	do	.38
Lytle Creek	Anglo-American Canaigre Co.	June 10	10.73	August 27	10.01
Total		June	79.88	September	63.15
Rising or return water		June	71.25	September	78.31
Discharge from wells		do	66.86	do	66.38
Total		June	138.11	September	144.69
Deduct flow from surrounding mountain streams.		do	79.88	do	63.15
Excess of return water		June	58.23	September	81.54

[a] Estimated.

Discharge measurements of mountain streams in San Bernardino Valley below Slover Mountain, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
San Antonio Creek	Division weir	June 2	6.43	August 26	5.18
Cucamonga Creek	In canyon	do	[a]2.08	do	1.04
Deer Creek	At headworks	do	[a]1.40	do	.70
Coldwater Creek	In canyon	July 1	.46	July 31	.16
Temescal artesian wells	do	do	7.00	August 30	7.00
Temescal Creek	Below lake	do	3.75	August —	3.00
Total			21.12		17.08

[a] Estimated.

Return waters in San Bernardino Valley below Slover Mountain and above Riverside Narrows, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
Lower Riverside canal	Near headworks at E. Riverside.	June 17	10.27	August 27	8.50
Spring Brook	South of Rubidoux Mountain.	June 19	2.92	August 28	1.27
Evans ditch	Right bank, ½ mile below bridge.	do	5.68	do	4.87
Rubidoux canal	Right bank, 1 mile south of county line.	do	8.94	August 27	8.50
Santa Ana River	4 miles below Riverside.	June 20	47.63	August 29	39.05
Total		June	75.44	August	62.19

Return waters in San Bernardino Valley between Riverside Narrows and the lower Santa Ana Narrows below Rincon, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
Small ditch	Right bank, 2 miles below Riverside Narrows.	June 20	3.75	August	[a] 3.75
Griffiths ditch	Right bank, sec. 28, T. 2 S., R. 6 W.	do	9.99	do	[a] 9.99
Townsend ditch	Left bank, sec. 28, T. 3 S., R. 7 W.	do	4.80	do	[a] 4.80
Small canal	Left bank, 2 miles below Rincon.	June 21	3.18	August 29	4.15
Cucamonga developments	At Red Hills	June	[a] 6.80	September 9	[b] 6.80
Santa Ana River	At lower narrows below Rincon.	June 21	79.81	August 29	62.67
	Total	June	108.33	August	92.16
Do	At Riverside Narrows.	do	47.63	do	39.05
Return water between Riverside and Rincon Narrows.		do	60.70	do	53.11
Total returning between Slover Mountain and Riverside Narrows.			75.44		62.19
Total returning between Slover Mountain and Rincon.			136.14		115.30
Surrounding mountain streams between Slover Mountain and Rincon.			21.12		17.08
Total excess of return water between Slover Mountain and Rincon.			115.02		98.22
Excess above Slover Mountain.			58.23		81.54
Grand total excess of return water in San Bernardino Valley above Rincon.			173.25		179.76

[a] Estimated. [b] Includes 1 second-foot developed at mouth of Cucamonga Canyon.

In considering the volume of return water at Riverside Narrows in the summer of 1898, as compared with the amount of irrigation water, the water that is applied for irrigation below the Colton or Bunker Hill dike should be included. A divide occurs about 1 mile west of Arlington, to the west of which the drainage is into Temescal Creek and not into Santa Ana River above Riverside Narrows. A portion of the water of the Riverside Water Company and the Gage canal—a varying quantity, probably 1,000 miners' inches in average volume—is applied to alfalfa fields and orange lands south of this divide. It is quite possible, however, that a portion of the water applied to the higher lands north of the divide and southwest of Riverside finds its way to the north of the divide.

Discharge measurements of Santa Ana River.

Date.	Point of measurement.	Discharge.	
		Miners' in.	*Sec.-feet.*
1888.			
July 16	Jurupa Narrows	505.0	10.10
July 17	do	525.0	10.50
Do	Auburndale bridge	728.5	14.57
August 21	Jurupa Narrows	425.5	8.51
August 22	Auburndale bridge	664.5	13.29
September 14	Jurupa Narrows	474.0	9.48
September 15	Auburndale bridge	709.5	14.19
1889.			
August 13	Jurupa Narrows	550.0	11.00
August 14	Auburndale bridge	777.5	15.55
September 27	Jurupa Narrows	560.0	11.20
September 28	Auburndale bridge	832.5	16.65
1890.			
August 12	Jurupa Narrows	937.9	18.76
August 13	Auburndale bridge	1,112.5	22.25
1891.			
September 9	Jurupa Narrows	775.0	15.50
September 10	Auburndale bridge	1,281.5	25.63
1892.			
September 10	Jurupa Narrows	1,469.1	29.38
September 11	Auburndale bridge	2,171.4	43.43
1899.			
August 30	do	2,655.0	53.10
September 12	do	2,992.0	59.83
1900.			
July 28	do	2,722.0	54.45
October 5	do	3,487.0	69.74

Of the foregoing measurements those for 1888 to 1892 were made by F. C. Finkle while he was chief engineer of the Jurupa Land and Water Company and the Stearns Ranchos Company. These measurements show the gradual increase, despite the drought, in volume of flow of the river at this point, due to the extension of irrigation on lands above.

Estimated monthly discharge of Santa Ana River and Santa Ana canal 2 miles above mouth of its canyon above Redlands, near Warmsprings.

[Drainage area, 188 square miles.]

Month.		Discharge in second-feet. Maximum.	Minimum.	Mean.	Total in acre-feet.	Run-off. Depth in inches.	Second-feet per square mile.
1896.							
September		91	41	69	4,124	0.41	0.37
October		186	54	71	4,372	.44	.38
November		56	34	37	2,148	.21	.19
December		48	37	39	2,435	.24	.21
1897.							
January		104	35	68	4,179	.41	.36
February		585	77	185	10,282	1.02	.98
March		465	70	124	7,014	.75	.66
April		190	113	150	8,899	.88	.79
May		113	48	76	4,690	.46	.40
June		86	60	79	4,723	.47	.42
July		102	70	83	5,077	.50	.44
August		100	54	75	4,628	.46	.40
The year		585	35	88	62,571	6.25	.47
1897.							
September		81	58	67	3,968	.39	.35
October		270	45	54	3,347	.33	.29
November		59	40	45	2,678	.27	.24
December		38	29	33	2,040	.21	.18
1898.							
January		67	42	49	2,987	.30	.26
February		86	43	48	2,688	.27	.26
March		51	36	40	2,448	.24	.21
April		43	37	39	2,333	23	.21
May		157	34	61	3,727	.37	.32
June		62	40	48	2,840	.28	.25
July		58	38	43	2,625	.26	.23
August		61	36	43	2,653	.26	.23
The year		270	29	48	34,334	3.41	.25
1898.							
September	River	45.0	28.0	38.0	2,223	0.22	0.20
	Canal			2.0			
October	River	36.0	19.0	26.0	1,581	.16	.14
November	do	34.0	18.0	22.0	1,285	.13	.12
December	do	28.0	22.0	22.0	1,364	.14	.12
1899.							
January	River	34.0	21.5	25.9	1,593	.16	.14
	Canal			2.0			
February	River	34.0	26.5	27.3	1,516	.15	.15
	Canal			4.0			
March	River	48.0	24.0	31.6	1,943	.19	.17
	Canal			7.0			
April	River	34.0	21.5	24.5	1,458	.14	.13
	Canal			5.0			
May	River	26.8	19.0	22.2	1,365	.14	.12
	Canal			2.0			
June	River	34.0	19.0	22.1	1,315	.13	.12
	Canal			0.0			
July	River	28.5	19.0	22.3	1,371	.14	.12
	Canal			0.0			
August	River	19.0	11.0	12.7	781	.08	.07
	Canal			0.0			
The year		48.0	11.0	24.7	17,795	1.78	.17
1899.							
September		12	10	12	690	0.07	0.06
October		19	12	17	1,015	.10	.09
November		49	17	21	1,268	.13	.11
December		36	18	23	1,427	.14	.12
1900.							
January		36	19	23	1,414	.14	.12
February		23	20	22	1,222	.12	.12
March		28	20	23	1,414	.14	.12
April		43	19	25	1,488	.14	.13
May		250	20	57	3,505	.35	.30
June		25	19	22	1,309	.13	.12
July		25	11	19	1,168	.12	.10
August		12	9	11	676	.07	.06
The year		250	9	23	16,596	1.65	.12

Estimated monthly discharge of Santa Ana River and Santa Ana canal 2 miles above mouth of its canyon above Redlands, near Warmsprings—Continued.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1900.						
September	16	11	12	714	.07	.06
October	16	12	14	861	.08	.07
November	1,564	14	107	6,367	.63	.57
December	31	25	28	1,722	.17	.15
1901.						
January	600	31	78	4,796	.47	.41
February	540	48	194	10,774	1.07	1.03
March	114	45	68	4,181	.41	.36
April	107	39	43	2,559	.26	.23
May	68	35	42	2,582	.25	.22
June	44	30	37	2,202	.22	.20
July	42	34	38	2,337	.23	.20
August	200	31	50	3,074	.31	.27
The year	1,564	11	59	42,169	4.17	.31

Drainage areas of Santa Ana River above Rincon.

	Square miles.
South of Mill Creek	10.0
Mill Creek	46.2
Santa Ana River	208.2
Plunge Creek	17.1
Reservoir between Plunge and City creeks	2.7
City Creek	21.6
Drainage between City and Sand creeks	1.9
Sand Creek	3.2
Little Sand Creek	1.6
Drainage between Little Sand Creek and East Twin Creek	2.5
East Twin Creek	9.2
West Twin Creek	5.3
Drainage between West Twin Creek and Devils Canyon	4.0
Devils Canyon	7.1
Cajon Pass Basin	88.0
Sycamore Flat	2.8
Lytle Creek	51.9
Total mountain drainage above Colton	483.3
Crafton Hills and San Timoteo Basin	135.0
San Bernardino valley lands above Colton	132.0
Total drainage area above Colton	750.3

Mountain drainage above Rincon and below Colton.

	Square miles.
Drainage north of Grapeland	2.7
San Savain Canyon	2.4
Morse Canyon	1.9
East Etiwanda Canyon	3.2
Day Canyon	6.9
Deer Canyon	4.2
Drainage between Deer Canyon and Cucamonga Canyon	3.7
Cucamonga Canyon	11.0

	Square miles.
Drainage between Cucamonga Canyon and San Antonio Canyon	1.2
San Antonio Canyon	26.7
Thompson Creek	5.5
Liveoak Creek	2.7
Total in mountains	72.1
Foothills around Riverside	62.0
Flat valley land between Rincon and Colton	393.0
Temescal Creek hills below Elsinore Lake	163.1
Chino Creek foothills	22.5

Summary of drainage areas.

	Square miles.	
Mountains above Colton	483.3	
Mountains above Rincon and below Colton	72.1	
Total in mountains above Rincon		555.4
Hills above Colton	135.0	
Hills around Riverside	62.0	
Hills of Temescal Creek below Lake Elsinore	163.1	
Hills of Chino Creek	22.5	
Total in hills above Rincon		382.6
Valley above Colton	132.0	
Valley below Colton and above Rincon	393.0	
Total in valley above Rincon		525.0
Total drainage area above Rincon		1,463.0

The precipitation for the seasons 1896–97 and 1900–1901 was about normal. Each year, however, was preceded by droughts. The discharge in second-feet per square mile of drainage basin of Santa Ana River proper, as given in preceding tables, was 0.45 second-foot per square mile in 1896–97, and 0.31 second-foot in 1900–1901. An estimated discharge for normal years of 0.40 second-foot per square mile from the mountainous portion of the basin above Colton is believed to be conservative. As the percentage of run-off increases with the depth of rainfall, the average annual discharge is greater than the run-off in years of average rainfall. The Bear Valley reservoir, which regulates the discharge from a portion of the basin of Santa Ana River, was completely emptied during both of the years mentioned, and consequently does not affect the totals. A portion of the larger floods are known to pass Colton, and are permanently lost so far as the gravel beds above Colton are concerned. Little surface run-off would occur from the flat and sandy valley lands and hills, but certainly an appreciable amount of the rainfall would sink into the ground and increase the underground supply. The latter supply is believed to be sufficient to offset the loss due to a portion of the larger floods passing the Colton dike unabsorbed. It is not claimed that these quantities are capable of exact determination. Many and expensive observations would be necessary to ascertain this, but it is thought that an estimate based upon existing data and experiences gained elsewhere will be of interest on this important subject. While the run-off per square mile of the Cajon Pass Basin is known to be less than that of the Santa Ana proper, that of Mill Creek and Lytle Creek is greater, and the Santa Ana Basin is probably typical of the average. The estimated annual run-off, in second-feet per square mile, from the 483 square miles of mountain drainage basins tributary to San Bernardino Valley above Colton, assuming the run-off to be 0.40 second-foot per square mile, is 193.3 second-feet. During average years probably 50 per cent of this is diverted for irrigation at the mouths of the mountain canyons, and half of the water applied for irrigation may be assumed to be lost by evaporation, the remainder sinking into the ground. Thus one-fourth of the discharge from the mountains may be considered as permanently lost during average years, leaving a net remainder of 75 per cent, or 145 second-feet, as a reasonable estimated annual recharge of these gravels.

In June, 1898, the total seepage and return water entering San Bernardino Valley above Rincon was 274.25 second-feet, as shown in the foregoing tables, and at the same time the aggregate flow from the surrounding mountain drainage basins was 101 second-feet, making a total of 375.25 second-feet. The develcped water around Pomona (amount not known), however, is not included, and portions of the return water obtained near Colton and used around Riverside doubtiess return to the river above Rincon. It is difficult, however, to analyze the situation further than has been done. Despite the recent dry years the increased flow of the river at Auburndale bridge is in all probability due to increased irrigation in the valley, particularly near Riverside, and is especially significant.

The Cucamonga Water Company derives its water from the Red Hills. The company supplies Cucamonga proper, also North Ontario, and irrigates about 5,000 acres of citrus fruits. In August, 1898, there were in addition 52 miners' inches (1.04 second-feet) of water developed at the mouth of Cucamonga Canyon. The Red Hills are so named from the red clay occurring there, which forms a dike across the sand and gravel drainage lines of Cucamonga Creek. This forces the underground water to the surface, where it appears in springs and cienagas. There is an aggregate length ot 8,000 feet of tunnels in this water-bearing land. There are 36 miles of 6-inch drain tiles in the distribution system.

The following is a compilation of all available measurements:

Discharge measurements, in miners' inches, of cienagas and water developments at Red Hills, near Cucamonga.

EAST SIDE.

Date.	Observer.	Creek div. box, 30-inch line.	Div. box No. 1, 16-inch line and Y tunnel (built 1886–87).	China cienaga.	Lone Star spring or tunnel.	Y tunnel (built prior to 1886).	Cienaga below tunnel No. 1.	Total without Lone Star.	Total.
Sept. 26, 1885	Wm. M. Fitzhugh	225.36	....	51.73	[a] 2.02	9.61 6.61 16.22	....	293.31	295.33
Nov. 30, 1886	J. P. Culver	261.43	64.67	11.46	2.02	....	....	337.56	339.57
July 24, 1887	F. Eaton	147.50	169.50	[a] 10.00	[a] 2.00	163.00	....	327.00	329.00
July 13, 1888	J. P. Culver	155.78	183.61	18.10	[b] 13.59	138.62	46.43	357.49	371.08
July 13, 1889	E. T. Wright	184.58	163.57	13.27	9.78	136.23	48.35	361.42	371.20
July 14, 1890	do	260.03	228.53	17.32	10.85	156.01	72.52	505.88	516.73
Do	J. P. Culver	266.82	238.04	18.50	11.25	165.55	72.49	523.36	534.61
July 14, 1893	E. T. Wright	....	....	....	....	152.42	....	....	....
Sept. 15, 1894	do	160.31	182.84	13.14	[a] 8.00	141.10	41.74	356.29	364.29
June 12, 1895	do	198.53	154.87	21.00	[a] 7.00	[a] 110.60	[a] 44 27	374.40	381.40
Aug. 20, 1896	F. E. Trask	132.40	137.90	11.25	[a] 7.00	....	....	281.55	288.55
Aug. 10, 1897	do	104.90	120.10	10.50	[a c] 9.42	....	....	235.50	244.92
Aug. 5, 1897	N. W. Stowell	....	....	....	9.42	....	....	....	....
Aug. 13, 1898	F. E. Trask	76.68	95.91	7.84	[d] 47.00	....	....	180.43	227.43
Apr. 1, 1899	N. W. Stowell	107.25	98.20	....	....	....	....	205.45	....
Do	Newman and Finkle	107.25	98.20	[a] 5.00	[e] 35.60	72.60	....	210.45	246.05
Aug. 21, 1899	E. T. Wright	[f] 91.58	80.95	....	([g])	56.17	24.78	172.53	[h] 199.53 247.53
Feb. 3 and 5, 1900.	Newman, Trask, and Finkle.	[f] 97.06	77.22	....	17.06	54.88	....	174.28	191.34

[a] Estimated.
[b] Tunnel.
[c] Extent of tunnel begun August 11.
[d] Measurement by N. W. Stowell.
[e] March 15.
[f] Including China cienaga.
[g] Flow, 27.00; pumped, 75.00.
[h] Flow.

Discharge measurements, in miners' inches, of cienagas and water developments at Red Hills—Continued.

WEST SIDE.

Date.	Observer.	Spring northwest of tunnel No. 2, portal.	West of cienaga D.	Picnic spring, cienaga C.	Artesian wells Nos. 1 and 2.	Tiburcio spring.	Tunnel No. 2, on 90-acre tract.	China garden.	Stowell wells and tunnel above 90-acre tract.	Rain previous season.	Total on 90-acre tract.	Grand total for Red Hills.
Sept. 26, 1885	Wm. M. Fitzhugh.	56.47	45.27	[a]9.00	....	[a]1.00	......	......	.....	10.81	111.74	406.07
Nov. 30, 1886	J. P. Culver	9.50	5.70 97.80 .90 104.40	18.40	....	2.16	.....	([b])	.....	21.83	134.46	474.03
July 24, 1887	F. Eaton	13.67	31.90	10.00	Fall '97	[a]1.00	......	[a]16.76	.....	14.50	73.33	402.33
July 13, 1888	J. P. Culver	3.14	38.89	5.38	15.14	1.59	[c]17.70	16.76	.....	17.76	98.60	469.68
July 13, 1889	E. T. Wright	3.94	40.53	17.33	15.14	1.81	54.02	[a]16.76	.....	20.97	149.53	520.73
July 14, 1890	.....do	3.08	71.98	30.53	13.98	.92	[d]73.82	[a]16.76	.....	25.45	211.07	727.80
Do	J. P. Culver	3.14	81.78	31.47	14.29	2.38	75.42	[a]16.76	.....	.....	225.24	759.85
June 29, 1893	E. T. Wright	.....	......	13.29	....	.....	......	......	.....	19.82	......	....
July 14, 1893	.....do	.....	......	......	....	.....	36.45	......	.....	.....	......	....
Sept. 15, 1894	.....do	.....	......	......	....	.....	......	......	.....	8.13	......	....
June 12, 1895	.....do	.....	......	......	....	.....	......	......	.....	20.98	......	.....
June 14, 1896	N. W. Stowell ..	.00	22.00	1.00	23.00	.....	[e]18.00	......	.00	.....	64.00	352.55
Aug. 20, 1896	F. E. Trask	.....	......	......	....	.....	......	......	.....	8.11	......	
Mar. 2, 1897	N. W. Stowell ..	.....	......	......	....	.....	......	......	46.00	.....	......	....
Aug. 10, 1897	F. E. Trask	.00	......	......	....	.....	......	......	.....	16.74	.....	
Aug. 5, 1897	N. W. Stowell ..	.00	20.00 7.00 27.00	[a].50	[f]20.25	.00	41.40	.00	.....	.....	89.15	334.07
Aug. 13, 1898	F. E. Trask	.00	......	......	....	.....	......	......	.....	8.24	......	
Aug. 14, 1898	N. W. Stowell ..	.00	[g]24.00	[a].50	[h]13.00	.00	26.00	.00	.....	.....	63.50	290.93
Apr. 1, 1899	.....do	.....	......	......	....	.....	......	......	.....	7.49	......	....
Do	Newman and Finkle.	.00	[i]15.49	......	7.90	.....	......	......	.....	.....	......	....
Aug. 21, 1899	E. T. Wright	.00	......	......	....	.....	......	......	.....	.....	......	
Aug. 25, 1899	E. T. Wright and F. C. Finkle.	....	3.13	......	2.68	.....	61.80	......	92.40	.....	67.61	267.14
Feb. 3 and 5, 1900.	Newman, Trask and Finkle.	.00	3.91	......	1.45	.....	......	......	.....	.....	......	252.81
Feb. 11, 1900	Trask and Finkle.	.....	3.81	.56	1.20	.....	55.90	......	76.25	.....	61.47	

[a] Estimated.
[b] China garden included in cienaga D.
[c] Construction begun in January, 1888.
[d] Length, 2,600 feet.
[e] Caved in.
[f] August 4, well No. 2 cut.
[g] June 12, not pumped.
[h] July 24, not pumped.
[i] March 15.

The following diagram, fig. 2, shows the relation that exists between the rainfall and developed water at Red Hills:

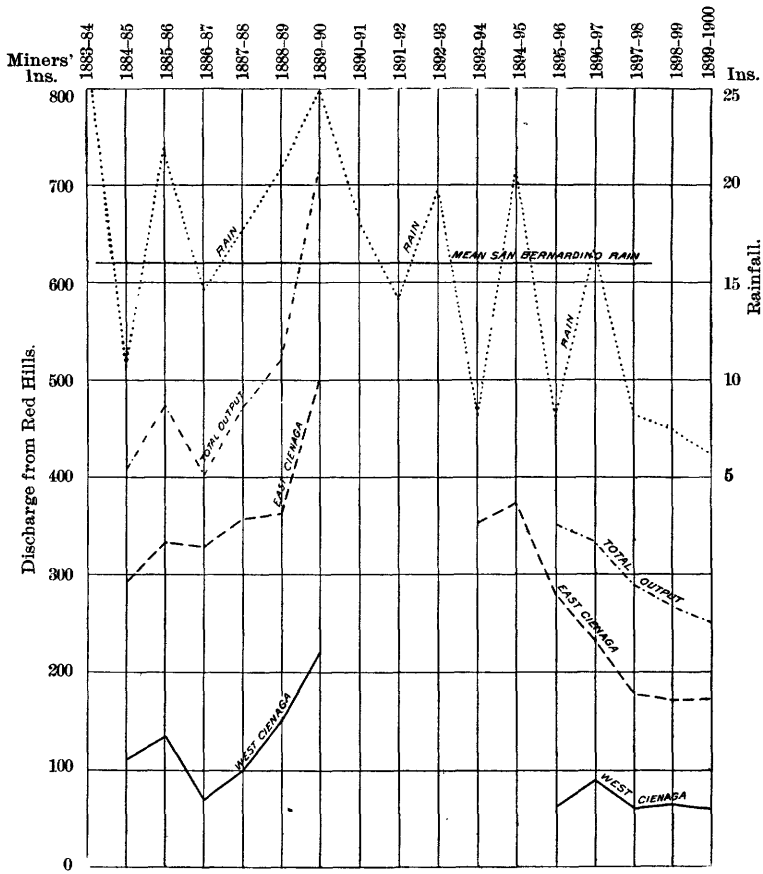


FIG. 2.—Diagram showing relation of rainfall to developed water at Red Hills. Dotted line shows rainfall, in inches, as measured at San Bernardino; dot-and-dash line shows discharge, in miners' inches, from all of the developments at Red Hills, exclusive of the Stowell wells; dash line shows discharge, in miners inches, of east cienagas and Y tunnel, exclusive of Lone Star; heavy solid line at bottom shows discharge, in miners' inches, from 90-acre tract at west end of hill, exclusive of the Stowell wells.

From 1888 to 1900 many lineal feet of tunnels were run and numerous wells were sunk at the Red Hills for new water supplies, but in spite of this development the amount of water available materially diminished—from 406 miners' inches to 253 miners' inches. Although this decrease is influenced by the diminished rainfall during the period, it is improbable that all of the work performed resulted in much if any permanent benefit to the irrigators. The gravel beds above the Red Hills are much smaller than those above Colton, and consequently are more quickly drawn down. The chief question in situations of this kind is how large a water supply can be counted upon to recharge the underground reservoir. This can be determined by measuring the area of the tributary drainage basin from the topographic atlas sheets of the United States Geological Survey. To this area should be applied the mean annual run-off. In this case the mean annual run-off, in second-feet per square mile, can be obtained from a study of records of discharge of San Gabriel and Santa Ana rivers. The Red Hills are shown on the Cucamonga atlas sheet of the Geological Survey, and are 2 miles northeast of North Ontario.

Estimated monthly discharge of San Gabriel River and canals near Azusa.

[Drainage area, 222 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	39	29	32.0	1,928	0.16	0.14
October	32	27	29.0	1,811	.16	.13
November	50	29	40.0	2,392	.20	.18
December	57	37	42.0	2,561	.22	.19
1896.						
January	51	26	37.0	2,275	.20	.17
February	54	36	41.0	2,358	.19	.18
March	169	38	111.0	6,825	.58	.50
April	91	40	54.0	3,213	.28	.25
May	42	29	36.0	2,214	.18	.16
June	26	13	19.0	1,131	.09	.08
July	15	9	12.0	738	.06	.05
August	36	9	14.0	861	.07	.06
The year	169	9	39.0	28,307	2.39	.17
1896.						
September	18	11	13.0	774	0.07	0.06
October	188	10	24.0	1,476	.13	.11
November	40	15	19.0	1,131	.09	.08
December	37	17	22.0	1,353	.12	.10
1897.						
January	147	25	58.0	3,617	.29	.26
February	1,713	64	345.0	19,146	1.58	1.55
March	1,765	294	466.0	28,623	2.42	2.10
April	370	201	294.0	17,519	1.48	1.32
May	196	94	145.0	8,851	.75	.65
June	91	54	68.0	4,033	.34	.31
July	52	27	38.0	2,343	.20	.17
August	34	22	26.0	1,613	.14	.12
The year	1,765	10	126.5	90,479	7.61	.57
1897.						
September	23	18	21.0	1,226	0.10	0.09
October	1,640	22	91.0	5,595	.47	.41
November	34	31	33.0	1,860	.15	.14
December	34	28	31.0	1,875	.16	.14
1898.						
January	63	27	40.0	2,453	.20	.18
February	70	32	40.0	2,241	.19	.18
March	83	28	35.0	2,131	.18	.16
April	37	25	33.0	1,950	.17	.15
May	83	25	36.0	2,223	.19	.16
June	30	14	19.0	1,159	.10	.09
July	15	9	11.0	672	.06	.05
August	9	5	7.0	456	.04	.03
The year	1,640	5	33.0	23,841	2.01	.15
1898.						
September	10	6	8	467	0.04	0.04
October	10	8	9	533	.05	.04
November	11	8	10	580	.05	.04
December	18	12	14	832	.07	.06
1899.						
January	33	15	23	1,414	.12	.10
February	28	20	22	1,244	.11	.10
March	40	18	26	1,623	.14	.12
April	28	16	21	1,262	.11	.10

Estimated monthly discharge of San Gabriel River and canals near Azusa—Cont'd.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1899.						
May	17	12	14	842	0.07	0.06
June	22	5	10	565	.05	.04
July	4	3	4	221	.02	.02
August	6	4	5	295	.03	.02
The year	40	3	14	9,878	.86	.06
1899.						
September	6	3	37	2,202	0.19	0.17
October	35	4	12	738	.06	.05
November	24	10	14	833	.07	.06
December	39	16	20	1,230	.10	.09
1900.						
January	89	22	32	1,968	.16	.14
February	23	18	20	1,150	.09	.09
March	30	16	20	1,230	.10	.09
April	26	13	17	1,012	.09	.08
May	86	16	37	2,275	.20	.17
June	22	8	15	893	.08	.07
July	10	4	6	369	.03	.03
August	5	4	4	246	.02	.02
The year	89	3	20	14,146	1.19	.09
1900.						
September	6	3	4	238	0.02	0.02
October	6	4	5	307	.02	.02
November	5,200	5	186	11,068	.93	.84
December	53	31	40	2,460	.21	.18
1901.						
January	1,450	28	169	10,391	.87	.76
February	2,605	137	696	38,654	3.27	3.14
March	440	135	221	13,589	1.15	1.00
April	130	95	110	6,545	.56	.50
May	272	83	121	7,440	.63	.55
June	93	41	63	3,749	.31	.28
July	41	24	30	1,845	.16	.14
August	27	15	20	1,240	.10	.09
The year	5,200	3	139	97,526	8.23	.63

Discharge measurements of mountain streams of San Gabriel Basin, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
San Gabriel River	Power company headworks (includes developed water).	July 1	15.37	August 23	7.38
Dalton Canyon	In canyon			August 25	.05
San Dimas Canyon	do			August 26	.06
Sawpit Canyon	do	July 1	.34	August 23	.00
Total		July	15.71	August	7.49

Return waters of San Gabriel Basin near El Monte Narrows, 1898.

Stream.	Point of measurement.	Date.	Discharge.	Date.	Discharge.
			Sec.-feet.		*Sec.-feet.*
Whittier ditch	El Monte road crossing	July 3	1.83	August 31	1.80
Do	Pumping plant	do	1.40	do	1.40
Temple ditch	In narrows	do	9.06	do	6.88
San Gabriel River	First channel—Baldwin's road.	do	8.79	do	7.81
Do	Old channel—Baldwin's road	do	6.18	do	6.17
Do	Camper's station	do	3.36	do	.63
Puente ditch	San Gabriel Narrows	do	2.44	do	.00
San Gabriel River	Old Mission bridge	do	29.79	do	27.91
Total flow in narrows.		do	62.85	do	52.60
Mountain streams		do	15.71	do	7.49
Excess of return water.		do	47.14	do	45.11

For a description of the settlement of the San Bernardino and Redlands districts, see the Nineteenth Annual Report of the United States Geological Survey, Part IV.

RIVERSIDE DISTRICT.

HISTORY.

The first irrigation movement in the Riverside district was made by the Silk Center Association in November, 1869. This was a colonizing enterprise for the production of raw silk. Arrangements were made for the purchase of 5,000 acres of land from the Jurupa and Rubidoux ranchos, and 1,400 acres of Government land were occupied under the United States land laws. The town of Jurupa was started on these lands, the name being changed in 1870 to Riverside. This association filed the first water notices for the settlement and began the construction of a canal in 1870. Silk culture was abandoned the year that the movement was initiated. New parties allied themselves with the colonizing movement, and the Southern California Colony Association was founded, with Judge J. W. North, president; Dr. J. P. Greves, secretary; Dr. K. D. Shugart, treasurer; and Mr. T. W. Cover, superintendent. Construction of the canals was begun in October, 1870. The first canal was built during the winter of 1870–71, on a grade of 1 inch to 100 feet, from a point on the south or left bank of Santa Ana River about 2 miles below Colton. The total length was 13.5 miles. It was 8 feet wide on the bottom, 12 feet wide on top, and 3 feet deep; the alignment and grade were very irregular. It had a capacity of a little more than 700 miners' inches (14 second-feet) down to the Spanishtown flume, and 500 to 600 miners' inches (10 to 12 second-feet) below that point. The conduit to the Pachappa Arroyo cost from $50,000 to $60,000. During the fall of 1871 this ditch was extended to Terquisquite Arroyo. By 1875 the ditch had been improved so that it carried 1,000 miners' inches (20 second-feet), but at that time not more than 500 acres were irrigated. This is now known as the old upper canal of the Riverside Water Company. The diversion is by means of a brush dam, and the conduit is wholly in earth. There are no engineering features of interest.

In 1874 S. C. Evans, of Fort Wayne, Ind., and W. F. Sayward, of San Francisco, purchased 8,000 acres of land adjoining Riverside and united with the owners of the San Jacinto Sobrante Rancho, which is situated still farther to the south, to construct another canal from Santa Ana River for the irrigation of their lands. The former of the proposed settlements was called the New England Colony and the latter the Santa Ana Colony. The Southern California Colony Association began suit to prevent the construction, which had been already started, of the new canal across their lands. The dispute was ended by the New England and Santa Ana colonies purchasing, in May, 1885, a four-sevenths interest in the original association for the sum of $50,000. In April, 1875, the Riverside Land and Irrigation Company was organized by the members of the three original colonies or companies, and by March, 1877, this new company had absorbed all of the land and water holdings of its predecessors. In 1876 the new or lower canal of the New England and Santa Ana colonies was completed, at a cost of $120,000, and during the season about 2,000 acres were irrigated by the two canals. In July, 1879, the Riverside Canal Company, which was organized for the purpose, purchased all of the water rights and conduits of the Riverside Land and Irrigation Company, the latter receiving as compensation all of the capital stock of the new company. The value of each share was placed at $20, and 20,000 shares were issued. It was further agreed that the stock should be adjusted so as to correspond with the number of acres for which water was obtained. The avowed original intention of the company was to have each share of stock cover a particular acre irrigated; but the sale of stock in some instances was made to persons who had not bought land from the company but had obtained it from the Government. By this method of disposing of the stock of the canal company those originally in power found that they would soon lose control, and therefore they passed new resolutions, assigning two shares of stock to each remaining acre, the canal company holding the shares at a par value of $10 each, one share to be issued with each acre of land and the other share to remain in the hands of the company until it had sold the majority of its lands, when the landowner could at his option purchase it at the original price.

The purpose of the Riverside Land and Irrigation Company was primarily to promote the sale of its irrigated lands. As their affairs progressed and the lands were sold the company naturally desired to continue its benefits by handling the waterworks of the irrigators and by expanding its water rights over more lands. Water rates were advanced from $1.92 an acre, in 1878, to $2.23 an acre, in 1881. These movements on the part of the company were naturally opposed by the irrigators, and a protracted struggle ensued. The irrigators organized the Citizens' Water Company with which to battle for their claims. About this time a State law was passed giving the county boards of supervisors the right to regulate water rates and compelling the continued delivery of water at uniform rates to irrigators to whom water had previously been sold. The Riverside Canal Company claimed that it had the right to charge such rates as would insure the maintenance of its plant and interest on the investment and to charge a bonus of $20 to landowners holding no stock. To this the irrigators replied that the original investment had been more than returned to the Riverside Canal Company from the sales of its irrigated lands. The courts, as is usual in cases of this nature, were slow and indecisive in their judgments. This dispute, which we see repeated in every irrigation locality, lasted from 1882 to 1885 and ended in the Holt compromise. By this agreement the Riverside Water Company was organized by the irrigators to deal in all classes of water property. They issued 24,000 shares of stock covering certain specified lands, to be an appurtenance thereof, two shares to apply to each acre, and afterwards to be transferable only with the land. Shares were issued for 6,000 acres of land then irrigated, and another 6,000 acres were specified for which water could be sold as a surplus was developed. This unirrigated land belonged to the old Riverside Land and Irrigation Company. It was transferred to the new company, called the Riverside Land Company, and one-half of the stock was issued to the Riverside Water Company and one-half to Evans and Felton, the latter the controllers of the old Riverside Land and Irrigation Company and the Riverside Canal Company. The Riverside Water Company paid to the Riverside Canal Company $70,120 in bonds and exchanged stock of the old company for stock in the new at the rate of two shares of the old stock for one share of the new. The cost of the purchase to the new company was about $120,000. Residents within the prescribed limits who did not own canal company stock were permitted to purchase it at the rate of $10 a share, two shares to the acre. The irrigators thus control the Riverside Water Company, elect their officers, and determine their own water rates. This method of management has proved successful, while both corporate and irrigation districts have been continuously unsatisfactory. It is an interesting fact that no definite decisions were reached through the courts, but that settlements were the result of compromise. The Riverside Water Company now successfully operates the plant. It delivers water to the stockholders at cost, and has improved and extended its works by the sale of bonds secured by the property of the corporation and its stockholders.[a]

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[a] The foregoing historical statement is largely obtained from Irrigation in Southern California, by William Ham. Hall, State engineer, 1888.

The general development of the Riverside district is shown in the following table:

Table showing commercial growth of Riverside.

Year.	Population.	Orange shipments.	Assessed valuation.	Post-office receipts.
		Carloads.		
1887		375	$3,586,933	$4,044
1888		725	3,978,699	10,288
1889		982	4,418,035	10,198
1890	4,682	1,500	4,588,890	11,591
1891		1,446	4,830,575	14,362
1892	7,395	2,100	5,834,000	15,458
1893		2,526	5,392,251	16,764
1894		1,928	4,958,247	16,243
1895		2,800	4,437,004	14,085
1896		2,018	4,588,181	14,147
1897	8,000	2,508	3,875,236	15,143
1898		4,000	[a]4,984,566 [b]3,038,603	16,513
1899		2,048	[a]5,123,645 [b]3,012,753	16,555
1900		[c]3,799 [d]4,300	5,499,895	19,336

[a] City valuation. [b] County valuation. [c] To date. [d] Estimated.

The city has two banks of deposit, one savings bank, thirteen churches, and eight schoolhouses. It has a debt of $120,000, and the tax rate is 65 cents on the hundred dollars. The ratio of its bank deposits and assessed valuation to its population makes it probably the first city in per capita wealth in the United States. The city covers 56 square miles, the corporate limits being extended to the outlying lands, largely for the purpose of local water and horticultural control. In June, 1893, it became the county seat of the newly formed county of Riverside.

The canals of the Riverside Water Company cover 12,000 acres of land, of which 8,500 acres are now being irrigated. The remaining 3,500 acres are to be sold and improved. The main canals aggregate 36 miles in length, while the lateral pipes, the flumes, the cemented and open ditches for distribution exceed 150 miles in length. Water is conveyed direct to every subdivision of the 8,500 acres under the irrigating system.

RIVERSIDE WATER COMPANY.[a]

WATER SUPPLY.

The Riverside Water Company obtains its supply from Warm Creek, from Santa Ana River, and from artesian wells.

Warm Creek has its source in San Bernardino Valley, 3½ miles east of the town of San Bernardino, and is fed entirely by springs and return water along its course. The flow is uniform, being about 80 second-feet during the irrigating season. It has no defined surface connection

[a] The writer is indebted to Mr. Kingsbury Sanborn for most of the information contained herein regarding this company.

A. HEADWORKS OF RIVERSIDE CANAL IN WARMSPRINGS CREEK.

B. HEADWORKS WEIR OF RIVERSIDE WATER COMPANY.

with the mountain drainage line. Its source is largely near Harlem Springs, about 4 miles east of the city of San Bernardino.

The surface water of Santa Ana River is all diverted near the mouth of its canyon above Redlands, and for miles the bed of the stream below that point is totally dry during the irrigating season, but gradually the underflow comes to the surface at points south of the town of San Bernardino, and uniting with the return waters from irrigation on the mesas on the north side of the river amounts to 8 second-feet and becomes a valuable adjunct to the Riverside Water Company's supply.

The artesian wells of the Riverside Water Company are located on several tracts of land, all situated in San Bernardino Valley east of Colton, San Bernardino, and the dike previously referred to. They vary in depth from 68 feet to 590 feet, and in diameter of the casings from 6 inches to 11 inches. The largest is a 9-inch well near Harlem Springs, 594 feet deep and flowing, on August 26, 1898, 3 second-feet of water.

The distinctive feature of the water supply of the Riverside Water Company is its constancy. Warm Creek is the principal source of supply. The volume that is available at the headworks of the canal (see Pl. IX) remains practically constant, winter and summer, dry years and wet years, except when the unusual floods from the mountain basins are projected far out into the valley, flowing continuously through to the narrows. As has previously been explained, the supply is largely regulated in the underground reservoirs of the valley. The point of diversion being at the lower level of the reservoir insures a continuous flow, even during dry years. The driest cycle of seasons of which there are records of stream flow is the five last past, and it is claimed by the water company that its supply was equal to the normal during the summer of 1898. On June 30, 1898, there were flowing in the canal at the old Colton mill, above all diversions, 3,473 miners' inches (69.46 second-feet) of water. This is considered a normal summer flow from the various sources of supply.

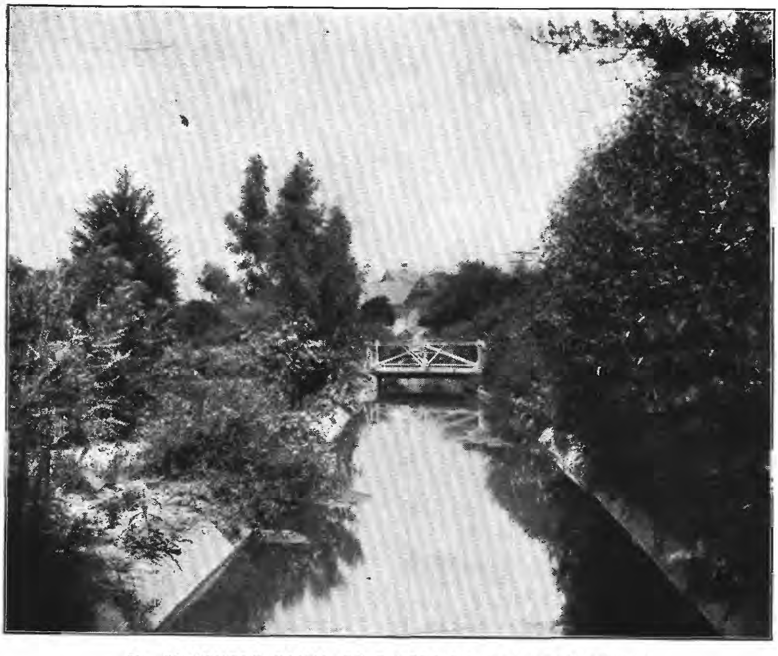
Construction of the Davis well, which was leased by the owner, Capt. Louis S. Davis, to the Riverside Water Company for the season of 1899, was started April 27, 1899. The well was completed May 12 of the same year. It is 510 feet in depth, has a 10-inch pipe, a No. 12 iron casing, and the same size all the way down. The cost was $804. The water all comes from the bottom of the well. When first finished it rose 34 inches above the top of the casing, and by weir measurement amounted to 350 miners' inches. The well is located in the northeast corner of lot 17, block 44, of the 12-acre survey of the San Bernardino Rancho. On October 2, 1899, it was flowing, by weir measurement, 233.7 miners' inches.

On April 3, 1900, the Riverside Water Company was successful in obtaining another large flowing well in San Bernardino County, the water in which rises 12 inches above the casing. The well yields more than 150 miners' inches, making it the second largest well in San Bernardino County. It is located near the Davis well. The strike came at a particularly opportune time, as Captain Davis refused to lease the Davis well to the water company this year (1900), and the water was shut off from the Riverside ditches about April 1, 1900. The strike was made at a depth of 540 feet. This well is the fourth in the district that is now flowing more than 100 miners' inches. The Riverside Water Company has a large tract of land in line with these wells.

MAIN CANAL.

The main canal of the Riverside Water Company has a capacity of 100 second-feet. It diverts water from Warm Creek, a half mile east of the town of Colton and just above the junction of Warm Creek with Santa Ana River, by means of a well-constructed brush dam. The canal follows along the west or right bank of Santa Ana River for a quarter of a mile. At that point a 6-foot drop is made through a turbine wheel which develops about 25 horsepower during the dry summer months. This power is used to pump 104 miners' inches (2.08 second-feet) of developed water from a pit and trench extending into and across the sandy bed of Santa Ana River. From this drop the water enters a cement-lined canal. Thence it crosses the Santa Ana in a substantial redwood box flume about 1½ miles long, supported the entire distance upon piling. (See Pl. LXIII, *B*, of the Twentieth Annual Report, Part IV, p. 554.) The flume box is 8 feet wide, 4 feet deep, and on a grade of 26 feet above the bed of Santa Ana River in the highest place. After crossing the river the water enters a 60-foot tunnel, then a short stone ditch, and finally the long tunnel, which is 3,250 feet in length, 7 feet and 8 inches wide at bottom, 8 feet and 4 inches wide at the 4-foot mark, and 6 feet high. The top of this tunnel is roofed with heavy timbers covered with redwood lagging and resting on brick piers laid in pure cement. The bottom and the walls between the piers are made of well-rammed concrete, the whole being covered with a coating of pure cement. After the water leaves the tunnel in its course toward Riverside it makes a drop of 40 feet at Highgrove and furnishes, from a Stillwell & Bierce turbine, 250 guaranteed theoretical horsepower, which is now used by the San Bernardino Electric Light and Power Company to develop electricity, which is supplied to Colton and San Bernardino for illumination and power purposes. At Riverside the upper canal is connected with the lower canal by a 32-foot fall, which furnishes power to the National Ice Company for the manufacture of ice. The canal runs through the city of Riverside, making four more drops before it reaches its destination in the Temescal Wash.

A. LINING RIVERSIDE WATER COMPANY'S CANAL WITH CEMENT PLASTER.



B. CEMENTED CANAL OF RIVERSIDE WATER COMPANY.

Owing to the loss of water by seepage and evaporation during the hot summer months of the irrigating season, and to save the expense of cleaning vegetation from the canals, it has been found economical to plaster the banks (see Pl. X). The usual method followed is to first thoroughly wet the canal, when dry, by building earth dams at intervals which will bring the water as near the top of the canal as possible. The water is allowed to soak into the ground and the remainder is drained off. After the canal has again become dry enough to work it is excavated to a subgrade three-fourths of an inch outside of the section of the bank and below the true grade. The lining is extended on each side of the top of the bank for a distance of 5 inches and a depth of three-fourths of an inch. Just before plastering, the banks of the canal are thoroughly wet, by spraying or sprinkling. The cement mortar, which is applied to a depth of three-fourths of an inch, is composed of one barrel of pure Portland cement to four barrels of clean, sharp sand thoroughly mixed dry on a floor, after which sufficient water is added to moisten to the proper consistency and the whole is again thoroughly mixed. The canal is first plastered on the sides and a selvage of 5 inches is built on each side of the top; the bottom lining is put in last. It is finally completed by washing with two coats of liquid cement. After the cement mortar is in place the canal is kept moist for six days, so that it will harden with uniform color.

MEASUREMENT OF WATER.

An important detail in connection with this canal system is the measurement and division of the water. Near the head of the main canal, where it crosses the Southern Pacific Railway's main line to Yuma, is a weir which measures the greater portion of the water diverted by the company. A device of local origin has been constructed for permanently recording the discharge over the weir. It is made in Riverside, by Mr. C. H. Watson, and costs, set up, about $50, or $40 in the shop.

AUTOMATIC WATER REGISTER.

This is a register for recording accurately the elevation of the surface of water in either a reservoir or a flowing stream. It consists of an upright revolving cylinder the motion of which is regulated by clockwork, covered by the record sheet of paper, which is ruled in vertical lines, each space representing one hour of time, and in horizontal lines measuring the elevation, which is marked upon the record sheet by a pencil fixed upon an upright rod terminating at its lower extremity in a float resting in the water. The register is inclosed in a substantial wooden box or case 45 inches in height, 17 inches in width, and 12 inches in depth, which is provided with a secure lock. The rod extending from the recording pencil to the float passes through the bottom of the box, and the float rests in a well of still water so connected with the main body of water as to maintain the same elevation of surface as the main body and still be free from wave motion and the effects of currents. The float is so weighted as to be steady in the water, and by the direct action of the rod it imparts to the recording pencil firmness and accuracy.

The register described, which is the size generally used to record the fluctuations of streams running over weirs and to measure in that way the volume of water in ordinary streams, has a cylinder which will record a rise or fall of 22 inches and upon one record sheet show the exact elevation of the water surface each hour for an entire week, at the end of which the clock must be wound and a new record sheet be placed upon the cylinder. The same record sheet can, however, be made to do service for four or five weeks by changing the elevation of the pencil at the beginning of each week and noting its relation to the datum. A telescoping arrangement of the float rod provides for this.

The revolution of the cylinder is produced by means of a cord passing over a small pulley at the end of the cylinder. This cord, which is treated so as to be unaffected by moisture, also passes over a pulley upon the spindle of the clock, and terminates at each end in a metal weight. These weights are so adjusted that the heavier one provides all the power to revolve the cylinder, the motion of which is steadied by the lighter weight and accurately regulated by the movement of the clock.

The recording pencil may be either an ordinary lead pencil or a pen. It is gently pressed upon the recording cylinder by an ingenious contrivance consisting of an arm or spring, and can be set back from the cylinder when necessary to change the record sheet.

This register is in use on many streams and by many water companies in southern California.

The water for irrigation is delivered, by means of vitrified pipes, to a small bay, from which it passes over a weir to the orchard lateral. A gate, known as the Watson gate, which is cheaply constructed and easily handled is inserted in the discharge pipe from the canal and set so as to give the desired head on the weir of the lateral. For a description of this gate see paper entitled Water Supply of San Bernardino Valley, in the Nineteenth Annual Report of the United States Geological Survey, Part IV, pages 595 to 596.

The constancy of the volume of the supply of water in this locality is particularly favorable to the use of these devices, which are local developments.

SALE AND DISTRIBUTION OF WATER.

The water is conveyed, by means of pipe lines and cement and earthen ditches, to the highest corner of each 10-acre lot. Irrigation water is sold for 15 cents a miners' inch (0.02 second-foot), twenty-four hours' run. The quantity that an irrigator may use is not limited. One miners' inch flowing twenty-four hours is equal to 12,925 gallons. When the water is piped under pressure and not measured it is sold at the rate of $10 an acre for the season, unrestricted service.

To 1899 the Riverside Water Company's irrigating system is said to have cost $837,757.83 and its domestic system $168,181.80. The following is the annual statement of the secretary of the company on December 1, 1899:

Assets.

Irrigating plant, value December 1, 1898		$822,118.28
Improvements, 1899:		
Cooley water right	$4,006.40	
Zanjero houses	71.95	
Telephone (construction)	184.50	
Lateral ditches	336.84	
Pipe laterals	2,315.16	
Engineering	350.81	
Storm ditch	700.30	
Artesian wells	5,097.98	
General improvements	2,575.61	
		15,639.55
Value of plant December 1, 1899		837,757.83
Domestic system, value December 1, 1898	167,496.70	
Improvements, 1899	685.10	
		168,181.80
Furniture and fittings		1,144.07
Rubidoux hotel site		1,000.00
Sinking fund		33,028.00
Live stock		863.25
Stock of Riverside Land Company		109,344.11
Due from domestic water users		2,452.44
Due from Riverside Land Company		13,315.23
Tools		7,432.61
Solvent accounts due		744.94
Cash on hand and in bank		7,032.68

Operating expenditures.

Legal expense	$2,452.00	
Telephone (operating)	395.84	
Bond expense	583.11	
Cook ranch	561.80	
Interest on bonds	33,221.53	
Interest and exchange	54.31	
Taxes	6,313.17	
Printing	125.00	
Advertising	66.38	

Stationery	$59.72	
Breaks in canals	107.95	
Repairs	4,938.25	
Salaries	5,757.00	
Cleaning canals and laterals	4,082.10	
Expense (office rent, etc.)	654.94	
Night watch	90.20	
Zanjero wages	5,097.15	
Domestic water salary	1,200 00	
Feed	462.15	
Postage	186.50	
Pipe repairs	274.64	
Temporary water leased	3,459.14	
		$70,142.88
Total		1,252,439.84

Liabilities.

Capital stock	236,380.00
Bonds payable in 1912	812,500.00
Dividends (from land company)	20,000.00
Loss and gain	86,058.77
Accounts payable	62.50

Operating income.

Ranch	$1,897.32	
Water sales by the inch	59,454.10	
Water sales by the acre	5,673.60	
Water power	4,891.65	
Domestic water	24,662.65	
Rent	859.25	
		97,438.57
Total		1,252,439.84

The receipts of the company for water service are shown in the following table:

Receipts of Riverside Water Company for water service.

Year.	Irrigating system.	Domestic system.	Year.	Irrigating system.	Domestic system.
1886	$21,418.81	$120.10	1893	33,884.91	23,151.10
1887	24,919.47	1,658.95	1894	40,738.80	22,284.60
1888	23,830.44	3,672.30	1895	33,594.43	22,362.43
1889	26,394.16	9,525.00	1896	35,277.05	22,463.76
1890	33,516.00	13,058.45	1897	49,725.88	21,719.60
1891	37,421.45	19,209.83	1898	52,282.93	23,972.01
1892	39,557.10	22,349.30	1899	65,127.70	24,662.65

The capital stock of the Riverside Water Company is $240,000, divided into 24,000 shares of $10 each, intended to cover 12,000 acres, two shares of stock being issued for each acre of land. Of this entire capital stock, to December 31, 1899, there had been paid in and stock issued for $236,380, or 11,819 acres. The amount of cash expended by the company to that date was $1,252,439; the value of the plant is estimated at $2,500,000. The amount expended annually since its organization, in purchase and construction, is shown by the following table:

Annual expenditures of Riverside Water Company in purchase and construction.

1885	$120,000.00	1893	$84,583.91
1886	27.00	1894	73,267.72
1887	598.56	1895	16,049.32
1888	64,657.28	1896	11,404.47
1889	311,962.02	1897	9,681.32
1890	41,362.22	1898	18,255.85
1891	178,666.59	1899	16,324.65
1892	59,118.72		

Water rates fixed by the board of city trustees of Riverside.

1885 to 1888, inclusive, 7½ cents for 1 miners' inch, 24 hours' run.
1889 to 1897, inclusive, 10 cents for 1 miners' inch, 24 hours' run, or $7 per acre per annum, unlimited service from pressure pipes.
1898 to 1900, inclusive, 15 cents for 1 miners' inch, 24 hours' run, or $10 per acre per annum, unlimited service from pressure pipes.

DOMESTIC SYSTEM.

Water for municipal and domestic purposes was at first obtained from the irrigating canals; but in 1886 the Riverside Water Company began the construction of its domestic system, by which artesian water for municipal and domestic uses is delivered through a well-conceived and comprehensive pipe system, under a pressure of not less than 70 pounds to the square inch. The capacity of the system is 3,000,000 gallons daily. The water supply is from eighteen artesian wells located in lot 4, block 65, San Bernardino Rancho, about 2½ miles east of the town of Colton. The wells vary in depth from 111 feet to 344 feet, and cost, on an average, $500 each.

In the fall of 1887 the first group, consisting of six 11-inch wells, were sunk to an average depth of 115 feet, and flowed, when finished, about 5 second-feet. These wells were sufficient to supply the domestic consumption of Riverside for several years; but as the demands for water increased the company found it expedient to construct more wells, which they did, using casings of smaller diameter and sinking the wells deeper in order to tap lower subterranean strata. The water from all of these wells is conducted through a gravity vitrified pipe line to a circular cement-lined reservoir, where it is aerified over a partition. (See Pl. VI, *B*.)

From the reservoir the water passes through three screens, of different size mesh, to a 17-inch steel pipe. Pipe of this size extends for a distance of 3.8 miles, when it is reduced to 16-inch steel pipe for the remainder of the distance (4.3 miles) to Riverside. The pipe line has a total fall of 172 feet to the center of the city of Riverside, and a capacity of 3,900,000 gallons daily. In the city the larger mains—6-inch, 8-inch, and 9-inch—run east and west and are connected at intersecting streets with smaller pipes. The fire hydrants are attached to the large mains and afford excellent fire service.

GAGE CANAL SYSTEM.[a]

The Gage canal is in Riverside and San Bernardino counties. Its initial point is in the bed of Santa Ana River, in lot 4, block 69, San Bernardino Rancho; or a more specific description would be SW. ¼ sec. 13, T. 1 S., R. 4 W., S. B. M. The initial point has an absolute elevation above sea level of 1,035 feet. The terminal point of the canal is at the south boundary of SE. ¼ sec. 19, T. 3 S., R. 5 W., S. B. M. The total distance between the two points, following the line of the canal, is 20.16 miles. The construction of the canal proper was begun in the year 1885 and was finished as far as flume No. 9, over Terquisquite Arroyo, in the year 1886. The actual work of construction of the remaining portion was begun in the spring of 1888 and was practically completed during that year. The whole of the canal was excavated, generally in the clay formation, on a grade of 2 and 3 feet to the mile, and to a uniform depth of 4 feet, with varying width of bottom.

The accompanying map (Pl. I) shows the location of the canal in relation to all of the intermediate points and the adjacent territory.

Pls. VII, *A*, and XI, and figs. 3 to 14, inclusive, show features of the system.

HISTORY.

The construction of the Gage canal was begun by Mr. M. Gage in the year 1885, and was finished so that water was run through it as far as Terquisquite Arroyo in the fall of 1886. During the winter of 1886-87 all of the tunnels were thoroughly cemented on the sides and bottom, to a depth of from 4 to 6 inches, with Portland cement concrete, and their tops were timbered.

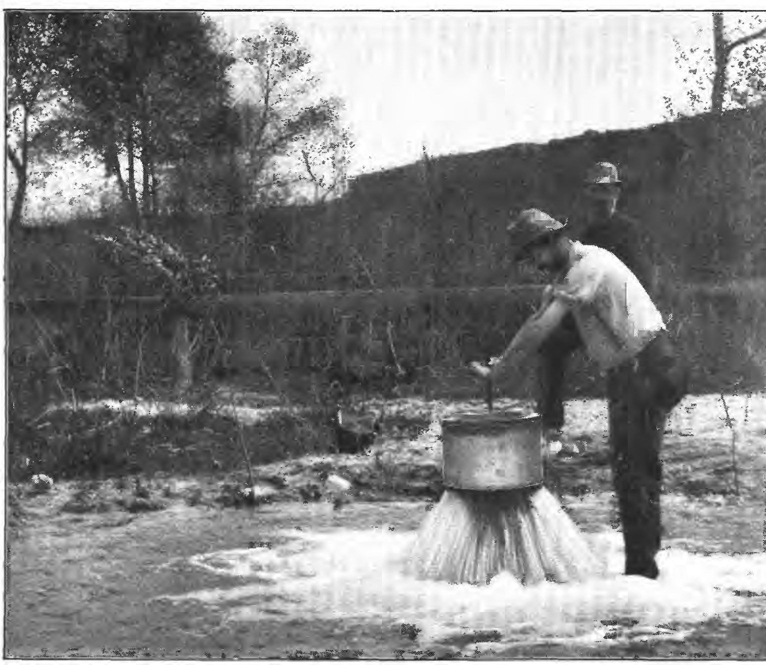
Up to that time the work was under the supervision of C. C. Miller, as engineer, and R. Gage, as superintendent of construction. On January 18, 1887, W. Irving took charge of the work as engineer, Mr. Gage remaining as superintendent of construction.

During the early part of the year 1887 a temporary connection was made between the head of the canal and the river, and water was run continuously to East Riverside in quantities varying from 300 to 500 miners' inches, as the demands of the owners of the land required.

The average grade of the canal between the head gates and Terquisquite Arroyo is about 2¼ feet to the mile, and the total distance 11.9 miles. During the spring of 1887 a survey of the continuation of the canal below Terquisquite Arroyo was made by W. Irving, the trial line being run and general location determined on or about March 15 of that year. The grade on which the continuation was made was about 2 feet to the mile, or about 0.04 foot to the station.

[a] The writer is indebted to Mr. William Irving, of Riverside, for most of the facts herein contained regarding the Gage canal.

A. WELL NO. 43 OF GAGE CANAL SYSTEM.



B. METHOD OF CAPPING ARTESIAN WELL OF THE GAGE SYSTEM.

On August 1, 1887, the permanent head gates were located and the work of construction was begun. In November, 1887, the water was turned into the canal through the new head gates, which are shown in fig. 3, page 86. In fig. 4, page 87, is shown a section of the headworks.

On August 15, 1887, the work of constructing a submerged dam for the diversion of water to the canal and for carrying the water from the sources on the north side of the river was begun, the dam being completed about the end of November of that year.

In the same year Mr. M. Gage claimed to be the owner of all of the water flowing in Santa Ana River at the point of diversion, which at that time was said would equal, on an average, about 450 miners' inches, or 9 cubic feet per second, during the irrigation months. At the same time Mr. Gage had developed, by means of fourteen artesian wells, about 600 miners' inches, as measured by G. O. Newman, making a total of 1,050 miners' inches, or 21 cubic feet per second. The owners of the Gage canal bought the Camp Carlton ditch, one of the old water rights of Santa Ana River, upon the ownership of which it based in part its claim to the total flow of the river at its headworks. In consideration of this transfer the vender was to receive water from the Gage canal.

At that time Mr. M. Gage was the owner of all of the lands known as the Orange Grove Homestead, amounting to about 2,300 acres and situated in and forming part of the San Bernardino Rancho. Santa Ana River flows through these lands for a distance of about 3⅓ miles, the course of the river being S. 65° W., on a line passing through points of entrance and exit. The lands described form both banks of the river throughout very nearly its entire course. In consequence, Mr. Gage, as riparian owner, claimed all of the water flowing in the river at that point. About the end of June, 1887, the Riverside Water Company entered suit against him, denying his right to take more than a certain amount of water from the river. The case was tried, and the judgment, which was given in the early part of 1888, limited the amount of water to be taken from the river by Mr. Gage during the irrigation season—including the months of May, June, July, August, and September—to 289.5 miners' inches. Under that decision it is presumed that during the remaining seven months all of the water flowing in the river may be taken out and used by those who can obtain it.

In the spring of 1888 the total available supply to the Gage canal was as follows:

	Miners' inches.
River water	289.5
Parish ditch, say	30.0
From wells	600.0
Total (1887, 1888)	919.5

Or 18.39 cubic feet per second.

During a flood in Santa Ana River in the month of February, 1888, the submerged flume was carried away, and up to the present time it has not been replaced.

In the latter part of 1887 and the early part of 1888 the portion of the canal below Terquisquite Arroyo was finally located, the terminal point being on the SE. ¼ sec. 19, T. 3 S., R. 5 W., S. B. M., 8.26 miles distant from the terminus of the upper section, measured on the line of the canal. This makes a total length of canal equal to 20.16 miles between the head gates and the lower end, or the point above described.

The work of construction on the second or lower section of the canal was begun in the early part of the year 1888, Grant Brothers having the contract for the earth work. Flumes Nos. 9 to 13, inclusive, were constructed by Mr. M. Gage, under the supervision of W. Irving, as engineer, and R. Gage, as superintendent of works, and the whole was practically completed in the early part of August of the same year (1888), except a short interval (about 1,700 feet) through sec. 21, T. 3 S., R. 5 W., S. B. M.

On March 31, 1888, the water was first turned into flume No. 9, over Terquisquite Arroyo, and from thence over to flume No. 10 and into the canal below for a distance of about 600 feet. After that date it was run to section 21, as already described. The amount of water running in the Gage canal during the month of July, 1888, was from 500 to 700 miners' inches, measured at flume No. 3, which was used for the irrigation of lands north of Terquisquite Arroyo, a portion of the water wasting at flume No. 11, Arlington Heights.

During the year 1888, commencing about the month of April, a number of wells were sunk in the river bottom near the point where Mountain View avenue crosses the river. This group of wells was known then and for sometime afterwards as group E. They were eleven in number, including two wells excavated in 1887 a short distance west of the avenue, the remaining nine being located east of the avenue, seven of them on the south side of the river and two on the north side. This group (E) of wells was redesignated in 1892, and they are now known as wells Nos. 28 to 38, inclusive, and form part of a general numbering (1 to 55) of all the wells tributary to the canal. They all are 10 inches in diameter, and at the time of excavation Nos. 28, 29, 33, 34, and 35 gave a very large flow and added greatly to the water supply. The combined flow of the eleven wells equaled 677 miners' inches.

During the year 1888 three additional wells were excavated on the east bank of the canal between flume No. 1 and the point where the Santa Fe Railroad crosses the canal. These wells are 10 inches in diameter. They formerly were known as part of group B, but now are known as Nos. 7, 8, and 9. They have added about 120 miners' inches to the general supply. At the end of the year 1888 the total water supply available was equal to about 1,500 miners' inches, as follows:

	Miners' inches
Group B (Nos. 7, 8, 9, 11, and 12)	250.0
Group C (Nos. 45, 46, 47, 48, 49, and 50)	258.0
Group D (Nos. 51, 52, 53, and 54)	45.0
Group E (Nos. 28 to 38, inclusive)	582.5
Parish ditch	75.0
River water	289.5
Total	1,500.0

or 30 cubic feet per second.

During the year 1889 the Gage canal below Terquisquite Arroyo was completed in all of its parts and the water was run to the lower end. Improvements all along the line between the head gates and the terminus were made to grade by releveling, cutting, and filling, by increasing the strength of banks in the fills and wherever else needed, and by relining the flumes to grade where they had settled on their foundations.

The maintenance of the canal was under the supervision of Mr. M. Gage, represented by Mr. Irving, as engineer, and the expense was borne by Mr. Gage, excepting the portion between tunnel No. 13 and Terquisquite Arroyo, which was partially borne by the East Riverside Water Company. Many serious breaks occurred during the year 1889, causing several days' interruption in irrigation and considerable expense for repairs.

The total cost of construction of the portion of the canal south of Terquisquite Arroyo, including flumes Nos. 9, 10, 11, 12, and 13, was $30,250.73, as follows: Cuts and fills, $14,849.81; flumes (2,750 feet), $13,900.92; engineering, $1,500. Total length of canal, 8.22 miles.

During the months of June and July, 1889, Mr. E. Low planted to orange trees the greater portion of the south-central 80 acres of sec. 35, T. 2 S., R. 5 W., S. B. M. On this land was used, in 1889, the first water from the Gage canal below flume No. 9 for a useful purpose.

During this and the previous year the lands of Arlington Heights were platted in a most thorough manner by Messrs Whitten and Rawson, under the supervision of Mr. Irving, the street divisions generally inclosing 40 acres and the block thus formed being subdivided into 10-acre lots. All acreage is exclusive of streets.

During the early spring of 1889 one more well was sunk, forming part of group B and now known as No. 10 in the general numbering.

On April 17, 1889, by request of the Home Life Insurance Company, of San Francisco, Prof. E. W. Hilgard, of the University of California, made an examination and measurement of all water flowing or possible to flow at that date from the water sources of the Gage canal. The following are the results of the measurements made while all of the sources were flowing simultaneously and had been flowing for about thirty-six hours. The designation of the wells which was adopted by

Professor Hilgard was the letters A, B, C, and D for certain groups of wells which afterwards were known as B, C, D, and E, the A in the latter enumeration representing the Hunt & Cooley wells, in which Professor Hilgard was not interested. In the following enumeration the latter designation has been adopted, making it agree with all of the other references, to which will be added the present numbering:

	Miners' inches.
Group B, or Nos. 7 to 12, inclusive (6 wells)	260.0
Group C, or Nos. 45 to 50, inclusive (6 wells)	225.0
Group D, or Nos. 51 to 54, inclusive (4 wells)	35.0
Group E, or Nos. 28 to 38, inclusive (11 wells)	571.0
Parish ditch	157.0
South side streams (estimated)	75.0
Water right in Santa Ana River	289.5
Total	1,612.5

On July 27, 1889, by request of the Riverside Water Company Mr. G. O. Newman, representing that company, and Mr. Irving, representing Mr. M. Gage, examined for the first time since the decision of the court was rendered the diversion of water from the river through the Gage canal. They measured the total flow in the canal on the weir at flume No. 3 and determined the net product to be 746 miners' inches.

	Miners' inches.
Wells of group E (Nos. 1, 2, 3, 4, 6, 7, and 8, or, according to the present numbering, Nos. 38, 37, 36, 35, 33, 32, and 31) total discharge	320.0
Water right in river	289.5
Parish ditch (estimated)	120.0
Total water flowing at head gate	729.5
Measured water flowing into head gates over weir	594.0
Balance unused	135.5

The difference between the amount of water at the head gates and that at flume No. 3 is accounted for by the discharge of the wells of group B below the head gates. On July 26 or the day previous there was a larger quantity of water discharging into the canal at the head gates, as shown by the following:

	Miners' inches.
Water right in river	289.5
Product of seven wells	300.0
Parish ditch	140.0
Total at lower weir	729.5
Deduct amount at head-gate weir	679.0
Balance unused	50.5

The flow of water in the canal during the year 1889 varied from a maximum of about 800 miners' inches in July to about 500 miners' inches in November.

During the year 1890 many changes and improvements were made in connection with the canal and the lands of Arlington Heights. Mr. Gage had visited England in the fall of 1889, and had interested capitalists in his enterprise of developing the lands at Arlington Heights. In furtherance of the project two representatives, Messrs. T. Waterhouse and Wilson Crewdson, were sent by them to Riverside to examine the property. Their report being favorable a company was formed, the capital stock of which was placed at $1,255,000, divided into 5,000 A shares of $250 each and 1,000 B shares of $5 each. On December 13, 1889, a provisional contract was entered into between Messrs. M. Gage and Wilson Crewdson, which was assigned to the new company, known as the Riverside Trust Company, Limited.

During the early part of the year 1890 pipe lines of riveted steel plate were laid on Adams and Jane streets, and substantial bulkheads were constructed in the canal where the pipe lines entered. A vitrified pipe line similarly connected was laid on Evans street as far as Dufferin avenue. During the fall and winter following the canal was lined with masonry at the lower fill, between Harrison and John streets, and at flumes Nos. 13, 12, 11, 10, and 9. Retaining walls of masonry were also constructed at the ends of all of these flumes, thus removing the woodwork from contact with the clay. In addition to this the fill at Hall's reservoir and Eighth street, north of Terquisquite Arroyo, was lined with masonry and cement plaster.

A portion of the Williams tract lying east of the east and north line of the bluff of Santa Ana River, amounting to about 430 acres, was purchased by the Riverside Trust Company, Limited, in 1890. This purchase extended the frontage on both sides of the river 1 mile farther to the east, thus making a continuous frontage due east-west of 4 miles, or by following the course of river about 4¼ miles.

During the year it was determined to construct a levee on the south side of the river, beginning at the head gates and extending east, and in connection therewith to construct a flume immediately behind it for the conveyance of water from the artesian wells, and if thought necessary to carry therein to the head gates the river water that could be taken out at a higher point. Piles 8 inches by 8 inches by 16 feet were driven at 16-foot intervals on the line determined for the levee, and an embankment of brush and sand was formed behind the piling and connected to it. The flume was placed 50 feet from the face of the levee. It was constructed of cedar framing and sheeting, and was gradually submerged below the surface of the ground as it extended up the river. About 1,000 feet of these works were built during the year, extending upstream from the old head gates.

No official measurement of the water of the Gage canal was made during the year 1890, measurements having been deemed unnecessary because there was not a scarcity of water. Well No. 55 (the Camp well) was excavated during the year, but was not then used as a part of the canal water supply. Its flow was estimated to be 50 miners' inches.

During the year 1891 pipe lines were placed on Maude, Horace, Washington, Gratton, Irving, Jackson, John, McAllister, and Stuart streets, and laterals from them were run to the lands of Arlington Heights, amounting in the aggregate to more than 1,000 acres. Masonry foundations were built for all of the flumes from No. 9 to No. 13, inclusive, and bulkheads were constructed at the canal for all of the entering pipe lines. Arrangements were made to cement the canal from the head gates to flume No. 6 wherever it had not already been cemented. During the latter part of the year contract therefor was made with Gray Brothers, of San Francisco, and work was begun in December between flumes Nos. 1 and 2. The work consisted of a thorough reconstruction of the canal by a realignment and regrading of all parts, resulting in a more perfect cross section. Plaster three-fourths of an inch thick, composed of one part Portland cement and four parts clean, sharp sand, was applied to all parts of the canal in natural banks; to all parts in made banks and side-hill work the outer slopes were lined with 6-inch masonry and then were plastered with cement. The ends of all flumes were incased in masonry abutments and retaining walls, freeing them from contact with the earth. During that year (1891) about 1,000 acres of land were planted on Arlington Heights. In 1889 an employee of the company was stationed at flume No. 3, whose duty it was to keep in repair the section of the canal along the bluff and to make a daily record of the quantity of water flowing in the canal at flume No. 3.

During the winter of 1890–91 floods carried away a portion of the levee and the casing of the channel behind it. This was owing to obstructions in the channel above the works, causing a diversion of the river which forced it to approach the levee at almost right angles, resulting in the cutting of a passage which exposed the channel behind to the destructive action of the water. During that season wells Nos. 1 to 6 and Nos. 13 to 27, inclusive, were excavated, making in the aggregate 21 additional wells.

The cementing of the canal as far as flume No. 6, as previously determined, was completed during the spring of 1892. In that year pipe lines also were placed on Arlington avenue and on Ana, Mary, Madison, Evans, St. Lawrence, Jefferson, Irving, Monroe, Van Buren, Robert, and Harrison streets, and a large number of laterals were extended from the mains to the lands and connected with the irrigating flumes. Considerable additional land was planted during the year, but not so much as during the previous year. Arrangements were also made to continue the cementing of the canal from the point where it had been completed in the spring to the upper end of flume No. 10, south of Terquisquite Arroyo. Contracts for this work were entered into with Gray Brothers. The work was begun during the month of December and continued during the remainder of the winter.

In this same year (1892) James Sheddan was made zanjero of the canal above flume No. 3, including head gates, artesian wells, and river, and the work of levee construction was carried on with vigor. The part of the levee between the head gates and well No. 39 was completed during the year and was tested by the floods of the following winter, with fairly satisfactory results. Wells Nos. 39 to 44, inclusive, were excavated, making 6 additional wells added to the system that year.

On November 11, 1892, careful measurements were begun of the total water supply of the Gage canal system developed up to that date, and were continued several days, for the purpose of determining many factors in connection with the water sources. The chief results are summarized in the following table:

Artesian wells of Gage canal system, 1892.

No. of well.	Distance apart.	Depth.	Diameter.	Temperature of water.	Pressure.	Capacity.
	Feet.	*Feet.*	*Inches.*	*Degrees.*	*Feet.*	*Miners' inches.*
1	0	656	10	75	25	5.00
2	1,216	534	10	74	70	32.50
3	296	382	10	74	76	29.00
4	525	482	10	74	74	41.20
5	561	320	10	73	23	3.50
6	265	784	10	74	80	45.00
7	4,620	196	10	70	11	13.70
8	353	190	10	70	11	21.00
9	204	142	10	70	11	3.50
10	320	148	10	68	12	3.20
11	714	141	7	67	28	24.50
12	80	181	7	68	29	21.60
13	765	426	10	70	16	86.50
14	530	472	10	70	17	101.50
15	1,680	518	10	64	17	62.50
16	190	388	10	66	50	50.00
17	175	380	10	65	50	32.00
18	480	386	10	62	50	27.00
19	330	196	10	62	17	43.50
20	270	124	10	62	12	9.50
21	260	116	10	62	13	24.70
22	270	134	10	62	17	50.50
23	265	168	10	62	11	36.00
24	265	166	10	62	14	26.00
25	320	152	10	62	14	19.70
26	280	123	10	62	13	21.00
27	320	125	10	62	14	9.00
28	280	144	10	62	15	38.00
29	310	140	10	62	16	28.30
30	790	138	10	62	13	11.20
31	430	106	10	64	15	3.70
32	35	130	10	64	16	16.20
33	315	146	10	63	18	41.00
34	550	116	10	63	16	48.00
35	130	134	10	63	15	30.50
36	120	116	10	64	16	16.00
37	680	147	10	66	16	42.00
38	90	122	10	66	16	28.75
39	276	115	10	66	17	10.50
40	1,090	169	10	66	17	77.15
41	474	193	10	66	14	63.50
42	510	192	10	66	17	85.75
43	510	390	10	66	18	109.75
44	500	224	10	64	20	92.75
45	1,580	123	7	62	25	76.50
46	15	133	7	62	25	6.70
47	15	133	7	62	25	24.40
48	40	139	7	62	25	29.33
49	50	211	7	62	23	28.40
50	40	100	7	62	25	15.00
55	1,590	300	10	64	22	80.00
Total						1,793.45

It will be understood that the gagings are minimum measurements taken at the end of the irrigation season and while all of the wells were running open and part of them had been running open during the season. The pressure (in feet) of each well was taken while it was closed. The average flow for each well is 35.15 miners' inches; the total flow is 1,793.45 miners' inches, or 23,243,112 gallons daily.

The work of completing the cementing of the canal was prosecuted during the first three months of the year 1893 and was completed in time for irrigation. Pipe lines were placed on Monroe and Gibson streets and laterals were laid to about 800 additional acres of land. An improved hydrant and hydrant box were adopted—the latter being formed of cement—and attached to all of the irrigation laterals and flumes that were put in during that year; in cases where new boxes were needed elsewhere the improved boxes were placed on the old forms. About 800 additional acres were planted to oranges and lemons during 1893, and arrangements were made during the latter months of that year for the cementing of certain portions of the canal south of flume No. 10 in the same manner as work already done, but the company decided this time to do the work under its own supervision. The work of excavating the channel behind the levee was also carried on, and was completed as far as the finished portion of the levee. The levee was extended up the river about a half mile, or a considerable distance above the adjacent wells. No additional wells were excavated during the year.

In 1894 the work of cementing the canal south of flume No. 10 was proceeded with during the spring months, and about 1,200 feet immediately south of the flume and Arlington avenue were cemented; water service was added to about 200 acres of land, which were planted the same year to orange and lemon trees. The trenching on the south side of the river was continued during the spring of that year, and at a distance of 5,650 feet (1.07 miles) upstream connection was made with the river. The river water owned by the Riverside Trust Company was diverted into this new channel, and the whole supply on the south side of the river, including the wells, was carried through the channel to the head gates. A channel on the north side of the river from the head gates upstream was also commenced and a large portion of it was finished that year.

During the years 1895 to 1898, inclusive, the levee in the river bottom was extended and added to from time to time, until now it extends on both sides of the river a distance of about 2 miles upstream from the original headworks.

WATER SUPPLY.

The water supply of the Gage canal system is, as already stated, largely from artesian wells. During years of drought the supply is wholly from wells. The number of wells has been increased from year to year, as the demand for water grew and as the old wells became silted up. It is also probable that the extreme drought from 1892 to 1900, coupled with the general increased demand upon this artesian basin, has reduced the flow of the wells. Their maintenance is remarkable, and is one of the numerous evidences of the vast extent of the supply.

The number of wells in the Gage system and their output are as follows:

	Miners' inches.
1887, 14 wells, approximately	600
Fall of 1888, 26 wells	1,135
Spring of 1889, 27 wells	1,091
October, 1892, 55 wells	1,793
June, 1899, 68 wells	1,440

In June, 1899, 55 of the 68 wells were flowing and 13 of them were not flowing. The maximum output is stated by the company to have been 1,440 miners' inches. The company has a right to 289.5 miners' inches at its headworks on Santa Ana River, but during recent dry years this has been of little value. On June 20, 1899, there were at that point 12 miners' inches, and on February 21, 1900, 20 miners' inches. The Parish ditch, which is said to have a normal flow of 120 miners' inches, is now dry.

The sources of water supply to this canal, including the right to develop additional water over an area of 488 acres forming part of a block of water-bearing land, are 2,831 acres, all of which are owned by the company. In 1893 the supply, including river water, was estimated as follows:

	Miners' inches.
Santa Ana River	289.50
Artesian wells, 55 in number, measured at their minimum flow (October 10, 1892)	1,793.45
Parish ditch	20.00
Total	2,102.95

The artesian wells are distributed over a considerable area, but generally extend (for a distance of 15,800 feet) along the canal bank and the river bottom, as shown on the map, Pl. I.

All of the wells were driven by means of a sand pump working inside of a thick, double iron casing or lining, the lining being forced down by means of hydraulic jacks as the pump continued to excavate. The lining is of No. 10 or No. 12 gage iron, in two thicknesses, so that it can be built up and made continuous by inserting inside and outside lengths alternately, each length being 2 feet long and breaking joint in the center. The casing fits so exactly that in a short time the lining becomes, by oxidation, water tight, at least sufficiently so for the purpose.

As already stated, in the spring of 1889 Prof. E. W. Hilgard, of the University of California, made an examination of the artesian water supply of the Gage canal system for the Home Life Insurance Company, of San Francisco. He was given exceptional opportunities for an exhaustive study, and his report, which is of general interest, is freely quoted from below. He states that the water supply at that time (April, 1889) was as follows:

	Miners' inches.
Supply from 27 wells	1,091
Parish ditch	157
Water right in Santa Ana River	289
South Side ditch (estimated)	75
Total	1,612

On June 30, 1898, there was flowing in the Gage canal at Palm avenue a total of 1,313 miners' inches; on June 20, 1899, 1,273 miners' inches; and on February 21, 1900, 1,129 miners' inches. A reference to the table of rainfall on page 17 will show that the last eight years have been years of unusual drought, and that the season of 1888–89 was in a group of wet years. These wells have, therefore, maintained their supply in the face of the drought and in spite of the fact that the underground gravel reservoir has been heavily drawn upon by other sources. (See general discussion of water supply, page 36.)

The following extracts are made from Professor Hilgard's report:

The bulk of the supply of the Gage Canal is at present from artesian wells, of which there are 42 on the Victoria tract. On the "water tract" proper there are 27 now flowing or ready to flow. These wells are located in four groups, designated by the letters of the alphabet, from A to D. The lettering for these groups of wells is that adopted in the State engineer's report on irrigation in southern California. The difference in the number of wells forming the several groups and the increased supply of water are due to the boring of additional wells since the State engineer's observations were made.

The wells of each group are separately numbered, in general upstream and counting from south to north. The following data show the number of each group, distances from each other and from the head gate of canal, and the measured flow of each well in miners' inches of 4-inch pressure, the measurement usually adopted in southern California.

GROUP A.

Six wells in line along the canal, the nearest being 2,400 feet from the head gate, and the total distance from No. 1 to No. 6, 1,665 feet.

Measurements of wells in group A.

Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.	Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.
	Feet.	*Inches.*	*Miners' inches.*		*Feet.*	*Inches.*	*Miners' inches.*
1	249	10	36	5	67	7	57
2	304	10	68	6		7	46
3	323	10	35				
4	722	10	18	Total			260

GROUP B.

Six wells occupying an area of somewhat less than an acre (3,900 square feet), distance 1,200 feet from the head gate in a northwest direction; distance from (center of) group C, 3,276 feet.

Measurements of wells in group B.

Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.	Number of well.	Distance from well next above.	Diameter of pipe.	Discharge.
	Feet.	*Inches.*	*Miners' inches.*		*Feet.*	*Inches.*	*Miners' inches.*
1	15	7	28	5	40	7	63
2	15	7	17	6		7	20
3	40	7	36				
4	50	7	39	Total			225

GROUP C.

Consisting of four weak wells, all with 7-inch pipe, among the first bored, and left as they are at an average depth of about 110 feet on account of difficulties encountered in the cobble layer at bottom, for overcoming which suitable tools were not then at hand. The wells are between 10 and 18 feet apart only, and yield from 7 to 12 inches of water each; total, 35 inches. One good 10-inch well would probably give better results than the four small ones.

This group is distant 4,550 feet northeast from group B and 2,100 feet from the center of group D. Area actually occupied, 360 square feet.

GROUP D.

This group consists of 11 wells (all with 10-inch pipe), ranging in depth from 110 to 160 feet. Nine are located on the south side of and mostly quite near to the river bed; two are near the north bank, one being in the present bed. The distance between the centers of groups A and B is about 5,800 feet; between D and B, 4,400 feet. The elevation above group B is about 18 feet; above group A, 31 feet. Area actually occupied by the group, 17 acres.

Measurements of wells in group D.

Number of well.	Distance from well next above.	Discharge.	Number of well.	Distance from well next above.	Discharge.
	Feet.	*Miners' inches.*		*Feet.*	*Miners' inches.*
1	80	51	8	440	22
2	687	51	9		37
3	117	43	10	300	56
4	139	55	11		74
5	566	82			
6	315	65	Total		571
7	42	35			

All the measurements recorded above correspond to the condition of the wells about thirty-six hours after all had been uncapped and had been running their full streams.

This point is of some importance, because measurements made immediately or soon after uncapping a well that has been closed for some time show at first a considerably larger dscharge, evidently due to accumulated pressure, or what might be called a "local head," requiring some time to run down to the nominal discharge.

DEGREE OF INTERDEPENDENCE OF WELLS.

The extent to which the discharge of any well or group of wells is influenced by that of others situated at a greater or less distance is a question of great practical interest, since upon the answer depends the aggregate amount of water to be expected from further developments on the "water tract" by boring additional wells. I have tested the point in a variety of ways, the more important being the following:

(1) Well No. 6 in group B has for some time past remained capped, with an inch pipe carrying the water to a dwelling house some 300 yards away, the water reaching the level of 26 feet above the casing when all the other wells of the group are capped. It was found when all the other wells are uncapped the water level at the house falls about 3 feet 7 inches. As stated above, the total flow of the wells of this group is 225 inches; that of No. 6, 20 inches. It is distant only 40 feet from well No. 5, having a flow of 63 inches, and all the rest of the group lie within 130 feet. Yet the measurement shows that the opening or shutting down of a flow of 205 inches, or more than ten times the amount of the flow of No. 6, influences its head to the extent of not quite 14 per cent, or three-quarters of 1 per cent of the total discharge of the group.

(2) Well No. 2 of group D had been steadily running for upward of a year, all the rest of the group, as well as those of groups B and C, being closed. It was then discharging about 61 inches. After nine other wells (Nos. 3 to 11, inclusive) had been uncapped, No. 2 was found to have decreased to 57 inches in the course of about three hours. On opening No. 1, within 80 feet of No. 2, its flow fell off to 55 inches, and forty-eight hours afterwards it had reached its minimum flow of 48.4 inches, which, however, five hours after was found to have risen again to 51 inches, the figure adopted in the table above. Such fluctuations of a few inches appeared of measurements made at different times of the day, in almost all cases of strong flow, possibly as the result of barometric variations or other diurnal causes.

It will be seen that in the case of this well the letting loose of 520 inches of water within an area of 17 acres immediately adjacent caused a decrease of the flow it had when running by itself of only 10 inches, being about one-sixth, or, say, 17 per cent, of its maximum flow when all the rest were closed, or 1¾ per cent of the total discharge of the group. It will be noted that this is very nearly the same ratio as in the case of well No. 6 in group B reported above.

(3) After the wells had all reached a state of sensibly normal discharge, groups C and D, with their aggregate discharge of 606 inches, were shut down about 5 p. m., in order to observe the effect on other groups.

Group B was measured at 10 p. m., and was found to be discharging 211 inches. Six hours before, when all the other wells were still open, the flow was 205 inches, thus showing an increase of 6 inches, possibly caused by the shutting down of an aggregate of 606 inches at the average distance of about a mile. This is a very slight effect at best, being less than 1 per cent of the total amount shut off, or three-fourths of 1 per cent of the total discharge concerned, and less than 3 per cent of the discharge of the five open wells of the group. But the fact that on the morning of the same day these wells stand credited with a discharge of 215 inches renders it even doubtful that the shutting down of groups C and D caused the observed increase, and that it was not merely due to diurnal variations referred to above and known to exist. Unfortunately my time did not permit of the continuation of the observations so as to settle this point definitely.

(4) On the following day, eighteen hours after the shutting down of all the other groups, representing an aggregate of 831 inches, at an average distance of about 5,000 feet, group A was remeasured. It was found that the discharge of well No. 1 had decreased from 36 to 29 inches, evidently in consequence of being loaded down with a quantity of gravel that had slid in from above, the pipe having

sunk below the ground level. In the rest of the group (Nos. 2 to 6) there had been an increase over the discharge observed in the afternoon of the previous day from 224 to 233 inches, a difference of 9 inches in the total discharge of the group, or 4 per cent of its volume, but only a little over a third of 1 per cent of the total discharge concerned.

(5) A striking proof of the relative independence of these wells of one another when situated at reasonable distances apart is found in the "local head." or accumulation of pressure that takes place so soon as an individual well is shut down. When measured immediately after uncapping, a well that has remained closed for some time is found to discharge from 15 to 17 per cent (in the large wells) more than its normal flow, to which it settles down after a lapse of from twenty to thirty hours. This accumulation and slow running down proves conclusively that we have here to do, not with an ordinary hydrostatic column, but with a mass of water so subdivided by the closely packed materials intervening between the vents made by the auger and in the interspaces in which the water is stored that a rapid transmission of pressure is not possible, *and that the laws of hydraulics and friction, rather than those of hydrostatics, must be held to govern the discharge.* Moreover, it proves that hundreds of inches of water discharge bear but a very small ratio to the total supply that lies behind these artesian fountains.

The nature of these materials as disclosed by the auger or sand pump is found to be gravel (ranging from pea size up to cobbles of greater diameter than even the 10-inch pipes), tightly packed with sand of various degrees of fineness. Cobbles nearly filling the pipes—over 7 pounds in weight—have in several instances been ejected by the water pressure from some of these wells. The character of these cobbles can not be mistaken; they represent the same rocks that have been and are now being brought down from the Santa Ana and Mill Creek canyons at the head of the valley, where a wilderness of the same materials (ranging all the way from fine sand up to bowlders of 5 feet in diameter) cover many square miles of surface and are shown in every break of the country. There, as well as in the borings, occasional sheets or strata of clay or other impervious materials alternate with the gravel and cobble deposits, and with the penetration of each such clay layer additional water pressure is obtained in the wells. The sources of Warm Creek, the Parish Ditch, and of such outflows as "Hunt's Spring" doubtless indicate the termination or the perforation from some cause of such impervious water-shedding strata not far from the surface.

On page 23 is an analysis of water from wells in groups A and D of this system.

In October, 1892, the owners of the Gage canal system conducted a series of experiments on 55 artesian wells and obtained results at variance with the previous experiment.[a] The numbers indicated in the first column of the table correspond with numbers on Pl. I and show the locations of the wells. The third column of the table gives the distance to the nearest well, the fourth column the static pressure, in feet, when each well is closed. The fifth column (final measurement, reduced to miners' inches) gives the amount of water that each well was flowing at the end of the experiment, when all of the wells following it in the table were open. For instance, when well No. 115, which corresponds to well No. 1 of the Gage Canal Company's numbering, was open and all of the other wells were closed its discharge was in both instances 5 miners' inches. When well No. 116 was open and

[a]This is probably due to the more complete development of the entire supply by the Gage Canal Company and others.

all of the other wells were closed its discharge was 46 miners' inches; but when all other wells following in the list were open its discharge was 32.5 miners' inches. The seventh column gives the percentage of decrease in the flow of this particular well under the foregoing conditions. The eighth column gives the cumulative number of the original measurement, in miners' inches. In other words, it is the sum of the flow of any well and of all of the wells preceding it in the table, on the basis of one well alone being open. For example, well No. 115 being open and all of the other wells closed, it flows 5 miners' inches. Well No. 116 being open and all of the others closed it flows 46 miners' inches. Then the cumulative number of the original measurement, in miners' inches, corresponding to well No. 116 would be the sum of these two volumes, or 51 miners' inches. The ninth column gives the cumulative number of final measurements, in miners' inches, which is the sum of the discharge, on the basis of the other wells all flowing; as, for instance, in the case of well No. 116, when the other wells are open it would discharge 32.5 miners' inches, which added to the discharge of well No. 115 gives a total for the two wells of 37.5 miners' inches. The tenth column gives the percentage of decrease at each point of comparison between the seventh and eighth columns. The last column of the table gives the temperature of the water.

Fifty-five wells are considered in these experiments, and while the total volume of water obtained increased as more wells were opened, the aggregate flow is not so great, by 52 per cent, as the sum of the flow of all of the individual wells.

From the foregoing it will be seen that in this particular instance a gain was made by boring as many as 55 wells, but it is also indicated that the number of wells could not be increased indefinitely at a financial profit.

Table showing effect of opening and closing neighboring artesian wells of the Gage canal system.[a]

Quadrangle.	New number of well.[b]	Old number of well.	Distance between wells.	Pressure.	Final measurement.	Original measurement.	Difference between original and final measurements.	Cumulative quantity of original measurements.	Cumulative quantity of final measurements.	Decrease in volume.	Temperature of water.
			Feet.	*Feet.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Degrees.*
San Bernardino	115	1	0	24.75	5.00	5.00	0	5.00	5.00	0	75.0
Do	116	2	1,216	70.40	32.50	46.00	30	51.00	37.50	27	74.0
Do	117	3	296	75.90	29.00	37.00	22	88.00	66.50	24½	74.0
Do	118	4	525	73.60	41.25	48.75	15	136.75	107.75	21½	74.0
Do	119	5	551	23.00	3.50	3.50	0	140.25	111.25	21	73.0
Do	120	6	265	80.50	45.00	51.75	13	192.00	156.25	19	74.0
Do	121	7	4,620	11.00	13.75	27.50	50	219.50	170.00	23	70.0
Do	122	8	353	11.00	21.00	46.00	55	265.50	191.00	28	70.0
Do	123	9	204	12.50	3.50	9.75	64	275.25	194.50	29	70.0
Do	124	10	321	12.50	3.25	6.00	46	281.25	197.75	30	68.5
Do	125	11	714	28.00	24.50	58.00	58	339.25	222.25	35	67.0

[a] Courtesy of W. Irving, engineer of Gage canal system.
[b] These are the numbers shown on Pl. I.

Table showing effect of opening and closing neighboring artesian wells of the Gage canal system—Continued.

Quadrangle.	Old number of well.	New number of well.	Distance between wells.	Pressure.	Final measurement.	Original measurement.	Difference between original and final measurements.	Cumulative quantity of original measurements.	Cumulative quantity of final measurements.	Decrease in volume.	Temperature of water.
			Feet.	*Lbs.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Miners' inches.*	*Miners' inches.*	*P. cent.*	*Degrees.*
San Bernardino	126	12	80	29.00	21.62	49.75	57	389.00	243.37	37½	8.0
Do	127	13	765	16.10	86.50	150.00	43	539.00	330.37	39	760.0
Do	128	14	530	16.95	101.50	162.00	37	701.00	431.87	39	70.0
Do	129	15	1,680	[a]17.00	62.50	80.50	23	781.50	494.37	37	64.5
Do	130	16	180	50.60	50.00	60.50	18	842.00	544.37	36	66.0
Do	131	17	175	50.00	32.00	37.50	15	879.50	576.27	35	65.0
Do	132	18	480	[a]50.00	27.00	71.50	63	951.00	603.37	37	62.0
Do	133	19	330	16.95	43.50	143.00	70	1,094.00	646.87	43	62.0
Do	134	20	270	12.00	9.50	60.00	84	1,154.00	656.37	44	62.0
Do	135	21	260	13.20	24.75	104.00	77	1,258.00	681.12	46	62.0
Do	136	22	270	16.90	50.50	146.00	66	1,404.00	731.62	48	62.0
Redlands	391	23	265	10.90	36.00	132.50	73	1,536.00	767.62	51	62.0
Do	392	24	265	13.80	26.00	68.75	62	1,605.25	793.62	51	62.0
Do	393	25	320	13.80	19.75	68.75	71	1,674.00	813.37	52	62.0
Do	394	26	280	12.60	21.00	75.00	72	1,749.00	834.37	54	62.0
Do	395	27	320	13.80	9.00	34.00	73	1,783.00	843.37	54	62.0
Do	396	28	280	15.00	38.00	88.50	58	1,871.50	881.37	53	62.0
Do	397	29	310	16.10	28.85	47.00	39	1,918.50	910.22	53	62.0
Do	398	30	790	12.60	11.25	30.00	63	1,948.50	921.47	53	62.0
Do	399	31	430	14.90	3.75	9.50	60	1,958.00	925.22	53	64.0
Do	400	32	35	16.10	16.25	28.50	48	1,986.50	941.47	53	64.0
Do	401	33	315	18.40	41.00	90.00	55	2,076.50	982.47	53	63.0
Do	402	34	550	(b)	48.00	98.30	52	2,174.80	1,030.47	53	63.0
Do	403	35	130	15.50	30.50	65.75	54	2,240.55	1,060.97	53	63.0
Do	404	36	120	16.10	16.00	29.50	46	2,270.05	1,076.97	53	64.0
Do	405	37	680	16.00	42.00	92.00	55	2,362.05	1,118.97	54	66.0
Do	406	38	90	16.00	28.75	48.75	41	2,410.80	1,147.72	53	66.0
Do	407	39	279	16.90	10.50	24.75	58	2,435.55	1,158.22	53	66.0
Do	408	40	1,090	16.90	77.15	166.00	53	2,601.55	1,235.37	53	66.0
San Bernardino	155	41	474	13.80	69.50	168.00	58	2,769.55	1,304.87	53	66.0
Do	156	42	510	16.90	85.75	169.00	50	2,938.55	1,390.62	53	66.0
Do	157	43	510	18.00	109.75	137.00	20	3,075.55	1,500.37	52	66.0
Do	158	44	307	20.00	92.75	146.00	37	3,221.55	1,593.12	51	64.0
Do	159	45	1,580	25.00	16.50	46.25	60	3,267.80	1,609.62	51	62.0
Do	160	46	15	25.00	6.70	16.75	60	3,284.55	1,616.32	51	62.0
Do	161	47	15	25.00	26.40	66.00	60	3,350.55	1,640.72	52	62.0
Do	162	48	40	25.00	29.33	50.84	60	3,401.39	1,670.05	51	62.0
Do	163	49	50	23.20	26.40	76.00	60	3,477.39	1,698.45	52	62.0
Do	164	50	40	25.00	15.00	[a]20.00	25	3,497.39	1,713.45	51	62.0
Redlands	409	51	4,440	19.00	00.00	7.00	100	3,504.39	1,713.45	52	64.0
Do	410	52	20	19.00	00.00	7.10	100	3,511.49	1,713.45	52	64.0
Do	411	53	25	19.00	00.00	7.00	100	3,518.49	1,713.45	52	64.0
Do	412	54	25	19.00	00.00	10.50	100	3,528.99	1,713.45	52	65.0
San Bernardino	169	55	5,070	22.00	80.00	150.00	56	3,678.99	1,793.45	52	64.0

[a] Estimated. [b] Left open.

DIVERTING DAM.

The river water is diverted into the canal by means of temporary brush and sand dams, which are renewed each year; but owing to the natural conditions in the river bottom the renewal is a work of small expense compared with the cost of permanent works sufficient to withstand the action of floods, which sometimes exceed 2,000 cubic feet per second over a bed composed of sand and gravel several hundred feet in depth. In a few hours after the river reaches its maximum discharge it recedes to its normal flow, when the whole of it can if necessary be diverted into the canal by throwing up an embankment of sand a few inches above the water surface.

HEAD GATES.

The head gates are strongly constructed of heavy timbers and have three sets of regulating gates, opened by means of ratchets and pin-

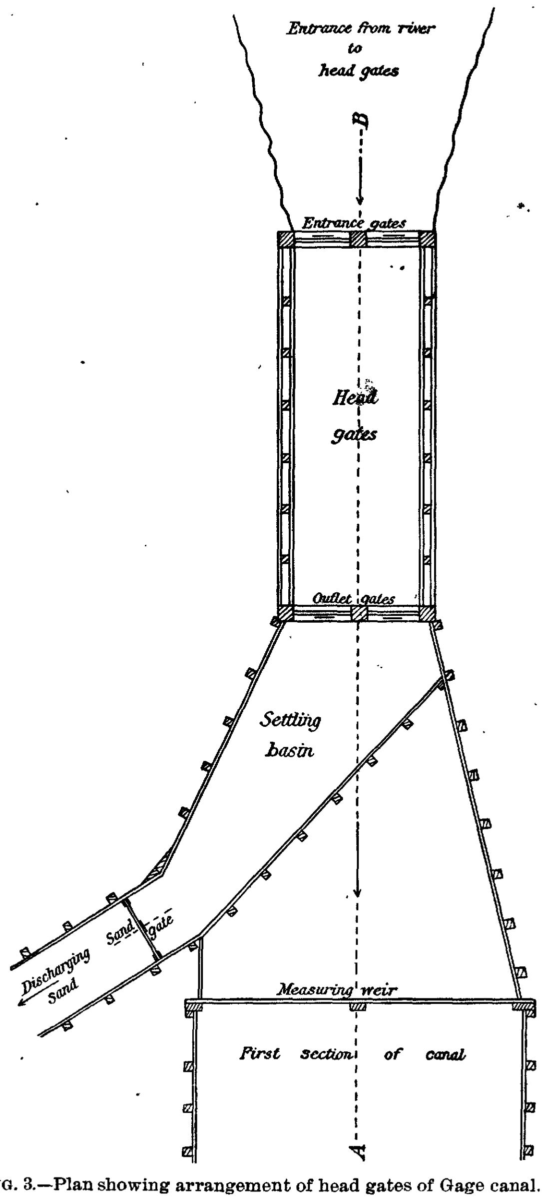


FIG. 3.—Plan showing arrangement of head gates of Gage canal.

ions, one set being sand gates for the discharge of the surplus water and the moving sand. (See fig. 3.)

The water discharges out of the head gates into a settling basin, from which it is measured over a weir into the canal. Figs. 3, 4, and 5 show the head gates and the measuring weir. In connection with the weir there is an automatic register by means of which a record is

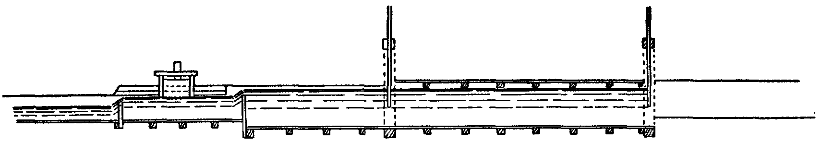


FIG. 4.—Section of headworks of Gage canal, on line A-B of fig. 3.

made of the amount of water flowing into the canal at all times during the irrigation season.

In addition to the automatic register there is an automatic electric alarm by means of which high and low water during the night are

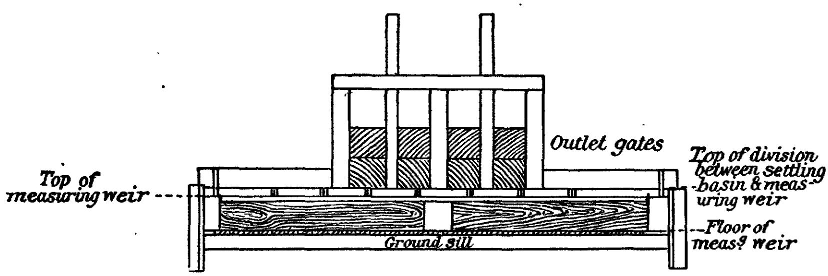


FIG. 5.—End elevation of measuring weir on Gage canal, showing end elevation of outlet gates beyond.

made known to the attendant. The cylinder on which the changes are traced receives its motion from a clock movement and makes one revolution in seven days.

The weir over which the water is measured is 23 feet long. The canal at the weir is 24 feet wide and serves as a settling basin for the moving sand, which at times causes trouble. For a distance of a few hundred feet from the head gates the banks of the canal are lined with wooden sheeting, gradually narrowing from a width on the bottom of 24 feet at the head gates to 10 feet where the cemented portion begins. From that point for a distance of 2,950 feet the canal gradually rises from the river bottom proper to the plain of the first mesa lands and to flume No. 1, over a small local arroyo; thence, at a distance of 8,500 feet, through the same mesa lands to flume No. 2, over a small creek; thence, at a distance of 15,650 feet, through the mesa lands to tunnel No. 1 and the base of a range of foothills; thence, at a distance of 21,050 feet, by a series of tunnels and along the face of

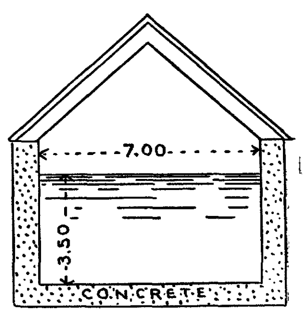


FIG. 6.—Section of tunnel No. 1, in earth, of Gage canal system.

the foothills to flume No. 3. A section of tunnel No. 1 is shown in fig. 6. The canal continues along the bluffs in a series of tunnels, fills, and flumes Nos. 4, 5, and 6 until it passes onto the upper plains at a distance of 27,200 feet. From that point it follows the natural contour of the land, crosses an arroyo by means of flume No. 8 (flume No. 7 being now a fill), and at a distance of 45,600 feet from its head it passes through the projecting point of a foothill by means of a tunnel, and then continues along the natural contour to flume No. 9, over Terquisquite Arroyo, at a distance of 62,800 feet, or 11.9 miles; then, by means of flumes, fills, and cuts, it crosses the arroyo between the foothills and follows the natural contour of the land to the end, the total length being 106,444 feet, or 20.16 miles.

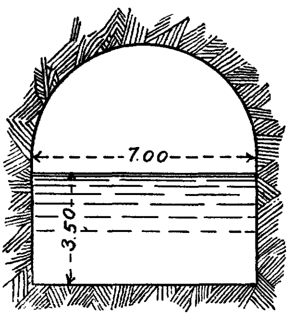


FIG. 7.—Section of tunnel in rock on Gage canal system.

CEMENT LINING.

Generally the slope of the sides of the canal is 4 perpendicular to 3 horizontal.

From the head gates to flume No. 10 the canal is lined with masonry, as are also all tunnels and fills, to a depth of 5 inches, and then is plastered with cement mortar; the remaining portions are lined with cement plaster to a thickness of three-fourths of an inch. Of the whole length of the canal (20.16 miles) 14.5 miles

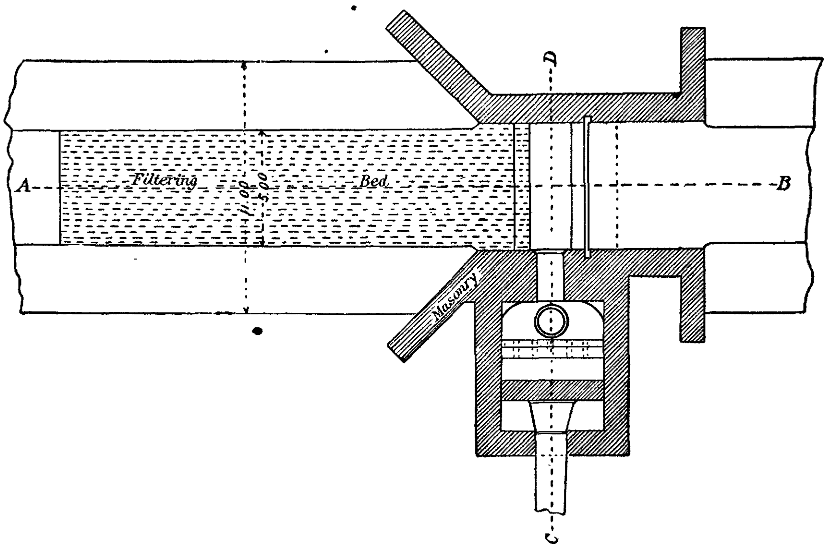


FIG 8.—Plan of bulkhead and orchard lateral connection on Gage canal system.

are lined with cement. Most of this work was done during the winter months from 1891 to 1894, and at an average cost of $1.50 per foot, or a total cost of $114,135. While it can be said that this cement lining has not stood well, it can also be said that it has stood better than was expected under the conditions. When in increasing the capacity of a channel it is a question of spending $75,000 in one case and $200,000 in the other case, and saving an important percentage of irrigation water, it may be excusable to take some risk. Large surfaces of cement coating three-fourths inch thick can not be expected to stand much strain under the action of storm waters, and it is to this action that nearly all ruptures of the coating are due. Had there been intervals of time during recent dry years to close the canal for repairs

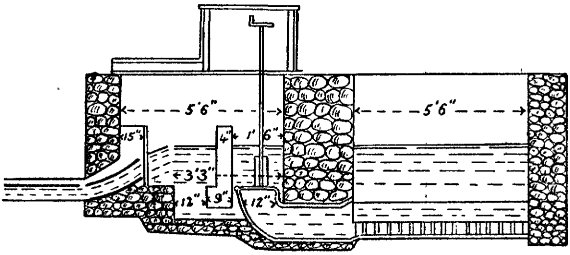


FIG. 9.—Cross section of bulkhead and orchard lateral on Gage canal system, on line C-D of fig. 8.

its condition would be much better. No repairs have been made during the last four years, and the estimated cost of a thorough renovation is less than $1,000, which spread over four years is only a fraction of 1 per cent of the original cost.

The cross section of the canal varies with the distance from the head gates. The bottom width below the head gates is 10 feet, as already stated, which is gradually reduced to 6 feet at flume No. 10; from that point to near the end the width is 5 feet. The canal has a uniform depth of 4 feet throughout its entire length.

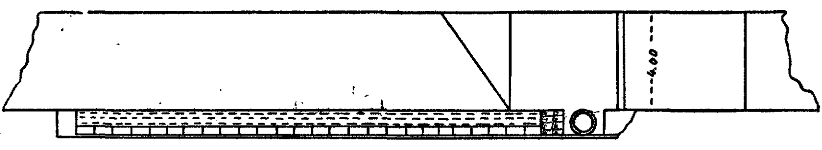


FIG. 10.—Longitudinal section of bulkhead and orchard lateral on Gage canal system, on line A-B of fig. 8.

The total length of tunnels is 5,250 feet. Where they pass through earth formation the bottom and sides are lined with concrete masonry and the roofs are heavily timbered.

The total length of flumes is 4,000 feet. All are strongly framed, rest on masonry foundations, and have retaining walls and foundations at each end where they connect with the other parts of the canal.

CAPACITY.

The capacity of the canal at various localities, as stated by the engineer of the company in 1899, is as follows:

	Miners' inches.
Canal 1.5 miles from headworks	9,646
Tunnel 3 miles from headworks	4,630
Flume 4 miles from headworks	4,270

	Miners' inches.
Weir 5.7 miles from headworks	2,215
Flume 7.5 miles from headworks	4,060
Flume 11.9 miles from headworks	3,166
Canal 12.5 miles from headworks	4,375
Flume 14.75 miles from headworks	3,436
Flume 18.5 miles from headworks	3,350
Pipe line (12-inch) to San Jacinto Land Company from south end of canal	346

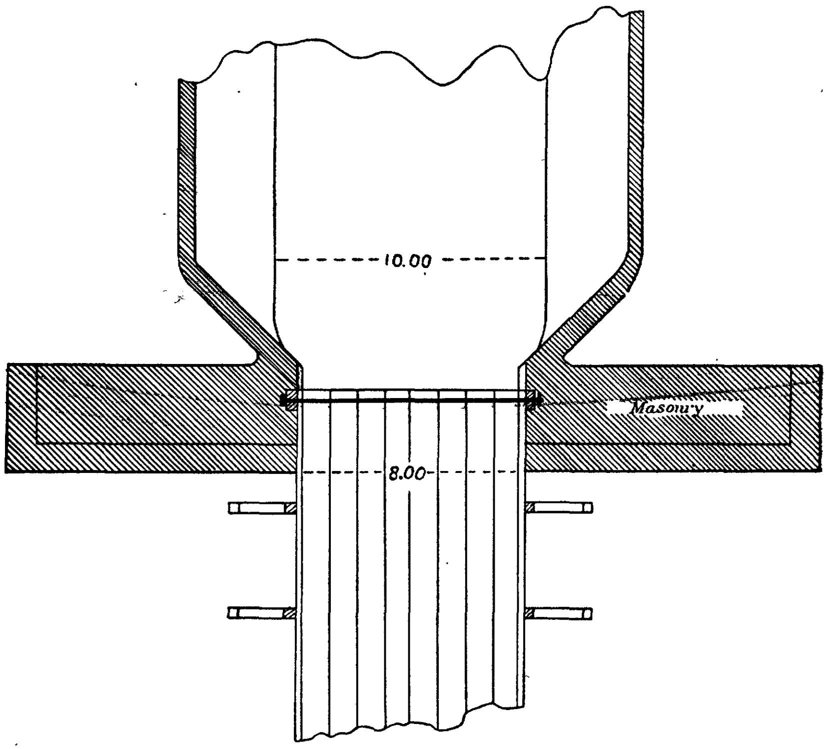


FIG. 11.—Plan showing junction of canal and flume on Gage canal system.

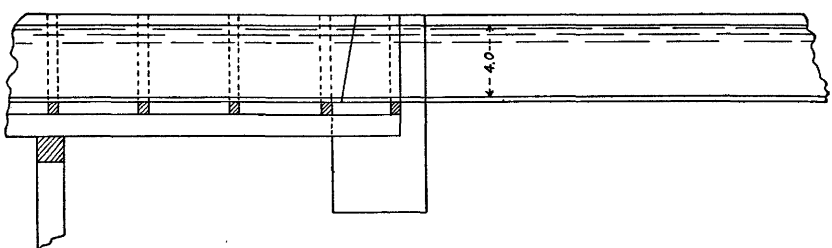


FIG. 12.—Longitudinal section of canal and flume on Gage canal system.

In 1899 the upper section of the canal was carrying 1,440 miners' inches; at the lower end of the middle section there were 742 miners' inches, while at the extreme southerly end of the canal the San Jacinto Land Company was taking out through its pipe line, for the supply to

530 acres under cultivation, all of the water remaining in the canal, viz, about 106 miners' inches, or 1 miners' inch to each 5 acres. This

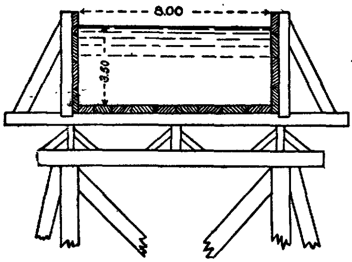


FIG. 13.—Section of flume and trestle on Gage canal system.

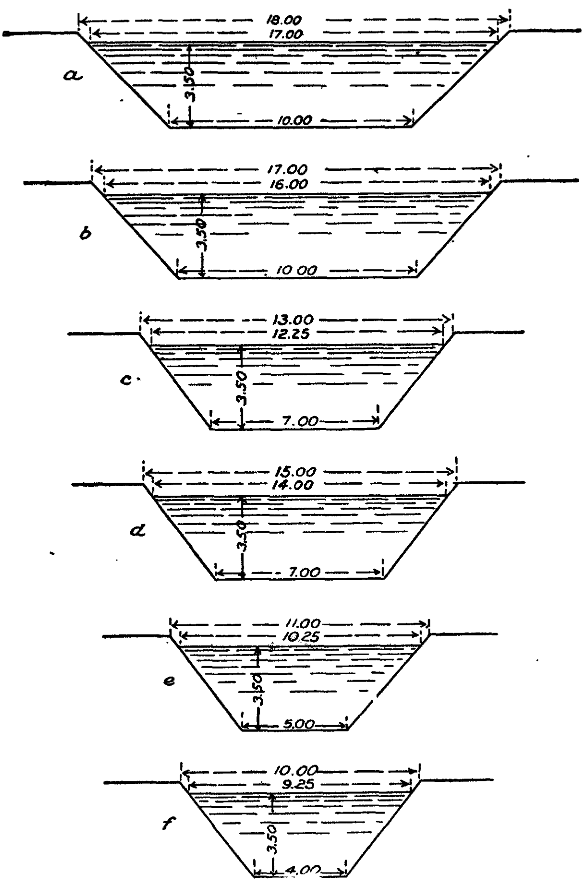


FIG. 14.—Cross sections of Gage canal: *a*, 336 feet from head; *b*, 1.62 miles from head; *c*, 3 miles from head; *d*, 8.55 miles from head; *e*, 18.69 miles from head; *f*, at terminus.

duty of 1 inch to 5 acres was then and still is in force on all cultivated lands under the Gage canal. The canal gave nearly the full water supply to its underlying lands during the drought of 1897–1900.

The following table gives the value of the hydraulic elements in the various sections of the canal.

Table showing value of hydraulic elements in sections of Gage canal.

	A.	B.	C.	D.	E.	F.
Distance from head, in miles	0.064	1.62	3	8.55	18.69	----------
Slope	.000413	.00052	.000383	.000478	.0004	0.0004
Area of cross section, in feet	47.25	45.5	33.25	33.67	26.68	23.18
Perimeter of cross section, in square feet	19.80	19.1	15.60	15.75	13.75	12.75
Hydraulic mean radius	2.38	2.38	2.13	2.13	1.94	1.82
Coefficient of roughness	.014	.014	.014	.014	.014	.014
Coefficient	121	121	119	119	118	118
Discharge, in miners' inches	8,953	9,646	5,635	6,380	4,375	3,686

DIVERSIONS.

East Riverside.—About 30,000 feet from the head gates the first distributing pipe in the East Riverside district connects with the canal, and from that point to flume No. 9, over Terquisquite Arroyo, distributing pipes enter the canal at intervals of about one-fourth of a mile. Throughout this whole distance metal valves inserted in brickwork are provided at all distributing points. (See figs. 8, 9, and 10.) The distribution system is under command of an officer whose duty it is to subdivide the water to the several owners in accordance with their shares and with the by-laws adopted by themselves, through their representatives, for its management and distribution. Fig. 11 shows the junction of canal and flume generally used on the Gage canal system.

The amount of land served by the canal in the East Riverside district, extending from the first diversion described to flume No. 9, its southerly limit, is 3,620 acres, nearly all of which is now under cultivation.

Lands served by Gage canal in East Riverside district.

	Acres.
Growing oranges	3,000
Growing lemons	40
Growing deciduous fruits	40
Growing alfalfa	40
Total cultivated area	3,120
Uncultivated area	500
Total	3,620

Arlington Heights.—At a distance of 71,900 feet from the head gates, and about 1½ miles from flume No. 9, the lands of Arlington Heights are reached. These lands are subdivided, by streets, at intervals of one-fourth of a mile, each block of about 40 acres being bounded by streets and the block again subdivided into 10-acre lots.

The total acreage served by the canal at Arlington Heights is a little more than 4,890 acres, divided as follows:

Lands at Arlington Heights served by Gage canal.

	Acres.
Growing oranges	2,200
Growing lemons	520
Growing grape fruit	170
Total cultivated area	2,890
Uncultivated area	2,000
Total area subject to canal	4,890

Pipe lines.—The distribution of water is by means of steel pipes carried down each street transverse to the canal, with lateral connections to each 10-acre lot, the water being carried to the highest point and furnished with a hydrant and measuring weir. From the hydrants open flumes are laid along the highest boundaries of the lots, from which the water is served to the irrigating furrows between the trees. At the end of each pipe line where it enters the canal bulkhead is a regulating valve and a measuring weir. (See figs. 8, 9, and 10.)

The main pipe lines on the streets vary in diameter from 10 inches at the canal to 6 inches at the lowest point. The greatest pressure to which the pipes are subjected is equal to a head of 164 feet, or 70 pounds to the square inch. The pipes are formed of riveted steel plate, No. 14 to 18 gage, coated with an asphaltum preparation.

On the distribution system of Arlington Heights there are 287 hydrants, or an average of one hydrant to each 10 acres. The hydrants are manufactured by the Lacy Manufacturing Company, of Los Angeles, from a special design by Mr. William Irving, engineer of the Gage canal system. Hydrants are furnished to the irrigators at a cost of $10 in place. Over the hydrant is set a cement hydrant box, which is made by the Gage Canal Company and set in place at an expense to the irrigators of $10 each, which represents the actual cost. In the distribution system of Arlington Heights there are the following lengths of steel pipe:

4,800 feet of 12-inch, costing 66 cents per foot laid.
4,000 feet of 10-inch, costing 56 cents per foot laid.
36,500 feet of 8-inch, costing 47 cents per foot laid.
88,400 feet of 6-inch, costing 36 cents per foot laid.
147,200 feet of 4-inch, costing 26 cents per foot laid

This represents a total cost of $92,660 for the pipe in that system.

Detailed data pertaining to the distribution system of East Riverside under the Gage canal can not be obtained, but the cost, using the Arlington Heights factor of acreage, which will give results very close to the correct figures, would be $102,000. The method of distribution for East Riverside lands under the Gage canal is similar to that described for Arlington Heights.

San Jacinto Land Company.—The following lands, which are adjacent to the south and west boundaries of Arlington Heights, are served by the Gage canal at its extreme southwesterly terminus:

Lands of San Jacinto Land Company served by Gage canal.

	Acres.
Growing oranges	452
Growing lemons	60
Growing grape fruit	18
Total cultivated area	530
Uncultivated area	120
Total area subject to canal	650

DUTY OF WATER.[a]

The duty of water under the Gage canal system is equal to 1 miners' inch to each 5 acres of land, continuous flow. Its equivalent is 0.02 cubic foot per second, which converted into the form of an equivalent annual rainfall equals very nearly 35 inches depth of water over the whole area of land. As the periods of irrigation are generally at intervals of one month, each monthly irrigation is equal to a rainfall of nearly 3 inches.

Under this system the purchaser of land becomes a shareholder in the canal and the water sources, and by virtue of his water stock has a voice in the management of everything pertaining to the water service. The management consists of a board of directors elected annually by the owners of the lands and the stockholders in the canal company.

The portions of the by-laws which provide for the issuance of stock carrying water rights and for the distribution of the water are as follows:

ARTICLE V.

CAPITAL STOCK.

SEC. 1. The board of directors shall cause to be issued certificates of stock to subscribers or purchasers of stock or to persons with whom the corporation may bargain or contract in relation to the purchase or use of water or water rights or property of any kind or character, and shall cause such stock and certificates thereof to be issued in accordance with the direction of any of the above-named persons; and thereafter shall cause to be issued to stockholders or their assignees certificates of stock, in accordance with law and their articles of incorporation and these by-laws and rights of the parties, which certificates shall be signed by the president and secretary; and all stock (or new stock issued or to be issued in lieu thereof) sold, bartered, or exchanged for the purpose of purchasing water to be supplied to or flowing in the canal or canals used or owned by the corporation shall have attached thereto and transferred therewith and evidenced by indorsement on the certificate thereof a water right or rights to the use of water delivered at the main canal in continuous flow under a 4-inch pressure in the proportion of one-tenth of an inch under said pressure to each share: *Provided*, That the board of directors shall, in their discretion, have power to affix to such water rights when

[a] Detailed descriptions of the use and duty of water under the Gage canal system are given in Bull. 86 U. S. Dept. Agr., office of Experiment Stations, Pt. 1, p. 74, Pt. II, pp. 131-148.

the same are first granted such terms or conditions as to application or use of water for specific purposes as they may contract or see fit, and to provide that such conditions shall be observed, otherwise such water right to be void, but thereafter such terms or conditions shall not be changed except by consent of the stockholder holding such water right: *And provided also*, That such water right shall be subject to the provision of the articles of incorporation in that behalf and to these by-laws or any amendments thereof and to the rules and regulations which are or may be from time to time adopted by the board of directors. Certificates of stock shall not be issued in less amount than one share.

SEC. 2. No transfer of stock shall be binding on the corporation unless duly entered on its books, nor shall stock be issuable until the owner thereof or his duly authorized agent shall have signed a receipt therefor on the stub of the stock-certificate book and until all the previous assessments and water rates as provided by these by-laws and the articles of incorporation, levied thereon according to the law and according to these by-laws and the articles of incorporation, have been fully paid.

ARTICLE VIII.

AS TO BY-LAWS.

These by-laws, or either or any of them, by section or article, may be repealed, amended, or added to, or new by-laws adopted in their stead, either by the stockholders at any meeting thereof or by the majority of the board of directors at any meeting thereof.

ARTICLE IX.

MISCELLANEOUS.

SEC. 1. An inch of water in these by-laws referred to is defined to be a continuous flow of water through an aperture one (1) inch square under a pressure of four (4) inches, measured from the center of such aperture to the surface of the water.

SEC. 2. Each stockholder is entitled to water in continuous flow, or its equivalent, taken monthly, according to the by-laws and regulations of the corporation. Should any stockholder desire to have furnished in one day the supply of water to which he is entitled for a certain number of days not to exceed thirty days (nor in excess of the capacity of the distributing pipe or pipes to his land or lands), he shall give the corporation at least four days' notice of such desire and accept the water on any day or days that the company may be able to arrange for the supply thereof.

COST.

The cost of the system to 1893 is as follows:

Cost of Gage canal system to 1893.

Main canal and connected works, including rights of way	$285,000
Distributing pipe lines and connected works	70,000
Artesian wells	50,000
Water sources and connected lands	175,000
Total	580,000

[For index see end of Part II, Water-Supply and Irrigation Paper No. 60, which contains descriptions of the East Riverside irrigation district, the Riverside-Highland Water Company, and the lower San Bernardino Valley above Rincon, also complete data of the 890 wells in the San Bernardino and Redlands quadrangles, and notes concerning the manufacture of Portland cement in southern California.]

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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.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn 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.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells 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.

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.

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.

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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.

Part II of the Nineteenth Annual contains a paper on "Principles and conditions of the movements of ground water," by F. H. King, and one on "Theoretical investigation of the motion of ground waters," by C. S. Slichter.

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Contains a "Report of progress of stream measurements for the calendar year 1899," by F. H. Newell; "Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming," by N. H. Darton, and "The High Plains and their utilization," by W. D. Johnson.

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