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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE HYDROLOGY OF SAN BERNARDINO VALLEY, CALIFORNIA

BY

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Los Angeles, Cal., February 16, 1905.

SIR: I transmit herewith the manuscript of a report on the hydrology of the San Bernardino Valley, California, and recommend that it be published as a water-supply paper. This report has been prepared by Mr. W. C. Mendenhall, geologist, under the general direction of Mr. N. H. Darton. It is one of a series of reports on the underground waters of the valley of southern California.

In this valley, where irrigation practice has attained a high degree of perfection, the underground waters are of very great importance, two-thirds of the irrigated acreage being dependent upon them either wholly or in part.

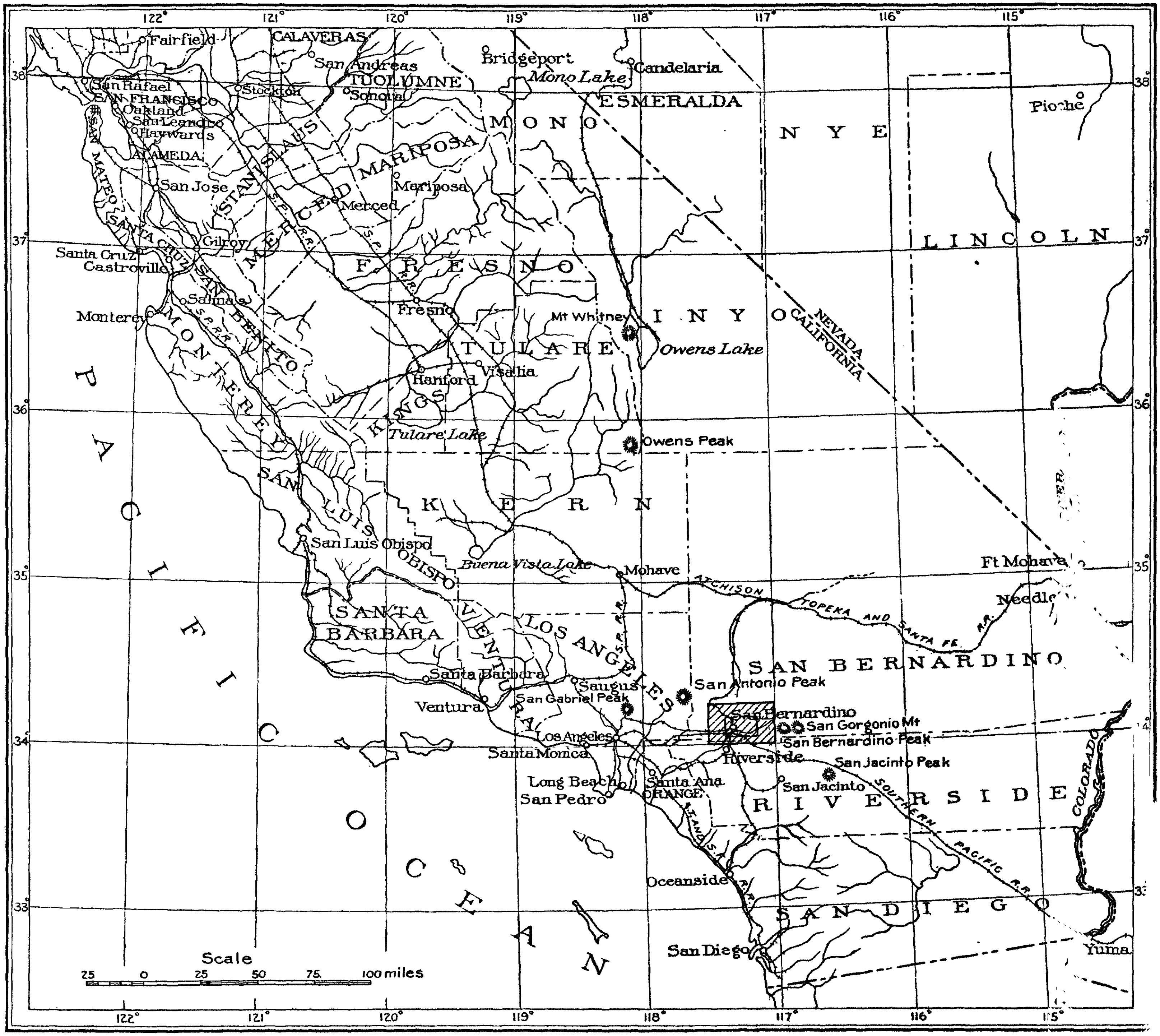
In this paper those phases of the geology which throw light upon the amount, distribution, and movements of these waters are described, and the effects of development and drought in bringing about those changes in water levels which have taken place in recent years are discussed.

The author has had constantly in mind, in the preparation of the paper, the needs of the practical irrigator and the questions which must arise in disputes concerning title to percolating waters.

Very respectfully,

F. H. NEWELL, *Chief Engineer.*

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



OUTLINE MAP OF SOUTHERN CALIFORNIA.

HYDROLOGY OF SAN BERNARDINO VALLEY, CALIFORNIA.

By Walter C. Mendenhall.

INTRODUCTION.

GEOGRAPHIC SITUATION.

The San Bernardino basin lies near the eastern end of the valley of southern California. Under the latter term is included that general lowland area which is definitely limited on the north by the San Gabriel and San Bernardino ranges and on the east by the latter range and the San Jacinto group, but whose southern boundary is irregular and difficult to define. In this direction there is an interdigitation of ridges and valleys as the Sierra Madre Range of San Diego County dies out toward the north. The more or less indefinite heights that represent its extension in this direction are separated by lowlands, which in turn are to be regarded as southwest lobes of the well-defined east-west valley that lies along the base of the San Gabriel Range.

Toward the west this greater valley opens directly to the Pacific, without the intervention of any extensive heights. The Santa Ana Mountains and the San Jose Hills project well into it from the southeast, at a distance of about 25 miles from the Pacific shore line, in the vicinity of Lordsburg, and reduce its width at this point to but a few miles. The San Gabriel basin and the coastal plain, separated by the low Los Angeles and Puente hills, lie west of this ridge. East of it are the Cucamonga and Chino plains, the Riverside basin, the numerous more or less isolated valleys of the upper San Jacinto drainage area, and the San Bernardino basin, which together form an interior subdivision of the greater valley. The San Bernardino basin is the northeastern part of this interior subdivision, and from the point of view of water supply is most important. It is separated on the east and south from the adjacent lowlands by the Crafton Hills, the ridge known as the Badlands, and the Jurupa Mountains. Toward the west it opens directly into the wide Cucamonga plains. It lies wholly within the valley portion of San Bernardino County and forms a part of the drainage basin of Santa Ana River, all of the streams which flow down into it from the San Bernardino and San Gabriel mountains being tributaries of this, the most important stream in southern California.

SETTLEMENT.

When in 1851 the first band of Mormon immigrants, led by Captain Hunt, descended through Cajon Pass into San Bernardino Valley, after a journey of months across the parched deserts from Salt Lake, the abundant springs of pure water and the living streams in the great cienaga must have appealed to them with a force which was greatly increased by the vivid memory of the loss of their companions by thirst in Death Valley but a short time before. It is not a matter of wonder that they decided that their wanderings should cease here and that forthwith they began the building of homes, in which they hoped to spend the rest of their lives.

As early as 1810 a mission settlement had been made at Politana, near what is now Bunker Hill, and somewhat later another of more importance and greater permanence was established at old San Bernardino, on the south side of Santa Ana River. Politana was destroyed by the Indians and abandoned soon after its foundation, but the San Bernardino branch mission flourished, and under the direction of the church fathers in charge there the Mill Creek zanja, the oldest irrigation ditch in the valley, was constructed between 1820 and 1830. When the missions were secularized by command of the Mexican Government in 1833, and their lands distributed to Mexican citizens by large grants, the San Bernardino rancho, which included nearly all of the cultivable lands of the valley, fell to members of the Lugo family, and from them it was purchased by the Mormon settlers in 1851 for $7,500.

DEVELOPMENT OF IRRIGATION.

When the Mormons came into possession, the Mill Creek zanja at old San Bernardino was the only irrigating work in this part of California. The wide area of moist lands above Colton, the limited numbers, the simple needs, and the pastoral habits of the first settlers, all combined to reduce the necessity for irrigation, so that the first ditch of their own building was not constructed until 1854. With this beginning, other small ditches were dug in the middle of the valley as the population slowly increased and the irrigated areas were gradually extended, but extensive projects were not undertaken until work was begun upon the first Riverside canal by a New England colony, the Silk Center Association, in 1870. By 1876 both the upper and lower Riverside canals had been completed, and thereafter a constantly increasing acreage was brought under cultivation by the water furnished by them, until in 1882 4,300 acres were reported as supplied by these systems, which at that time depended upon the flowing waters of Warm Creek and Santa Ana River.

During this period the waters from other streams tributary to San Bernardino Valley were diverted and utilized upon the available lands. City Creek water had at first been applied only to the lower lands, to which it could be most easily conducted; but in 1874 a canal was constructed by which it was taken to the "bench" lands in the vicinity of what is now Highlands. The superior value of the bench lands even at this early date was rapidly coming to be recognized.

The Highlands ditch, by which the waters of Santa Ana River were first taken out upon the East Highlands mesa, was built in 1881 and 1882.

In 1883 the construction of the Bear Valley dam was begun, and with its completion in 1884 the reclamation of the valuable citrus lands of the Redlands mesa was accomplished. The success of this project was marred by bad financiering and by a serious overestimate of the amount of water which it would render available, so that although it brought into the productive zone a large acreage of fertile lands which were useless before its completion, these positive gains were accompanied by serious losses.

The tendency constantly observable throughout this period was to extend cultivation to higher ground. The first canals had served only the lowest lands adjacent to the river bottoms; but these lands, subject as they were to frost, proved to be not so well adapted to the valuable citrus fruits as the warmer benches. Encouraged by the success of the earlier projects and recognizing the growing value of the mesas, Matthew Gage, in 1885, undertook the construction of a higher canal from which it was proposed to irrigate a belt of the Riverside mesa lying entirely above the older Riverside canal systems. The Gage canal was constructed in sections and was finally completed to its present terminus in 1888. Unlike the other large canals of San Bernardino Valley, it has depended from the first chiefly upon developed underground waters, and the 7,500 acres of splendid citrus lands which it has brought into the productive zone indicate the results that may be accomplished by the use of such waters.

Since the completion of the Gage system other projects have been put through, but development has been less rapid since the early eighties, partly because the available water supplies were generally utilized in the projects which had been developed by that time and partly because the unfavorable commercial conditions prevailing during the early nineties made investors generally much more conservative.

Among the later developments worthy of note are those of the Riverside Highlands Water Company, organized in 1898, whose latest plant for the supply of the higher parts of the old East Riverside district was installed in 1904. The final result of all of this development has been the reclamation of about 54,000 acres in the Redlands, San Bernardino, and Riverside quadrangles. Nearly all of this acreage depends upon the water supply from the San Bernardino Mountains, either utilized directly as it flows from the canyons or recovered later from underground reservoirs.

By tracing in this incomplete review the development of the irrigation projects within the valley from the time when only the low-lying lands within reach of the old Mill Creek zanja, constructed by the Mission fathers, or those in the moist bottoms which needed no artificial watering, or only such as could be given by the simplest of ditches, were utilized, to the later periods when the superior value of the bench lands came gradually to be recognized and costly and carefully designed irrigation works were planned for their redemption, we gain some comprehension of the constantly increasing demand for water and its concurrently increasing value.

The most important single element in bringing about this development has been the growth of the citrus industry since the foundation of the Riverside colony in 1870. The first citrus trees were probably some seedling oranges grown about old San Bernardino rather as ornamental trees than because they were conceived to be of commercial value. Indeed, before the building of the transcontinental railway lines, which gave the fruit a wide market, they could be of but little importance, since local consumption has never been sufficient to provide a profitable market. In the Riverside colony, however, citrus trees were planted early as a commercial venture, and from a modest beginning there, down on the lower lands under the old Riverside canal, the groves have gradually crept up the slopes to the warm, fertile, frostless soils of the mesa (Pl. II, *A*) until now these lands wherever cultivated are producing the best fruits of the district.

The steady increase of acreage under the various systems and the increasing maturity of the groves first planted have called for constant extensions of the irrigating systems. With the increase in acreage there has gone a constant improvement in irrigation practice and in methods of cultivation, so that the amount of water in use for citrus orchards has diminished from 1 miner's inch for each 3 acres to 1 inch for 5 or 6 acres, and many successful horticulturists maintain that even this diminished amount may be reduced not only without harm but with positive benefit to the soils and groves. The improvement in practice which has already taken place means that the amount of water used for irrigation has by no means increased as rapidly as the area cultivated, yet there has been a slow general increase, as the following table will show.

A. RIVERSIDE-HIGHLANDS IRRIGATION DISTRICT.

B. BALDWIN LAKE.

The available measurements of the waters secured from the San Bernardino basin above Colton are as follows:

Quantity of water from San Bernardino basin above Colton, Cal.

Date.	Quantity.	Observer.
	Second-feet.	
September, 1898	144.69	Kingsbury Sanborn.
August, 1899	110.14	Do.
September, 1900	125.6	Do.
September, 1902	120.21	Do.
August and September, 1903	155.25	Do.
August, 1904	143.98	Do.

Some plants have been installed below Colton during this period, and the waters which they have developed have been used to augment those secured above the "dike;" hence the table does not indicate fully the increase.

BIBLIOGRAPHY.

Since irrigation has necessarily been practiced to some extent almost since the first settlements in this valley, the sources of the water have been the subject of more or less study. Usually these studies have been directly connected with individual enterprises and have been confined to small areas. Their results have not been published for general distribution, but, if preserved at all, are to be found in the records of the various irrigation districts and irrigation companies. A few general papers, however, exist upon one or another phase of the water problem. First to be mentioned is the volume on "Irrigation in Southern California," by William Hamilton Hall, State engineer of California, published in 1888. This work includes a history of practically all irrigation projects completed in this part of the State at the time of its publication. Less attention was paid to developments of underground waters than to surface systems, both because the former were not at that time recognized as of such supreme importance as at present, and because the engineering features were the chief object of Mr. Hall's studies. Nevertheless, this volume remains the most complete general account extant of southern California irrigation systems and is invaluable to a student of the history of the water problem in the southern section of the State.

The results of a later and much more thorough study of the water supply, irrigation developments, and irrigation practice in upper San Bernardino Valley have been embodied in a paper entitled "Water Supply of San Bernardino Valley," by J. B. Lippincott. This paper was published in Part IV of the Nineteenth Annual Report of the

United States Geological Survey, and readers are referred to it for details of the organization of companies operating along the northern and eastern edges of this valley, and for descriptions of the engineering features of interest there.

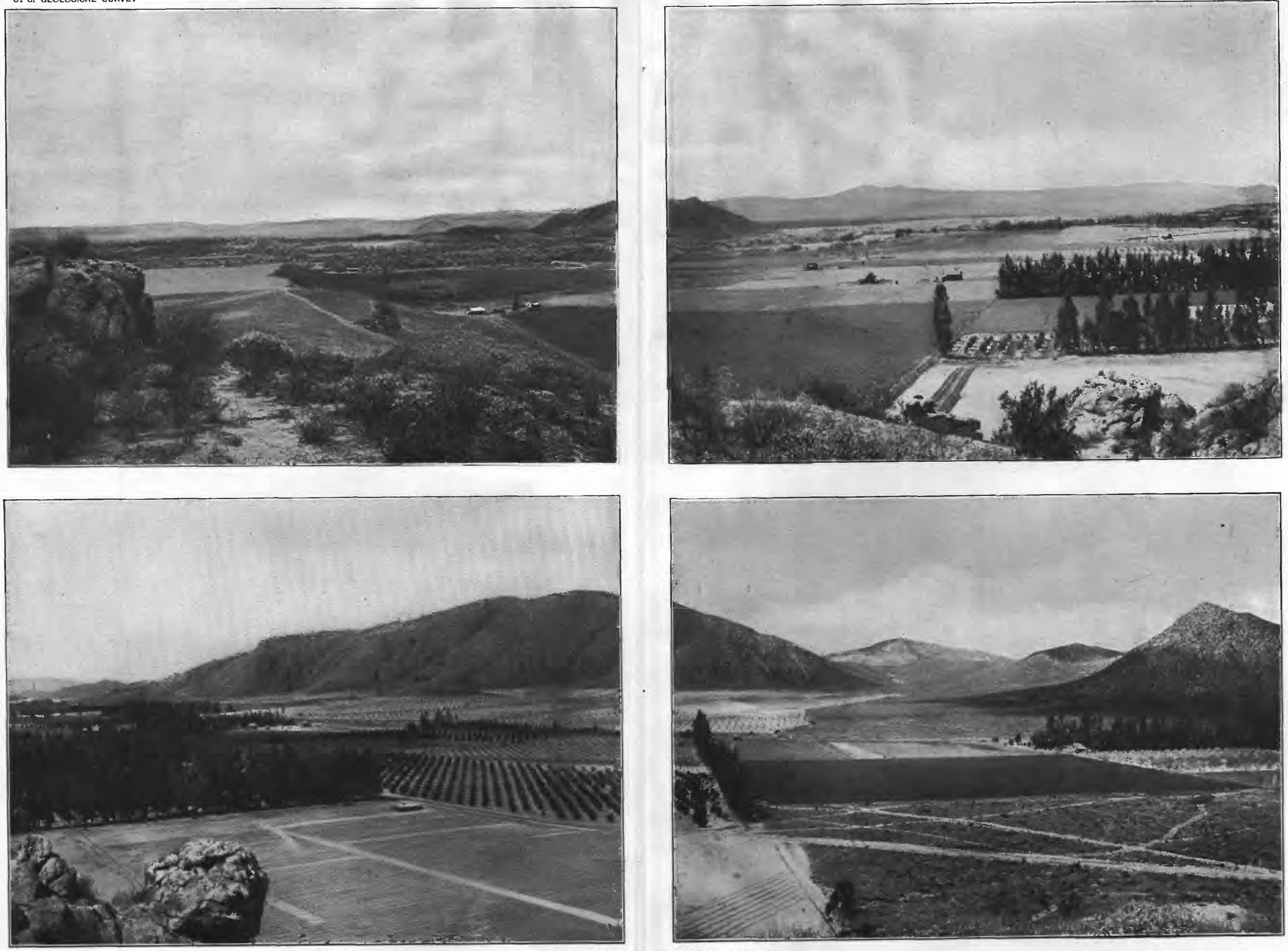
A later paper by Mr. Lippincott, entitled "Development and Application of Water near San Bernardino, Colton, and Riverside, Cal.," has been issued in two parts, as Water-Supply Papers Nos. 59 and 60, of the United States Geological Survey. This paper includes the results of Mr. Lippincott's studies in the lower, western, and southern parts of the basin and the contiguous regions. In it, as in the earlier paper, particular attention is paid to the surface supplies, to engineering features, and to the organization and operation of districts and water-distributing corporations.

Results of measurements of stream flow made by Mr. Lippincott in his capacity of resident hydrographer of the Geological Survey, or by his assistants, have appeared from time to time in the progress reports of the division of hydrography, and these have been assembled with similar data from other parts of California in a volume entitled "California Hydrography," issued by the Geological Survey in 1903, as Water-Supply Paper No. 81. This volume includes the measurements of the year 1902.

The United States Department of Agriculture has issued, as a reprint from its Office of Experiment Stations Bulletin No. 9, a volume entitled "Report of Irrigation Investigations for 1901," which includes a valuable paper by Prof. E. W. Hilgard on the "Subterranean Water Supply of the San Bernardino Valley." Professor Hilgard has conducted investigations in San Bernardino Valley at several periods, and has paid particular attention to the supply of the Gage Canal Company. By cooperating closely with the engineers of this organization he has assembled a body of facts which have unique value in a study of the underground waters, and will have increasing value as they are augmented by accumulating data.

In the same volume is a paper by the late William Irving, engineer of the Gage Canal Company, on the "Duty of Water under the Gage Canal, 1901." This paper is one of a series issued by Mr. Irving, in which the duty is discussed for the years 1899, 1900, and 1901, the earlier papers appearing in Bulletins Nos. 86 and 104 of the Department of Agriculture, Office of Experiment Stations.

In addition to these papers issued by experts from one or another of the departments of our Government, many scattered data upon particular phases of the question of water supply are to be found in the court records, as a part of the the testimony introduced in the numerous suits which have been filed from time to time.



VIEW OF THE WEST RIVERSIDE DISTRICT

RAINFALL.

It is well understood that southern California is a semiarid region. The precipitation varies widely, however, in different localities, being greater on and near the higher mountains and less in the broad expanses of plain.

Rainfall records, Riverside, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rainfall for season.
1881	......	......	......	......	......	......	0.48	0.25	1.30	0.74	0.03	0.00	2.80
1881–82	0.00	0.00	0.10	0.40	0.25	0.40	1.70	1.40	1.08	.72	.08	.18	6.31
1882–83	.00	.00	.00	.13	.29	.20	.09	.83	.89	.26	.25	.00	2.94
1883–84	.00	.00	.00	.97	.00	2.25	.84	7.94	6.56	1.67	1.99	.52	22.74
1884–85	.00	3.00	.00	.12	.12	2.56	.77	.00	.01	2.15	.24	.00	8.97
1885–86	.00	.00	.00	.02	1.34	.62	2.68	1.38	1.95	1.43	.00	.00	9.42
1886–87	.00	.00	.00	.00	.54	.04	.13	3.30	.02	1.70	.17	.02	5.92
1887–88	.00	.00	.00	.75	.87	.85	4.17	1.05	3.84	.18	.05	.00	11.76
1888–89	.00	.00	.00	.00	2.83	3.37	.87	1.30	5.10	1.83	.25	.00	15.55
1889–90	.00	.00	.09	1.35	1.82	7.80	4.44	1.96	.60	.06	.09	.00	18.21
1890–91	.00	.05	.79	.13	.32	3.21	.13	6.36	.40	1.04	.46	.00	12.89
1891–92	.00	.00	.13	.03	.00	1.29	.00	2.60	1.07	.00	1.32	.00	6.44
1892–93	.00	.00	.00	.29	.28	.94	3.01	1.95	5.71	.24	.04	.00	12.46
1893–94	.33	.00	1.27	1.08	.67	2.05	.69	.33	.70	.00	.00	.00	7.12
1894–95	.00	.26	.20	.05	.00	5.22	6.48	1.09	2.54	.29	.26	.00	16.39
1895–96	.00	.00	.00	.00	1.25	.24	1.72	.00	3.16	.56	.58	.00	7.51
1896–97	.02	.23	.00	2.07	1.48	.92	3.38	3.07	1.62	.03	.03	.00	12.85
1897–98	.00	.04	.09	1.67	.02	.95	1.74	.12	.80	.18	.27	.00	5.88
1898–99	.00	.00	.00	.00	.01	1.38	2.09	.89	.90	.00	.13	.30	5.70
1899–1900	.00	.00	.00	1.03	.57	.41	1.01	.01	.95	.74	1.29	.00	6.01
1900–1901	.00	.00	.00	.28	2.51	.00	2.67	2.74	.12	.00	.54	.00	8.86
1901–2	.00	.00	T.	.80	.12	T.	.90	1.81	2.23	.23	.16	.05	6.30
1902–3	T.	.00	T.	.09	1.09	1.64	.94	1.24	5.22	2.49	.03	.00	12.74
1903–4	T.	T.	.43	.05	.00	.03	.15	1.21	3.22	.58	.08	......	5.75

Average, 23 seasons, 9.90 inches.

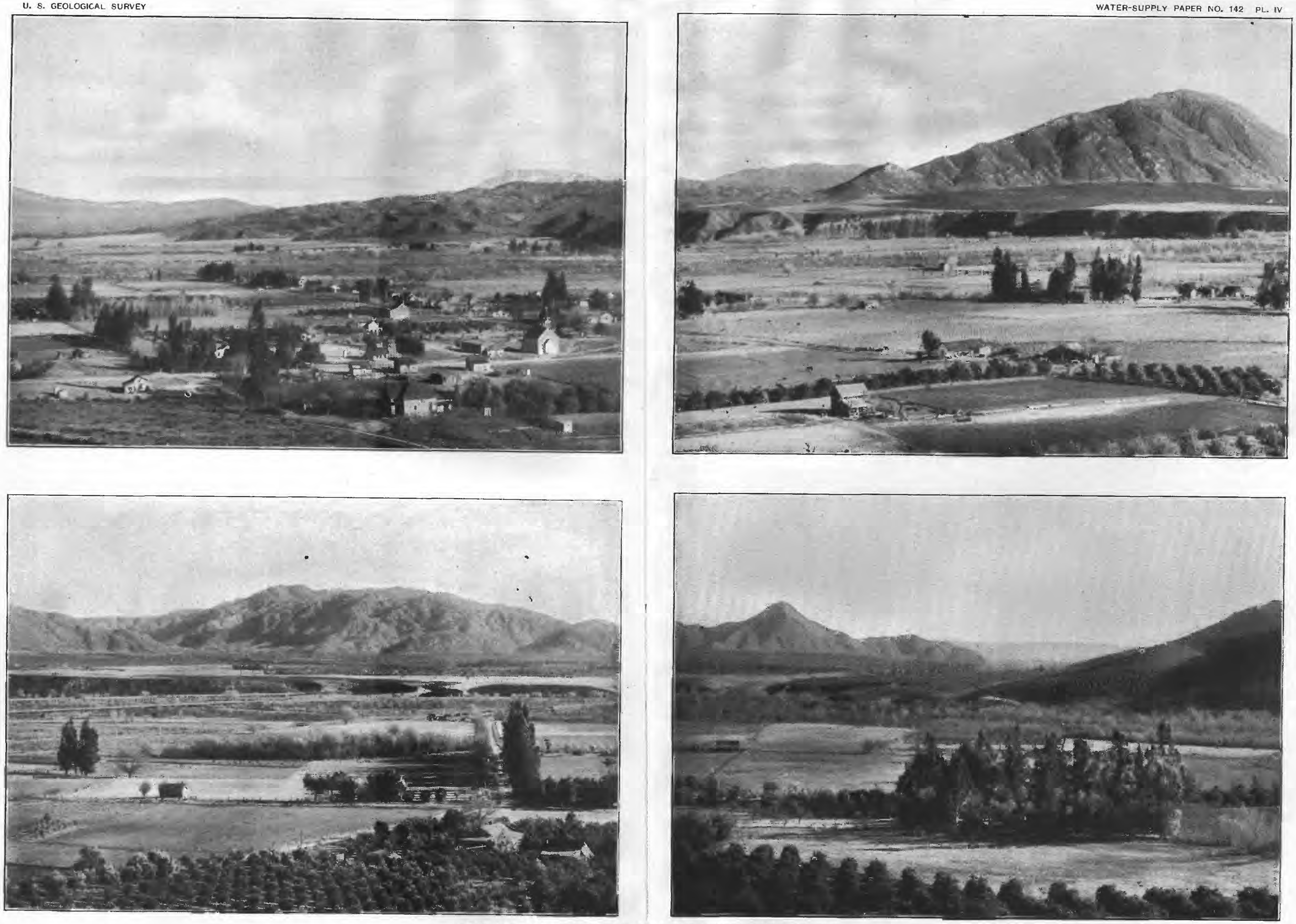
This distribution follows directly from the fact that the mountains are the rainmakers. The valley of southern California opens to the Pacific, and the moisture-laden winds from this great water body pass inland over the valley lands without marked disturbance of their temperature until they are forced up over the surrounding mountain ranges, where they are cooled and the greater part of their moisture is precipitated. This concentration of the rainfall on and near the mountains is partly illustrated by the available records, although these are not complete for mountain stations. The average at Riverside for twenty-three years is 9.90 inches, for thirty-four years at San Bernardino 15.06 inches, and a doubtful record for the ten wet years preceding 1894 at Bear Valley dam is 57.49 inches. Even though the reliability of the last record is doubtful, and since at best it was continued only during a period when the rainfall of this part of the State was 30 per cent above the average, so that a more nearly correct figure may be obtained if it is reduced by one-half, yet with this liberal reduction it is nearly double the valley records, and thus illustrates the much heavier precipitation at the mountain tops.

Rainfall records, Colton, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rainfall for season.
1877	......	......	......	......	......	......	1.64	T.	1.72	1.00	1.58	0.00	5.94
1877-78	0.00	0.00	0.00	0.07	0.35	1.93	1.94	5.16	1.38	2.99	.71	.00	14.53
1878-79	.00	.00	.00	.24	.30	1.68	1.79	.74	.03	1.75	.10	.08	6.71
1879-80	.00	.00	.00	.13	1.15	2.49	.99	.76	1.05	2.19	.00	.00	8.76
1880-81	.00	.00	.00	.13	.27	2.37	.74	.90	1.39	.28	.00	.00	6.08
1881-82	.00	.00	.00	.28	.38	.00	2.23	1.28	1.51	1.08	.00	.50	7.26
1882-83	.50	.00	.00	.50	.19	.30	.52	1.72	1.00	.45	.75	.00	5.93
1883-84	.00	.00	.00	.60	.00	2.23	1.00	11.38	4.05	2.85	2.90	.32	25.33
1884-85	.00	.25	.00	.25	.12	3.93	1.00	.00	.00	2.08	.22	.00	7.85
1885-86	.00	.00	.00	.00	1.92	.52	2.78	.40	3.54	.50	.00	.00	9.66
1886-87	.00	.00	.00	.00	.80	.00	.21	3.64	.00	1.94	T.	.00	6.59
1887-88	.00	.00	.00	.00	.70	.80	4.89	.42	3.68	.43	.00	.00	10.92
1888-89	.00	.00	.00	.00	2.37	3.26	.86	.88	4.47	1.02	.60	.00	13.46
1889-90	.00	T.	.04	1.59	1.26	7.41	2.94	1.15	.50	.00	.00	.00	14.89
1890-91	.00	.06	.67	.00	.19	2.45	.00	6.48	.25	.80	.90	.00	11.80
1891-92	.00	.00	.00	.00	.00	.87	2.27	3.36	.80	.24	1.44	.00	8.98
1892-93	.00	.00	.00	(.48)	.90	1.45	2.40	2.91	6.64	.16	.00	.00	15.14
1893-94	.30	.00	.00	1.18	.22	1.93	.20	.55	2.00	.10	.50	.00	6.68
1894-95	.00	.00	.45	.15	.00	5.70	6.88	1.01	2.94	1.08	1.05	.00	19.26
1895-96	.00	.00	.00	.00	1.16	.00	1.10	.00	2.91	.25	.38	.00	5.80
1896-97	.00	.10	(.06)	2.28	.94	1.11	3.52	3.96	2.70	.00	.15	.85	15.67
1897-98	.00	.00	.00	2.20	(.66)	.30	1.48	.23	.80	.10	.34	.00	6.11
1898-99	.00	.00	.00	T.	T.	.45	1.57	.45	1.55	.00	.00	T.	4.02
1899-1900	.00	.00	.00	.00	1.96	.55	1.06	.00	.95	1.59	.89	.00	7.00
1900-1901	.00	.00	T.	.32	6.47	.00	3.44	4.28	.08	.00	1.00	.00	15.59
1901-2	.00	.00	.00	1.18	.23	.00	.70	2.77	3.07	2.56	.00	.00	10.51
1902-3	.00	.00	.00	.15	.97	1.66	1.42	1.60	5.51	4.37	.00	.00	15.68
1903-4	.00	.00	.00	.00	.00	.00	.00	1.60	4.40	.82	T.	......	6.82

Average, 27 seasons, 10.63 inches.

The practical effect of the low rainfall over the valley lands is that only those crops which grow rapidly and mature quickly can be raised successfully without irrigation. Barley and oats for hay and grain are the principal crops successfully cultivated, and during unusually dry periods the grain may fail to mature and even the hay prove only a partial crop. Some vineyards in the sandy lands, an occasional small grove of olive trees, and a few apricots are also cultivated without the artificial application of water, but much the greater portion of the acreage cultivated, and all of the more valuable lands, are under irrigation.



VIEW OF EAST RIVERSIDE MESA AND SANTA ANA VALLEY.

Rainfall records, Redlands, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rainfall for season.
1889	......	......	......	......	......	......	0.68	1.47	5.70	0.99	0.58	0.00	9.42
1889-90	0.00	0.28	0.31	1.50	0.52	13.72	4.69	3.03	.89	.16	.68	.00	25.78
1890-91	.00	2.16	.88	.29	.00	3.02	.00	9.28	1.19	.91	1.10	.23	19.06
1891-92	.00	1.63	.97	.00	.00	1.51	.87	4.37	2.06	.13	.00	.00	11.54
1892-93	.00	.00	.03	.00	.63	1.58	3.02	3.93	7.22	.26	.00	.00	16.67
1893-94	.21	.00	.69	.95	.50	3.46	1.43	1.04	1.01	.25	.64	.00	10.18
1894-95	.00	.09	.17	.07	.00	7.38	8.66	1.30	3.29	1.37	.57	.00	22.90
1895-96	.00	.00	.00	.03	2.03	.52	1.52	.24	3.96	.01	1.14	.06	7.51
1896-97	.01	.00	.00	1.72	2.07	1.37	5.11	5.83	3.00	.14	.63	.00	21.88
1897-98	.06	.00	.83	2.38	.16	.70	1.96	.79	.99	.31	2.15	.00	10.33
1898-99	.10	.00	.00	.04	.22	.62	1.92	.71	1.50	.08	.24	.87	6.30
1899-1900	.00	.04	.05	.65	1.28	.46	1.20	T.	.78	2.03	1.41	.00	7.90
1900-1901	.04	.00	.50	.53	3.88	.00	2.25	3.79	.46	T.	1.62	.04	13.11
1901-2	.00	.00	.00	.92	.09	T.	1.64	2.58	2.82	.36	.08	.31	8.80
1902-3	.07	.00	.00	.06	1.40	1.50	1.16	1.41	5.86	3.88	.48	.00	15.82
1903-4	.00	.21	.54	.06	.00	.00	.29	1.50	4.55	.82	.48	.00	8.45

Average, 16 seasons, 13.48 inches.

This very condition of aridity is not without compensating advantages. It is recognized by soil experts everywhere that arid lands are generally fertile. Abundant rainfall leaches the soils of certain valuable soluble fertilizing elements. In the arid regions these soluble elements are retained in the soils, which are correspondingly productive. Aridity also means a large proportion of bright, clear days, and therefore, where water can be artificially applied to the soils, the best of growing conditions. The bench lands about San Bernardino Valley combine these advantages. Their soils are fertile, warm and equable as to temperature, free from alkalinity, and where water has been applied to them have become among the most valuable agricultural lands in the United States. Citrus fruits of the better varieties are cultivated upon them, practically to the exclusion of other crops.

Rainfall records, San Bernardino, Cal.

Year.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	Rainfall for season.
1870-71	0.00	0.00	0.02	0.09	3.11	0.89	6.91	2.21	0.19	0.34	0.11	0.07	13.94
1871-72	.00	.04	.13	.60	.88	3.91	.00	2.20	.37	.79	.06	.06	8.98
1872-73	.00	.18	.04	.00	1.17	4.40	6.50	1.25	.51	.84	.21	.00	15.10
1873-74	.00	1.06	.02	.01	.74	5.73	5.51	8.76	1.08	.48	.42	.00	23.81
1874-75	.00	.00	.06	1.82	1.88	2.20	7.20	.15	.22	.07	.05	.00	13.65
1875-76	.00	.00	.00	.00	7.50	.02	6.55	1.92	3.41	.44	.03	.03	19.90
1876-77	.00	.00	.00	.20	.40	.00	3.50	4.03	.83	.26	.30	.00	9.52
1877-78	.00	.00	.00	.86	.50	3.95	3.33	6.68	2.57	1.71	.66	.07	20.33
1878-79	.07	.00	.02	.14	.05	4.70	3.59	1.00	.50	1.20	.24	.03	11.54
1879-80	.11	.02	.01	.94	3.40	6.50	1.56	1.33	1.45	5.00	.04	.00	20.36
1880-81	.00	.00	.00	.14	.67	8.80	1.40	.36	1.66	.46	.01	.00	13.50
1881-82	.00	.00	.00	.80	.27	.50	1.11	2.65	3.30	2.91	.00	.00	11.54
1882-83	.00	.00	.00	.10	.15	.45	1.60	1.10	2.82	2.95	.00	.00	9.17
1883-84	.19	.00	.53	.85	.09	2.63	1.63	12.20	9.95	5.68	3.17	.59	37.51
1884-85	.00	.00	.00	.00	.11	3.75	2.79	.11	.28	1.89	1.69	.19	10.81
1885-86	.00	.00	.00	.39	4.36	1.20	6.34	2.52	4.18	2.36	.32	.16	21.83
1886-87	.00	.00	.00	.00	.11	.61	.39	6.44	4.41	1.90	.42	.22	14.50
1887-88	.11	.04	.09	1.17	2.29	1.91	4.01	3.60	3.41	.58	.52	.03	17.76
1888-89	.00	.00	.00	.05	4.12	4.64	.93	1.50	6.55	2.05	1.13	.00	20.97
1889-90	.17	.63	.11	2.30	2.23	10.85	5.44	2.52	.89	.00	.31	.00	25.45
1890-91	.13	2.16	.88	.58	1.27	3.02	.00	7.78	.06	.53	1.67	.00	18.08
1891-92	.00	.91	.93	T.	T.	1.67	3.24	3.30	1.75	.37	2.10	.08	14.35
1892-93	.00	.00	.00	.16	1.02	2.23	4.53	3.37	8.00	.48	.03	.00	19.82
1893-94	.20	.00	.05	1.05	.30	2.28	1.26	.88	1.15	.40	.56	.00	8.13
1894-95	.00	.16	.37	.15	.00	7.25	7.39	1.14	3.44	.64	.44	.00	20.98
1895-96	.00	.00	.00	.00	1.14	.66	2.02	.00	2.92	.37	1.00	.00	8.11
1896-97	T.	.17	.00	2.10	.98	1.09	3.40	5.40	3.41	.08	.11	.00	16.74
1897-98	T.	.00	.13	2.10	.21	.57	2.10	.60	.97	.48	1.08	.00	8.24
1898-99	.00	.00	.00	.03	.05	.44	2.03	.51	3.22	.07	.19	.95	7.49
1899-1900	.00	T.	.01	.81	1.47	.84	.92	.00	.92	1.96	1.71	.00	8.64
1900-1901	.34	.00	.23	.36	6.10	.00	3.48	4.58	.43	.56	1.23	.05	17.36
1901-2	.00	.27	.07	1.09	.28	.04	1.65	3.02	3.89	.57	.12	.15	11.15
1902-3	.01	.00	.00	.09	1.94	1.94	1.96	1.67	6.47	3.10	.24	.00	17.42
1903-4	.00	.15	.46	.07	.00	.00	.18	2.21	5.34	.80	.16	.00	9.37

Average, 34 years, 15.06 inches.

The average seasonal rainfall at San Bernardino for thirty-four years is 15.06 inches. It is estimated by meteorologists[a] that a record which has been kept for thirty-five years gives an average that is within 2 per cent of the correct final average, so that for practical purposes it may be assumed that this San Bernardino average is final. It is interesting to note that the average for the last eleven seasons, beginning with that of 1893–94, has been but 12.15 inches, nearly 20 per cent less than the general average, while for the ten preceding seasons the average was 20.11 inches, or more than 33½ per cent above the general average. The fact that the last decade has been one of

[a] Binnie, Alexander R., The mean or average rainfall and the fluctuations to which it is subject: Proc. Inst. Civ. Eng., vol. 109, 1892. pp. 89-172.

low rainfall is very generally recognized, but it is not by any means so clearly understood that the preceding decade, with which the last

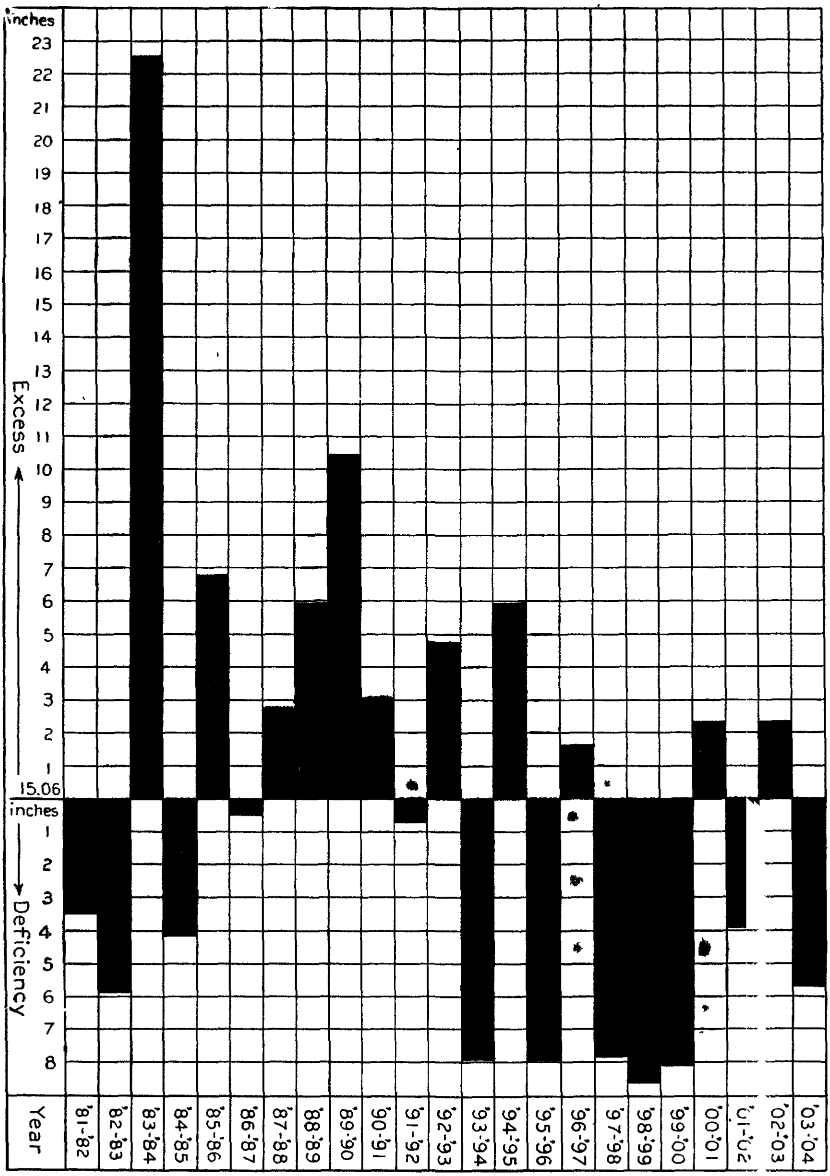


FIG. 1.—Chart showing variation from average rainfall at San Bernardino, Cal. *a*, Average for 34 years (15.06 inches).

is usually compared, was one of great excess. This decade includes the phenomenal season of 1883–84, with a precipitation of 37.5 inches, 12 inches more than that of any other season in the thirty-four years, and probably much the wettest winter in a half century. The driest season in the record is that of 1898-99, with a rainfall of 7.49 inches, only half of the average, and the driest group of three years is that ending with the winter of 1899-1900, with an average of 8.12 inches.

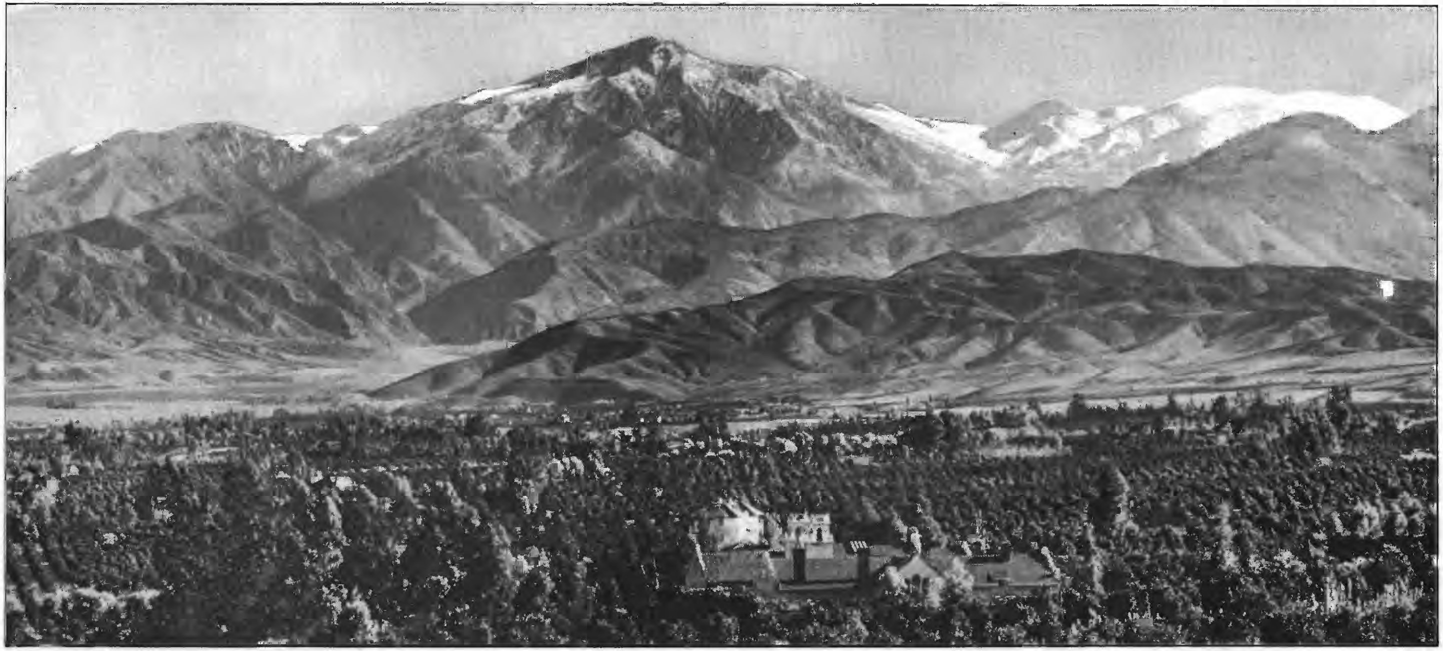
It is also perhaps not clearly understood that in countries of low rainfall there will be more seasons below the average than above it. The less the average rainfall the greater this preponderance of dry seasons. With an average of 15 inches, as at San Bernardino, the preponderance is not great, there having been eighteen seasons below and sixteen above during the last thirty-four years. At San Diego, with an average of about 9.5 inches, there have been twenty-nine seasons below this average and twenty-five above it during the last fifty-four winters. This condition arises from the fact that where the rainfall is low the occasional very wet winter gives an excess of precipitation equal to or even more than the whole amount of the average, while there are no seasons with an equally great deficiency; hence more than one winter of minimum rainfall is required to balance a winter of maximum. To illustrate, during the season of 1883-84 37.51 inches fell at San Bernardino. The lowest rainfall of which we have record is that of the winter of 1898-99, with a precipitation of 7.49 inches. The first was 22.45 inches above the average, the other but 7.57 inches below, so that nearly three years of this minimum would have to be combined with one of the maximum to give the average. There can not be a deficiency of more than 15.06 inches, while there is no limit mathematically to the excess.

SOILS.

The soils of the upper part of the valley of southern California may, for convenience of discussion, be classed as indigenous and introduced. By the former are meant those which are due to the decay of the underlying or immediately adjacent rock masses; by the latter, those which have been brought by stream action from some distant source.

In the ultimate analysis nearly all valley soils belong to the latter class, since rocks of sedimentary origin themselves represent material which was transported at an earlier time from some more or less distant point. But for our purpose the origin will not be traced so far back. If the soil is derived from an underlying or adjacent rock mass it is classed as indigenous, whether that mass is a late sediment or not.

The soils of the valley bottoms belong in all cases to the derived type. They are the immediate products of the erosional activity of



REDLANDS AND SAN BERNARDINO AND SAN GORGONIO PEAKS.

the streams, which with the uplifting of the mountain masses began the work of canyon cutting, depositing the material which they removed in this process over the lowlands beyond the canyon mouth.

The gravels and soil, then, in the alluvial fan built about the mouth of any canyon, represent only the rocks that are found within the drainage basin of the stream which flows from it. In the lower area about the junction of two fans the rock types of each are mingled, and well out near the center of the valley, where the various tributaries join, there will be a type due to a mixture of all the contributing varieties.

The soil-producing materials yielded by the canyon of the Santa Ana are largely derived from the dioritic rocks which outcrop almost exclusively in its basin. Mill Creek, in addition to dioritic and schistose rocks, yields a noticeable percentage of sandstone. Farther west schistose and gneissoid elements are contributed by Plunge Creek, City Creek, and East and West Twin creeks, while from the lower part of Devil and Badger canyons there is a considerable addition of limestone and marble.

Lytle Creek, which, because of its relatively large and constant flow, has built out a big alluvial fan at the south base of the San Antonio Mountains, flows throughout its course through schistose rocks, and bowlders of these are numerous in its wash.

San Timoteo Canyon is cut in gravels and clays from Beaumont down to Redlands Junction. It has carried into the lower valley comparatively little material, and that little is fine in comparison with the débris of the great fans in front of the mountain canyons, although it contains bowlders and gravels derived from the older gravel beds which outcrop on either side of the canyon.

This alluvial material, which forms the greater part of the floor of the present valley, is very coarse and absolutely untillable about the mouths of the large canyons, where the lands are in the original desert condition. The vineyards about Grapeland are planted on the rather coarse upper slopes of the Lytle Creek fan, while the Rialto citrus groves are on a lower, finer portion of the same feature. The low bench which lies north of Redlands and extends west from Mentone nearly to Colton is of coarse gravel near its upper portion; fine gravel and sand, on which excellent crops of grapes are produced, midway; and sandy clay and loam farther down, in the vicinity of Idlewild. One group of low sand dunes has formed north and west of Slover Mountain. These generally are untilled, although, since they are low and no longer in motion, it is probable that they could be successfully cultivated if sufficient water were available.

Clays which are often sandy lie in the central part of the valley in the artesian belt, where they are sometimes mixed with vegetable mold. They represent the lowest and finest phase of the alluvial-fan deposits laid down just back of the dam formed by the Bunker Hill ridge.

Thus it is seen that the introduced soils exhibit great variety in texture and a less marked variation in composition, the latter variant depending upon the origin of the material in one or the other portions of the surrounding mountains and the later admixture of vegetable matter, while the former depends largely upon the distance of the soil particles from their source.

The mesa soils exhibit somewhat less marked differences. Over the high lands south and east of Riverside they are derived largely from the underlying and adjacent diorites, so that here they have many of the characteristics of a granitic sand. Generally they are coarser along the easterly higher parts of this mesa and finer in the lower parts nearer Arlington. Since that part of the mesa which lies north of Terquisquito Arroyo and extends through the east Riverside district to the bluff above Santa Ana River is built up of gravels and alluvium, instead of being floored by the massive diorites of the region farther south, the soil is freer from grit than in the latter locality, being, indeed, a rich loam over much of the area.

The soil of the Redlands bench, including Smiley Heights, Redlands Heights, and the slope south of Crafton, is a clay or loam, sometimes gravelly, derived from the weathering of an old alluvium, which, except in its distribution and probable extent, is not unlike that which the rivers are depositing in the great débris cones to-day. Its material is somewhat finer, clay predominates to a greater degree, and the old weathered red surfaces testify to slower deposition, or perhaps to longer exposure to atmospheric agencies before deposition.

The Highlands and East Highlands benches and that lying between the Mill Creek and Santa Ana canyons furnish similar soils derived from the old alluvial-fan material. That, like the modern alluvium, is somewhat coarser next to the mountains and near the mouths of the greater canyons. But even where coarse it contains a notable admixture of clay, which furnishes a basis for a fertile soil.

The most absorptive soils extensively cultivated are probably the sands of the low river terraces north and northeast of Redlands, and perhaps those least absorptive are the clays of the bottom lands about San Bernardino. Absorptive capacity depends, among other things, upon the coarseness of the soil particles, or, as it has been well expressed, upon the "effective size of grain." Hence the clay and loam soils, whether upon the mesa lands or in the bottoms, require much less water for irrigation than the more open sands and gravelly soils. Another element which is of the utmost importance in determining the amount of water that must be applied in order to mature crops is the character of the subsoil. If this is coarse and open, readily draining the water from the cultivated surface, the waters brought for irrigation may quickly pass down out of reach of the plant roots. On the other hand, a compact and impervious hardpan holds the waters until they are absorbed by the plants. If bed rock lies just under the soil it may serve the same purpose. An excellent example of the effect of this latter relation is to be found near the eastern end of the Jurupa Mountains. The road from Bloomington to West Riverside runs through a wide valley separating an eastern outlier of this group from the main mass. The soils within this valley are a result of the decay in place of the diorites and schists of the hills. They are not of great depth and the massive and almost impervious rock is just beneath them. A small apricot orchard has been planted in the north end of this pass, about 2½ miles southwest of Bloomington, and although not irrigated it is in a flourishing condition and yields abundant crops. The orchard is young and has been in bearing practically only during the years of light rainfall, which began with the winter of 1897–98. The explanation, it is believed, is to be sought in the fact that the impervious bed rock at this point is so near the surface. The water which accumulates through winter rainfall seeps very slowly over this gently sloping floor, and the slight spring and summer seepage from the surrounding hills and slopes is also held here within reach of the plant roots until the crop is matured. In less favorable localities apricots require irrigation, or without it are uncertain in yield.

WATER SUPPLY.

The ultimate source of all the water to be found in San Bernardino Valley is the rainfall within the drainage basins tributary to it. This statement needs to be clearly made at the beginning of any discussion, because it is constantly stated that some remote point, like Colorado River, or even the Pacific Ocean, may, by a process never clearly explained, supply the bountiful waters found in the San Bernardino cienaga. Aside from the inherent impossibility of such waters rising above their sources, or being filtered free of salt in the case of the Pacific, it is to be remembered that the intervening hills and mountains are much more effective and impenetrable dams than any built by man. The fissures within them are not extensive, and the great faults which mark the more important passes through them are so sealed by the pressures that accompanied their formation as to be nearly, if not quite, as impervious as the unbroken rock.

EFFECT OF FORESTS.

The precipitation which is the source of all the water falls almost exclusively in the winter months, from November to April, inclusive.

Practically all of that which falls upon the flat and porous valley lands is absorbed immediately or returns to the air at once by evaporation. Of the greater amount which falls upon the mountain slopes, a large proportion is absorbed by the soil and humus where vegetation has not been destroyed by fire and the unprotected soil swept from the bare rocks by succeeding storms. This moisture, taken up by the vegetable mold, the soil, and the rock débris, is released slowly during the succeeding months and is the source of the important summer flow of the mountain streams. The denser the vegetable growth and the thicker the soil cover on the mountain slopes the more effective this direct storage of the winter rains and the more uniform the stream flow during the summer months. These facts are brought out by some measurements made for the Bureau of Forestry in the San Bernardino Mountains in 1899 and published in a paper by J. W. Toumey, entitled "The Relation of Forests to Stream Flow." The following extract contains the essence of the paper:

In a careful study of the behavior of the stream flow on several small catchment areas in the San Bernardino Mountains it has been found that the effect of the forest in decreasing surface flow on small catchment basins is enormous, as shown in the following tables, where three well-timbered areas are compared with a nontimbered one:

Precipitation and run-off during December, 1899.

Condition as to cover.	Area of catchment basin.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
	Sq. miles.	*Inches.*	*Acre-feet.*	*Per cent.*
Forested	0.70	19+	36−	3
Do	1.05	19+	73+	6
Do	1.47	19+	70−	6
Nonforested	.53	13−	312+	40

At the beginning of this rainy season, in early December, the soil on all four of these basins was very dry as a result of the long dry season. The accumulation of litter, duff, humus, and soil on the forest-covered catchment areas absorbed 95 per cent of the unusually large precipitation. On the nonforested area only 60 per cent of the precipitation was absorbed, although the rainfall was much less.

Rainfall and run-off during January, February, and March, 1900.

Condition as to cover.	Area of catchment basin.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
	Sq. miles.	*Inches.*	*Acre-feet.*	*Per cent.*
Forested	0.70	24	452+	35
Do	1.05	24	428+	33
Do	1.47	24	557+	43
Nonforested	.53	16	828+	95

The most striking feature of this table, as compared with the previous one, is the uniformly large run-off as compared with the rainfall. This clearly shows the enormous amount of water taken up by a dry soil, either forested or nonforested, as compared with one already nearly filled to saturation. During the three months here noted on the forested basins about three-eighths of the rainfall appeared in the run-off, while on the nonforested area nineteen-twentieths appeared in the run-off.

Rapidity of decrease in run-off after the close of the rainy season.

Condition as to cover.	Area of catchment basin.	Precipitation.	April run-off per square mile.	May run-off per square mile.	June run-off per square mile.
	Sq. miles.	*Inches.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
Forested	0.70	1.6	153—	66—	25—
Do	1.05	1.6	146—	70—	30—
Do	1.47	1.6	166+	74—	30+
Nonforested	.53	1	56+	2—	0

The above table clearly shows the importance of forest in sustaining the flow of mountain streams. The three forested catchment areas, which during December experienced a run-off of but 5 per cent of the heavy precipitation for that month and which during January, February, and March of the following year had a run-off of approximately 37 per cent of the total precipitation, experienced a well-sustained stream flow three months after the close of the rainy season. The nonforested catchment areas, which during December experienced a run-off of 40 per cent of the rainfall and which during the three following months had a run-off of 95 per cent of the precipitation, experienced a run-off in April (per square mile) of less than one-third of that from the forested catchment areas, and in June the flow from the nonforested area had ceased altogether.

In view of these facts, which illustrate conditions of wide application, no policy can be conceived which would be more suicidal than one which would permit the stripping of forests or the destruction of these or the chaparral by fires. The immediate and direct result would be the washing away of the earth and humus by the first winter rains, and thereafter destructive floods in winter and dry stream beds in summer. The opposite policy—that of preserving and extending the forest and brush cover—may be expected to tend slowly, and almost imperceptibly perhaps, but none the less surely, toward an equalization of the summer and winter flow of the mountain streams. No public work is deserving of fuller support and more hearty cooperation on the part of the citizens of southern California than this of conservation of the existing plant growth and of forest extension. It is one of the curious anomalies of human nature, but one to which Department workers are well used, that those who have had the work of forest preservation in hand have often had to meet bitter opposition from the very citizens whose vital interests they were at the time protecting.

Before the advent of man in San Bernardino Valley all the waters of the mountain streams, except during periods of exceptional flood, promptly sank when they reached the coarse débris cones at the mouths of their canyons and continued their journey seaward through the porous sands and gravels with which the valleys are filled. They rose to the surface again only when in their underground passage they reached some impervious obstacle like the Bunker Hill dike above Colton, or the bed-rock obstructions at Riverside Narrows and in the lower canyon of the Santa Ana.

The developments of the last fifty years, however, and especially of the last thirty, have resulted in the appropriation of practically all of the normal flow of these streams for purposes of irrigation. Much the greater part of this diverted stream water is returned to the land within the valley in the process of irrigation, but when thus used and spread out over a large acreage of relatively fine soil a very much larger proportion evaporates directly than when the water entered the coarse gravels at the mouths of canyons previous to its diversion; and another important percentage is absorbed by the growing plants and is transpired through them into the air.

RETURN WATERS.

The percentage of irrigation water which returns to the underground reservoirs must vary greatly in different localities and with varying soils and irrigation customs. The sandy soils of some of the bottom lands are so loose that the water percolates rapidly through them and much of it is beyond the reach of the plant roots before it can be absorbed. In the finer loam and clay soils, especially those underlain by an impervious hardpan which checks the escape downward of irrigation water, probably but a small percentage avoids evaporation and absorption and so returns to the ground water. This will be especially true where the better irrigation methods are practiced and no more water is put upon the soil than is needed.

In view of these variable and uncertain elements which enter into the problem, it becomes impossible to estimate with accuracy the proportion of diverted stream water which again becomes available for use as return water from irrigation. It can only be said that the percentage must vary within wide limits, perhaps such wide limits as 5 and 50 per cent, and that with improvements in irrigation practice it will become constantly less. Nevertheless, in certain favorable situations, it seems to be of considerable importance, and may result in changing an arid section to one with an abundant or even a superabundant supply. Thus, in the western and lower part of the Riverside colony, within a restricted area, ground waters have increased during years past until bogs have formed and drainage ditches have become necessary. Fifty second-feet of water are constantly applied in irrigation to the higher lands which drain in this direction, and in the past, and to a less marked extent at present, there has been over-irrigation in a part of the area.

Santa Ana River, between the intake of the lower Riverside canal and the Auburndale Bridge, has been increasing in volume since measurements were first made in 1888. The following table indicates the extent of the increase between Riverside Narrows and the Auburndale Bridge, but as practically all of the water flowing at the first point rises below the intake of the lower Riverside canal, the difference between the earlier and the later measurements there is also to be regarded as due to an increase in the volume of rising ground waters.

Discharge measurements of Santa Ana River.

Date.	Point of measurement.	Discharge.	
		Miner's inches.	*Second-feet.*
1888.			
July 16	Jurupa or Riverside Narrows	505.0	10.10
July 17	do	525.0	10.50
July 17	Auburndale Bridge	728.5	14.57
August 21	Jurupa or Riverside Narrows	425.5	8.51
August 22	Auburndale Bridge	664.5	13.29
September 14	Jurupa or Riverside Narrows	474.0	9.48
September 15	Auburndale Bridge	709.5	14.19
1889.			
August 13	Jurupa or Riverside Narrows	550.0	11.00
August 14	Auburndale Bridge	777.5	15.55
September 27	Jurupa or Riverside Narrows	560.0	11.20
September 28	Auburndale Bridge	832.5	16.65
1890.			
August 12	Jurupa or Riverside Narrows	937.9	18.76
August 13	Auburndale Bridge	1,112.5	22.25
1891.			
September 9	Jurupa or Riverside Narrows	775.0	15.50
September 10	Auburndale Bridge	1,281.5	25.63
1892.			
September 10	Jurupa or Riverside Narrows	1,469.1	29.38
September 11	Auburndale Bridge	2,171.4	43.43
1899.			
September 9	Jurupa or Riverside Narrows	1,984.5	39.69
September 12	Auburndale Bridge	2,991.5	59.83
1900.			
July 27	Jurupa or Riverside Narrows	1,920.5	38.41
July 28	Auburndale Bridge	2,722.0	54.45
1901.			
August 30	Jurupa or Riverside Narrows	1,693.5	33.87
August 27	Auburndale Bridge	2,185.0	43.70

Discharge measurements of Santa Ana River—Continued.

Date.	Point of measurement.	Discharge.	
1902.		*Miner's inches.*	*Second-feet.*
October 10	Jurupa or Riverside Narrows	2,162.5	43.25
September 2	Rincon Bridge [a]	3,750.0	74.90
1903.			
August 25	Jurupa or Riverside Narrows	2,035.0	40.70
August 19	Rincon Bridge [a]	3,000.0	60.00

[a] Measurements are now made at Rincon wagon bridge, instead of at Auburndale Bridge as formerly. Measurements made at these two points, by W. B. Clapp, on September 23, 1903, indicate that the flow at the former point is about one-third more than at the latter.

This rather remarkable increase is usually attributed to return waters from irrigation in the vicinity of Riverside, Pomona, and Ontario, and it is probable that the greater part of it is correctly assigned to this cause, but there is another possibility which deserves to be considered. The decade of excessive rainfall ending in the early nineties thoroughly saturated the gravels near the mountains in this part of the State. Subsurface percolation varies widely in rate, this being dependent upon the coarseness of the material through which the water passes. Rates between zero and 96 feet per day have been measured by Mr. Homer Hamlin[a] in the narrows of Los Angeles River, and rates with lower maxima are reported by Professor Slichter from Mohave River below Victorville and from the Paso de Bartolo. If a rate of 25 feet a day, or less than 2 miles a year, is assumed, the increasing flow of Santa Ana River during the last sixteen years may be due in part to the slow escape to the river of the waters that accumulated in the alluvium near the mountains during the decade of wet years preceding the present dry epoch, since these waters would have to pass through from 10 to 20 miles of gravels between the canyon mouths and the part of the Santa Ana in question. No criteria are known by which we can distinguish between these two possibilities at present. If the Santa Ana shrinks again later during a period when the minimum rainfall of the present decade is due to reach it, we can conclude that its fluctuations are to be attributed to this slow passage of the waters of wet and dry periods through the underground pores. If, on the other hand, its increased flow is maintained or continues to increase, this will prove that it is due to returning irrigation waters.

[a] Hamlin, Homer, Underflow tests in the drainage basin of Los Angeles River: Water-Sup. and Irr. Paper No. 112, 1905, pp. 34–50.

SAN BERNARDINO ARTESIAN AREA.

About 1870 it was found that a pipe sunk 50 to 100 feet into the earth, anywhere within the area of moist lands now forming the well-known San Bernardino artesian basin, would yield flowing water. During the succeeding decade many wells of small bore were sunk, chiefly for domestic purposes, and in some instances the water was piped through dwellings, the artesian pressure being quite ample in many cases to force it wherever needed in the houses.

The rapid development of the valley during the decade from 1880 to 1890, coupled with the fact that practically all surface waters had been appropriated by that time, led to an extensive use of the underground waters of the artesian belt as a source of water supply. During the later eighties and the early nineties the great majority of the wells of the Gage canal system were put down, and the Riverside Water Company considerably augmented its supply from Warm Creek and the Santa Ana by sinking a number of deep wells within the artesian belt. The Lytle Creek cienaga was also developed as a source of domestic water by the cities of San Bernardino and Colton, and for irrigation water by a number of irrigation districts.

The seemingly unlimited amount available in the great cienaga, and the resistance which it had offered previous to 1897 to the drains upon it during the preceding decade of rapid development, led to great confidence in it and gave many the impression that as a source of water it was independent of seasonal variations in precipitation, of diversions of streams tributary to the valley, or of drafts upon its stored supply. The concurrence of the series of years of low rainfall, beginning with the winter of 1897–98, with the gradually increased use of waters developed during the preceding decade, soon produced its effect, however, and for some years the artesian area has been shrinking, the flow of wells within it diminishing, and the water plane without it rapidly falling. An increase of rainfall at once affects water levels, as is shown by the seasonal increase of flow from artesian wells during the winter and the particularly noticeable rise in water levels after the winters of 1900–1901 and 1902–3. In most cases, however, these improvements in conditions do not last through the succeeding dry season because of the heavy drafts now being made upon the basin. The general reduction in flow and lowering of the water plane, although most clearly recognized during the dry years succeeding 1896–97, had been noticeable earlier. A few artesian wells are reported to have ceased flowing as early as 1890 or 1891, and a number about the borders of the basin had ceased before 1896.

Before considering further the drafts upon the artesian supply and their probable ultimate effect it is necessary to discuss the origin, outlines, and underground conditions of the artesian basin, since its capacity as a storage reservoir, the rapidity with which its supply may be renewed, and the rate at which this supply may be drawn upon depend upon these underground conditions.

ORIGIN OF SAN BERNARDINO BASIN.

A great fault runs northwest and southeast through Cajon and San Gorgonio passes and along the base of the San Bernardino Mountains. In the movement along this fracture a portion of the earth's crust north of the present valley was uplifted and now forms the San Bernardino Mountains, while the valley itself represents a great depressed area south of the fracture.

Another crustal movement, whose beginning at least may well have been contemporaneous with the first, both being very late geologically, resulted in the lifting of a ridge—the formation of an irregular arched wrinkle—extending from the San Jacinto Mountains northwestward along the line of the Badlands, which separate San Timoteo Canyon from San Jacinto Valley. The rocks which were folded into this arch are soft shales and sandstones and gravelly alluvium, like that deposited by the rivers now in San Bernardino Valley. This fold can be traced on the surface as the Bunker Hill dike to a point nearly 2 miles somewhat south of west of San Bernardino. It probably extends even farther in the direction of Lytle Creek Canyor as an underground feature, buried beneath the modern wash, but there is no surface indication of its presence there.

This clay and gravel ridge has been the most effectual of subsurface dams, against which the modern stream wash has accumulated, and behind which the waters percolating seaward through this wash have been stored, the excess rising in springs and flowing over the dam, to sink again in the sands and gravels below.

It is not possible to determine in detail the character of the floor of the San Bernardino basin, but we can gain a conception which is probably correct in its general outlines by a consideration of the nature of the surface whose deformation gave rise to it.

Before the San Bernardino Mountains were uplifted and San Bernardino Valley was formed subaerial erosion had reduced an earlier topography to a condition in which the valleys were wide and generally level and the mountains low, although often steep, because the granitic rocks from which they were carved weather characteristically into steep forms.

Such a surface is now to be found in the triangle at whose vertices are Riverside, Elsinore, and San Jacinto. Other fragments of this old landscape are, it is believed, still preserved in practically the condition in which they existed previous to the deformation in Bear Valley and its continuation about Baldwin Lake (Pl. II, *B*), in Holcomb Valley, in Little Bear Valley, and in other of the areas now forming some of the higher parts of the San Bernardino Mountains.

The topography of these higher areas, where it has not been altered by modern gorge-producing agencies, consists of broad valleys with ridges of moderate elevation between them and is much like that in the region north of Elsinore. It is believed that these two regions, now so widely separated geographically and in elevation, once formed a continuous surface, and that San Bernardino Valley, between them, was a part of this surface, like the other parts in character and developed with them.

DEPTH OF THE BASIN.

When the series of earth strains which deformed the region came into play, Perris Valley was raised slightly, the San Bernardino Mountains were raised much more, and San Bernardino Valley, between them, sank until parts of its old surface came to occupy a position below sea level. How much below it, it is not possible to tell with any exactness, since the deepest wells bored in the center of the valley do not reach bed rock, and the character of the movement and of the land affected was such that it is difficult to estimate the amount of the displacement. An estimate, which, however, is little more than a guess, may be made by considering the maximum relief preserved upon the old surface and applying the criteria thus obtained to San Bernardino Valley.

The heights about Bear Valley usually do not rise more than 3,000 feet above its level; those surrounding the other flat mountain valleys rarely attain this relief. The Jurupa Mountains stand nearly 3,000 feet higher than bed rock in the neighborhood of Bloomington. The peaks within Perris and San Jacinto valleys are generally less than 2,000 feet above the floors of the surrounding lowlands, where the depth to these is known. On the whole, it seems fair to assume about 3,000 feet as the maximum relief on the old surface.

North of a median line through the San Bernardino basin a range of low bed-rock hills rises through the modern wash. These are believed to be hills inherited, like the Jurupa Mountains, from the predeformation surface. On the supposition that they originally stood at about 3,000 feet above the valley floor, this should now be only 2,000 or 2,500 feet beneath San Bernardino.

By assuming that the average slope of the hills, before their burial under the modern wash, was 1,000 feet to the mile—a supposition which is believed to be sufficiently conservative—and that this slope was continuous from the little bed-rock mound below Del Rosa southwestward to the line of disturbance marked by the Bunker Hill dike—a supposition which seems likely to give a greater depth to bed rock than the true one—we reach the conclusion that the latter lies less than 3,000 feet beneath San Bernardino. Nothing whatever is known of the details in the buried old topography under the modern gravels. Perhaps bed-rock hills exist there which differ from those that rise above the wash along the northern edge of the valley, only in that they are not so high and have been completely covered by the modern alluvium, or the floor of the middle of the valley, extending northwest and southeast beneath San Bernardino, may be relatively smooth like that of Perris Valley. Whatever its character, the rough estimate of 3,000 feet or less from the present surface to it is the best that can be made with the data at hand. (Fig. 2.)

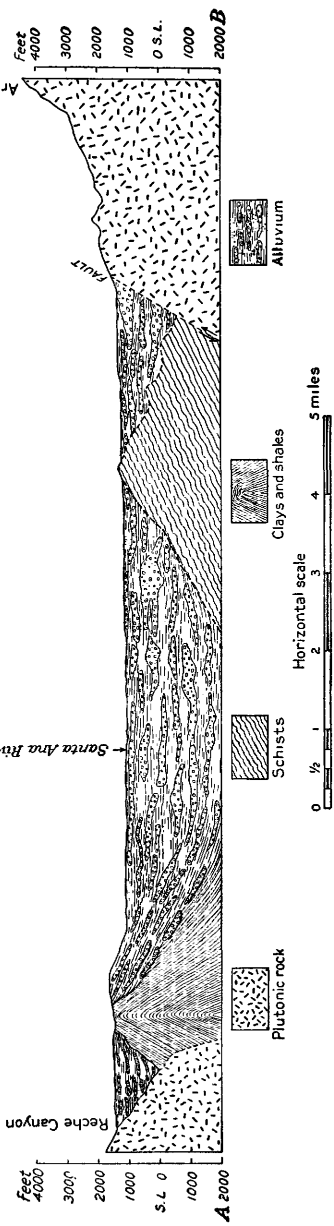


FIG. 2.—Approximate section across San Bernardino Valley along the line A-B, Pl. XII.

GENERAL CLASSES OF ROCKS.

From the point of view of the water supply, the rocks of the upper San Bernardino region may be subdivided into two general classes—those which outcrop everywhere in the higher mountain regions and in many of the hills within the valleys, and the clays and alluvium which fill the valleys, underlie most of the fertile mesas, and form the greater part of the low hills known as the Badlands between San Jacinto and upper Santa Ana valleys. Pl. XII shows the distribution of the water-bearing and non-water-bearing rocks of the region.

The rocks of the first group technically include such widely different varieties as schists, gneisses, diorites, marbles, quartz-porphyries, sandstones, and conglomerates, but they have the common characteristic of relative compactness, and so absorb and store but little water. The sandstones and conglomerates which are included in this class, although belonging to a group of rocks which in many regions are valuable water bearers, are here so changed by metamorphic processes as to be practically impervious, as is the case with the schistose sandstones of the Jurupa Mountains, or are so broken and so closely folded that their stored water is too small in amount and too doubtful in position to be of value, as is true of the sandstones in the lower part of Mill Creek Canyon, and of those which form a narrow interrupted band along the south foot of the San Bernardino Mountains from East Highlands to Cajon Pass.

The rocks of the second group are the important ones from the point of view of the water user. They consist largely of alluvium, i. e., of sands, gravels, and clays which have been deposited by streams under conditions very similar to those prevailing in San Bernardino Valley to-day, but at their base is a rather widespread series of fine clays and shales, which outcrop along the axis of the Badlands ridge and at various points on the western flanks of the San Jacinto Mountains. These clays carry fresh-water fossils, and their presence indicates that an inland lake whose extent is uncertain existed at least along the southern border of what is now the San Bernardino basin in late Tertiary times, before the earliest of the valuable water-bearing gravels were deposited.

From the fineness of these clays we infer that no very marked relief existed near by at the time of their deposition, because high mountains usually yield coarse detritus, and from the fact that they are bent into sharp folds we know that extensive earth movements have taken place since their deposition. These two facts lead to the belief that the clays are older than the formation of San Bernardino Valley and the San Bernardino Mountains. They were likely deposited in a lake like Bear Lake, but much larger, on the old land surface of rather moderate relief which existed in this part of southern California before the present high mountains came into existence. The topography of that time, it is inferred, was much like that of Perris Valley or of the higher parts of the San Bernardino Mountains at present—that is, there were wide, nearly level valleys, and from these rose ridges or peaks to moderate elevations of a few hundred, or in extreme cases of perhaps a few thousand, feet.

The old lake probably occupied the lowest of the valleys of that time, and within it islands of the granitic or gneissoid bed rock rose, perhaps, as the Box Springs and Lake View mountains now rise above the Perris and San Jacinto plains. It seems probable that these fine deposits extend under at least a part of the San Bernardino cienaga, and that in deep drilling they may be encountered before the granitic bed rock is reached. The beds laid down in the bottom of this lake were too fine to be of value as water bearers, but they furnish a comparatively impervious plane above which the waters accumulate, and when thrown into a fold across the course of a river, as in the case of the Bunker Hill dike, they force to the surface the waters percolating through the porous gravels above them, or if an impervious clay layer intervenes between the porous stratum and the surface, they dam back the water so that it is held under pressure and flows when the upper bed is pierced by a drill.

Some time after the deposition of the Badlands clays which have been described, a series of crustal movements began, which folded the clays and seems to have elevated the San Bernardino and perhaps other mountain masses until they stood well above the adjacent valleys, but were perhaps 2,500 feet lower than at present. It is probable that at the same time San Bernardino Valley subsided somewhat, so that its rock floor, sheeted over by the lacustrine silts, stood at a lower elevation than before the movement. At any rate, conditions prevailed which were much like those of the present. Mountain streams were active; they cut deep canyons and carried the products of their erosional activity out into the lowlands as they now do. This detritus contained much coarse material, but on the whole was probably not quite so coarse as the fan material of to-day. It was widely distributed over the lowlands south of the mountains—bowlder beds, sand beds, and clays alternating in an uncertain succession until many hundreds of feet of alluvium were piled up.

At the close of this epoch in the geographic development of the region, movement was resumed along the lines followed during the earlier period. This movement lifted the San Bernardino Mountains to their present elevation. It raised the earlier deposited alluvial wash into the sloping mesas of Smiley Heights and Redlands Heights. It probably resulted in the uplift of the Yucaipe bench to a position somewhat higher than that it had occupied before, and the coarse bowlder beds south of San Timoteo Canyon were given the strong northerly dip which they now have. San Bernardino Valley, which had been depressed in the earlier movement and filled by the erosion following, seems to have again subsided. After this readjustment of the relations of valley and plain, stream activity was renewed, erosion became more active than ever, the present deep canyons were cut, the modern fans were built, and the great alluvial filling, which makes the present surface of San Bernardino Valley and serves as such a valuable storage reservoir for irrigation and domestic waters, accumulated.

This, in brief, is the history of the geologic and physiographic processes which have given us the conditions that now exist and have resulted in the deposition of the gravels that serve as porous reservoirs and the clays that act as impervious caps that confine the water under pressure or as equally impervious bottoms to the water basins. Such a sketch completed, we are in a position to discuss intelligently and more minutely the formations which are water bearing, their

A. LATER ALLUVIUM EXPOSED ALONG THE EDGE OF EAST RIVERSIDE MESA.

B. THE LATER ALLUVIAL FAN ABOUT KENWOOD.

character, distribution, attitudes, and storage capacity, and to draw from the discussion some practical conclusions.

The two important water-bearing formations are, as may readily be inferred from the preceding discussion, the two series of deposits of river wash, which will be spoken of as the earlier and the later alluvium. They are much alike in character, having been deposited under very similar conditions, the differences being that the later alluvium is somewhat coarser than the earlier, has a smaller amount of cement gravel—that is, bowlders embedded in a hard clay, which is often sandy—and has less extensive beds of clay sufficiently pure to be practically impervious to water. Another difference is not in character, but in attitude, the beds of the later alluvium being in just the position in which they were deposited by the rivers that brought their materials from the mountain canyons, while the beds of the earlier alluvium have been disturbed since their deposition—have been given marked dips in one or another direction and have been raised in places until they are now much higher than when deposited. Since water always flows down grade when free, these attitudes are important in their effect upon the circulation of the contained waters.

ALLUVIAL FANS.

Extensive accumulations of coarse or poorly assorted stream-deposited rock fragments, such as constitute alluvial fan material or glacial débris, always indicate that, for some reason, the process of rock disintegration is more rapid than that of removal. In glaciated regions piles of unsorted rock fragments testify to a rapidly accumulated supply concentrated at certain points. In arid regions the very differently arranged masses of débris bear witness, not necessarily to especially rapid accumulation, but to slow removal, because of a dearth of the universal agent of removal, water. Hence, where other conditions, such as character of rocks, height of mountains, etc., are equal, greater aridity is indicated by steeper fans of greater mass and coarser material.

The accumulations take place in glaciated regions because, although the volume of water, which is the great distributing agent, is large, the material is supplied in such quantities that the rivers can not successfully cope with the problem of its removal. It gathers, therefore, and forms the rubble heaps. In the arid regions the same result is attained because of another condition—the smallness of the water supply and the consequent incapacity of the streams. Disintegration may not take place more rapidly than in humid regions, but removal is much slower, hence the spectacle, not rare in the Mohave Desert, of mountains nearly buried under the material which has resulted from their own slow breaking down. With an accession of rainfall the process of removal is accelerated, and the fans formed earlier are gullied and gradually worn away. It is thus seen that the extent of the alluvial cone accumulations is, within certain restrictions, a measure of aridity. Their presence means limited rainfall; the greater their extent the less the mean annual precipitation where conditions of topography and of rock masses are similar, and the less their extent the greater the precipitation.

The alluvial cones of San Bernardino Valley (Pl. VIII), therefore, testify to the partial aridity of its climate. As these are small in relation to the mountains about whose bases they are found, when compared to those about the bases of the desert ranges, so the valley rainfall is large as compared to the desert rainfall. Yet the striking general fact remains that the most important subterranean water-storage reservoirs of San Bernardino Valley came into existence partly because of the limited rainfall of that region.

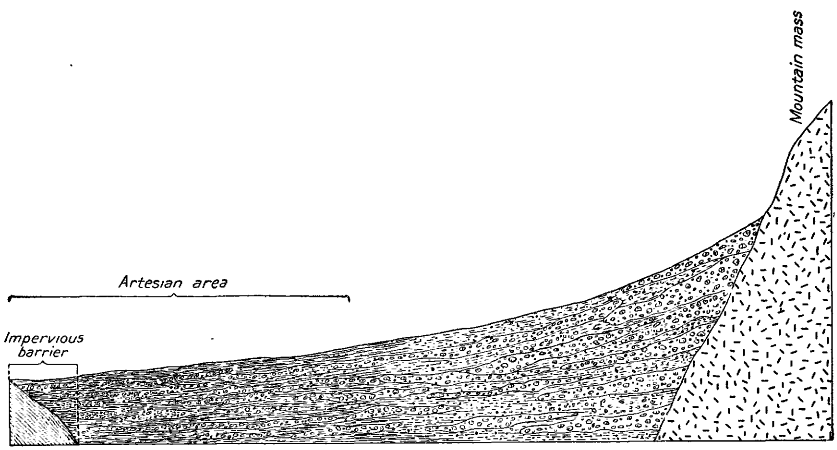


FIG. 3—Diagrammatic longitudinal section of alluvial fan.

The conditions under which this alluvium has accumulated are, in general terms, simple. Variations in temperature, which cause unequal expansion of the different minerals constituting a rock; freezing of the moisture which has entered rock fissures in the higher mountains; slow solution of some minerals by rain waters, thus releasing others; the forcing apart of rock masses by the roots of different forms of vegetation; and the occasional shattering by earthquake shocks, all help to initiate the disintegration of the rocks of the mountain areas. Once a fragment is loosened, gravity or moving water carries it to a lower point. Thus, in the canyons, quantities of rock débris are constantly accumulating. The normal light flow of the summer season removes only the very fine or the soluble matter. The greater part of the work of removal is accomplished during the brief storms, when torrents rush through these constricted defiles, their carrying capacity increasing at the enormous ratio of the sixth power of their velocity. At such times great bowlders are readily moved and smaller ones are rolled long distances. Gradually they are worked along toward the mouth of the canyon. As soon as the stream reaches the open valley it spreads, loses velocity, and drops its load, the heavier fragments being deposited first and the lighter ones carried farthest. Thus the alluvial cone, coarsest and steepest near the base of the mountain and finer and flatter at a greater distance, gradually accumulates. With a succession of years of heavy storm, trains of bowlders will be carried far down the slope and dropped over the finer deposits which collected during preceding years when the precipitation was light. Or, as one channel is built up in the manner in which a river builds up its bed higher than the surrounding areas, the course of the stream will shift on its fan to a lower channel; earlier-formed deposits will be cut away and fine material will be deposited upon coarse, or coarse upon fine.

Moderate storms may bring heavy material to the mouth of the canyon and there drop it. A succeeding heavier storm will pick up the coarse material laid down in the bed of the stream, move it farther out the slope, cutting into the earlier-deposited burden in the process, and so establishing a new course which will be filled in its turn.

After violent storms, during which turbulent waters highly charged with silt spread far and wide over the sands and gravels of the fans, a film of fine mud is usually found over the river wash; it has been deposited as the muddy flood waters subsided and sank into the sand and gravel. Not all of this fine suspended material was left at the surface, but much must have been carried down by the sinking waters, gradually filtered out from them as they percolated through the porous deposits, and left as a clay cement in the interstices between the sand and gravel grains. Much of that muddy film left at the surface may be later carried down in a similar way by local rains and become a cement for the coarser material. It is believed that in this way originated a part of the "cement gravel" and "cement sand" so often reported by drillers and so well exposed in sections of the first alluvium along the sides of San Timoteo Canyon. It makes a stratum practically as impervious to water as one of pure clay. Others of these cement beds probably represent "hardpans," formed just beneath what was the surface at the time of its formation, but which since has been deeply buried by the growth of the fan.

From this outline of the manner in which the alluvium accumulates it will be seen that it forms an extremely irregular mass of sands, gravels, and clays. Its stratification is very rude, not to be compared in regularity with that in materials deposited by the still waters of lakes and seas, but it is more perfect at a distance from the source of

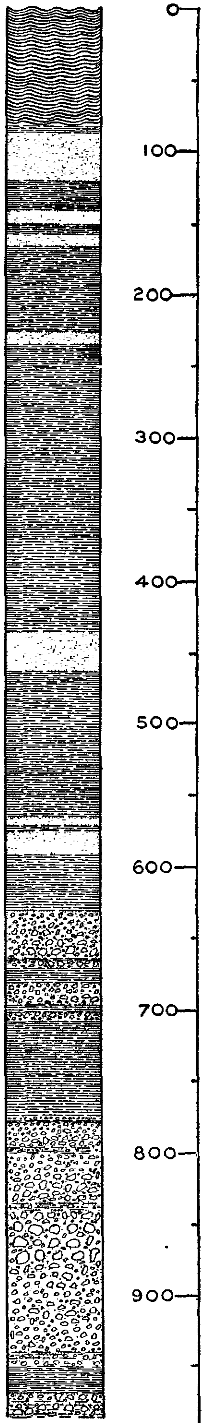


FIG. 4.—Section of the Bucher well.

the material than near it. The general arrangement is radial, the deposits spreading out fanlike from the mouth of the canyon, a particular bed often becoming wider as well as finer at the greater distances, just as the stream itself spreads out over a greater expanse as it reaches the flatter lands some distance from the canyon mouths. Cross-bedding and local unconformities are abundant. Where old river deposits are exposed for examination, as along the bluff forming the north edge of the Riverside-Highlands mesa (Pl. VI, *A*), channels filled with sand and gravel are to be seen cutting across earlier deposits of coarser or finer material, thus forming "pockets" and explaining fully the discordance often observed in the records of adjacent wells (figs. 5, 6, and 9), a water-bearing gravel stratum or a clay bed in one being entirely absent in another near by because in the shifting of channels it has been cut away after deposition.

WELL RECORDS.

Hundreds of wells have been sunk in the valley of the Santa Ana in the last twenty-five years in the search for water for domestic purposes or for irrigation, and the records of these illustrate abundantly the conditions which have just been described. Excavations in the wash north of Redlands show a mass of roughly stratified sand, gravel, and bowlders, all open, pervious material through which the water can percolate freely. Higher up in the Santa Ana channel the bowlders become large, the fine material becomes smaller in amount and coarser, and the size of the open spaces greater, although the percentage of voids is less, because the space occupied by each large bowlder is free from voids.

Within the limits of the present and the original artesian basin the characteristic feature is the presence of extensive sheets of clay (figs. 4, 5, 6, and 9). They are the finer deposits in this lower part of the fan, as the sands and fine gravels are the finer deposits at higher points. While in some of the well logs along the extreme lower edge of the water-bearing lands clay entirely free from grit is encountered, about the borders it becomes sandy, so that at times the driller is in doubt as to whether it should be classified as a fine sand or as a sandy clay; hence, while we have not continuous sections upon which to base a judgment, it is highly probable that upstream the clays merge into fine sand, then into coarse sand, and so represent only the marginal phases of the finer fan deposits. Their porosity must likewise gradually increase upstream from the cienaga, so that, whereas they are impervious caps along the lower borders of the basin, they become open and permit seepage, especially under pressure at higher points.

These clay beds are distributed at various horizons between the surface and the bottoms of the deepest wells drilled, whose depth is about 1,000 feet. The fact that they are often sandy, so that one driller will class a bed as fine sand while another calls the same stratum clay, together with the distinctively irregular character of stream deposits, the local unconformities resulting sometimes in the complete cutting out of a bed at one point and its replacement by another usually coarser, makes the correlation of the minor individual beds through the medium of well records a very uncertain undertaking indeed, and one which it is not possible to carry out unless the wells studied are very near together. In a group of wells within a prescribed area, however, it is usually possible to subdivide the strata into broad units which may be recognized in each well.

This is illustrated in the case of the group of wells belonging chiefly to the Gage Canal Company, and lying from 1 to 2 miles northeast of Loma Linda (fig 5). Throughout this group, originally very important as a source of artesian water, and still yielding a limited supply by natural flow, although many pumps are now installed, a cap of clay 50 to 100 feet thick is first pierced by the drill. Beneath this clay cap is a bed of sand and gravel, often coarse, varying from 100 to 200 feet in thickness. This gravel is saturated, and although the water is not now under sufficient head to flow, it is a satisfactory source from which to pump. This same extensive gravel bed is pierced by two deep wells, designated "P" and "O" of the Gage system on the west bank of the canal just north of Colton avenue, and by an important group of shallow wells east of the extension of D street, San Bernardino. These latter wells belong to the Riverside Water Company and to the Riverside Highlands Company, and since their surface elevation is 50 to 100 feet lower than that of the Gage wells above noted, they flow readily, although the head is not great enough to produce a flow in the less advantageously situated Gage wells.

Below this higher, clearly marked gravel series is a zone of interbedded sands, clays, and gravels about 200 feet thick. The occasional gravel streaks of this series contain water under pressure, so that it flows or rises nearly to the surface. Under this is found a second heavy and apparently rather regular gravel mass in which flowing water is obtained. As it lies 500 to 600 feet beneath the surface, it is tapped by only the deeper wells, and has been pierced by but one or two, so that its extent and regularity are problematical.

In a group of wells lying just west of the Victoria tract and north of the Southern Pacific Railroad, from which the city of Riverside gets

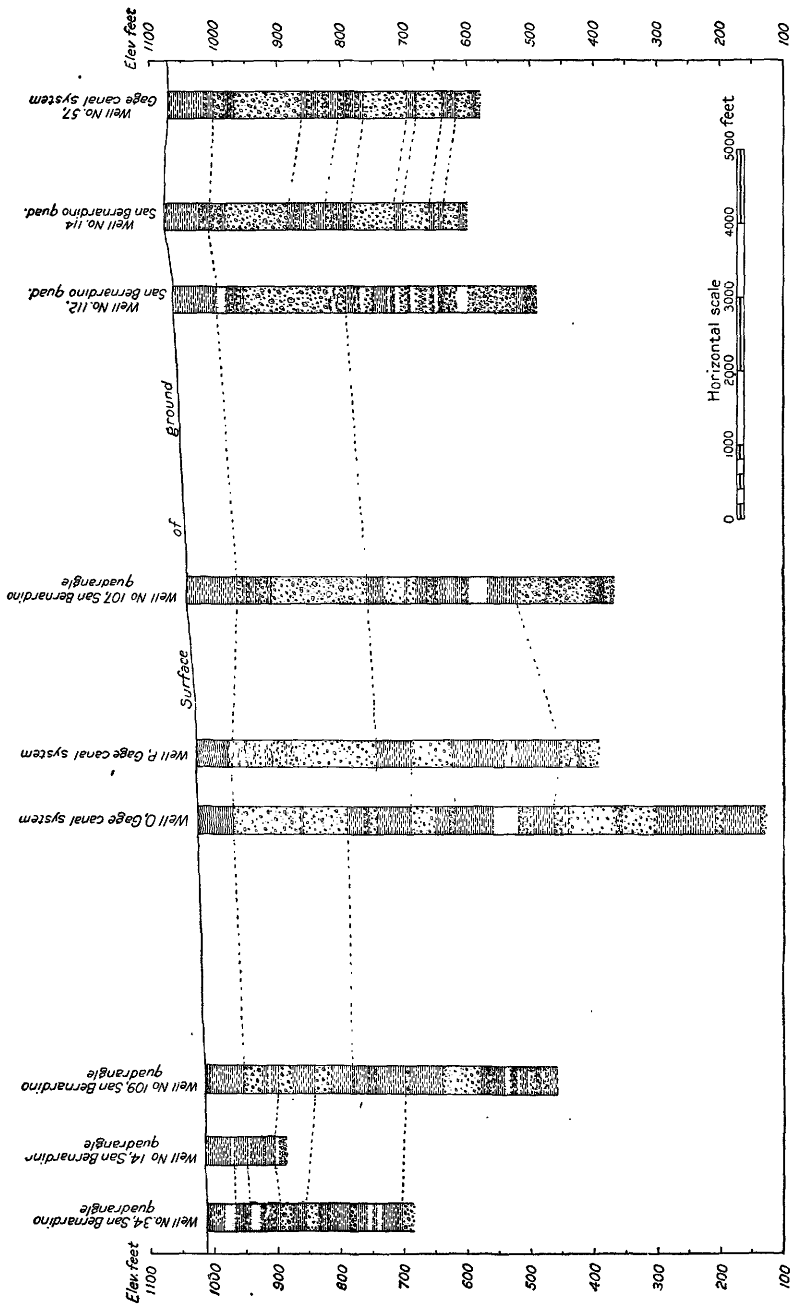


FIG. 5.—Well sections along line A-B, Pl. XII.

its domestic water supply, the upper clay stratum of the Gage wells is recognizable, although sometimes divided into two or more parts by sandy layers. A bed of coarse water-bearing gravel immediately beneath this occupies the same relative position as the upper heavy bed in the Gage wells, but when penetrated seems to be much thinner. It may be the thin edge of a heavy gravel lens, whose maximum thickness is revealed in the Victoria group. As records are available from only two of these wells which exceed 500 feet in depth, no data exist for an attempt to correlate the deeper strata with those of adjacent groups.

All of the wells which have been considered lie in the lowest part of the San Bernardino cienaga; they therefore exhibit a greater proportion of fine material and a greater regularity in stratification than is to be found in other portions of the basin that lie nearer the mountainous areas and nearer the source of supply of the alluvium.

This is illustrated by a comparison of the records of those wells which lie along Warm Creek from Waterman avenue northeast to Harlem Springs. Many of these wells show a gravel bed immediately beneath the surface soil, although, in the westernmost and deepest, the Waterman avenue well of the Riverside Water Company, the drill passed through 140 feet of clay before entering any extensive gravel body (fig. 6).

Wells but a few hundred feet apart, as, for instance, the first of the new wells drilled by the city of San Bernardino in the Antill tract in 1904, and one of the near-by wells of the Riverside Water Company, exhibit such disparity in the succession of strata that a clay or gravel bed in one can not with any certainty be recognized in the other. The easternmost wells of this group have much less clay than those farther west.

Outside the artesian area, well records show but little of the clay element. A number of records have been examined from the vicinity of Arrowhead station eastward, and, as is to be expected, the drill penetrates a succession of sand and of coarse and fine gravel strata with only here and there a thin bed of clay, or sandy clay or hardpan. The important element in artesian conditions, the superincumbent impervious cover, is absent from the records here, and it is quite unlikely that it would be found at any depth.

The wells drilled in the Lytle Creek wash likewise show a preponderance of coarse material, with only an occasional bed of clay or of cement, the latter acting in many cases as the impervious cap. In the group of wells about the old cienaga a few feet of peaty soil, representing the swamp growth on the original site of the springs, is penetrated by the drill near the surface. One record gives the depth of this organic matter as 24 feet.

The records discussed thus far have been exclusively from the later alluvium, which fills the present valley bottoms and is much more important as a source of water than the older folded beds of the earlier alluvium.

An examination of the records from the latter formation, about Redlands, in Yucaipe and San Timoteo canyons and in Yucaipe Valley (figs. 7 and 8), discloses the fact that while not lacking in bowlder and gravel beds, although these are less abundant and less extensive than in the later alluvium, the cobble beds, when they do occur, are often sealed. Their interspaces are not open, but are filled with clay, which renders the beds practically impervious to water. Artesian waters

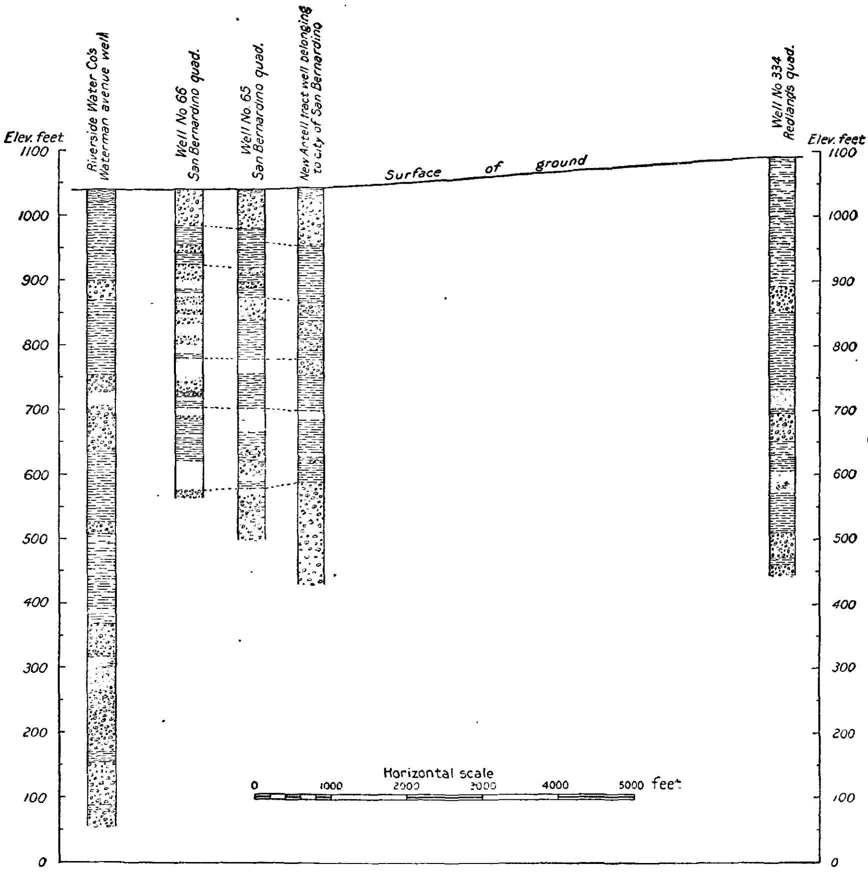


FIG. 6.—Well sections along line E–F, Pl. XII.

are found, however, in the older alluvium when open gravels are encountered and the right structural conditions exist. Good examples are the Dunlap group of wells in Yucaipe Valley; the flowing wells in the neighborhood of Singletons in San Timoteo Canyon, and the hot wells in the Badlands north of Moreno. Water is found under pressure, so that it rises above the stratum in which it was encountered, but it does not flow in the wells of the Redlands Water Company near the city reservoir and in a number of wells recently drilled in Yucaipe Canyon between its mouth and the Dunlap ranch (fig. 8).

The explanation of this difference between the records of the wells in the older and the newer alluvium, the preponderance of the clayey element in the former, is probably to be found in a consideration of the conditions under which each originated.

It will be remembered that the first alluvium is conceived to represent the detrital products which the streams swept into the lowlands as a result of their vigorous revival with the first uplift of the San Bernardino Mountains to an elevation less than that which they have now by 2,000 or 2,500 feet. Before this uplift, although the surface exhibited distinct relief, the predominant features were the wide valleys which separated the relatively low hills. Erosion before the uplift was not especially active, so that opportunity for rock decay was much better than now. The ultimate products of all rock decay are clays, hence a clay mantle must have covered much of that earlier surface. With the uplift which revived the streams and set them at work cutting canyons and depositing the products of that activity in the adjacent wide valley as the earlier alluvium the greater part of this clay mantle was swept away and formed an important part of the resulting deposits. It mingled with the bowlders, which were the direct products of the canyon cutting, or settled in basins relatively free from coarser material as nearly pure clay beds. When the second uplift came and the second epoch of sedimentation began, the earlier, more abundant clays were practically all gone, and only sands and gravels and those clays which are but rock flour ground up in the erosional processes resulted. Some of the earlier clays lying long upon the surface where they formed were well oxidized, and are therefore red. Red clay bands in the earlier alluvium testify to this origin. The clays interbedded with the modern gravels of the San Bernardino cienaga are never of this color.

Another very much less potent cause of the difference in clay contents between the earlier and the later alluvium, but one which may have exerted some influence, is the great difference in the amount of water discharged upon the two formations. All

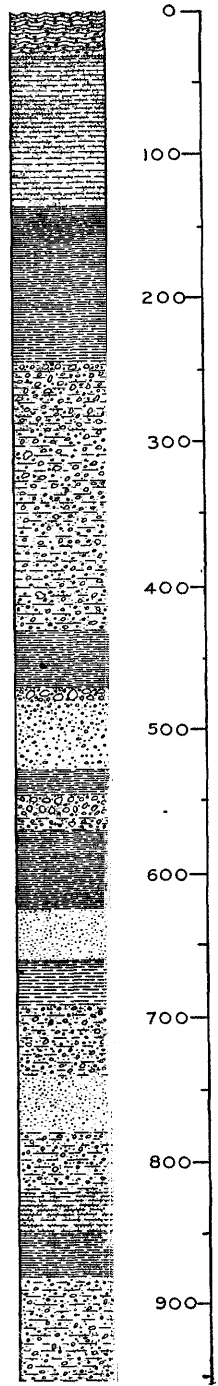


Fig. 7.—Section of the South Mountain Water Company's deep well in Yucaipe Valley.

of the important streams—Lytle Creek, Cajon Creek, East Twin Creek, City Creek, Plunge Creek, Mill Creek, and Santa Ana River—flow out upon the later alluvium and sink into it. The older alluvium gets only the local rainfall and the drainage from the southern slope of the San Bernardino Mountains between Mill Creek and San Gorgonio Pass. The amount of water seeking underground passage through the older beds is many times less than that which is concentrated in the later, so that whatever carrying and scouring power water percolating underground may have to clear bowlder beds of their fine interstitial material is much more efficiently exerted in the later than in the older beds.

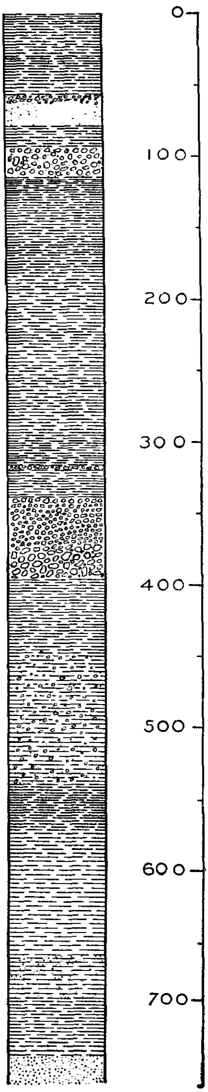


FIG. 8.—Section of Frink Brothers' well in Yucaipe Canyon.

It is to be remembered also that the earlier alluvium is the product of erosion brought into play by a less pronounced relief than that of the present, and therefore less vigorous and yielding finer material. This condition may have had its influence in bringing about the differences which exist between the two deposits.

The abrupt changes from conditions under which extensive coarse bowlder beds were deposited to those resulting in the deposition of fine clays, as shown in the well sections of the San Bernardino cienaga, admit of two or three explanations. Minor phenomena of this character are probably adequately accounted for on the hypothesis of shifting river channels. There are abundant historical examples of limited action of this kind, if historical proof were needed, but the existence of an alluvial fan is itself proof that the stream which built it has at different periods flowed down different radii of the fan. A stream on a growing fan is constantly building up its bed. As soon as that bed becomes enough higher than an adjacent tract to give the latter a steeper grade, the stream during some flood will break through the low confining banks which it has built and flow in the more advantageous channel until that has been built high enough to be abandoned in turn for a lower course. Thus the fans grow. The process is most obvious in the upper, steeper parts, where stream action is the paramount force. It is probably essentially the same in its lower course, but with less abrupt and violent action and more effective modification by other agencies, such as the growth of vegetation and the formation of wind-blown sand dunes. Yet in most cases it is very effective here. The action of these arid-land streams during the periods of flood is like that of normal streams in that the greatest volume of water, the

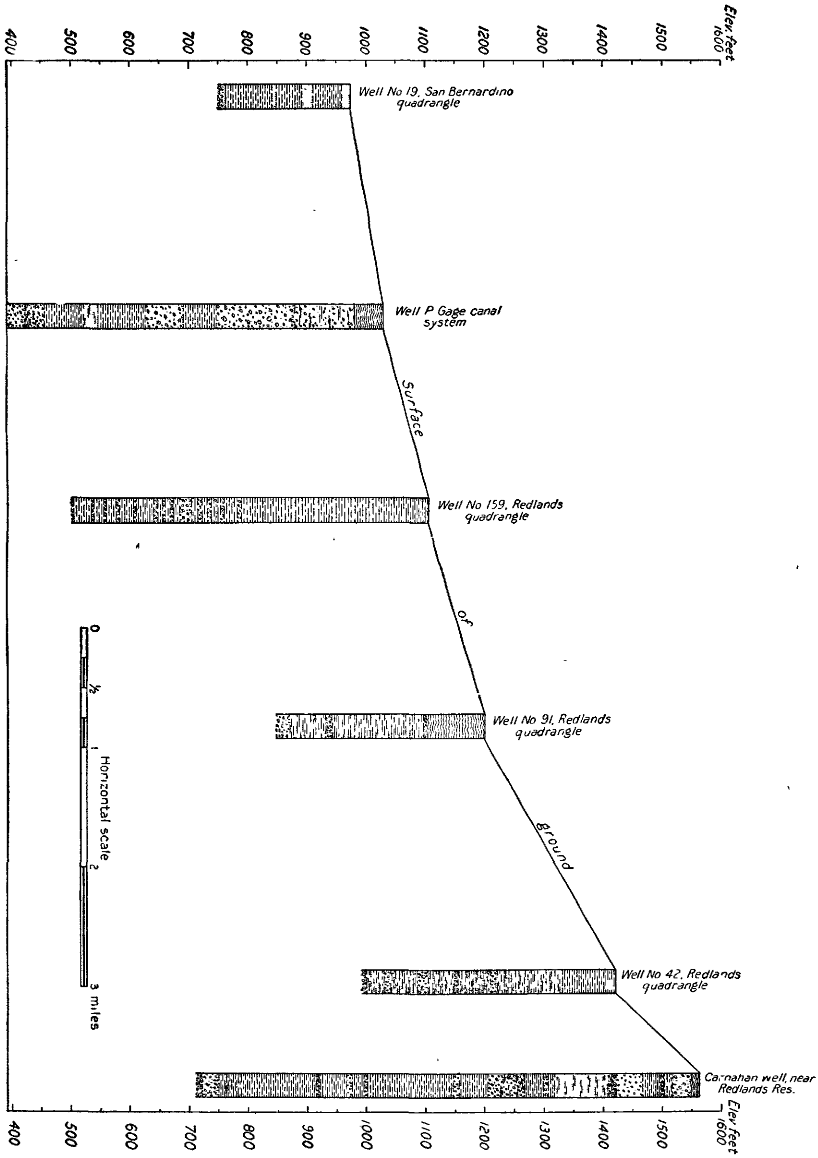


FIG. 9.—Well sections along line G-H, Pl. XII

swiftest current, and the greatest carrying power are concentrated in a main channel and a more moderate current and a greatly lessened carrying power are found outside of this channel on the adjacent flooded lands. Coarse and heavy material is therefore transported and finally deposited in the channel, while only fine material is carried out over the adjacent flood plain. A train of coarse gravel may thus extend from the head of the fan far down the stream's course, while on either side of it the contemporaneous deposits are fine silts which eventually harden into impervious clays. When a river channel shifts in the growth of the fan in the manner sketched above, what was formerly the river bed may be abandoned entirely or be reached only by the thin edge of the flood waters, which deposit only sands or fine silts. These are in this manner laid down over previously deposited gravels, producing the sharp alternations which the well sections often reveal.

Where deep and laterally extensive bodies of gravel exist beneath the present surface, such as the one which underlies the Victoria tract of the Gage Canal Company and apparently extends west in the direction of Colton as far as the Bunker Hill dike, their presence at least suggests climatic conditions at the time of deposition which were different from those of the present.

Now, gravels are deposited only in the narrow washes which form the channels of the streams and only as incidents of the major floods. In the lower part of the Santa Ana wash, at present, the greater part of the surface alluvium is sand, bowlders and coarse gravels being relatively unimportant. But the gravel stratum under consideration, which is from 100 to 200 feet thick over an area of at least one and probably of several square miles, appears from the drill records to be even coarser and heavier than the surface wash. Seemingly the conditions which resulted in the deposition of the latter are scarcely adequate to account for these coarse cobbles. It may be that slight differences in climate existed when these gravels were laid down. An increase of a few inches in the annual rainfall at present would greatly stimulate stream activity and result in transporting coarse material to much greater distances from the canyon mouths than now. Especially would this be true if such a period of increase were to follow one of drought, during which the fans were steepened by the dropping of stream loads on the upper slopes because of the decreased transporting power due to the lessened rainfall. These periods of increased and lessened rainfall, if they really are to be regarded as one of the causes of the alternation of coarse and of fine deposits, must have been centuries long. Measured in inches, the accumulations by river deposition are very slight for any single year. One or two hundred feet even of coarse alluvium must have required at least as many years to accumulate as there are feet of material, and the finer deposits represent a much longer time, as they represent slower deposition. Yet, geologically, the time required for the filling of the entire San Bernardino basin has been but short. Well-preserved trunks of trees are cut by the drill at depths of several hundred feet. They are darkened and perhaps somewhat flattened by the weight of superincumbent material, but are not otherwise greatly altered. They have been buried centuries, perhaps, but scarcely epochs

THE CIENAGA.

The streams of an arid or semiarid region normally exist as surface flows only within the mountain valleys where there is no heavy accumulation of wash over the bed rock. As soon as they reach a point where a considerable mantle of débris exists they sink to bed rock or to the ground-water level and continue their course by percolation through the porous accumulations. This was the habit of all streams tributary to San Bernardino Valley previous to their appropriation at the canyon mouths for irrigation purposes. Only a part of the rarer floods following heavy winter rains reach the sea over the surface. Whenever in their subterranean course the waters encountered an impervious barrier of any kind, they accumulated behind it until they rose to its level and flowed over it, precisely as stream waters are ponded back of a dam until they rise to the level of its crest. When such an obstruction extended to the surface of the ground the waters were forced out as springs and again became surface flows. In southern California these lands of rising waters are given the old Spanish name "cienaga."

Generally in the alluvial material where ground waters exist under pressure the compact stratum, whatever be its nature, which confines them is not entirely impervious. There is leakage through it, and the leaks, when they extend to the surface, become the springs which characterize the cienaga lands. In almost every instance those lands which, as the region developed, became important artesian basins were recognized as moist land before development through the occurrence of these springs, but, although the cienagas in so many cases proved to indicate artesian conditions, and the greater artesian basins were always indicated by them, a few of the minor basins are not thus marked, and the distribution of the springs in the important basins sometimes fails to give any adequate guide to the extent or outlines of the artesian area. It is rare, of course, that a subsurface dam extends just near enough to the surface to force the percolating waters out without expressing itself topographically. A ridge, or at least a series of mounds, is apt to be found athwart a stream's course along the lower limit of the cienaga (Pl. XI). The lands just above this are flat and often ill drained. The waters rising and evaporating here, under the influence of the effective southern sun, leave behind them their salt content, and thus alkali lands may result. They are, perhaps, less characteristic of the valley cienagas than of the rarer and less extensive examples occurring in the desert. The drier air and the fiercer heat here, acting upon a smaller water supply, cause a relatively much larger evaporation and result in the deposition of a greater percentage of the contained alkalies. These, in some instances, act as a firm cementing material, particularly where calcium carbonate is an abundant salt, so that the site of the spring may be built up into a low alkaline terrace, which interrupts the even slopes of the desert wash. The Box S Springs, just north of the San Bernardino Mountains, are an example of this class of cienaga.

UNDERGROUND CIRCULATION.

A fact which has already been frequently mentioned is that the waters of the living mountain streams during periods of normal flow disappear promptly in the gravels at the mouths of the mountain canyons. The greater discharges of the minor floods are likewise usually absorbed before they have passed far out upon the stream washes. Only a part of the infrequent greater floods escapes to the sea as a surface flow. These absorbed normal and flood waters percolate slowly seaward underground along courses which are determined by the extent and permeability of the valley filling and by the presence or absence of impervious obstructions, such as buried or partly buried bed-rock masses, or of folds in the alluvium itself, which may deflect or obstruct the waters.

When experiments have been made to determine the rate and direction of movement in the ground waters, it has usually been found that the flow is in the direction in which the general water plane slopes, although local exceptions may exist. The general position and attitude of this plane in San Bernardino Valley have been determined at two periods (Pl. VII). Its slope, although not uniform, is general toward the lowest part of the valley occupied by the Santa Ana wash. It is in the same direction, although not at the same rate, as the surface gradient. The seepage of the underground waters, which is generally slow, although at a varying rate, is, like the surface slope, toward the lowest point of the basin. The rate of seepage, however, is much greater along the lines of the porous gravels which mark the washes of the present and of the past than in the interareas of sand and soil and clay. So great is the difference in rate that it seems likely that the form of the water surface undergoes a more or less regular annual alteration. It is believed to arch along the line of the washes during the rainy season, draining slowly from these laterally, toward the less pervious areas on either side. During the dry season, on the other hand, when the open material of the washes, draining freely because of its porosity, loses its waters before the adjacent soils, the surface of the water plane is depressed in the vicinity of the washes. The adjacent lands then drain toward the washes, as they drain away from them during the wet season. Such a zone in which there is a seasonal reversal of the direction of percolation may be expected to border the loose gravels of all flood-water channels (fig. 10).

The checking of the rate at which the water moves seaward, as soon as it sinks into the rubble of the valley alluvium, together with the fact that the porous buried strata through which it percolates have no definite banks as have surface streams, results in the spreading out of the water beneath the surface into a broad zone through which it moves seaward at varying rates. In San Bernardino Valley these zones, representing the percolation from the mountain tributaries, Lytle Creek, Cajon Creek, Devil Canyon, East Twin Creek, Plunge Creek, and Santa Ana River and Mill Creek, and in winter from the direct rainfall within the valley itself, converge in the basin about San Bernardino into the wide, irregular area 40 or 50 square miles in extent and situated near the center of the valley, which is especially valuable because of the accessibility of its stored water.

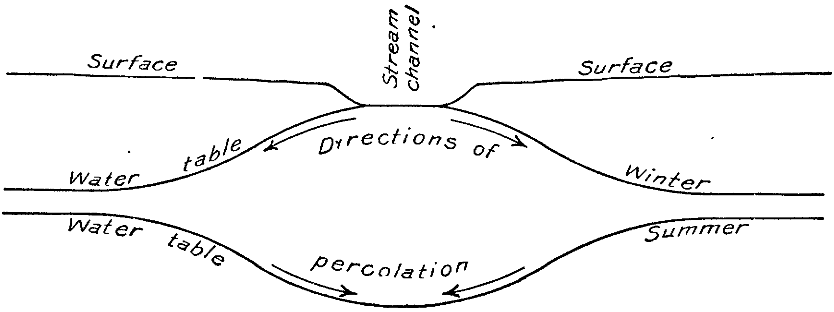


FIG. 10.—Diagrammatic cross section of summer and winter water table beneath a stream channel.

The interareas between these zones, where they are saturated, probably receive their waters, in part at least, by lateral seepage from the zones themselves. The rate of movement through the gravels in San Bernardino Valley has not been investigated. Measurements of the rate where comparable conditions exist have been made by Prof. C. S. Slichter[a] in Mohave River near Victorville, Cal., and in the Paso de Bartolo, through which the waters of the San Gabriel flow; and by Mr. Homer Hamlin[b] in Los Angeles River in and above Los Angeles, Cal. At Victorville velocities of 6, 8, 20, 35, 48, and 64 feet a day were determined, and an average of 50 feet has been assumed. In the Paso de Bartolo the much lower rates of 3½, 4, 5½, and 7 feet a day were determined. In the extensive series of tests made by Mr. Hamlin, extremes ranging between 0 and 96 feet a

[a] Slichter, Charles S., The motions of underground waters: Water-Sup. and Irr. Paper No. 67, U. S. Geol. Survey, 1902, p. 43 et seq.

[b] Hamlin, Homer, Underflow tests in the drainage basin of Los Angeles River: Water-Sup. and Irr. Paper No. 112, U. S. Geol. Survey, 1905.

day were measured. Measurements were attempted on many strata which gave results lower than could be detected by the methods used. Mr. Hamlin believes that his methods are sufficiently refined to measure a movement of less than 1 foot a day, so that where no flow was detected it is assumed that the alluvium is practically impervious.

The average flow in 26 of Mr. Hamlin's tests, all of which gave measurable rates of movement, is 23 feet a day in round numbers. Since the majority of these tests were made in the narrows of Los Angeles River, 20 miles below the mouth of Tujunga Canyon, it may be assumed that at least as high an average velocity is maintained through the pervious strata in the Santa Ana River wash above Colton. It may be, indeed, that a higher average is maintained there. Twenty-three feet a day is 8,395 feet, or a little more than 1½ miles, a year. At this rate waters which enter the gravels at the head of the Santa Ana wash would appear at the Bunker Hill dike seven or eight years later. The facts probably are that a portion of these waters appears there in very much less time, while another portion, passing through less pervious strata, requires a much longer time. The effective percolation is always that of the greater rate through the coarser material, since its discharge of available water is vastly greater than that of the slower percolation.

The fact that the water plane all over the basin responds promptly to an increase of rainfall is not an argument against the deliberate movement of the underground water. The water plane rises as a hydrostatic effect of the introduction of more water at any point within the basin and not as a result of flow from the point of entry to all the points affected.

The rate at which flood waters are absorbed by the alluvial gravels and the total amount thus added to the underground reservoirs by any given storm are matters of great interest but are difficult to determine. Mr. W. B. Clapp, hydrographer, conducted a series of measurements of a number of streams in southern California during the spring of 1903 to determine the rate of absorption of flood waters. On April 16 of that year a moderate rain accompanying a low temperature resulted in a small flood discharge and a well-maintained later flow, as much of the precipitation was in the form of snow at the greater altitudes. On April 24 the streams discharging into the San Bernardino basin were measured and the proportions of this flow diverted and absorbed were determined. The measurements were made with a limited force, and therefore it was not possible to carry them out at as many points as was desired. Nevertheless the results are of great interest. Similar measurements were made on May 16 and the results of both are shown in the accompanying table, which gives the total amount of water absorbed by the alluvium during the two twenty-four-hour periods.

Amount of water discharged in twenty-four hours from tributary streams and sinking in Santa Ana River basin above Colton, Cal.

[W. B. Clapp, hydrographer.]

APRIL 24, 1903.

Stream.	Diversions.	Waste.	Diversions.	Waste.	Total.	
	Cubic feet.	*Cubic feet.*	*Acre-feet.*	*Acre-feet.*	*Cubic feet.*	*Acre-feet.*
Santa Ana	1,382,400	10,022,400	32	230	11,404,800	262
Mill Creek	432,000	6,998,400	10	161	7,430,400	171
Plunge Creek		1,987,200		46	1,987,200	46
City Creek		1,900,800		44	1,900,800	44
East Twin Creek		864,000		20	864,000	20
West Twin Creek		743,040		17	743,040	17
Lytle Creek	561,600	4,881,600	13	112	5,443,200	125
Total	2,376,000	27,397,440	55	630	29,773,440	685

MAY 16, 1903.

Stream.	Diversions.	Waste.	Diversions.	Waste.	Total.	
Santa Ana	4,060,800	4,147,200	93	95	8,208,000	188
Mill Creek	4,233,600	1,641,600	97	38	5,875,200	135
Plunge Creek	518,400	259,200	12	6	777,600	18
City Creek	604,800	345,600	14	8	950,400	22
East Twin Creek	172,800	259,200	4	6	432,000	10
West Twin Creek	172,800	172,800	4	4	345,600	8
Lytle Creek	1,296,000	1,209,600	30	28	2,505,600	58
Total	11,059,200	8,035,200	254	185	19,094,400	439

The rate at which this absorption took place is indicated for one of the streams, the Santa Ana, by fig. 11. During the earlier measurement, that of April 24, a flood of 197 second-feet was completely absorbed in 8 miles, while on May 16 a flow of 67 second-feet had disappeared within a distance of 5 miles, more than one-third of the loss occurring in the last half mile, when the velocity was least.

During the first measurement water from the measured streams was flowing into the underground reservoir at the rate of about 317 cubic feet a second, and during the last measurement at the rate of about 100 cubic feet a second. It is of interest to note that the first rate is somewhat more than double that at which water is withdrawn from the same basin during the irrigating season, while the later measurement indicates absorption at a rate equal to two-thirds of the rate of withdrawal during the irrigating season. During great floods this recharge must take place at a very much greater rate, but it is evident that this is necessary, since it continues for a comparatively brief period, while the withdrawals are continuous for nine or ten months of the year.

ORIGIN OF HEAD WITHIN THE ARTESIAN BELT.

The alluvial deposits of the streams tributary to the San Bernardino basin have been laid down by the streams as they have built the sloping plain upon which they now flow. All of the deposits, fine and coarse, therefore have a distinct dip toward the lowest part of the basin. All of these strata abut against the arch in the earlier alluvium, which is known as the Bunker Hill dike. Where coarse beds in the lower part are capped by finer ones, which either are

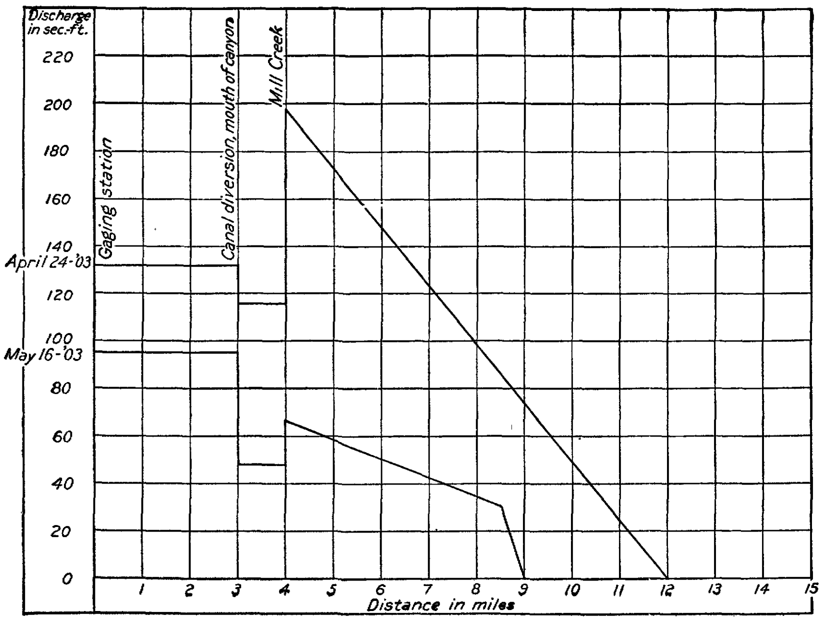


FIG. 11.—Diagram showing sinking of flood waters of Santa Ana River in stream bed.

impervious or are so compact that water leaks upward through them more slowly than it enters the coarse underlying strata, artesian conditions result. As the gravel and bowlder beds and the finer overlying clays and sands occur at a number of horizons, water under pressure is found at a number of depths within the artesian area. The wells whose yield has been greatest are of moderate depth. Three of the Gage wells, all less than 200 feet deep, flowed more than 400 inches of water each in 1892. Four others are reported to have yielded near 300 inches each in the same time. Two of these wells were 300 feet deep or less, one was 426 feet, and another 582 feet deep. All have ceased flowing or have greatly decreased in yield, but the shallower ones were the earliest exhausted. One of the best yielding wells of the

Riverside Water Company originally was a 330-foot well in the tract which furnishes the city of Riverside with its domestic supply. Two other famous wells belonging to the water company, about 2 miles east of San Bernardino, flowed between 150 and 200 inches of water each when they were first put down. They were drilled in 1900, and have been among the most productive of the late wells. The yield from them has fallen off greatly of late, but they have not ceased to flow. One of the new wells put in by the city of San Bernardino in the Antill tract in 1904 measured at the time of its completion somewhat more than 90 inches. A 984-foot well belonging to the Riverside Water Company, situated near the intersection of Waterman avenue and Third street, and yielding about 120 inches, is now one of the strongest flowing wells in the valley, although earlier wells have at some time flowed several times as much. The experiences of the water companies go to show that while the coarsest gravels and the freest flows have been secured at very moderate depths, the head under which these waters exist is easily drawn down. The deeper wells are more lasting, although usually more moderate in their first yield.

A not unusual experience in San Bernardino Valley is to secure a first flow from a shallow well 100 or 200 feet deep, and after this has ceased to flow with the lapse of years, to sink a deep well in the same vicinity and again secure a satisfactory flow from a lower horizon. The direct inference from these phenomena is that the water-bearing beds are separated by intervening strata of clay or fine sand, and so are independent sources of water under different heads. Another hypothesis advanced by the engineers of the district is that all the waters of the basin are under the same head, originating in the lowest artesian stratum, but that much pressure is lost through frictional resistance, as these waters rise from the lowest level through fine-grained beds to the coarse beds above; when they are tapped at a higher level, therefore, they are under much less pressure than when tapped at deeper points. This hypothesis requires that all pressures originate in a lower bed, and means that all of the artesian waters within the San Bernardino cienaga rise from this lowest horizon.

The other hypothesis, that of separate water horizons with independent intakes—those of the shallower beds well down from the canyon mouths toward the center of the basin, those of the deeper beds farther up toward the head of the alluvial fan—supposes all the waters to be simply percolating waters at any horizon, which have been caught beneath the upstream edges of the various impervious clay masses as they have worked seaward. Since these clays exist at various horizons, their confined waters are tapped at various depths.

To determine which of these hypotheses is correct would require a series of carefully conducted experiments upon the interdependence of deep and shallow wells. The experiments first conducted by Professor Hilgard[a] upon the interdependence of the wells of the Gage canal system in 1889 throw no light upon the relations existing between wells of greater and of less depth, since the only wells available for measurements and in any way involved at that time were the early shallow bores less than 200 feet deep.

The later extensive series of records made by the engineers of the Gage system in the fall of 1892 upon the 55 wells which were the source of supply for the canal at that time, while not carried out with the idea of distinguishing between deep and shallow wells, or of showing the interdependence of these grouped according to their depth, do throw some light upon the problem. The essential results of these measurements are assembled in the following table:

Records of wells of Gage canal system, San Bernardino, Cal.

Quadrangle.	No. of well.	Serial No.	Distance of nearest well.	Depth of well.	Elevation.	Size of well.	Temperature of water.	Original measurements.	Final measurements.	Per cent decrease from original to final measurements.	Cumulative total of original measurements.	Cumulative total of final measurements.	Percentage of loss in final total.
			Yards.	*Feet.*	*Feet.*	*In.*	° *F.*	*Miner's inches.*	*Miner's inches.*				
San Bernardino.	115	1	0	656	1,033.15	10	75	5.00	5.00	0	5.00	5.00	00
Do....	116	2	1,216	534	1,033.63	10	74	46.00	32.50	30	51.00	37.50	27
Do....	117	3	296	582	1,033.75	10	74	37.00	29.00	22	88.00	66.50	24.5
Do....	118	4	525	482	1,033.96	10	74	48.75	41.25	15	136.75	107.75	21.5
Do....	119	5	561	320	1,034.19	10¼	73	3.50	3.50	00	140.25	111.25	21
Do....	120	6	265	784	1,034.29	10	74	51.75	45.00	13	192.00	156.25	19
Do....	121	7	4,620	196	1,036.14	10¼	70	27.50	13.75	50	219.50	170.00	23
Do....	122	8	353	190	1,036.28	10¼	70	46.00	21.00	55	265.50	191.00	28
Do....	123	9	204	142	1,036.36	10	70	9.75	3.50	64	275.25	194.50	29
Do....	124	10	321	148	1,036.49	10¼	68.5	6.00	3.25	46	281.25	197.75	30
Do....	125	11	714	141	1,036.78	7	67	58.00	24.50	58	339.25	222.25	35
Do....	126	12	80	181	1,036.81	7	68	49.75	21.62	57	389.00	243.37	37.5
Do....	127	13	765	426	1,037.12	10	70	150.00	86.50	43	539.00	330.37	39
Do....	128	14	530	472	1,037.33	10	70	162.00	101.50	37	701.00	431.87	39
Do....	129	15	1,680	518	1,048.22	10	64.5	80.50	62.50	23	781.50	494.37	37
Do....	130	16	180	388	1,048.66	10	66	60.50	50.00	18	842.00	544.37	36
Do....	131	17	175	380	1,049.23	10	65	37.50	32.00	15	879.50	576.27	35
Do....	132	18	480	386	1,049.44	10	62	71.50	27.00	63	951.00	603.37	37
Do....	133	19	330	198	1,052.44	10	62	143.00	43.50	70	1,094.00	646.87	43
Do....	134	20	270	124	1,056.94	10	62	60.00	9.50	84	1,154.00	656.37	44
Do....	135	21	260	116	1,055.16	10	62	104.00	24.75	77	1,258.00	681.12	46
Do....	136	22	270	134	1,056.75	10	62	146.00	50.50	66	1,404.00	731.62	48
Redlands.	391	23	265	168	1,057.81	10	62	132.50	36.00	73	1,536.00	767.62	51
Do....	392	24	265	166	1,058.67	10	62	68.75	26.00	62	1,605.25	793.62	51
Do....	393	25	320	152	1,060.88	10	62	68.75	19.75	71	1,674.00	813.37	52
Do....	394	26	280	123	1,063.34	10	62	75.00	21.00	72	1,749.00	834.37	54
Do....	395	27	320	125	1,065.60	10	62	34.00	9.00	73	1,783.00	843.37	54

[a] Hilgard, E. W., Subterranean water supply of the San Bernardino Valley: Bull. No. 119, Office of Exp. Sta., U. S. Dept. Agric., p. 116.

Records of wells of Gage canal system, San Bernardino, Cal.—Continued.

Quadrangle.	No. of well.	Serial No.	Distance of nearest well.	Depth of well.	Elevation.	Size of well.	Temperature of water.	Original measurements.	Final measurements.	Per cent decrease from original to final measurements.	Cumulative total of original measurements.	Cumulative total of final measurements.	Percentage of loss in final total.
			Yards.	*Feet.*	*Feet.*	*In.*	° *F.*	*Miner's inches.*	*Miner's inches.*				
Redlands.	396	28	280	144	1,062.28	10	62	88.50	38.00	58	1,871.50	881.37	53
Do....	397	29	310	140	1,064.27	10¼	62	47.00	28.85	39	1,918.50	910.22	53
Do....	398	30	790	138	1,075.05	10	62	30.00	11.25	63	1,948.50	921.47	53
Do....	399	31	430	106	1,074.58	10	64	9.50	3.75	60	1,958.00	925.22	53
Do....	400	32	35	130	1,074.28	10	64	28.50	16.25	48	1,986.50	941.47	53
Do....	401	33	315	146	1,070.72	10	63	90.00	41.00	55	2,076.50	982.47	53
Do....	402	34	550	116	1,064.69	10	63	98.30	48.00	52	2,174.80	1,030.47	53
Do....	403	35	130	134	1,063.49	10	63	65.75	30.50	54	2,240.55	1,060.97	53
Do....	404	36	120	116	1,060.89	10	64	29.50	16.00	46	2,270.05	1,076.97	53
Do....	405	37	680	147	1,057.05	10	66	92.00	42.00	55	2,362.05	1,118.97	54
Do....	406	38	90	122	1,058.15	10	66	48.75	28.75	41	2,410.80	1,147.72	53
Do....	407	39	279	115	1,059.01	10	66	24.75	10.50	58	2,435.55	1,158.22	53
Do....	408	40	1,090	169	1,053.14	10¼	66	166.00	77.15	53	2,601.55	1,235.37	53
San Bernardino.	155	41	474	193	1,050.54	10	66	168.00	69.50	58	2,769.55	1,304.87	53
Do....	156	42	510	192	1,046.29	10	66	169.00	85.75	50	2,938.55	1,390.62	53
Do....	157	43	510	390	1,044.13	10¼	66	137.00	109.75	20	3,075.55	1,500.37	52
Do....	158	44	307	224	1,041.76	10	64	146.00	92.75	37	3,221.55	1,593.12	51
Do....	159	45	1,580	123	1,044.87	7	62	46.25	16.50	60	3,267.80	1,609.62	51
Do....	160	46	15	133	1,044.87	7	62	16.75	6.70	60	3,284.55	1,616.32	51
Do....	161	47	15	133	1,045.02	7	62	66.00	26.40	60	3,350.55	1,640.72	52
Do....	162	48	40	139	1,047.67	5	62	50.84	29.33	60	3,401.34	1,670.05	51
Do....	163	49	50	211	1,047.87	7	62	76.00	26.40	60	3,477.39	1,698.45	52
Do....	164	50	40	100	1,046.42	7	62	20.00	15.00	25	3,497.39	1,713.45	51
Redlands.	409	51	4,440	127	1,077.27	7	64	7.00	.00	100	3,504.39	1,713.45	52
Do....	410	52	20	127	1,076.83	7	64	7.10	.00	100	3,511.49	1,713.45	52
Do....	411	53	25	125	1,077.14	7	64	7.00	.00	100	3,518.49	1,713.45	52
Do....	412	54	25	125	1,077.45	7	65	10.50	.00	100	3,528.99	1,713.45	52
San Bernardino.	169	55	5,070	300	1,036.71	10	64	150.00	80.00	56	3,678.99	1,793.45	52

The total flow when all the wells were open was 52 per cent less than the cumulative total yielded by adding the results obtained by measuring each well when all others were closed. If the wells are grouped according to depth, however, some significant relations are brought out.

Of the 55 wells, 39 are less than 200 feet deep. The decrease in the individual flow of these wells from a maximum, when all but one are closed, to a minimum, when all are open, ranges from 25 to 100 per cent, and the total when all are open is 62 per cent less than the cumulative total. Eleven of the 55 wells are between 200 and 500 feet deep. The decrease in the flow of individual wells in this group, resulting from the opening of all the wells, varied between 0 and 63 per cent, and the falling off from the cumulative total to the final total was 33 per cent, about half that of the much larger group of shallower wells. A third group of 5 wells, ranging in depth from 500 to nearly 800 feet, showed individual decreases in flow, as the other wells were opened, from 0 to 37 per cent, with an average of 18 per cent—much less than either of the shallower groups. When the wells are grouped in this way and the data examined, it is clear that, on the whole, the deep and the shallow wells behaved very differently during the tests.

The shallowest wells, forming the largest group, show the greatest individual and average decrease; a second group, intermediate in number of wells and in depth, shows an intermediate decrease; while the smallest group, consisting of the deepest wells, shows the least falling off in yield as the other wells are opened.

It seems safe to conclude from this showing that there is not free connection between the shallower and the deeper water-bearing horizons; indeed, the wells of each group behave much as would be expected if they tapped wholly independent sources of water. It is not probable, however, that this is true. The irregular character of the alluvial deposits, the abundant unconformities and local channels within them, and the fact that each bed of clay and gravel is probably quite limited in lateral extent, make it probable that imperfect and devious connections exist between the deeper and the higher water-bearing horizons. The alluvial fans do not give the ideal artesian conditions of a practically impervious cover and a pervious underlying stratum, but rather of a less pervious superincumbent bed and a more pervious water-carrying bed below. Just as the water leaks through the topmost clay cap of the Warm Creek and Santa Ana basins to the surface as springs, so it probably leaks from the lower horizons into the upper. So long as this leakage is less rapid than the supply of water to the bed through natural sources, pressure will be maintained and artesian conditions will continue. Imperfect connection of this sort probably exists between the chief water-bearing horizons throughout the artesian basin, and it may account for the reported sensitiveness of deep or shallow flowing wells to pumping in shallow or deep ones near by.

DECLINE OF THE WATERS.

Water users throughout the valley have felt in various ways the general diminution of the supply of underground waters within the last ten years. The large irrigating and domestic companies have been affected through the lessened flow of surface streams upon which they formerly depended for a large part of their supply or through the diminished yield of wells and the necessity of installing pumping plants where originally naturally flowing waters sufficed.

Local users, ranchers, and others have found that lands formerly moist enough for pasture and ordinary crops are now dry and require irrigation, and that domestic wells must be frequently deepened in order to follow the declining ground water. In some cases the question of supply is becoming acute and the increased cost of water almost prohibitive for certain crops in unfavorable localities. Personal bitterness often results and suits are instituted to prevent developments on adjacent land.

About the general fact of the decline of the ground waters and of the lessened flow of wells there is no dispute (fig. 12 and Pl. VII). The relation of this decline to decreased rainfall on the one hand and to the drafts upon the stored underground waters through developments of various kinds upon the other is a subject of earnest discussion, and, indeed, upon a correct answer to it must depend the future attitude of the citizens toward further reclamation of lands and toward the successful maintenance of a part of those already reclaimed.

Changes in water level in wells in Redlands quadrangle between 1900 and 1904.

No. of well.	Owner.	Location.	Elevation of surface.	Elevation of water.		Change in water level.
				1900.	1904.	
			Feet.	Feet.	Feet.	Feet.
1	Doctor Meeker	Sec. 16, T. 1 S., R. 2 W.	1,996	1,718	Dry.	− 3+
2	Ward, Mills & Co	Sec. 21, T. 1 S., R. 2 W.	2,005	1,933	1,955	+22
5	Mrs. M. A. Brown	Sec. 22, T. 1 S., R. 2 W.	2,250	2,225	2,223	− 2
7	R. P. McIntosh	Sec. 20, T. 1 S., R. 2 W.	1,910	1,818	1,832	+14
9	L. Lyons	Sec. 16, T. 1 S., R. 2 W.	2,075	2,052	2,062	+10
14	W. J. French	Sec. 19, T. 1 S., R. 2 W.	1,720	1,560	1,556	− 4
28	Garland estate	Sec. 25, T. 1 S., R. 3 W.	1,570	1,394	([a])	−29+
42	C. L. Hayes	Sec. 27, T. 1 S., R. 3 W.	1,420	1,270	([b])	−30+
43	O. W. Harris	Sec. 34, T. 1 S., R. 3 W.	1,503	1,303	([c])	− 3+
45	A. C. Fowler	Sec. 32, T. 1 S., R. 3 W.	1,250	1,140	Dry.	−60+
46	L. C. Smith	do	1,215	1,135	([d])	−10+
48	E. Vache	do	1,260	1,200	1,182	−18
56	H. Bermudas	do	1,210	1,156	1,187	+31
60	R. T. Curtis	Sec. 29, T. 1 S., R. 3 W.	1,123	1,073	1,055	−18
66	Gansnor & Renwick	Sec. 30, T. 1 S., R. 3 W.	1,140	1,110	1,085	−25
80	Mrs. S. W. Sylvera	Sec. 29, T. 1 S., R. 3 W.	1,200	1,170	1,137	−43
83	S. Mansfield	do	1,193	1,154	1,143	−11
84	A. Lenanon	do	1,186	1,156	1,131	−25
94	W. A. Nichols	Sec. 28, T. 1 S., R. 3 W.	1,246	1,194	1,176	−18
102	Willis Miller	Sec. 21, T. 1 S., R. 3 W.	1,290	1,203	1,187	−16
109	C. A. Shaw	do	1,267	1,217	1,185	−32
113	A. Gregory	do	1,245	1,194	1,175	−19
117	S. Ronzone	Sec. 16, T. 1 S., R. 3 W.	1,257	1,192	1,166	−26
120	M. R. Gay	Sec. 17, T. 1 S., R. 3 W.	1,220	1,170	1,145	−25
123	J. F. Boyd	Sec. 16, T. 1 S., R. 3 W.	1,290	1,180	1,180	0
124	Wm. Lindenberg	Sec. 20, T. 1 S., R. 3 W.	1,220	1,180	1,155	−23
125	H. S. Drew	Sec. 19, T. 1 S., R. 3 W.	1,167	1,133	1,137	+ 4
126	James Smith	do	1,164	1,130	1,113	−17
130	Clark & Brotherton	Sec. 20, T. 1 S., R. 3 W.	1,195	1,162	1,147	−15
131	J. J. Pendergast	Sec. 29, T. 1 S., R. 3 W.	1,200	1,166	1,159	− 7
132	H. H. Cole	Sec. 30, T. 1 S., R. 3 W.	1,140	1,108	1,095	−13

[a] Dry at 1,365 feet. [b] 1902, 1,240 feet. [c] 1902, 1,300 feet. [d] Dry at 1,125 feet.

Changes in water level in wells in Redlands quadrangle between 1900 and 1904—Continued.

No. of well.	Owner.	Location.	Elevation of surface.	Elevation of water.		Change in water level.
				1900.	1904.	
			Feet.	*Feet.*	*Feet.*	*Feet.*
129	H. R. Scott	Sec. 19, T. 1 S., R. 3 W.	1,120	1,108	(a)	- 8+
145	E. F. Van Leuven	Sec. 25, T. 1 S., R. 4 W.	1,103	1,083	1,070	-13
155	F. Morris	Sec. 32, T. 1 S., R. 3 W.	1,260	1,195	1,165	-30
289	N. Sutherland	Sec. 4, T. 1 S., R. 3 W.	1,227	1,160	1,134	-26
290	Pattee & Nye	Sec. 5, T. 1 S., R. 3 W.	1,200	1,150	1,126	-24
291	G. J. Fowler	do	1,180	1,127	1,110	-17
292	R. F. Cunningham	do	1,160	1,120	1,105	-15
334	Mrs. Haws	Sec. 6, T. 1 S., R. 3 W.	1,125	1,125	1,115	-10
350	Jane C. Goodman	do	1,140	1,128	1,108	-20
386	State of California Hospital	Sec. 5, T. 1 S., R. 3 W.	1,110	1,078	1,064	-14

a Dry at 20 feet.

Changes in water level in wells in San Bernardino quadrangle between 1900 and 1904.

No. of well.	Owner.	Location.	Elevation of surface.	Elevation of water.		Change in water level.
				1900.	1904.	
			Feet.	*Feet.*	*Feet.*	*Feet.*
73	W. L. Zader	Sec. 29, T. 1 S., R. 4 W.	980	930	920	-10
76	Mrs. B. R. Atkins	Sec. 30, T. 1 S., R. 4 W.	980	938	923	-15
78	W. G. Soares	do	875	871	863	- 8
104	Riverside Trust Co	Sec. 24, T. 1 S., R. 4 W.	1,077	1,077	1,072	- 5
178	G. W. Curtis	do	1,088	1,063	1,045	-18
181	W. A. Thomas	do	1,078	1,076	1,068	- 8
189	E. M. Cooley	Sec. 27, T. 1 S., R. 4 W.	1,019	959	977	+18
199	Washington School	do	1,043	966	961	- 5
201	Fred Pooles	Sec. 33, T. 1 S., R. 4 W.	955	907	895	-12
277	G. Renwick	Sec. 8, T. 1 S., R. 4 W.	1,090	1,055	1,050	- 5
280	E. Memory	Sec. 20, T. 1 S., R. 4 W.	982	927	920	- 7
282	C. H. Westmyer	Sec. 8, T. 1 S., R. 4 W.	1,069	1,062	1,048	-14
316	Geo. M. Cooley	Sec. 36, T 1 N., R. 4 W.	1,150	1,108	1,090	-18
317	do	do	1,150	1,108	1,090	-18
317a	do	do	1,150	1,108	1,090	-18
318	E. J. Stiles	Sec. 35, T. 1 N., R. 4 W.	1,196	1,157	1,146	-11
319	Jas. Dickson	do	1,179	1,145	1,131	-14
329	Muscupiabe Land and Water Co.	Sec. 23, T. 1 N., R. 4 W.	1,288	1,143	1,115	-28
341	H. N. Stones	Sec. 34, T. 1 N., R. 4 W.	1,141	1,087	1,078	- 9
354	S. F. Kelley	Sec. 28, T. 1 N., R. 4 W.	1,170	1,121	1,095	-26
357	S. H. Johnson	do	1,182	1,122	1,082	-40
364	F. Alvarado	Sec. 32, T. 1 N., R. 4 W.	1,188	1,135	1,118	-17
367	D. W. White	Sec. 4, T. 1 S., R. 4 W.	1,109	1,089	1,074	-15
370	F. L. Holcomb	Sec. 33, T. 1 N., R. 4 W.	1,128	1,100	1,078	-22
375	Dexter Field	Sec. 5, T. 1 S., R. 4 W.	1,147	1,112	1,089	-23
389	S. E. A. Palmer	Sec. 33, T. 1 N., R. 4 W.	1,176	1,124	1,099	-25
398	N. M. Swarthout	do	1,142	1,115	1,094	-21
400	J. H. Lytle	do	1,166	1,135	1,086	-49
416	H. H. Ham	Sec. 34, T 1 N., R. 4 W.	1,121	1,090	1,075	-15
445	A. W. Bemis	Sec. 5, T. 1 S., R. 4 W.	1,114	1,104	1,077	-27
450	M. D. Reynolds	do	1,116	1,094	1,076	-18
457	J. F. Cadd	Sec. 4, T. 1 S., R. 4 W.	1,068	1,057	1,052	- 5
458	H. E. Gardner	Sec. 5, T. 1 S., R. 4 W.	1,089	1,079	1,063	-16
470	Charles Morris	Sec. 26, T. 1 S., R. 4 W.	1,078	1,063	1,054	- 9

At one point within the valley systematic measurements of the water level have been continued through a term of years. For these measurements we are indebted to the Gage Canal Company, its enlightened management, and its able engineers. The "Williams" well, in which these measurements have been made, is near the east end of the Victoria tract, and on the south side of Santa Ana River. In 1892 and in the spring of 1893 this was a flowing well. It has not flowed since, but each year it has declined, until in June, 1904 the water level was 38 feet below the surface (fig. 12).

During the three years preceding 1898 the measurements were made only at long intervals and the details of the decline were not determined. Since that date measurements have been made frequently, and it is found that while the average condition is one of decline, this is at a varying rate, and is interrupted by periods of rise, so that a profile of the attitude of the water plane, with months used as the time units and feet as the units of elevation, exhibits a series of pulsations, the water level rising each spring in consequence of the winter rainfall and declining from that time until after the beginning of the next rainy season. These upward movements were especially marked during the springs of 1901 and 1903, the rainfall at San Bernardino in the preceding winters having been heavier than the average for thirty-four years. Between the 1st of October, 1900, and the 1st of April, 1901, the water level rose nearly 9 feet, and a rise of 8 feet is shown between February 1 and June 1, 1903, but the crest of the 1903 rise was 10 feet lower than that of the spring two years before, showing clearly the marked general lowering.

Again, a curve showing the average decline since observations began is markedly steeper during the period from 1896 to 1900 than before or since, thus indicating that, however many causes have been operative in producing the effect observed, the diminished rainfall during those dry years was a most potent factor. The situation of this well near Santa Ana River results in prompt responsiveness to periods of heavy precipitation or of drought, and accounts for the strongly marked annual fluctuations in water level, which are not observed in wells at greater distances from important waterways. In the latter cases the percolation of the flood waters for long distances through sand and gravel smooths out the waves and reduces them to an average.

Mr. Gudeman Johnson, north of San Bernardino, has kept a record of the water level in his well for some years past, and while there are some long intervals in it during which no measurements were made, it is sufficiently full to show the absence of such marked annual pulsations as are characteristic of the Williams record. Yet its general results are identical: It shows a decline of 27 feet from June, 1899, to June, 1904, a lowering of the plane of saturation of more than

5 feet a year. It likewise shows a markedly steeper gradient for the dry period preceding 1901 than for the four seasons following, during two of which, 1900–1901 and 1902–3, the precipitation at San Bernardino has been above the average of the last thirty-four years, although, since the deficiency during 1901–2 and 1903–4 was greater than the excess for the other two winters of the four, the final result is a deficiency for the period of more than 5 inches (fig. 13).

Although outside San Bernardino Valley and influenced somewhat by local conditions, a profile of the water plane at Anaheim, Cal., as determined by Mr. J. B. Neff, is here introduced for comparison (fig. 14), and for general confirmation of the effect observed in the case of the interior wells. The total decline of the water level in

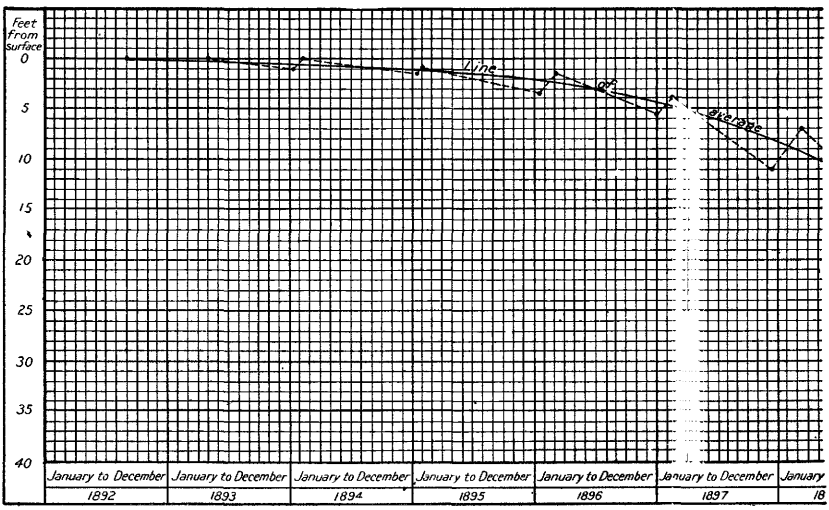


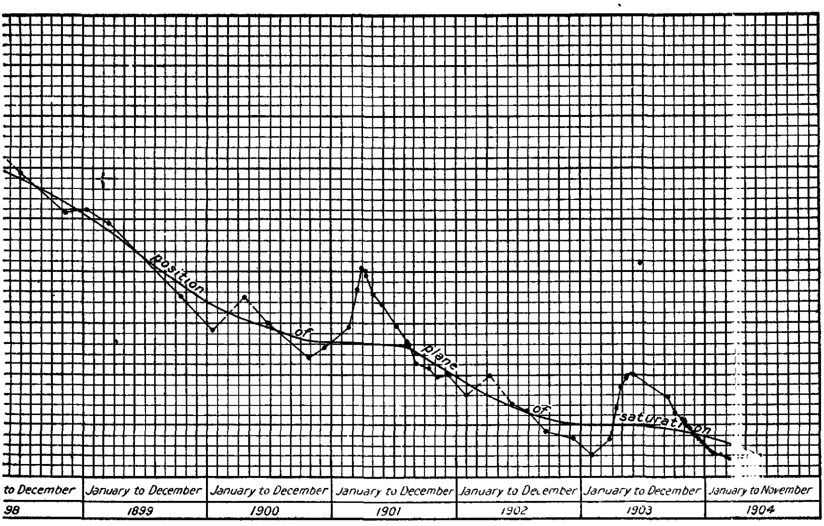
FIG. 12.—Chart showing variation

this well from the beginning of observations in February, 1898, to January 1, 1905, is 27 feet 8 inches. In this well also the lowering of the water level was much more rapid during the years preceding the winter of 1900–1901 than since. In it also there is a definite rise of the water plane during the early months of 1901 and 1903, although this rise is of smaller magnitude than in the case of the Williams well.

The significant thing about all of these profiles is that the gain effected during the winters of slight excess was in each instance lost before the end of the succeeding dry season. Only two doubtful points can be selected in the Williams profile in which the ground-water level is higher than at a corresponding time during the previous year. These two points are the crests of the floods of 1901 and 1903, and in every case the lowest point of any particular year is lower than the lowest point of the preceding year. This is true of the years

1900–1901 and 1902–3, during which the rainfall was 2 inches above the average. The loss in these cases was small, but distinct.

In Mr. Neff's well, at Anaheim, where the pulsations are distinctly less in magnitude, the loss between June 1, 1903, and June 1, 1904, was 2 inches, and between November 4, 1900, and November 8, 1901, 3 inches. These dates are the most favorable that can be selected, and each pair spans a year during which the rainfall exceeded the average by about 2 inches, or over 13 per cent. Years of more than average precipitation, then, have very decidedly checked the rate of decline of the ground waters, but have not brought about a cessation of that decline. The average precipitation will be even less efficient, and if maintained through a term of years during which



of water level in the Williams well.

there should be no change in the amount drawn from the basin, the surface of the stored subterranean waters would inevitably continue to fall, although, of course, at a less alarming rate than during the period preceding the winter of 1900–1901.

It is not possible with the data at hand to predict the effect of a series of wet years like the decade from 1883 to 1893, but such a prolonged wet period is not likely to occur again within a generation. A scrutiny of the available records shows that it has not been duplicated in a half century.

A very large percentage of a moderate precipitation evaporates at once or is required to moisten the surface soil. The proportion which as run-off becomes available for recharging the subterranean reservoirs increases at a rapidly accelerating rate as rainfall increases. At the same time less irrigation is necessary during winters of heavy rainfall, and a large proportion of the reduced irrigation is accomplished by surface waters, the streams during such seasons flowing near their maximum. Hence, at such a time, drafts upon the underground supplies are diminished and additions to them are increased, resulting in a rapid improvement of conditions. Our profiles of water levels, however, indicate that such improvements will not be permanently effective in the San Bernardino basin unless the rainfall is in excess of 17½ inches, and records indicate that only one year in three exhibits such an excess.

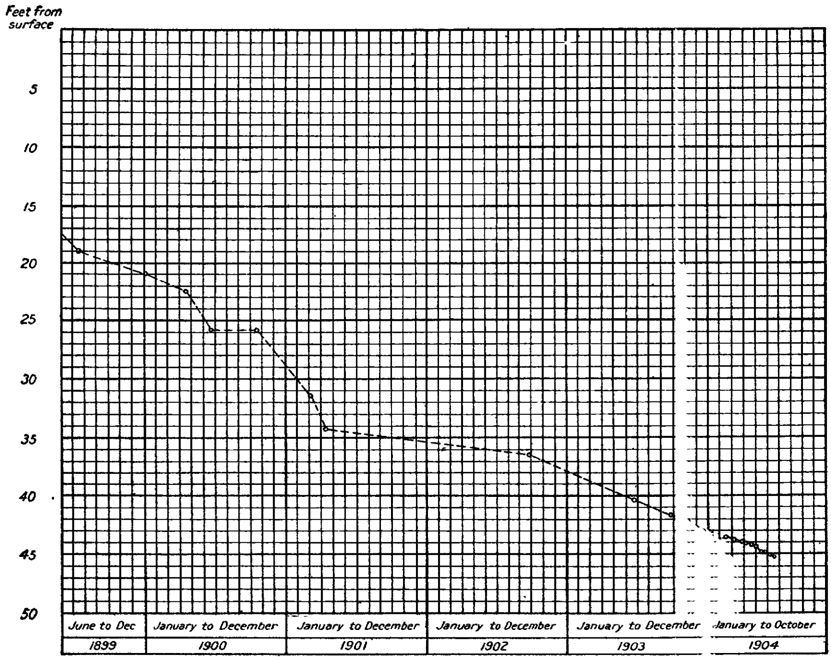


FIG. 13.—Chart showing variation of water level in the Johnson well, near San Bernardino.

Accompanying this decline of the ground waters there has been a definite decrease in the extent of the artesian basin. The San Bernardino basin was probably about at its maximum late in the eighties. At that time its area was approximately 30 square miles. In 1900, after the three especially dry winters of 1898, 1899, and 1900, it had shrunk to approximately 15.3 square miles, and at the beginning of 1904 there had been a further slight shrinkage to 14 square miles (Pl. VII).

A phenomenon which expresses the same condition as the falling water plane and the decreasing artesian area is that of decreasing pressure within the artesian belt. This results in a falling off in artesian flow and a lessening of the yield from springs which rise in the moist lands. The following table, in which the amounts of natural rising waters and of developed waters within the basin during the last six years are shown, indicates the character of this change.

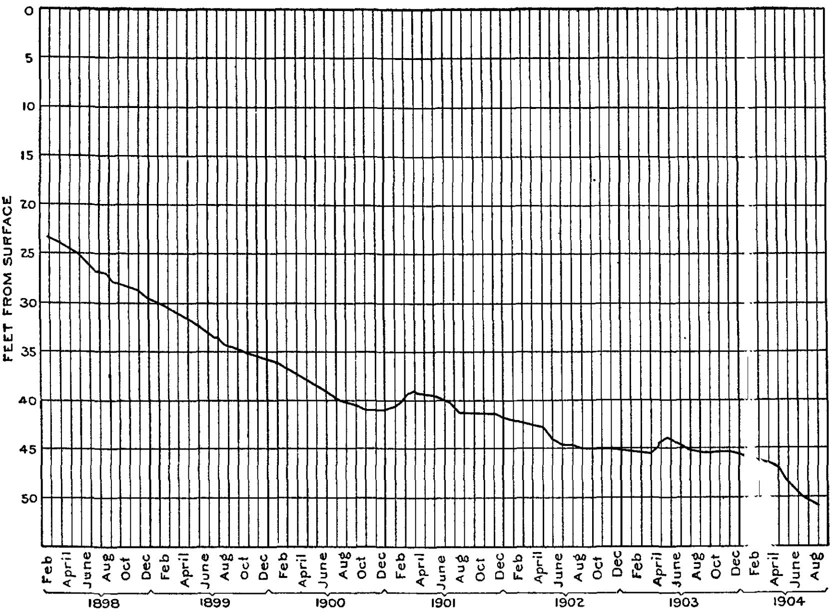


FIG. 14.—Chart showing variation of water level in the Neff well, near Anaheim,

Comparison by years of flowing water and developed water above Colton, Cal.

[Kingsbury Sanborn, observer.]

Date.	Flowing water.	Developed water.	Total.
	Second-feet.	*Second-feet.*	*Second-feet.*
September, 1898	78.31	66.38	144.69
August, 1899	44.68	65.46	110.14
September, 1900	54.18	71.42	125.60
September, 1902	38.52	81.69	120.21
August and September, 1903	45.55	109.70	155.25
August, 1904	38.62	105.36	143.98

The measurements indicate an irregular but none the less marked decrease in the natural flowing waters accompanying an equally marked increase in the quantity of developed waters. The latter has been made necessary in order that the total supply might be kept up. The causes of these shrinkages, which have been thus set forth in some detail, are twofold—the decreased rainfall of the last decade, and the increased development of waters during the same and a preceding period.

The average rainfall at San Bernardino during the last thirty-four years, which may be accepted as typical of the upper valley, has been 15.06 inches. This should be within 2 per cent of the final correct average rainfall for that point. While on the southern slopes and summits of the San Bernardino Mountains the precipitation has been heavier, and in parts of the lowlands more remote from the mountains it has been lighter, the percentages of variation from the normal at any selected point may be safely assumed to be approximately equal to that at San Bernardino. Here, while the general average is 15.06 inches, the average for the last eleven years is 12.14 inches, giving a total deficiency of over 32 inches for that period, and for the last seven years the average has been but 11.36 inches a year. Such a deficiency in a region where all the normal run-off is appropriated at the canyon mouths and only the excess is set free to recharge the gravels that form the underground reservoirs means a proportionately very large reduction in the latter element. And necessarily during years of drought the drain upon the underground supply is greater than during years of normal or excessive rainfall, because during the latter periods several of the winter irrigations may sometimes be omitted, the flowing wells capped, and the pumping plants shut down for a time. Hence, in addition to the decreased supply there have been increased demands on the underground waters during the last ten years, demands independent of the gradual increase in water required by increasing acreage and the greater maturity of groves.

Enterprises like the Bear Valley dam and the suggested reservoir at Filirea Flat, on the upper Santa Ana, although most economical when the region as a whole is considered, necessarily reduce the amount of water available for recharging the gravels below them and thus act unfavorably upon the districts dependent upon the supply in these gravels for irrigation. These dams retain practically all the water which falls above them in their respective drainage basins, so that this supply, instead of escaping during the winter, to be absorbed in large part by the gravels, is stored and used for irrigation, and the underground reservoirs receive only the uncertain amount of return waters from the groves.

In addition to these reductions in the supply through decreased rainfall and developments at the headwaters, there have been many additional wells sunk within the basin for domestic supplies for the growing tributary cities; by the old established companies to maintain the supply necessary to preserve the acreage served by them and to make up for the loss through the shrinkage of surface streams like Warm Creek and the Santa Ana, at one time a prolific source of irrigation water; and by new companies for the reclamation of new tracts.

An attempt to estimate the amount of water which may be taken from the basin without drawing upon the reserve supply is fraught with difficulties. The amount of water stored in the gravels of the valley is undoubtedly very great. Mr. Lippincott[a] has estimated roughly that their capacity is 6,400,000 acre-feet, an estimate which unquestionably is sufficiently low. This amount, if it could be made available, would supply the canals above Colton for sixty years without the annual additions from rainfall.

As a matter of fact, but a small proportion of it is commercially available. These saturated gravels have been penetrated to depths of over 1,000 feet, and it is estimated that in the center of the valley they may exist at 3,000 feet below the surface. The depth from which water can be pumped at a profit depends upon the value of the crops raised by its use and upon the cost of its distribution. The maximum at present may be accepted as 250 feet, and at this depth certainly less than 20 per cent of the stored waters of the valley could be reached. It is obvious, however, that this water should not be taken out any faster than it is annually restored. The rate of this recharge is a difficult problem.

No definite results can be reached by an attempt to estimate the amount of water which is directly contributed to the basin, since the amounts supplied by rainfall within the valley, or by floods from the mountains, or by seepage through the gravels below the measured surface flows of tributary streams, or by the minor unmeasured canyons about the margin of the basin, or by return waters from irrigated lands which drain back into the valley, must all remain undetermined factors.

By approaching the subject in another way, however, suggestions which appear to be of value result. The Williams and the Neff measurements upon the water plane have already been discussed in part. In each of these the gradient of the decline in water level flattens during the years 1900–1 and 1902–3, until it becomes nearly horizontal. The rainfall during each of these years was more than 17 inches at San Bernardino, where the normal is about 15 inches. If we accept the probable assumption that 2½ inches more than the normal rainfall would check the decline under present conditions of development, and that it might also be checked by reducing the drafts upon the basin by the same percentage, we arrive at the conclusion that about 115 second-feet may be withdrawn without permanently reducing the reserve supply.

Some steps have been taken by the greater irrigating companies, which are dependent upon the underground supplies of San Bernardino Valley, to check the escape of the floods that pass the Bunker Hill dike, in order that more time may be given for their absorption by the porous sand and gravel filling of the basin. Thus far

[a] Lippincott, J. B., Development and application of water near San Bernardino, Cal.: Water-Sup. and Irr. Paper No. 59, U. S. Geol. Survey, 1902, p. 23.

these efforts have been confined to the construction of a number of low sand ridges across the Santa Ana wash. They check the minor floods for a time and are considered of value by those who have planned them.

More elaborate systems for distributing flood waters over wider areas of fan material, so as to secure a much greater absorption of floods than is brought about by these temporary structures, have been suggested and may eventually be definitely planned and carried out. The control of the great floods, with their heavy load of débris and their high velocity, offers especial engineering difficulties and may never be undertaken, but it is thought that smaller floods, the larger part of which are wasted, may be so distributed as to greatly increase the proportion which at present sinks.

Failure or decrease in output are familiar conditions in artesian districts. The causes are manifold and vary with the region. One of the most familiar examples is that of the Denver basin,[a] discovered in 1884. In a few years 400 wells had been drilled in that district, and many of them gave strong flows under good pressure. By the end of 1890 nearly all had ceased to flow and many were permanently abandoned. The explanation given for the failure in this case was the low porosity and transmission capacity of the water-bearing rock. The water which flowed when the wells were first sunk had accumulated by very slow percolation through long periods. When this supply was withdrawn the fine grain of the transmitting rock prevented a renewal sufficiently rapid to keep up the pressure.

Other cases exist where the failure of a particular well is due not to general conditions within the district, but to faulty construction of the well itself, or to filling by sand or débris from below or above, or, as in the case of the wells at Savannah, Ga.,[b] to a slow sealing of the pores in the water-bearing stratum by gelatinous deposits or microscopic plant growth. The failure of an individual well, when not due to some general cause which affects the artesian supply as a whole, will not be accompanied by the failure of neighboring wells, and if another well is sunk in the vicinity its flow in this case will be as great as that of the original well.

The high porosity, the coarse grain, and the unconsolidated character of the gravels of San Bernardino Valley preclude the possibility of failure due to the causes which were effective at Denver. Local diminution of flow often results from the clogging of small-bore wells, and the accumulation of sand and gravel at the bottom of a well, with a consequent falling off in the yield, is testified to by a lessened depth as determined by sounding. The majority of the failures,

[a] Eldridge, G. H., Artesian wells, in Geology of the Denver basin in Colorado: Mon. U. S. Geol. Survey, vol. 27, 1896, p. 428.

[b] Slichter, C. S., Motions of underground waters; Water-Sup. and Irr. Paper No. 67, U. S. Geol. Survey, 1902, p. 94.

however, are clearly general in their character and affect whole groups, particularly those of moderate depth and those near the eastern and northern borders of the basin. These results are due to a gradual reduction of head through a drawing down of the supply.

The general conclusions to be drawn from the foregoing discussion may be summarized thus:

(*a*) The shrinkage of the artesian area, the lessened yield of artesian wells, and the lowering of the ground-water level outside the artesian boundary are marked.

(*b*) The rapid rate of this shrinkage is due to the combination of continuous development and decreased rainfall. Either acting alone would produce similar but less pronounced results.

(*c*) Average rainfall, while the present drafts upon the underground waters within the basin continue, will not restore the original water level, but will permit the waters to decline gradually.

(*d*) Rainfall of at least 17½ inches at San Bernardino, with a proportional precipitation over the drainage basin of the upper Santa Ana, is required to check the declines while drafts continue at the present rate. Records indicate that on the average this amount of rain may be expected one year in three.

(*e*). A long wet winter may restore the declines of several seasons of average rainfall or less, but since declines must be expected during at least two seasons in three it is obviously unwise to increase present drafts upon the basin.

(*f*) Strict economy in the use of water, improvements in irrigation practice, and a definite and fully supported policy of forest conservation and restoration are essential to the well-being of this valley. It is believed that much may be done also to improve conditions in the underground reservoirs by the construction of dams to check floods and distribute them over broader areas, to the end that they may be more fully absorbed. So far as the writer is aware this last means of preventing waste was first suggested by Prof. E. W. Hilgard in 1902.[a] Recently it has been given renewed attention by engineers of southern California and tentative steps toward it have been taken by the Riverside companies, which, for at least two winters past, have checked and distributed the Santa Ana floods with gratifying results.

OTHER ARTESIAN AREAS.

YUCAIPE BASIN.

On the Dunlap ranch in the Yucaipe Valley a number of artesian wells, varying from moderate depths to over 800 feet, were drilled between 1895 and 1900. The water secured has been piped to Red-

[a] Subterranean water supply of the San Bernardino Valley: Rept. of irrigation investigations for 1901, Bull. U. S. Dept. of Agric., No. 119, 1902, pp. 133-134. The subject has also been discussed by Mr. F. E. Trask, in an essay published in the Rural California, June, 1903, entitled "Water Conservation in Southern California."

lands and forms an important part of the supply there. This interesting group taps a water supply in the earlier alluvium, a source entirely different from that in which the water at San Bernardino is found. The beds of this older alluvium form the Yucaipe bench, make the hills on either side of San Timoteo Canyon, and extend eastward beyond the area under consideration toward San Gorgonio Pass (fig. 15 and Pl. IX). South of Yucaipe Valley they dip gently northward, the dip increasing in steepness toward the axis of the Badlands ridge which separates San Timoteo Canyon from San Jacinto Valley (fig. 15). This attitude of the beds is due to crustal movements since their deposition. North and east of the Yucaipe they lie horizontal or have slight south and west dips, which may not be structural but only representative of the original depositional slope.

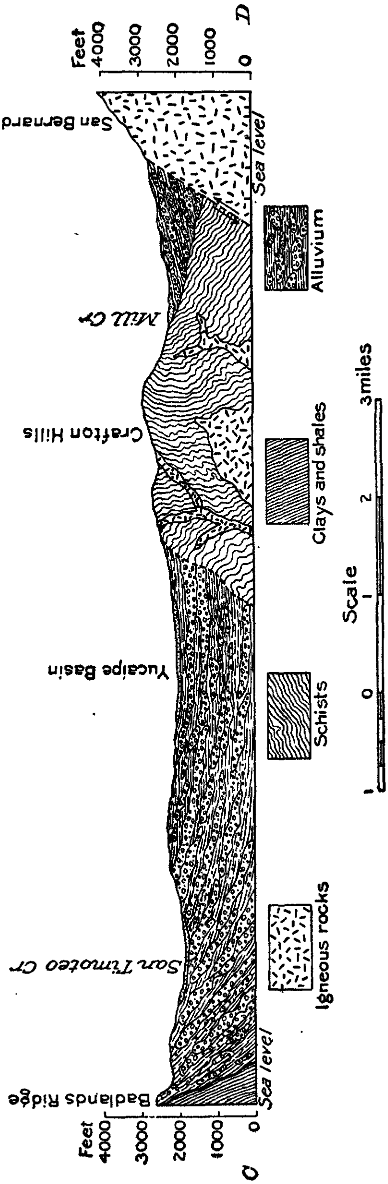


FIG. 15.—Approximate section across the Crafton Hills and Yucaipe Valley along the line C–D, Pl. XII.

The Crafton Hills and the heights on either side of Reservoir Street Canyon are of schistose or igneous bed rock. These two areas are undoubtedly connected, although the connection is buried under alluvium through the lower intervening region. It is probable, too, that the pass between the Crafton Hills and the mountains just east of Mill Creek Canyon is underlain at a moderate depth by bed rock, so that the Crafton Hills mass makes, as it were, a wing dam extending southwest some miles from the San Bernardino Mountains into the alluvial areas. All the streams draining south and west from the hills that separate Mill Creek from the wide valley to the south sink into this old alluvium and percolate slowly through it toward the lower levels.

VIEW OF SAN TIMOTEO CANYON AND THE NORTHWARD-DIPPING EARLIER ALLUVIUM.

They are checked by the Crafton bed-rock mass, and in the vicinity of the mouth of Liveoak Canyon or above meet the northward dips of the alluvium. In the basin thus formed the waters collect under pressure and flow when the porous gravels are tapped by wells. The ordinary overflow from this basin must percolate around the southwestern foot of the Redlands Heights bed-rock area, since its lowest outlet lies in this direction. In the past, after long-continued periods of excessive rainfall, when the Yucaipe gravels had become saturated to higher levels than at present, the canyon through which lies the continuation of Reservoir street toward Yucaipe Valley probably became a spillway. Springs and small areas of peaty land near the head of the canyon are evidences for this hypothesis.

In lower Yucaipe Canyon, a mile or two above its junction with San Timoteo Creek, waters under pressure have been found at depths of several hundred feet. They rise practically to the surface, but do not flow, or flow but little. These waters and those tapped by the Singleton wells in San Timoteo Canyon, as well as those which are the sources of springs in the short northern tributaries of the latter, are probably all supplied from the underground waters gathered in the drainage basin of the upper San Timoteo and its tributaries and percolating along the lines of least resistance toward Santa Ana River. The Crafton Hills bed-rock obstruction and the northern dip of the alluvium south of this obstruction must tend to concentrate the waters in the pervious strata in a relatively narrow zone extending from a short distance south of Bicknell station, on the Southern Pacific, to the vicinity of Redlands Heights. The Redlands wells near the reservoir, and the Redlands Heights wells farther south, are regarded as tapping the principal underground outlet for the drainage area east of Crafton Hills and west of Beaumont. As this area is not large and the precipitation, except on that very small portion of it which forms a part of the slope of the San Bernardino Range, is slight, the waters can not exist in great volume, and so will not bear excessive development. Thus far they seem to have been drawn upon moderately and with excellent judgment.

As has been stated before, the gravels of the earlier alluvium are partially consolidated. They seem, on the whole, to be less pervious than those of later date, and are therefore somewhat inferior in transmission capacity. Because of these two conditions—limited supply and low transmission power—no wells of very great yield have been opened and none are to be expected.

The favorable area for development has been pretty well outlined by the wells which have been bored. It includes the flat valley of the Yucaipe in the vicinity of Dunlaps (Pl. X, *A*), and the area south of it to the Southern Pacific at El Casco and for a short distance above. Westward it extends to beyond Redlands Heights, which it underlies. Within this area it is expected that wherever porous gravels are encountered by the drill a fair supply of water will be found. The deeper waters are under pressure, and where the well is started at a low point, as in the bottom of one of the deep arroyos, water may rise nearly to the surface. In wells which are begun on high ground a heavy lift will be necessary. While porous water-bearing gravels are usually found in the well sections, they are less numerous and less certain than in the newer gravels of the valley about San Bernardino. Furthermore, the irregular character of all of this alluvial material precludes the possibility of predicting accurately where coarse gravels are present and where not. Only exploration by the drill can determine this point.

RIVERSIDE BASIN.

Just north of Riverside, in the basin of Spring Brook, four wells have been drilled which yield flowing water, and the springs by which the small stream is fed indicate the probable extension of artesian conditions beyond the area determined by the wells.

A mile or more above the Salt Lake Bridge at Riverside Narrows is a small flowing well which furnishes water for domestic purposes, and other artesian wells now filled, or abandoned for other reasons, are reported from the same vicinity.

At Riverside Narrows Santa Ana River enters a narrow gorge cut in the dioritic bed rock of the region, and the underground waters are forced to or near the surface as they approach this obstruction. In consequence, the river bed, dry for some miles below Slover Mountain, here carries a perennial stream of respectable proportions. The effect of this diorite mass is similar to that produced by the ridge of folded clays which crosses the course of the Santa Ana above Colton and has been discussed as the Bunker Hill dike.

The river wash which has accumulated against the mass is saturated, it contains coarser and finer material in alternating strata, and as these, deposited by the river, slope in the direction of its flow, water entering the coarser members at a higher level farther up the stream is to be found under pressure at a lower level farther down the stream. The waters of the Elliotta, Stansell, and Evans wells above Riverside probably enter the gravels soon after they have passed over the Bunker Hill fold, and their head is only that which accumulates in the few intervening miles. There is little doubt that the water percolates under the High Grove and East Riverside mesas, which are underlain by river alluvium, deposited at a time when the Santa Ana or one of its distributaries flowed through this lowland.

These gravels about Riverside are not generally as coarse as those above the Bunker Hill dike, since they are farther from their origin in the mountains; hence they are somewhat less free water bearers, although excellent in this respect. Flood waters have access to them

A. YUCAIPE VALLEY AND ARTESIAN LANDS.

B. NONARTESIAN WATER-BEARING LANDS IN SANTA ANA VALLEY.

chiefly through the porous wash of the river below Bunker Hill, while the basin above is supplied by the waters absorbed by all of the alluvial fans distributed along the base of the San Bernardino Range.

The Riverside basin is shallower and has a smaller area than the large basin northeast of it, but it has not yet been very heavily drawn upon, and it is benefited by the return waters from a large acreage about Rialto and East Riverside. It should be capable of supplying much larger drafts than have as yet been made upon it, and although the waters thus developed will have to be pumped to the accessible lands, and so will prove more expensive than San Bernardino basin waters now are, the difference in cost may be expected to lessen as the latter waters become more expensive, so that it may soon become financially practicable for the Riverside irrigator to utilize more of these near-by waters and thus reduce the great drafts upon the larger and more important San Bernardino basin.

The city of Riverside is now (1904) installing a domestic system which will utilize a part of these waters. They are to be pumped to a reservoir on Rubidoux Hill and distributed thence to the city mains. Thus used they will augment the supply that now flows by gravity from artesian wells in the San Bernardino basin.

GROUND WATERS.

By ground waters are meant subsurface waters outside the artesian areas (Pls. VII and VIII), which therefore are not found under sufficient pressure to flow by gravity, but become available for irrigation only by means of some sort of pumping device. They have precisely the same origin as the artesian waters—i. e., the rainfall—and, indeed, when they lie above the artesian basin, may later become artesian by passing beneath an impervious cap in the course of their slow movement seaward under the influence of gravity. Below and outside of the basin they constitute the normal subsurface zone of saturation, whose upper limit slopes generally with the soil surface, but at a different rate, so that where the fan material lies high and is open textured it may be hundreds of feet to the ground-water level. This is probably true in the vicinity of Grapeland and some miles southward. Nearer the axis of the valley these waters are nearer the surface and are drawn upon more or less freely for irrigation and for domestic purposes. Their approximate position relative to the surface, where data enough exist for determination, is shown on Pl. VII for the years 1900 and 1904.

West of Lytle Creek the water lies at so low a level and the wells are so few that no attempt has been made to show the position of the water plane, data being entirely insuffiicient for this purpose.

From a point a mile or more below Crafton eastward the water level seems to have changed but little during the last few years. In a zone immediately surrounding the artesian basin, however, there has been a distinct change in the water level, a decline varying in amount from zero at the edge of the artesian area to 50 feet in extreme cases some distance back.

On pages 57 and 58 are given tables in which the elevation of the water plane at two periods, four years apart, is shown for a number of wells distributed widely over San Bernardino Valley.

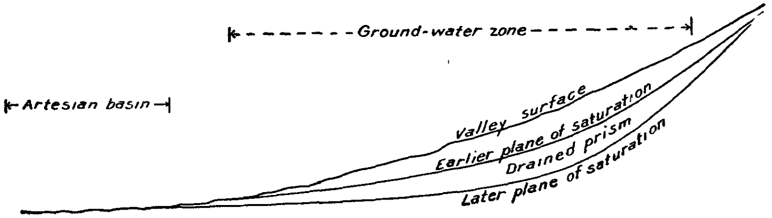


FIG. 16.—Diagrammatic cross section of drained prism in alluvial-fan material.

It is to be noted that the earlier and the present elevations of the water plane are approximately equal at both the upper and the lower edges of the ground-water zone—i. e., the past and the present planes of saturation unite near the artesian limit and again well up the alluvial fans, their most marked divergence being along a median line of the zone, a cross section of the drained prism being thus crescentic in form (fig. 16).

TEMPERATURES.

Waters with temperatures much above the normal are not at all unusual in San Bernardino Valley, nor in other parts of southern California. The region in general is not one of recent volcanic activity, so that, in the majority of cases at least, we have no bodies of fresh intrusive or effusive rock to appeal to as a source of heat. On the other hand, there have been abundant recent dynamic disturbances, as is proved clearly on structural grounds, and the slight earthquakes which occur from time to time suggest that minor movements may be taking place almost constantly along the established fault lines. The enormous friction from these movements must raise the earth temperatures very notably along the lines of disturbance, and the fractured zones adjacent to the faults must sometimes provide easy channels through which surface waters may reach greater depths, become heated, and rise again as hot springs, or through which rock waters with the temperatures of their origin may escape to the surface.

If we consider the distribution of the hot springs we find that, with a few unimportant exceptions, they occur along these definite structural lines, or if we reverse the process and trace the major fault lines we find them marked in many instances by thermal waters.

The most extensive and important group of hot springs is that which issues from crevices in the gneissoid bed rock at the south base of the San Bernardino Range in the vicinity of East Twin Creek Canyon.

THE BUNKER HILL DIKE.

The easternmost group of these is known as the Arrowhead Springs, from the peculiar figure of a gigantic arrow outlined by the vegetation on the mountain side above them. Numerous springs issue here at various temperatures, the highest measured by the writer being 184° F. One-half mile farther west an even greater volume of hot water, estimated at 5 or 10 miner's inches, issues from a number of springs that flow usually from the bowldery alluvium along the lower course of Waterman Canyon (West Twin Creek), but occasionally directly from bed rock. Much of this water has a temperature of 140° or 150°, and even higher as it first issues. A small group of warm springs is found about a mile east of Arrowhead Peak, and in the canyon of the Santa Ana, 2 miles from the edge of the mountains, is another conspicuous warm spring.

The line of disturbance whose western extension is marked by the Bunker Hill fold (Pl. XI) is even more definitely outlined by a series of wells and springs with temperatures above the normal. Within the San Bernardino basin itself a temperature of 72° is found in the mixed waters from three wells pumped into one distributing pipe near the San Bernardino city reservoir. Another well whose waters have a temperature of 90° has been bored about a mile northwest of Bunker Hill and just north of the dike. The latter location is one in which numerous wells of abnormal temperature are found. The "Hobo" well, the Urbita well, and the Topp well, all near Bunker Hill, have temperatures varying from 85° to 105°. Farther eastward a group of shallow wells belonging to the Riverside Water Company, and distributed along the north bank of Santa Ana River, just east of E street extended, have temperatures of 71° to 73°, although less than 100 feet deep in many instances.

Near Loma Linda a number of wells of the Gage canal system discharge waters at temperatures of 70° to 75°, but in these cases the depths are greater, ranging from 320 to 656 feet. Farther east and entirely outside the territory under discussion in this paper, but worthy of mention here because they occur along the same structural line, are the Eden, the Relief, and the Ritchie hot springs, which issue from bed rock near the zone of structural weakness.

This distribution is in itself strong evidence that the heat which is imparted to the underground waters originates, in many cases at least, in the zones of crustal movement, especially the faults, which are a conspicuous feature of the geology of southern California.

Within the San Bernardino Valley lowland, temperatures, except as they are high along the line of the Bunker Hill dike, have a rather erratic distribution. The mean annual atmospheric temperature of the valley is about 62° F., and the ground waters and the waters from the majority of the shallow flowing wells have the normal temperature of 62° to 64°; but at Harlem Springs waters originally issued at various temperatures up to 115°. The flowing waters of the Payne well, 642 feet deep, situated 2 miles south of San Bernardino, have a temperature of 112°. The water of the Urbita Springs well has a temperature of 102° to 105°, and other wells which have been mentioned near the Bunker Hill dike exhibit temperatures ranging from 70° to 90°.

When we come to consider temperature gradients—i. e., the number of feet it is necessary to go in depth for each degree rise in temperature from the normal of 62° or 63°—we find such wide extremes as 1° in 3 feet in the "Hobo" well, No. 23, San Bernardino quadrangle, and 1° in 114 feet in one of the Riverside Water Company's deep wells on East Third street. The accompanying table of depths and temperatures illustrates the wide diversity, both in temperatures and in temperature gradients, throughout the valley.

Temperatures in wells in San Bernardino Valley, California.

Number of well.	Depth of well.	Measured temperature at surface.	Theoretical temperature on basis of 1° increase for each 60 feet depth.	Departure from theoretical temperature.	Temperature gradient.
	Feet.	°*F.*	°*F.*	°*F.*	*Feet.*
53	68	71	63	+8	8
R 361	68	86	63	+23	3
17	81	73	63	+10	7
252	83	68	63	+5	16
18	92	73	64	+9	8
23	121	98	64	+34	3
8	125	68	64	+4	21
125	141	67	64	+3	28
123	142	70	64	+6	18
124	148	68.5	64	+4.5	23
R 330	150	68	65	+3	25
234	158	85	65	+20	7
328	169	76	65	+11	12
126	181	68	65	+3	30
R 327	185	80	65	+15	10
122	190	70	65	+5	24
121	196	70	65	+5	24
19	225	71	66	+5	25
R 329	231	72	66	+6	23
R 385	300	115	67	+48	6
119	320	73	67	+6	29
297	451	90	70	+20	16
R 375	460	72	70	+2	46
128	472	70	70	0	59
118	482	74	70	+4	40
104	506	70	70	0	64

Temperatures in wells in San Bernardino Valley, California—Continued.

Number of well.	Depth of well.	Measured temperature at surface.	Theoretical temperature on basis of 1° increase for each 60 feet depth.	Departure from theoretical temperature.	Temperature gradient.
	Feet.	*°F.*	*°F.*	*°F.*	*Feet.*
106	517	73	71	+ 2	47
116	534	74	71	+ 3	44
465	544	68	71	− 3	91
117	582	74	72	+ 2	49
San Bernardino city well on Antill tract	614	69	72	− 3	88
112	642	112	73	+39	16
115	656	75	73	+ 2	50
315	682	68	73	− 5	114
Urbita new well	740	78	74	+ 4	46
120	784	74	75	− 1	65
Waterman avenue well, Riverside Water Co	984	75	78	− 3	76

The results can not be accepted rigidly, because in some cases well tubing has been cut at several points and the waters whose temperature is given are therefore mixed waters from undetermined horizons. In one or two other cases the yield of the wells is small, the waters rise but slowly, and sensible changes may therefore have taken place in their passage upward to the surface where the temperatures were measured. But when due allowance is made for these inaccuracies a wide variation remains to be accounted for.

The alternate undisturbed beds of sand, gravel, and clay which fill this valley should exhibit a thermometric gradient which is lower rather than higher than the normal of 1 degree for each 50 or 60 feet increase in depth, which has been established by observations in shafts and deep mines in consolidated rock in various parts of the world. A lower gradient is to be expected, because this alluvium has been deposited recently and with great rapidity, and so may be supposed not to have acquired fully the normal earth temperature. An additional reason for expecting low temperatures is its porosity and the consequent free circulation of meteoric waters, which tend to carry the mean annual temperature of the surface to depths. The low gradients exhibited by the new Antill tract wells of the city of San Bernardino and by the Riverside Water Company's wells Nos. 465 and 315, gradients of 88 to 114 feet per degree, seem to bear out this hypothesis of relatively low temperatures at moderate depths, due to lag in the rise of earth temperatures or to transfer of surface temperatures to depth through the medium of circulating waters. Such low temperatures are to be expected under the conditions which prevail in this basin, but where higher temperatures are found special explanations seem to be required.

Along the line of the Bunker Hill disturbance the occurrence of high temperatures is fully explained by the known geologic conditions. This ridge represents an anticlinal arch, the strata, which farther north occur at greater depths, being brought near to the surface here by the fold. Hence, the waters percolating along the porous beds at depths near the center of the valley and acquiring the temperatures appropriate to those depths are here found and tapped near the surface as they rise toward the anticline with the inclosing strata.

High temperatures found near the center of the basin, as in the case of the Payne well or more especially the group at Harlem Springs, can not be explained in this way, as they do not occur in connection with anticlinal structures. There are two or three possible explanations for the presence of these hot waters, but sufficient evidence does not exist to decide between them.

Just as springs in the artesian basins represent leakage to the surface through the impervious cap which confines the waters, and as all the water-bearing horizons in the alluvium probably are imperfectly connected by leakage from one horizon to another, so the hot wells and springs found near the middle of the valley may represent similar leakage from near the bottom of the basin to the surface. Again, the occurrence of strong springs of heated waters along the north edge of the valley, as in the case of the Arrowhead group—waters which sink into the alluvium and are reenforced there perhaps by other flows of hot water from near the fault line, flows which pass directly from the heated rocks of the faulted zone into the alluvium without discharging upon the surface at all—at once suggests that it may be these heated waters percolating seaward through the alluvium along rather definite channels which escape as springs at the head of Warm Creek, or are tapped there by comparatively shallow wells. Of these two hypotheses, leakage from near the bottom of the basin to the surface and percolation of hot water from the fault zone toward the center of the basin, the latter seems the more reasonable as an explanation of the Harlem Springs group, while the former is favored as an explanation of the temperature of waters situated like the Payne well, comparatively near the Bunker Hill dike, which forces heated deep waters toward the surface.

CHEMICAL CHARACTER OF THE WATERS.

The waters of the San Bernardino artesian basin are very pure, as the subjoined analyses will show. They are, in effect, mountain waters which have passed for a few miles underground through sands and gravels whose drainage is free, so that they have had little opportunity to dissolve the salts contained in the resistant minerals of the rocks.

Professor Hilgard[a] records three analyses, two from groups of wells in the Gage canal system and a third from Warm Creek, at the mill. The results are as follows:

Analyses of well water, San Bernardino Valley, California.

[In parts per 100,000.]

	Gage system artesian wells.		Warm Creek.
	Group D, No. 5.	Group A, No. 2.	
Sodium chloride (common salt)	0.63	0.91	2.57
Sodium sulphate (Glauber's salt)	1.93	3.13	5.82
Sodium carbonate (sal soda, black alkali)	1.02	.21	2.00
Potassium sulphate	.60	.63	.80
Total soluble residue	4.18	4.88	11.19
Calcium sulphate	....	.78	1.46
Calcium carbonate	10.17	12.12	7.62
Magnesium carbonate	2.32	2.49	2.53
Silica	2.44	2.39	3.24
Total insoluble residue	14.93	17.78	14.85
Total solids	19.11	22.66	26.04

Dr. A. K. Johnson, of San Bernardino, has furnished the following analysis of waters from the Lytle Creek group of wells, which, until recently, furnished all of the water for the San Bernardino system.

[James A. Shedd, analyst.]

	Parts per 100,000.
Sodium chloride	1.75
Calcium sulphate	1.71
Calcium carbonate	5.56
Magnesium carbonate	3.62
Iron and alumina	1.4
Silica	3.75
Total solids	17.79

The following partial analysis of the warm water (112° F.) from the Payne well is from the California Agricultural Experiment Station, E. W. Hilgard, director:

	Parts per 100,000.
Soluble residue (sodium chloride, sodium sulphate, sodium carbonate, potassium sulphate)	12.56
Insoluble residue:	
Calcium sulphate, calcium carbonate, magnesium carbonate, silica (very small)	22.93
Organic matter and chemically combined water	2.37
Total	37.86

[a] Hilgard, E. W., Subterranean water supply of the San Bernardino Valley: Report of irrigation investigations for 1901, U. S. Dept. Agric., p. 134.

All of these waters are in constant use for irrigation or for domestic purposes, and the small proportion of salts, particularly of the harmful soluble varieties, makes them very desirable for this use.

Professor Hilgard points out that both the Gage canal and the Warm Creek waters contain percentages of the fertilizing potassium sulphate which are unusual in ground waters and amount to 47 and 63 pounds per acre, respectively, on the basis of a duty of 1 miner's inch to 5 acres. In the other analyses the potash was not separately determined.

The hot wells and springs of the valley are very generally utilized for baths or medicinal purposes in connection with health resorts. Some complete and partial analyses are available which illustrate their character.

Mr. F. M. Coulter, of Los Angeles, has furnished the following analysis of water from one of the Arrowhead Springs:

Analysis of water from Arrowhead Springs, California.

[E. W. Hilgard, analyst.]	Parts per 100,000.
Sodium chloride (common salt)	14.148
Sodium sulphate (Glauber's salt)	73.483
Potassium sulphate	6.922
Calcium sulphate	2.323
Magnesium sulphate	.253
Calcium carbonate	2.323
Magnesium carbonate	.555
Lithium	Trace.
Borine	Trace.
Strontium	Trace.
Silica	8.550
Organic matter	Trace.
Total solids	108.557
Free sulphureted hydrogen, cubic inch per gallon	.622

The appended analysis, also made under Professor Hilgard's direction, illustrates the character of the water from the Urbita Hot Springs, near San Bernardino:

Analysis of water from Urbita Springs, California.

	Parts per 100,000.
Sodium chloride	3.2
Sodium sulphate, Potassium sulphate (small amount),	20.4
Sodium carbonate	7.40
Calcium sulphate, Calcium and magnesium carbonate,	1.5
Silica	1.0
Chemically combined water, etc	8.00
Total	41.5

An old analysis of the Harlem Springs water, accredited to Professor Woodbridge, of Pasadena, shows the following solids present:

Analysis of water from Harlem Springs, California.

	Parts per 100,000.
Sodium chloride	3.89
Sodium sulphate	14.36
Potassium sulphate	Trace.
Sodium carbonate	3.20
Calcium carbonate, etc	4.47
Silica	3.15
Total	29.07

The large proportion of the laxative medicinal salt, sodium sulphate (Glauber's salt), in all these hot waters is worthy of note.

TABLES OF FLOW.

For a number of years measurements of stream flow and of the amounts of water carried in the various canals of San Bernardino Valley have been made by the United States Geological Survey and by engineers engaged in private practice. The results have been published from time to time in the water-supply papers of the Survey, but for convenience of reference those which are of greatest importance to water users in the valley are assembled in the tables that follow:

MILL CREEK.

Discharge measurements of Mill Creek at headworks of Crafton canal, San Bernardino County, Cal..

Date.	Hydrographer.	Discharge.
		Second-feet.
July 29, 1896	J. H. Quinton	14.2
April 12, 1898	J. B. Lippincott	15.7
April 29, 1898	do	18.9
June 12, 1898	do	18.1
July 23, 1898	do	11.8
September 8, 1898	do	13.1
October 18, 1898	F. H. Olmsted	15.3
November 9, 1898	do	15.2
December 8, 1898	do	12.6
January 12, 1899	S. G. Bennett	10.8
February 18, 1899	do	10.4
March 23, 1899	do	15.6
May 6, 1899	do	14.6
May 31, 1899	do	11.6
June 15, 1899	do	6.8
July 15, 1899	do	7.4

Discharge measurements of Mill Creek at headworks of Crafton canal, etc.—Continued.

Date.	Hydrographer.	Discharge.
		Second-feet.
July 27, 1899	S. G. Bennett	4.3
August 24, 1899	do	[a] 5.7
August 24, 1899	do	[b] 1.5
April 14, 1900	do	10.8
May 5, 1900	do	[a] 39.0
May 5, 1900	do	[c] 8.0
July 13, 1900	do	[a] 5.4
July 13, 1900	do	[b] 3.4
October 2, 1900	W. W. Cockins, jr	[d] 8.6
March 30, 1901	S. G. Bennett	20.0
July 6, 1901	do	23.3
December 5, 1901	do	14.5
April 5, 1902	do	15.7
April 5, 1902	do	[a] 5.4
May 31, 1902	do	19.2
July 10, 1902	do	10.8
September 3, 1902	W. B. Clapp	5.3
November 5, 1902	S. G. Bennett	12.3
April 1, 1903	W. B. Clapp	1,280
April 24, 1903	W. B. Clapp and J. C. Clausen	39
May 16, 1903	W. B. Clapp	68
June 9, 1903	do	46
July 1, 1903	do	29
September 1, 1903	do	22
March 22, 1904	W. B. Clapp and E. C. Murphy	17.6
September 21, 1904	W. B. Clapp	14.1
November 11, 1904	E. C. La Rue	11.2

[a] In creek.
[b] Pumped.
[c] Canal.
[d] Of which 1.35 second-feet is pumped.

SANTA ANA RIVER.

Discharge measurements of Santa Ana River and canal at Warm Spring, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
June 20, 1896	J. B. Lippincott	80.05
July 28, 1896	J. H. Quinton	74.70
November 21, 1896	J. B. Lippincott	35.18
January 27, 1897	do	47.58
March 4, 1897	do	105.70
June 15, 1897	do	82.74
July 1, 1897	A. Q. Campbell	90.79
July 6, 1897	do	71.37
August 8, 1897	do	74.96
September 30, 1897	do	65.48
November 14, 1897	do	47.21
January 8, 1898	do	34.28
March 9, 1898	A. H. Crowe	50.82
April 11, 1898	J. B. Lippincott	39.28
April 29, 1898	do	42.33
June 12, 1898	do	39.06
July 23, 1898	do	47.56
September 8, 1898	do	36.67
October 18, 1898	F. H. Olmsted	30.70
November 9, 1898	do	21.78
December 8, 1898	do	24.74
January 12, 1899	S. G. Bennett	38.00
February 18, 1899	do	32.04
March 23, 1899	do	37.22
May 6, 1899	do	29.24
May 31, 1899	do	22.10
June 15, 1899	do	19.80
July 15, 1899	do	25.90
July 27, 1899	do	23.55
August 24, 1899	do	10.86
April 14, 1900	do	22.66
May 5, 1900	do	24.40
July 13, 1900	do	22.30
November 20, 1900	do	102.00
November 22, 1900	do	[a] 15.64
February 5, 1901	do	101.00
February 23, 1901	do	110.00
March 4, 1901	do	102.00

[a] Calculated.

Discharge measurements of Santa Ana River and canal at Warm Spring, etc.—Continued.

Date.	Hydrographer.	Discharge.
		Second-feet.
March 30, 1901	S. G. Bennett	44.60
July 6, 1901	do	39.30
August 20, 1901	do	30.78
October 8, 1901	do	45.20
April 5, 1902	do	55.20
May 31, 1902	do	29.00
July 10, 1902	do	23.50
September 3, 1902	W. B. Clapp	24.20
November 5, 1902	S. G. Bennett	18.00
February 6, 1903	W. B. Clapp	40
April 1, 1903	do	4,906
April 2, 1903	do	1,068
April 3, 1903	do	565
April 24, 1903	W. B. Clapp and J. C. Clausen	132
May 16, 1903	W. B. Clapp	95
June 30, 1903	do	56
August 31, 1903	do	41
November 24, 1903	do	26
January 29, 1904	do	26
March 4, 1904	do	33
March 12, 1904	do	43
March 22, 1904	W. B. Clapp and E. C. Murphy	39
April 20, 1904	W. B. Clapp	68
April 21, 1904	do	59
May 14, 1904	do	36
May 28, 1904	do	39
June 29, 1904	do	46
September 21, 1904	do	58
November 11, 1904	do	19

PLUNGE CREEK.

Discharge measurements of Plunge Creek at the headworks in the canyon, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
June 12, 1898	J. B. Lippincott	2.30
September 9, 1898	do	.20
March 25, 1899	S. G. Bennett	10.90
August 25, 1899	do	.50
July 12, 1900	do	.34
April 7, 1902	do	12.40
September 4, 1902	W. B. Clapp	.37
April 23, 1903	W. B. Clapp and J. C. Clausen	23.00
May 17, 1903	W. B. Clapp	9.00
September 11, 1903	do	.60
September 21, 1904	do	.60

CITY CREEK.

Discharge measurements of City Creek at mouth of canyon, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
June 11, 1898	J. B. Lippincott	3.03
September 9, 1898	do	.07
March 25, 1899	S. G. Bennett	8.80
August 25, 1899	do	.17
July 12, 1900	do	.16
October 1, 1900	W. W. Cockins, jr	.21
April 7, 1902	S. G. Bennett	12.5
September 4, 1902	W. B. Clapp	.2
April 23, 1903	W. B. Clapp and J. C. Clausen	22.00
May 17, 1903	W. B. Clapp	11.2
September 11, 1903	do	.2
September 22, 1904	do	.5

EAST TWIN CREEK.

Discharge measurements of East Twin Creek in canyon, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
June 11, 1898	J. B. Lippincott	2.06
September 9, 1898	do	.73
March 24, 1899	S. G. Bennett	4.38
August 25, 1899	do	.74
July 12, 1900	do	.77
October 1, 1900	W. W. Cockins, jr	.57
April 4, 1902	S. G. Bennett	4.9
September 4, 1902	W. B. Clapp	.4
April 23, 1903	W. B. Clapp and J. C. Clausen	10.0
May 17, 1903	W. B. Clapp	4.8
September 11, 1903	do	.4
September 22, 1904	do	.6

WEST TWIN CREEK.

Discharge measurements of West Twin Creek in Waterman Canyon, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
June 11, 1898	J. B. Lippincott	2.14
September 9, 1898	do	.38
March 21, 1899	S. G. Bennett	3.00
August 21, 1899	do	.20
July 12, 1900	do	.22
October 1, 1900	W. W. Cockins, jr	.16
April 4, 1902	S. G. Bennett	3.20
September 4, 1902	W. B. Clapp	.13
April 23, 1903	W. B. Clapp and J. C. Clausen	8.6
May 18, 1903	W. B. Clapp	4.4
September 11, 1903	do	.30
September 21, 1904	do	.40

LYTLE CREEK.

The following measurements were made by A. H. Koebig and G. O. Newman in connection with suits in which the title to the water supply of this creek was involved:

Discharge measurements of Lytle Creek at mouth of canyon, San Bernardino County, Cal.

Date.	Discharge.	Date.	Discharge.
	Second-feet.		*Second-feet.*
June 3, 1892	35.58	August 19, 1894	11.44
September 20, 1892	18.70	August 25, 1894	12.32
September 30, 1892	22.04	October 3, 1894	16.20
October 28, 1892	20.64	September 2, 1895	56.10
November 21, 1892	22.04	September 30, 1895	40.78
November 27, 1892	20.68	March 3, 1896	18.08
September 7, 1893	49.20	April 23, 1896	19.14
September 18, 1893	49.20	April 24, 1896	18.60
September 25, 1893	46.34	April 25, 1896	20.52
October 4, 1893	45.30	May 3, 1896	18.52
June 6, 1894	17.96	May 4, 1896	17.26
June 8, 1894	15.50	May 10, 1896	18.16
July 10, 1894	13.22	May 25, 1896	15.32
July 11, 1894	13.22	May 26, 1896	12.84
July 25, 1894	13.36		

The following measurements were made by the United States Geological Survey:

Discharge measurements of Lytle Creek at mouth of canyon, San Bernardino County, Cal.

Date.	Hydrographer.	Discharge.
		Second-feet.
July 24, 1896	J. H. Quinton	15.7
June 10, 1898	J. B. Lippincott	10.7
August 27, 1898	F. H. Olmsted	10.0
August 29, 1899	S. G. Bennett	12.5
June 8, 1900	do	6.2
September 29, 1900	W. W. Cockins, jr	4.6
April 4, 1902	S. G. Bennett	19.9
September 5, 1902	W. B. Clapp	5.0
April 1, 1903	do	1,790.0
April 22, 1903	W. B. Clapp and J. C. Clausen	63.0
May 19, 1903	W. B. Clapp	29.5
July 2, 1903	do	16.5
September 12, 1903	do	14.7
September 22, 1904	do	9.2

CANALS ABOVE COLTON.

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

[K. Sanborn, observer.]

Name of ditch.	1898.		1899.			1900.			Sept., 1902.	Aug. and Sept., 1903.	1904.	
	June.	Sept.	Mar.	June.	Aug.	Mar.	June.	Sept.			May and June.	Aug.
Barnhill pumping plant	......	......	......	......	......	......	......	......	......	0.80	0.85	0.77
Beam ditch	0.67	0.65	0.72	0.52	0.40	0.68	0.50	0.33	0.22	.08	.02	.00
Bloomington pumps	5.26	5.49	(*a*)	5.93	3.05	3.80	3.68	3.28	.00	8.82	.00	5.61
Brown tract—artesian well	......	......	......	......	......	......	......	......	......	.11	......	......
Camp Carlton ditch	.61	1.20	2.13	1.62	1.02	2.55	2.60	1.67	1.70	2.20	2.50	2.60
Carr pumping plant	......	......	......	......	......	......	......	......	......	......	......	.72
City of Colton (total all pumps)	6.82	7.40	3.20	5.49	3.89	4.94	3.21	3.54	3.53	3.17	3.00	2.06
City of San Bernardino	......	......	......	......	......	......	......	......	......	......	2.69	2.81
Colton Terrace Water Co	1.97	1.61	1.69	1.30	1.30	1.69	1.54	1.53	1.08	......	.34	.34
Cooley tract—artesian wells	......	......	......	......	......	......	......	......	......	2.70	......	......
Daly ditch	.63	.67	.71	.51	.51	.72	1.12	.54	.00	......	......	......
Gage canal:												
Diversion	1.16	1.16	.72	.24	.64	.39	.29	.17	.00	......	......	......
Palm avenue	26.26	25.07	26.68	25.22	23.47	21.96	22.23	27.85	30.17	30.82	27.80	31.96
Garner tract—artesian well	......	......	......	......	......	......	......	......	......	.77	......	......
Haws & Talmage ditch	.84	.00	.28	.00	.00	.00	.00	.00	.00	......	......	......
Hunter pumping plant	......	......	......	......	......	......	......	......	......	1.79	1.82	1.54
Hurd tract—artesian wells	......	......	......	......	......	......	......	......	......	.21	......	......
Johnson & Hubbard (pumping plant)	......	......	......	......	......	......	......	......	......	.42	.67	.39
Lamb pumping plant	......	......	......	......	......	......	......	......	......	.24	.24	.25
Lawson Well Co	......	......	......	......	......	......	......	......	......	.59	.65	.50
Logsdon & Farrell ditch	.72	.63	1.61	1.15	.54	1.26	.49	.20	.00	......	......	......
Lytle Creek Water and Improvement Co	......	......	......	......	......	......	......	......	......	......	......	4.00
McIntyre ditch	.37	.04	.82	.15	.00	.14	.01	.00	.00	......	......	......
McKenzie ditch	2.54	2.08	9.40	3.86	2.00	2.30	1.57	1.69	.00	.00	.67	.58
Meeks & Daly ditch	8.42	17.00	17.00	15.48	10.45	13.94	13.78	14.68	13.40	12.87	16.30	16.75
Merryfield pumping plant	......	......	......	......	......	......	......	......	......	......	.90	.80
Mount Vernon Water Co	......	......	......	......	......	......	......	......	......	......	91	.91
Orange Land and Water Co	......	......	......	......	......	......	......	......	......	1.08	1.14	1.12
Rabel Dam ditch	5.37	3.07	2.36	1.54	.94	.54	.35	.07	.00	......	......	......
Ranchero pumping plant	1.75	1.64	1.64	1.00	.41	.24	.55	1.33	2.28	1.09	1.46	1.30
Riverside Highlands Water Co (Lytle Creek)	4.40	4.43	4.25	2.08	2.00	6.59	5.38	3.70	......	8.98	7.92	2.00
Riverside Highlands Water Co. (Santa Ana River)	......	......	......	......	......	......	......	......	......	......	......	6.85
Riverside Water Co. (Flume Pump No. 1)	......	......	......	......	......	......	......	......	} 5.03	4.08	.79	2.99
Riverside Water Co. (Flume Pump No. 2)	......	......	......	......	......	......	......	......		2.63	1.76	2.52
Riverside Water Co. (mill flume)	3.12	3.36	5.30	7.29	2.56	2.67	2.17	.94	.50	.00	2.68	.00
Riverside Water Co. (mill pump)	1.94	2.04	(*a*)	1.77	1.67	(*a*)	1.88	1.52	1.20	......	1.32	1.38
Riverside Water Co. (River Ditch Pump No. 1)	......	......	......	......	......	......	......	......	......	} 5.79	5.47	4.92
Riverside Water Co. (River Ditch Pump No. 2)	......	......	......	......	......	......	......	......	......		3.86	4.22

a Pumps not run.

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

Name of ditch.	1898.		1899.			1900.			Sept., 1902.	Aug. and Sept., 1903.	1904.	
	June.	Sept.	Mar.	June.	Aug.	Mar.	June.	Sept.			May and June.	Aug.
Riverside Water Co. (upper canal)	59.04	61.34	60.53	53.92	52.04	61.94	52.94	61.02	47.97	55.90	42.40	38.13
Rogers pumping plant	.....	.....	.....	.....	.....	.....	.....	.....	4.38	4.44	.....	.....
Rosedale Water Co	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.60	.50
Shay & Stout ditch	2.30	2.08	2.23	1.13	.90	.51	.40	.16	.00	.....	.....	.....
Swamp ditch	1.00	1.02	.85	.77	.69	.70	.89	.86	.93	.42	.51	.47
Ward & Warren ditch	2.32	2.32	3.09	.62	1.56	2.55	1.70	.53	1.88	1.61	.....	.....
West Riverside 350-inch pumping plant	.....	.....	.....	.....	.....	.....	.....	.....	5.94	3.41	6.52	5.35
Whiting ditch	.26	.01	.76	.25	.01	1.12	.13	.00	.00	.....	.....	.....
Whitlock ditch	.34	.38	.47	.28	.09	.23	.00	.00	.00	.....	.....	.....
Wozencraft tract artesian well	.....	.....	.....	.....	.....	.....	.....	.....	.....	.23	.....	.....
Total	138.11	144.69	146.44	132.11	110.14	131.46	117.41	125.61	120.21	155.25	123.24	127.86

LIST OF WELLS.

In Water-Supply Paper No. 60, Mr. J. B. Lippincott published lists of the most important of the wells in the Redlands and San Bernardino quadrangles. The edition of this paper was exhausted soon after its issue; therefore the lists are here republished. No attempt has been made to revisit all wells or to secure complete revised data on water levels and yield, and such evidence as has been secured on the first of these points appears in Pl. VII and in the tables on pages 57 and 58. The data, therefore, as they are published here, represent conditions as they existed in 1900.

Wells in Redlands quadrangle.

[*Abbreviations used in well records.*—Under "Method of lift:" Hand=hand pump. Horse=horsepower machine. Electric=an electric motor. Centrifugal=a centrifugal pump. Gas=a gasoline engine. Wind=a windmill. 14 wind=that water is pumped by a 14-foot windmill. In case of the gasoline engines, electric motors, etc., the accompanying figures indicate the horsepower. Under "quantity of water:" Good indicates a good supply of water. Small indicates a small or deficient supply of water.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
1	Doctor Meeker	Sec. 16, T. 1 S., R. 2 W.	1900	Dug, 4 by 6 foot	1,995	1,718	130		$1,100			
2	Ward, Mills & Co.	Sec. 21, T. 1 S., R. 2 W.	1900	do	2,005	1,933	125	Gas	750			
3	Crafton Water Co.	Sec. 7, T. 1 S., R. 1 W.	1900	Dug, 5 by 6 foot	3,010	2,992	132	Centrifugal; electric	2,000	$2,500	1.38	Irrigation.
4	do	Sec. 8, T. 1 S., R. 1 W.	1900	Dug, 5½ by 6½ foot.	3,650	3,648	93	do	a 6,000	2,500	2.70	Do.
5	Mrs. M. A. Brown	Sec. 22, T. 1 S., R. 2 W.	1879	Dug, 4 by 4 foot	2,250	2,225	27	Wind		100		Domestic.
6	Geo. McIntosh	do	1899	do	2,230	2,189	70	Centrifugal; electric				Irrigation.
7	R. P. McIntosh	Sec. 20, T. 1 S., R. 2 W.	1900	Dug, 4½ by 4½ foot.	1,910	1,818	103	Cylinder pump; gas	700	925	.14	Do.
8	L. Lodge	Sec. 16, T. 1 S., R. 2 W.	1900	Dug, 4 by 6 foot	2,060	2,050	70	do		1,500	.30	Do.
9	L. Lyons	do	1900	do	2,075	2,052		do				Do.
10	T. P. Christian	Sec. 17, T. 1 S., R. 2 W.	1900	do	1,900	1,748	180	do		1,500		Do.
11	F. Wieder	Sec. 29, T. 1 S., R. 2 W.	1900	Dug, 4 by 5 foot	1,830	1,779	100	do	450	950		Do.
12	E. J. Roberts	Sec. 28, T. 1 S., R. 2 W.	(b)	Dug, 4 by 6 foot	2,200	2,192		Horse	300			Do.
13	H. H. Garstin	Sec. 29, T. 1 S., R. 2 W.	1900	Bored, 10-inch	2,000	1,905	241	Cylinder pump; gas	800	1,430	.06	Do.
14	W. J. Tench	Sec. 19, T. 1 S., R. 2 W.		Dug, 4 by 6 foot	1,720	1,560	163					Irrigation; domestic.
15	East Redlands Water Co.	Sec. 36, T. 1 S., R. 3 W.	1900	Bored, 12-inch	1,805	1,621	514	Cylinder pump; gas	2,200		.32	Irrigation.
16	E. & D. Conkling	Sec. 31, T. 1 S., R. 2 W.	1899	Bored, 10-inch	1,795	1,545	350	do		2,200	.40	Do.
17	M. S. Crosswell	Sec. 24, T. 1 S., R. 3 W.		Dug, 4 by 6 foot	1,540	1,378	163	do			.12	Do.
18		Sec. 33, T. 1 S., R. 2 W.		Dug, 2½ by 4 foot	2,120	2,060	60					
19	Mr. Gregory	do	1892	Dug	2,130	2,123	10	Hand	20			Domestic.
20	Dunlap estate	Sec. 4, T. 2 S., R. 2 W.	1899	Bored, 10-inch	2,040	2,040		Centrifugal; gas			.50	Irrigation.
21	do	do	1895	Bored, 7-inch	2,075	2,077	142	Artesian			.005	Domestic.
22	do	do	1900	Bored, 10-inch	2,100	2,100	800	do	2,950		.015	Irrigation.
23	do	do	1900	do	2,090	2,090		do				Do.

24	Houghton & McNee	....do	1895	Dug, 3 by 4 foot	2,270	2,227	43	Wind				Domestic.
25	Geo. Clyde (tunnel)	Sec. 26, T. 1 S., R. 2 W		Hydraulic, 4 by 6 foot.	2,700	2,700	97	Gravity	c 300		.02	Irrigation; domestic.
26	Mr. Biggin	Sec. 34, T. 1 S., R. 2 W	1899	Dug, 6 by 6 foot	2,224	2,163	65				.16	
27	South Mountain Water Co.	Sec. 33, T. 1 S., R. 2 W	1900	Bored, 10-inch	2,160	2,132	965+	Centrifugal; steam				Irrigation.
28	Garland estate	Sec. 25, T. 1 S., R. 3 W	1900	....do	1,570	1,394		Cylinder pump; gas				Do.
29	C. D. Fowler	Sec. 5, T. 1 S., R. 3 W	1891	....do	1,180	1,125	70					
30	West Redlands Water Co.	Sec. 35, T. 1 S., R. 3 W	1899	Bored, 12-inch	1,600	1,530	226	Cylinder pump; gas	1,250	2,500	.40	Do.
31	....do	....do	1899	Bored, 10-inch	1,620	1,529	248		1,080			Do.
32	....do	....do	1899	Bored, 12-inch	1,626	1,536	243	Cylinder pump; gas	1,700	2,500	.36	Do.
33	Redlands Heights Water Co.	Sec. 1, T. 2 S., R. 3 W	1900	Bored, 10-inch	1,880		300		1,200			Do.
34	Mr. Painter (?)	Sec. 8, T. 2 S., R. 2 W	1899	Dug, 4 by 6 foot	1,975	1,932	60					
35	....do	....do	1899	....do	1,975	1,932	46					
36	Mrs. Diaz	Sec. 14, T. 2 S., R. 3 W		Bored, 7-inch	1,545	1,456	96	Hand	125	20		Domestic.
37	C. W. Blue	....do	1898	....do	1,523	1,455	110	Wind	200	75		Domestic; irrigation.
38	A. Gregory	Sec. 27, T. 1 S., R. 3 W	1895	....do	1,379	1,274	168	....do	250	500	.016	Domestic.
39	W. McConkey	....do	1898	....do	1,380			....do				Do.
40	D. Madell	....do	1898	....do	1,377	1,277	171	....do	274		.001	Do.
41	G. H. Garland	Sec. 26, T. 1 S., R. 3 W	1899	Bored, 10-inch	1,450	1,261	246	Cylinder pump; gas		3,000	.40	Irrigation.
42	C. L. Hayes	Sec. 27, T. 1 S., R. 3 W	1899	....do	1,420	1,270	428	....do	850	1,400	.30	Do.
43	O. W. Harris	Sec. 34, T. 1 S., R. 3 W	1895	Bored, 7-inch	1,503	1,303	312	Cylinder pump; electric.	600	800	.075	Do.
44	Horace Evans	Sec. 33, T. 1 S., R. 3 W	1899	Bored, 10-inch	1,455	1,259	660	Cylinder pump; gas	1,900	1,400	.18	Irrigation; domestic.
45	A. C. Fowler	Sec. 32, T. 1 S., R. 3 W	1898	Bored, 9-inch	1,250	1,140	170	....do	250	300	.10	Irrigation.
46	L. C. Smith	....do	1898	Dug, 3 by 3 foot	1,215	1,135	83	Wind	90	65	.003	Domestic.
47	P. B. Fussell	....do	1897	Bored, 12-inch	1,253	1,195	165	....do	330	230		Irrigation; domestic.
48	E. Vache	....do	1885	Bored, 7-inch	1,260	1,200	140	....do	170	75		Domestic.
49		Sec. 4, T. 2 S., R. 3 W	1893	....do	1,350	1,290	150	....do				Stock.
50	W. D. Covington	....do	1893	....do	1,325	1,290	157	Hand	350	20	Small.	Do.
51	....do	....do	1893	Bored, 10-inch	1,300	1,300	750	Artesian	2,000		.002	Domestic; stock.
52	D. S. Jordan	....do	1899	Bored, 7-inch	1,395	1,379	56	Wind	80	90	.001	Domestic; irrigation.

a Well and tunnel 250 feet long.

b Not completed.

c Tunnel 97 feet long.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
53	Redlands Domestic Water Co.	Sec. 35, T. 1 S., R. 3 W.	1899	Bored, 10-inch	1,560	1,503	......	Centrifugal; electric	$1,800	......	0.80	Domestic; irrigation.
54	Wood, Bill & Davis	Sec. 33, T. 1 S., R. 3 W.	1899	....do	1,305	1,225	462	Cylinder pump; gas	1,200	$1,800	.40	Do.
55	D. H. Gillan	Sec 32, T. 1 S., R. 3 W.	1899	Bored, 8-inch	1,245	1,157	438	Air compressor; gas	......	3,000	.50	Do.
56	H. Bermudas	....do	1893	Bored, 7-inch	1,210	1,156	112	Hand	......	3	......	Domestic.
57	N. B. Hinckley estate	....do	......	Bored, 10-inch	1,177	1,021	700+	Wind	......	......	......	Domestic; irrigation.
58	Wm. Curtis	Sec. 30, T. 1 S., R. 3 W.	1885	....do	1,144	1,076	76	....do	150	100	.002	Domestic.
59	E. C. Curtis	Sec 29, T. 1 S., R. 3 W.	1895	Bored, 7-inch	1,120	1,070	96	....do	160	75	.002	Do.
60	R. T. Curtis	....do	1895	....do	1,123	1,073	86	....do	140	100	.003	Do.
61	W. M. Curtis	....do	1899	Bored, 12-inch	1,125	1,079	415	Cylinder pump; gas	900	1,800	.70	Irrigation.
62	N. B. Curtis	....do	1895	Bored, 7-inch	1,126	1,076	84	Wind	140	60	.001	Domestic.
63	N. B. Hinckley estate	Sec. 30, T. 1 S., R. 3 W.	1899	{Bored, 36-inch {Bored, 11-inch	1,150	1,103	65 271	Centrifugal; gas	900	800	.42	Irrigation.
64	L. & M. Frink	....do	1889	Bored, 7-inch	1,140	1,112	62	Wind	100	163	......	Domestic.
65	Mrs. P. S. Stewart	....do	1898	....do	1,144	1,109	76	....do	150	65	.001	Do.
66	Gansnor & Renwick	....do	1898	....do	1,140	1,110	200	....do	320	90	.003	Domestic; irrigation.
67	Redlands Water Co	Sec. 35, T. 1 S., R. 3 W.	1899	Bored, 10-inch	1,563	......	......	Centrifugal; electric	......	......	......	Irrigation.
68	Mrs. M. Robison	Sec. 30, T. 1 S., R. 3 W.	1870	Dug, 3-foot	1,110	......	24	Hand	......	......	Dry.	
69	Southern Pacific R. R. Co.	Sec. 31, T. 1 S., R. 3 W.	1890	Bored, 7-inch	1,176	1,116	75	....do	145	20	......	Domestic.
70	W. F. Whittier	....do	1898	{Bored, 10-inch {Bored, 7-inch	1,410	1,208	294 212	Cylinder pump; gas	1,000	935	.14	Domestic; irrigation.
71	....do	....do	1898	{Bored, 14-inch {Bored, 10-inch	1,150	1,108	276 84	Force pump; gas	1,020	......	.80	Irrigation.
72	Owen Buchanan	....do	1898	Bored, 7-inch	1,265	1,149	237	Cylinder pump; gas	379	800	.14	Do.
73	W. J. Lawrence	....do	1898	....do	1,230	1,143	190	....do	304	700	.12	Do.

74	Frink Bros	Sec. 30, T. 1 S., R. 3 W.	1899	Bored, 36-inch; bored, 10-inch.	1,147	1,105	335	Centrifugal; gas	800	700	.62	Do.
75	Rhoda Wilson	do	1899	Bored, 7-inch	1,138		59	Wind	95	65	.001	Domestic.
76	D. Van Leuven	do	1900	Bored, 9-inch	1,132	1,098	63	Hand	65	14		Do.
77	E. Hankins	Sec. 28, T. 1 S., R. 3 W.	1899	Bored, 12-inch	1,254	1,200	290	Cylinder pump; gas	800	1,300	.40	Irrigation; domestic.
78	J. A. Osborn	do	1899	Bored, 10-inch	1,225	1,173	320	Centrifugal; gas	880		.50	Do.
79	do	do		Bored, 7-inch	1,224	1,174	190	Wind	300	72	.001	Domestic.
80	Mrs. S. W. Sylvera	Sec. 29, T. 1 S., R. 3 W.	1891	do	1,200	1,170	90	do		80	.001	Do.
81	A. B. Cook	do	1897	Bored, 10-inch	1,206	1,166	110	Centrifugal; gas	220	800	.40	Domestic; irrigation.
82	S. Mansfield	do	1900	do	1,195	1,163	340					
83	do	do	1890	Bored, 7-inch	1,193	1,154	109	Wind	175		Small.	Do.
84	A. Lenanon	do	1895	do	1,186	1,156	130	Cylinder pump; horse	208	40		Domestic.
85	John Furney	do	1890	do	1,179	1,139	60	Wind	100	150	.003	Domestic; irrigation.
86	Barton Land and Water Co.	do	1891	do	1,180	1,137	63	Hand	100			Domestic.
87	M. D. Easton	do	1890	do	1,121	1,101	45	Wind	80	70	.003	Do.
88	Barton Land and Water Co.	do	1891	do	1,130	1,100	48	Hand				Do.
89	J. R. Campbell	do	1893	do	1,190	1,155	103	do	190	25		Do.
90	Carl Furst	do	1891	Bored, 5½-inch	1,215	1,180	114	do	165	35		Do.
91	S. E. Rockwell	do	1900	Bored, 10-inch	1,200	1,170	356	Cylinder pump; gas	1,000	860	.34	Irrigation.
92	J. Hickey	do	1898	Bored, 9½-inch	1,226	1,190	152	do	314	700	.20	Irrigation; domestic.
93	B. M. James	do	1899	Bored, 10-inch	1,230	1,198	220	do	418	900	.34	Do.
94	W. A. Nichols	Sec. 28, T. 1 S., R. 3 W.	1891	Bored, 7-inch	1,246	1,194	122	Hand				Domestic.
95	do	do		Bored, 10-inch	1,255	1,206	284	Cylinder pump; gas	530	1,000	.36	Irrigation.
96	W. D. Tobey	Sec. 29, T. 1 S., R. 3 W.		do	1,204		324	do				Do.
97	S. A. Grover	Sec. 28, T. 1 S., R. 3 W.	1899	do	1,253	1,183	231	do	700	1,100	.40	Domestic; irrigation.
98	Schee Bros	do	1899	do	1,280	1,210	425	do	1,400	1,500	.50	Do.
99	W. F. Schee	do	1894	Pored, 7-inch	1,291			do				Irrigation.
100	Redlands Water Co	Sec. 35, T. 1 S., R. 3 W.	1899	Bored, 10-inch	1,565			Centrifugal; steam			1.56	Do.
101	Barton Land and Water Co.	Sec. 28, T. 1 S., R. 3 W.	1900	do	1,315	1,225	250					
102	Willis Miller	Sec. 21, T. 1 S., R. 3 W.	1893	Bored, 7-inch	1,290	1,203	123	Wind	200	125	.002	Domestic.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
103	S. A. Grover	Sec. 21, T. 1 S., R. 3 W.	1890	Bored, 7-inch	1,294	.....	.....	Wind	.....	.....	.....	Domestic; irrigation.
104	C. Cutting	do	1894	do	1,320	1,220	170	Cylinder pump; gas	$337	$340	.....	Do.
105	Myron Sherman	Sec. 27, T. 1 S., R. 3 W.	1892	Bored, 8-inch	1,331	1,221	145	Cylinder pump; electric.	450	300	.....	Do.
106	J. S. Hale	Sec. 21, T. 1 S., R. 3 W.	1897	Bored, 11-inch	1,272	1,202	295	Cylinder pump; gas	600	1,300	0.48	Irrigation.
107	do	do	1890	Bored, 7-inch	1,265	1,201	105	Wind	159	200	.002	Domestic; irrigation.
108	do	Sec. 17, T. 1 S., R. 3 W.	1896	Bored, 10-inch	1,220	1,164	86	do	160	75	.015	Irrigation.
109	C. A. Shaw	Sec. 21, T. 1 S., R. 3 W.	1893	Bored, 7-inch	1,267	1,217	96	do	138	87	.005	Domestic; irrigation.
110	Lewis Deck	do	1895	do	1,278	1,213	220	Cylinder pump; gas	363	678	.15	Do.
110a	do	do	1895	do	1,278	1,213	150	do	.....	.....	.15	Do.
111	I. E. Shaw	do	1890	do	1,247	1,197	90	Hand	150	25	.....	Domestic.
112	Alise Van A. Lea	do	1898	Bored (2)	1,253	.....	70 130	Cylinder pump; gas	500	700	.....	Not used.
113	A. Gregory	do	1890	Bored, 7-inch	1,245	1,194	100	Wind	.....	.....	.....	Domestic.
114	Gladysta Land and Water Co.	Sec. 20, T. 1 S., R. 3 W.	1899	Bored, 11-inch	1,240	.....	.....	Cylinder pump; gas	.....	.....	.....	Irrigation.
115	Frank Hess	Sec. 21, T. 1 S., R. 3 W.	1897	do	1,243	1,188	163	Centrifugal; gas	326	800	.24	Domestic; irrigation.
116	C. S. Lombard	Sec. 16, T. 1 S., R. 3 W.	1897	Bored, 10-inch	1,246	1,182	180	Cylinder pump; gas	.....	.....	.30	Do.
117	S. Ronzone	do	1899	Bored, 9-inch	1,257	1,192	98	Wind	235	200	.014	Do.
118	Thos. Blakeley	do	.....	Bored	1,254	.....	.....	Electric	.....	.....	.....	Irrigation.
119	Elza Boger	do	1899	Dug, 4 by 4 foot; bored, 9-inch.	1,255	1,185	132	(a)	.....	.....	.....	
120	M. R. Gay	Sec. 17, T. 1 S., R. 3 W.	1896	Bored, 11-inch (2).	1,220	1,170	105	Air compressor; electric.	200	.....	.22	Do.
121	W. W. Story	Sec. 16, T. 1 S., R. 3 W.	1900	Bored, 10-inch	1,262	1,193	163	Cylinder pump; gas	400	1,500	.50	Domestic; irrigation.

122	John Dostal	Sec. 15, T. 1 S., R. 3 W.	1897	....do	1,403	1,230	174	Wind	348	140	Small.	Domestic.
123	J. F. Boyd	Sec. 16, T. 1 S., R. 3 W.	1896	Bored, 10-inch (2).	1,290	1,180	100 110	Cylinder pump; gas	500	900	.20	Irrigation; domestic.
124	Wm. Lindenberg	Sec. 20, T. 1 S., R. 3 W.	1893	Bored, 7-inch	1,220	1,180	93	Wind	140	150	.009	Do.
125	H. S. Drew	Sec. 19, T. 1 S., R. 3 W.		Bored, 14-inch Bored, 10-inch	1,167	1,133	164 291	Cylinder pump; gas	1,300	1,300	.60	Do.
126	James Smith	....do	1892	Bored, 7-inch	1,164	1,130	90	Hand	150	10		Domestic.
127	Bryan estate	Sec. 20, T. 1 S., R. 3 W.	1900	Bored, 10-inch Bored, 8-inch	1,190	1,143	510 118	Centrifugal; gas			.40	Irrigation.
128	A. M. Ham	Sec. 30, T. 1 S., R. 3 W.	1887	Bored, 7-inch Bored, 5-inch	1,155	1,120	150 300	Cylinder pump; gas	1,500	900		Domestic; irrigation.
129	P. H. Covington	Sec. 10, T. 2 S., R. 3 W.		Bored, 7-inch	1,440	1,392	58	Hand				
130	Clark & Brotherton	Sec. 20, T. 1 S., R. 3 W.	1900	Bored, 10-inch; bored, 8¼-inch.	1,195	1,162		(a)				Domestic.
131	J. J. Prendergast	Sec. 29, T. 1 S., R. 3 W.	1893	Bored, 10-inch	1,200	1,166	422	Cylinder pump; gas	1,200	800	.30	Irrigation; domestic.
132	H. H. Cole	Sec. 30, T. 1 S., R. 3 W.	1888	Bored, 7-inch	1,140	1,108	82	Wind	140	180	Small.	Do.
133	H. S. Drew	Sec. 19, T. 1 S., R. 3 W.	1886	....do	1,138		70	....do	140	150	.001	Domestic.
134	C. M. Baxter	Sec. 30, T. 1 S., R. 3 W.	1899	Bored, 10-inch	1,147	1,116	100	Centrifugal; gas			.60	Irrigation.
135	....do	....do	1892	Bored, 7-inch	1,147	1,113	80	Hand				Domestic.
136	C. H. Lehmann	Sec. 19, T, 1 S., R. 3 W.	1891	Bored, 10-inch	1,129	1,103	458	Cylinder pump; gas	1,300	900	.40	Irrigation; domestic.
137	A. E. Cole	Sec. 30, T. 1 S., R. 3 W.	1892	Bored, 7-inch	1,125	1,104	100	Wind	160	100	.005	Do.
138	A. McCrary	....do	1891	....do	1,120	1,093	40	Hand	64			Domestic.
139	H. R. Scott	Sec. 19, T. 1 S., R. 3 W.		....do	1,120	1,108	503	Centrifugal; gas	1,000	1,000		Irrigation; domestic.
140	....do	....do	1879	Bored, 6-inch	1,127	1,109	500					
141	E. H. Durnford	Sec. 24, T. 1 S., R. 4 W.	1894	Bored, 7-inch	1,103	1,093	500	Centrifugal; gas			.60	Domestic; irrigation.
142	James Birch	....do	1890	....do	1,096	1,087	300					Domestic.
143	....do	....do		....do	1,098	1,081	100					
144	D. W. Roach	....do	1899	....do	1,102	1,087	85	Hand	130	24		Do.
145	E. F. Van Leuven	Sec. 25, T. 1 S., R. 4 W.	1890	....do	1,103	1,083	48	Wind			.001	Do.
147	W. J. Doran	Sec. 30, T. 1 S., R. 3 W.	1900	Bored, 10-inch	1,106	1,086	100	....do	200			Do.
148	L. R. Van Leuven	....do	1882	Bored, 7-inch	1,108	1,093	270	....do	600	109	.001	Domestic; irrigation.

a Unfinished.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
149		Sec. 30, T. 1 S., R. 3 W		Bored, 7-inch	1,120			Wind				Domestic; irrigation.
150	O. Taylor	Sec. 32, T. 1 S., R. 3 W	1897	do	1,210		75	do		$120	0.003	Do.
151	H. C. Hamanway	do		do	1,209			Hand				
152	G. J. Grant	do	1896	Bored, 7-inch (2)	1,206			Gas				Irrigation; domestic.
153	S. L. Gregg	do		Bored, 7-inch	1,202			Wind				Domestic.
154	H. C. Hamanway	do	1899	Bored, 10-inch	1,250	1,198	200	Cylinder pump; gas			.32	Irrigation.
155	T. Morris	do	1890	Bored, 7-inch	1,260	1,195	125	Wind			.002	Irrigation; domestic.
156	S. V. Horton	do	1891	do	1,270	1,195	125	do	$200	175	.01	Do.
157	C. T. Covington	Sec. 4, T. 2 S., R. 3 W	1891	do	1,455	1,415	65	Hand	100	25		Domestic.
158	Mrs. Van Leuven	Sec. 25, T. 1 S., R. 4 W	1896	do	1,105	1,085	78	do	150	15		Do.
159	J. H. Pierson	Sec. 24, T. 1 S., R. 4 W	1884	Bored, 6-inch	1,104	1,103	605	Centrifugal; gas	10,222	1,200	.60	Domestic; irrigation.
160	F. M. Strang	Sec. 10, T. 2 S., R. 3 W	1897	Dug, 3 by 3 foot	1,500	1,423	79	Hand	77	4		Domestic.
161	Railroad School	do	1891	Bored, 7-inch	1,527	1,427	118	do	180	25		Do.
162	D. Mulvahill	do	1891	do	1,470	1,439	61	do	115	22		Do.
163	R. P. Lauretzen	do		do	1,550	1,474	106	do				Do.
164		Sec. 4, T. 2 S., R. 3 W		do	1,430			do				Do.
165	—— De Garmo	Sec. 8, T. 2 S., R. 3 W		do	1,575	1,485	164	Wind				Do.
166	Smiley Brothers	Sec. 4, T. 2 S., R. 3 W		Dug, 7 by 7 foot	1,347	1,330	23	Centrifugal; gas			.50	Irrigation.
277	L. F. Cram	Sec. 3, T. 1 S., R. 3 W	1895	Bored, 12-inch	1,305	1,189	147	Wind	1,000	100	Small.	Domestic; irrigation.
278	C. C. Tyler	Sec. 2, T. 1 S., R. 3 W	1900	Dug, 4 by 5 foot	1,305							
279	John McBride	Sec. 6, T. 1 S., R. 2 W	1900	Dug, 4 by 4 foot	1,650	1,636	65	Centrifugal; gas	500	400		Irrigation; domestic.
280	do	do	1894	Hydraulic, 4 by 6 foot.	1,654	1,654	130	Tunnel, 130-foot, flows	250		.02	Irrigation.

281	Cram Brothers	Sec. 2, T. 1 S., R. 3 W	1899	Dug, 4 by 4 foot	1,600	1,485	120		300		
282	E. Highland Orange Co	Sec. 35, T. 1 N., R. 3 W	1900	Bored, 12-inch; Bored, 10-inch	1,630	1,610	280; 140	Tunnel, flows	1,680		.26	Domestic; irrigation.
283	do	do	1900	Dug, 4 by 4 foot; bored, 10-inch.	1,680	1,666					
284	W. M. Bristol	Sec. 34, T. 1 N., R. 3 W	1899	Dug, 5 by 5 foot	1,650	1,634	50	Cylinder pump; gas		1,250	.30	Irrigation.
285	Highland Domestic Water Co.	Sec. 27, T. 1 N., R. 3 W	1899	Dug, 7 by 9 foot	1,440	1,411	65	2 cylinder pumps; 2 gas engines.		a 1,500	1.10	Domestic.
286	Highland Well Co	Sec 28, T. 1 N., R. 3 W	1899	Dug, 8 by 5 foot	1,431	1,415	46	Cylinder pump; gas			.68	Irrigation.
287	J. C. Weeks	Sec. 3, T. 1 S., R. 3 W	1900	Dug, 4 by 4 foot; bored, 12-inch.	1,295	1,181	(b)				
288	H. S. Stroven	do	1898	Bored, 10-inch	1,253	1,173	165	Cylinder pump; gas	400	1,160	.40	Irrigation; domestic.
289	N. Sutherland	Sec. 4, T. 1 S., R. 3 W	1898	Dug; bored, 12-inch.	1,227	1,160	78					Not used.
290	Pattee & Nye	Sec. 5, T. 1 S., R. 3 W	1900	Dug, 6 by 8 foot; Bored, 10-inch	1,200	1,150	50; 100	Rotary pump; steam			.60	Irrigation.
291	G. J. Fowler	do	1899	Dug, 5-foot	1,180	1,127	55	Hand	50	17		Domestic.
292	R. F. Cunningham	do	1890	Dug, 6-foot	1,160	1,120	43	Centrifugal; steam	150	1,450	.80	Irrigation.
293	do	do	1899	Bored, 7-inch	1,147	1,103	36	Hand	160	15		Domestic.
294	do	Sec. 31, T. 1 N., R. 3 W	1900	Dug, 5 by 5 foot; Bored, 10-inch	1,260	1,226	135; 90	Steam			1.04	Irrigation.
295	Redlands Water Co	Sec. 35, T. 1 S., R. 3 W	1899	do	1,568						
297	C. K. Matteson	Sec. 7, T. 1 S., R. 3 W	1884	Dug	1,103	1,080	25	Hand	30	4		Domestic.
298	do	do	1894	Bored, 10-inch	1,103	1,083	44	Centrifugal; gas	175	510	.60	Irrigation.
299	Geo. Gustave	do	1900	Dug, 4 by 6 foot	1,101	1,082	25	do	50		.30	Irrigation; domestic.
300	do	do		Dug, 3 by 4 foot	1,103	1,085	19				
301	Mrs. H. Taylor	do		Dug, 3-foot	1,102	1,080	25	Centrifugal: steam				Irrigation.
302	C. Wiltshire	Sec. 6, T. 1 S., R. 3 W	1895	Driven, 2-inch	1,102	1,080	27	Hand		25		Domestic.
303	Mrs. H. Taylor	Sec. 7, T. 1 S., R. 3 W	1891	Bored, 3-inch	1,101		235	do	300		3.00	Domestic; irrigation.
304	W. F. Somers	do	1900	Bored, 10-inch	1,101	1,081	(c)				
305	Mrs. Golden	Sec. 12, T. 1 S., R. 4 W	1900	do	1,099	1,099		Artesian				Irrigation.
306	do	do	1898	Bored, 8-inch	1,102	1,102	744	do	1,600		d 1.10	Domestic; irrigation.

a Two engines. b Unfinished. c Not completed. d December, 1898.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
307	W. F. Somers	Sec. 7, T. 1 S., R. 3 W	1895	Dug	1,098	1,080	20	Hand	$20		7.00	Domestic.
308	....do	....do	1899	Dug, 3 by 3 foot	1,097	1,079	20	....do	20		4.00	Stock.
309	John Kaus	....do	1899	Bored, 8-inch	1,103	1,085	20	Steam	40			Domestic.
310	F. P. Sargent	Sec. 13, T. 1 S., R. 4 W	1894	Driven, 2-inch	1,096	1,084	24	Hand	15	$10		Do.
311	S. E. Fitzhugh	Sec. 12, T. 1 S., R. 4 W	1888	Bored, 3-inch	1,080	1,073	234	....do	500	6		Do.
312	....do	....do	1885	Bored, 7-inch	1,081	1,064	20	....do	35	6		Do.
313	W. Borne	Sec. 7, T. 1 S., R. 3 W		Dug, 3½ by 3½ foot	1,103			....do				Do.
314	Geo. Covalt	....do	1899	Bored, 7-inch	1,104	1,079	30	....do		4		Do.
315	W. F. Somers	Sec. 1, T. 1 S., R. 4 W		Bored, 3-inch	1,099	1,095	283	....do				Do.
316	W. K. Bledsoe	....do		Dug, 4½-foot	1,103	1,086	21	....do	25	3		Do.
317	T. J. West	....do	1900	Dug, 5-foot	1,093	1,090	20	Centrifugal; steam	400	820	1.30	Irrigation.
318	S. Van Leuven	Sec. 6, T. 1 S., R. 3 W	1883	Bored, 3-inch	1,104	1,105	309	Wind				Irrigation; domestic.
319	Ed. Dailey	....do	1890	....do	1,102	1,091	325	Hand				Domestic.
320	....do	....do	1890	....do	1,106	1,105	320					Not used.
321	....do	....do	1885	....do	1,103	1,093	350	Hand				Domestic.
322	W. A. Brouse	....do	1899	Dug	1,104	1,084	22	....do	25	5		Do.
323	....do	....do	1884	Dug, 5-foot	1,104	1,084	26	Centrifugal; steam	150	630	.50	Irrigation.
324	....do	....do	1893	....do	1,106	1,086	25	....do	150	620	.50	Do.
325	Herman Smith	....do	1899	Dug, 4 by 4 foot	1,109	1,084	27	Hand	100	12		Domestic.
326	J. Friedmann	....do	1885	Dug, 6-foot	1,107	1,090	22	Centrifugal; steam	130	485	1.00	Irrigation; domestic.
327	J. Dunlap	Sec. 1, T. 1 S., R. 4 W		Bored, 3-inch	1,102	1,102	185	Artesian			.18	Domestic.
328	H. C. Keller	....do	1880	Bored, 2-inch	1,104	1,104	169	....do			.02	Do.
329	A. Roberts	Sec. 6, T. 1 S., R. 3 W	1892	Bored, 3-inch	1,105	1,105	231	....do	426		.005	Do.
330	Warm Creek School	....do	1885	Bored, 2-inch	1,106	1,101	150	Hand	175			Do.
331	W. L. McKenzie	Sec. 1, T. 1 S., R. 4 W	1875	....do	1,105	1,105	320	Artesian			.01	Irrigation; domestic.

332	Wm. Shay	Sec. 31, T. 1 N., R. 3 W.	1890	Bored, 3-inch	1,103	1,103	150	....do	300	....	.06	Domestic.
333	Wm. Clyde	Sec. 6, T. 1 S., R. 3 W.	1889	Bored, 2-inch	1,106	1,106	146	....do	150	....	.03	Irrigation; domestic.
334	Riverside Water Co	Sec. 1, T. 1 S., R. 4 W.	1898	Bored, 10-inch	1,086	....	648	....do	....	....	....	Irrigation.
335	....do	....do	1898	....do	1,088	....	590	....do	1,100	....	1.20	Do.
336	....do	....do	1898	Bored	1,085	....	384	....do	....	....	....	Do.
337	....do	....do	....	....do	1,084	1,084	440	....do	....	....	....	Do.
338	Redlands Domestic Water Co.	Sec. 35, T. 1 S., R. 3 W.	1899	Bored, 10-inch (2)	1,640	1,550	243 400	Centrifugal; electric	650	....	.80	Domestic.
339	Thos. Shay	Sec. 31, T. 1 N., R. 3 W.	1888	Bored, 7-inch	1,103	1,089	20	Hand	30	5	....	Do.
340	....do	....do	1895	Dug, 4 by 4 foot Bored, 8-inch	1,098	....	80	Cylinder pump; gas	300	1,680	.50	Irrigation.
341	R. T. Clyde	Sec. 6, T. 1 S., R. 3 W.	1880	Bored, 2-inch	1,105	1,105	133	Artesian	100	....	....	Domestic; irrigation.
342	F. L. Talmadge	....do	1880	....do	1,106	1,106	135	Hand	100	5	....	Domestic.
343	Talmadge & Haws	....do	1897	Bored, 10-inch	1,140	1,132	425	Centrifugal; gas	850	986	2.00	Irrigation.
344	Mrs. Haws	....do	1898	Bored, 2-inch	1,125	1,125	100	Hand	75	3	....	Domestic.
345	John D. Clark	Sec. 31, T. 1 N., R. 3 W.	1899	Bored, 3-inch	1,130	1,130	125	Artesian	120	....	.02	Domestic; irrigation.
346	....do	....do	1892	....do	1,132	1,132	50	....do	45	....	....	Do.
347	D. R. Seely	Sec. 33, T. 1 N., R. 3 W.	1890	....do	1,250	1,176	124	Wind	....	....	.005	Domestic.
348	....do	....do	1899	Bored, 12-inch	1,285	1,110	195	Cylinder pump; gas	....	....	....	Irrigation.
349	W. D. Stevens	Sec. 5, T. 1 S., R. 3 W.	1894	Dug, 8-foot Bored, 10-inch	1,180	1,130	40 60	Centrifugal; gas	....	815	.60	Irrigation; domestic.
350	Jane C. Goodman	Sec. 6, T. 1 S., R. 3 W.	1894	Bored, 3-inch	1,140	1,128	284	Wind	625	108	.001	Do.
351	Jas. Roddick	Sec. 5, T. 1 S., R. 3 W.	1898	Dug, 4-foot	1,143	1,114	30	Centrifugal; gas	....	250	.20	Do.
352	Saml. Roddick	Sec. 6, T. 1 S., R. 3 W.	1899	Driven, 1½-inch	1,139	1,117	27	Hand	7	10	....	Domestic.
353	W. F. Talmadge	....do	1885	Bored, 7-inch	1,148	1,132	30	Wind	....	80	.001	Domestic; irrigation.
354	....do	....do	1891	Bored, 3-inch	1,146	1,131	41	Hand	....	6	....	Domestic.
355	A. Downey	....do	1899	Driven, 1¼-inch	1,143	1,131	21	....do	4	3	....	Do.
356	F. A. Haws	....do	1899	Driven, 1½-inch	1,130	1,120	26	....do	5	5	....	Do.
357	E. S. Haws	....do	1899	....do	1,130	1,120	20	....do	5	5	....	Do.
358	Mrs. M. C. Haws	....do	1895	Bored, 3-inch	1,125	1,125	125	Artesian	250	....	....	Do.
359	Walter Shay	Sec. 31, T. 1 N., R. 3 W.	....	Bored, 7-inch	1,110	....	....	Hand	....	....	....	Do.

Wells in Redlands quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
360	Kohl Bros	Sec. 32, T. 1 N., R. 3 W.	1890	Bored, 6-inch	1,147	1,129	60	Wind			.001	Domestic.
361	H. D. Rabel	Sec. 31, T. 1 N., R. 3 W.	1896	Bored, 2-inch	1,140	1,140	68	Artesian	$40			Do.
362	do	do	1898	Bored, 3-inch	1,142	1,142	86	do	70		.01	Do.
363	do	do	1898	do	1,139	1,139	44	do	30		.25	Do.
364	do	do		do	1,137	1,137	72	do	70		.005	Do.
366	D. J. Carpenter	Sec. 24, T. 1 N., R. 4 W.	1900	Dug, 6 by 9 foot	1,470	1,447	25					
367					1,475	1,475	71				.06	
368					1,474	1,474	123				.10	
369					1,474	1,474	193				.08	
370	D. J. Carpenter & Co.	do		Bored, 7-inch	1,476	1,476	184	Centrifugal; gas		$1,100	.14	Irrigation.
371					1,473	1,473					.10	
372					1,473	1,473	127				.10	
373					1,473	1,473	167				.06	
374	W. J. Lindville	Sec. 30, T. 1 N., R. 3 W.	1899	Bored, 10-inch	1,270	1,140	368	Cylinder pump; gas		3,000	.36	Do.
375	Mrs. R. L. Burcham	Sec. 31, T. 1 N., R. 3 W.	1899	Bored, 12-inch	1,224	1,154	460	do	1,200	2,250	.70	Do.
376	E. K. Henderson	Sec. 30, T. 1 N., R. 3 W.	1899	Bored, 3-inch	1,233	1,133	134	Wind	150			Domestic.
377	Jas. McCafferty	Sec. 31, T. 1 N., R. 3 W.	1896	Bored, 7-inch	1,225		80–100	Cylinder pump; gas		2,500	.40	Irrigation; domestic.
378	J. D. Clark	do	1897	Bored, 11-inch	1,170		106	do			.40	Irrigation.
379	P. W. Gray	do	1893	Bored, 7-inch	1,170	1,120	139	Wind			.03	Domestic; irrigation.
381	John Lin Foster	Sec. 32, T. 1 N., R. 3 W.	1894	Bored, 10-inch	1,220		95	do	600	(a)	.003	Do.
382	P. H. Gleason	do	1900	Dug, 4 by 4 foot	1,250	1,175	78	do			.002	Do.
383	E. L. Cumbl	do	1897	do	1,128	1,091	38	Hand	50			Domestic.
384	A. C. Pierce	do	1898	do	1,210	1,150	62	Wind	120	140	.005	Domestic; irrigation.
385	Kohl Bros	do	1898	Bored, 10-inch	1,148	1,136	300	Centrifugal; gas	600	700	1.60	Do.

386	State of California Hospital for Insane.	Sec. 5, T. 1 S., R. 3 W	......	....do	1,110	1,078	85	Centrifugal; electricity	....	....	1.60	Irrigation.
387	Geo. Fowler	Sec. 32, T. 1 N., R. 3 W	1888	Dug, 3 by 3 foot	1,165	1,137	29	Hand	....	....	....	Domestic.
388	C. D. Fowler	Sec. 5, T. 1 S., R. 3 W	1895	Dug, 4 foot	1,168	1,135	34	....do	....	....	....	Do.
389	J. Bagwell	Sec. 32, T. 1 N., R. 3 W	1900	Dug, 4 by 4 foot; bored, 12-inch.	1,230	1,117	153	Cylinder pump; gas	....	....	.20	Irrigation.
390	A. A. Boyd	....do	1895	Dug; bored, 7-inch	1,290	1,138	202	....do	....	....	.22	Irrigation; domestic.
391	Gage Canal Co	Sec. 13, T. 1 S., R. 4 W	1891	Bored, 10-inch	1,058	1,058	168	Artesian	....	....	b4.306	Irrigation.
392	....do	....do	1891	....do	1,059	1,059	166	....do	....	....	b1.521	Do.
394	....do	....do	1891	....do	1,063	1,063	123	....do	....	....	b1.712	Do.
395	....do	....do	1891	....do	1,066	1,066	125	....do	....	....	b.594	Do.
396	....do	Sec. 18, T. 1 S., R. 3 W	1887	....do	1,062	1,062	144	....do	....	....	b2.131	Do.
397	....do	....do	1887	Bored, 10¼-inch	1,064	1,064	140	....do	....	....	b1.011	Do.
398	....do	....do	1888	Bored, 10-inch	1,075	1,075	138	....do	....	....	b.605	Do.
399	....do	....do	1888	....do	1,075	1,075	106	....do	....	....	b.188	Do.
400	....do	....do	1888	....do	1,074	1,074	130	....do	....	....	b.563	Do.
401	....do	....do	1888	....do	1,071	1,071	146	....do	....	....	b2.212	Do.
402	....do	....do	1888	....do	1,065	1,065	116	....do	....	....	b3.176	Do.
403	....do	....do	1888	....do	1,064	1,064	134	....do	....	....	b1.424	Do.
404	....do	....do	1888	....do	1,061	1,061	116	....do	....	....	b.594	Do.
405	....do	Sec. 13, T. 1 S., R. 4 W	1887	....do	1,057	1,057	147	....do	....	....	b2.254	Do.
406	....do	....do	1887	....do	1,058	1,058	122	....do	....	....	b1.026	Do.
407	....do	....do	1892	....do	1,059	1,059	115	....do	....	....	b.484	Do.
408	....do	....do	1892	Bored, 10¼-inch	1,053	1,053	169	....do	....	....	c8.105	Do.
409	....do	Sec. 18, T. 1 S., R. 3 W	1886	Bored, 7-inch	1,077	......	127	(d)	....	....	c.286	Do.
410	....do	....do	1886	....do	1,076	......	127	(d)	....	....	c.302	Do.
411	....do	....do	1886	....do	1,077	......	125	(d)	....	....	c.270	Do.
412	....do	....do	1886	....do	1,077	......	125	(d)	....	....	c.416	Do.

a Included in cost of well.
b Flow of wells Nos. 391 to 412 is given for October, 1892.
c December, 1898.
d Wells 409 to 412 are pumped by 15-horsepower gas engine and centrifugal pump, raising 2 second-feet of water. These were artesian wells when sunk.

Wells in San Bernardino quadrangle.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
1	Riverside Water Co	Sec. 27, T. 1 S., R. 4 W	1887	11-inch pipe	1,014	1,014	115	Artesian			*a*0.329	Domestic.
2	do	do		do	1,015	1,015	118	do			*b*.284	Do.
3	do	do		do	1,015	1,015	113	do			*b*.117	Do.
4	do	do		do	1,016	1,016	111	do			*b*.153	Do.
5	do	do		do	1,014	1,014	112	do			*b*.117	Do.
6	do	do		do	1,016	1,016	120	do			*b*.150	Do.
7	do	do	1888	7-inch pipe	1,013	1,013	128	do	$400		*b*.150	Do.
8	do	do	1888	9-inch pipe	1,016	1,016	125	do	525		*b*.096	Do.
9	do	do	1888	9.5-inch pipe	1,018	1,018	123	do	500			Do.
10	do	do	1888	9-inch pipe	1,017	1,017	127	do	550			Do.
11	do	do	1888	do	1,021	1,021	201	do	800		*b*.125	Do.
12	do	do		do	1,020	1,020	141	do	650			Do.
13	do	do	1889	do	1,015	1,015	127	do	525			Do.
14	do	do	1889	do	1,014	1,014	125	do	550		*b*.068	Do.
15	do	Sec. 22, T. 1 S., R. 4 W	1889	11-inch pipe	964	964	86	do	480		*c*.442	Irrigation.
16	do	do	1889	9-inch pipe	981	981	123	do			*c*.083	Do.
17	do	do	1889	do	955	955	81	do			*c*.900	Do.
18	do	do	1889	do	955	955	92	do			*c*.361	Do.
19	do	Sec. 16, T. 1 S., R. 4 W	1889	do	972	972	225	do			*b*.158	Do.
*d*20	do	do	1889	7-inch pipe	978	978	75					
*d*21	do	do	1891	do	971	971	175					
22	do	do	1889	9-inch pipe	973	973	55	Artesian			.173	Do.
23	do	do	1889	do	974	974	121	do			.355	Do.
24	do	Sec. 22, T. 1 S., R. 4 W	1889	7-inch pipe	989	989	192	do			*c*.175	Do.
25	do	do	1889	9-inch pipe	968	968	81	do			*c*.207	Do.
26	do	do	1889	do	967	967	83	do			*c*.361	Do.

27	....do	....do	1889	....do	981	981	103	....do	....	....	c.952	Do.
28	....do	....do	1889	....do	970	970	83	....do	....	....	e.273	Do.
29	....do	....do	1889	....do	979	979	101	....do	....	....	e.640	Do.
30	....do	....do	1890	....do	978	978	97	....do	....	....	e1.417	Do.
31	....do	....do	1890	....do	980	980	165	....do	....	....	e.569	Do.
32	....do	....do	1890	....do	979	979	165	....do	....	....	e.616	Do.
33	....do	Sec. 27, T. 1 S., R. 4 W.	1891	9.5-inch pipe	1,012	1,012	330	....do	....	....	b3.28	Domestic.
34	....do	....do	1891	....do	1,012	1,012	326	....do	....	....	....	Do.
35	....do	Sec. 22, T. 1 S., R. 4 W.	......	....do	977	977	82	....do	255	....	f.860	Irrigation.
37	....do	Sec. 27, T. 1 S., R. 4 W.	......	....do	1,012	1,012	249	....do	....	....	....	Domestic.
38	....do	Sec. 1, T. 1 S., R. 4 W.	1892	7-inch pipe	1,083	1,083	187	....do	662	....	g.027	Irrigation.
39	....do	....do	1893	9.5-inch pipe	1,083	1,083	396	....do	....	....	g.714	Do.
42	....do	Sec. 27, T. 1 S., R. 4 W.	1893	....do	1,011	1,011	344	....do	....	....	....	Domestic.
43	....do	Sec. 1, T. 1 S., R. 4 W.	1894	....do	1,086	1,086	420	....do	630	....	h1.452	Irrigation.
44	....do	Sec. 22, T. 1 S., R. 4 W.	1896	9-inch pipe	979	979	133	....do	250	....	e.971	Do.
45	....do	....do	1896	....do	979	979	173	....do	420	....	....	Do.
47	....do	Sec. 3, T. 1 S., R. 4 W.	1898	....do	1,025	1,025	168	....do	500	....	....	Do.
51	....do	Sec. 22, T. 1 S., R. 4 W.	......	8-inch pipe	954	954	78	....do	....	....	....	Do.
52	....do	....do	......	....do	955	955	94	....do	....	....	....	Do.
53	....do	....do	1898	....do	956	956	68	....do	....	....	....	Do.
54	....do	....do	1898	....do	957	957	68	....do	....	....	....	Do.
55	....do	....do	1898	7-inch pipe	958	958	92	....do	....	....	....	Do.
56	....do	....do	1898	....do	959	959	75	....do	....	....	....	Do.
57	....do	....do	1898	8-inch pipe	960	960	92	....do	128	....	....	Do.
58	....do	....do	1898	7-inch pipe	960	960	87	....do	157	....	i.456	Do.
59	....do	....do	1898	8-inch pipe	961	961	85	....do	138	....	i.622	Do.
60	....do	....do	1898	7-inch pipe	961	961	93	....do	173	....	i.456	Do.
61	....do	....do	......	8-inch pipe	952	952	......	....do	....	....	....	Do.
62	....do	Sec. 15, T. 1 S., R. 4 W.	1898	....do	985	985	183	....do	....	....	i.34	Do.
65	....do	Sec. 2, T. 1 S., R. 4 W.	1900	10-inch pipe	1,040	1,040	540	....do	....	....	2.39	Do.
66	....do	....do	1900	....do	1,035	1,035	580	....do	....	....	2.606	Do.
67	Wm. Roach	Sec. 6, T. 2 S., R. 4 W.	1889	7-inch pipe	904	852	130	10 wind	200	$160	.015	Irrigation; domestic.

a 1890. b 1891. c 1896. d Well filled and covered with sand from flood and lost. e 1896. f 1892. g 1900. h 1894. i 1898.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
68	Wm. Roach	Sec. 6, T. 2 S., R. 4 W.	1875	7-inch pipe	905	852	70	12 wind	$105	$130	.006	Irrigation.
69	Mrs. Douglas	....do	1893	....do	895	835	112	Wind			.015	Irrigation; domestic.
70	Louise Peña	Sec. 12, T. 2 S., R. 5 W.	1888	Dug, 3 by 4 foot	835	815	22	....do		110	Small.	Domestic.
71	P. Evans	....do	1900	10-inch pipe	840	840	400	Artesian			1.000	Irrigation.
72	P. Baca	....do	1899	Dug, 3 by 3 foot	852	832	22	Hand	20		Small.	Domestic.
73	W. L. Zader	Sec. 29, T. 1 S., R. 4 W.	1894	Dug, 3-foot diameter.	980	930	52	8 wind	40	35	Small.	Do.
74	D. Jones	....do	1888	....do	980		70	Wind	100	200		
75	T. J. Smith	Sec. 30, T. 1 S., R. 4 W.	1890	....do	974		38	....do				
76	Mrs. B. R. Atkins	....do	1897	....do	980	938	59	9 wind		500	Small.	Do.
77		....do		Dug, 3 by 3 foot	886	871	17	Hand				Do.
78	M. G. Soares	....do		....do	875	871	6	....do				Do.
79	Thos. McGraw	Sec. 35, T. 1 S., R. 5 W.	1895	Dug, 4 by 4 foot	875	837	39	....do	70	14	Small.	Do.
80	Henry Carson	Sec. 10, T. 2 S., R. 5 W.	1900	Dug, 3-foot diameter.	831	784	49		40	40		Do.
81	Dan Baker	....do	1885	6-inch pipe	826	786	60	Hand		20		Do.
82	Mrs. Burgess	Sec. 34, T. 1 S., R. 5 W.		Dug, 4 by 4 foot	988	848	150	Wind				Not used.
83	T. Pulley	Sec. 10, T. 2 S., R. 5 W.	(a)	Bored, 20-inch	881	808	89					
84	Mrs. L. M. Henry	....do	1898	6-inch pipe	895	787	128	Wind				Irrigation; domestic.
85	T. Pulley	....do	1896	Dug, 3-foot diameter.	850	780	72	....do	50	120		Do.
86	John Miller	....do	1900	....do	866	800	69	....do	40			Domestic.
87	Ed. Bridson	Sec. 15, T. 2 S., R. 5 W.	1898	7-inch pipe	840	780	100	10 wind	150	150		Domestic; stock.
88	J. Rogerson	....do		Dug, 4 by 4 foot	830	794	37	Hand				Domestic.
89	Mrs. A. Parks	....do		7-inch pipe	810	793	28	Wind				Domestic; stock.

90	H. C. Parks	Sec. 9, T. 2 S., R. 5 W	1887	Dug, 3-foot diameter.	850	784	75	do	325	180		Do.
91	Scott La Rue	do	1900	do	845	742	107	do	100	285		Do.
92	Emuel Spooner	Sec. 8, T. 2 S., R. 5 W	1896	Dug, 4 by 4 foot	850	750	105	do	115			Do.
93	do	do	1900	do	850	750	107		125			
94	W. J. Thomas	Sec. 7, T. 2 S., R. 5 W	1900	Dug, 4½ by 4 foot	847	817	35		70			Domestic.
95	E. Thomas	do	1899	Dug, 3 by 3 foot	850	814	41	Wind	75	150		Irrigation.
96	do	do	1894	do	841	817	26	Hand	40			Domestic.
97	Mrs. H. M. Thurber	Sec. 12, T. 2 S., R. 6 W	1896	Dug, 5-foot diameter.	800	782	28	Wind				Irrigation; domestic.
98	F. D. Lewis	Sec. 13, T. 2 S., R. 6 W		Dug, 4 by 4 foot	795	775	40	10 wind				Domestic.
99		Sec. 12, T. 2 S., R. 6 W		do	789	770	31	do				Do.
100	John Parkhurst	do	1898	Dug, 6-foot diameter.	818	807	13.5	12 wind	100	135		Do.
101	J. R. Johnston	Sec. 6, T. 2 S., R. 5 W		Pipe line								Domestic; stock.
102	I. McBride	Sec. 12, T. 2 S., R. 6 W	1892	Dug, 3.5 by 3.5 foot	813	787	55	8 wind	80	100	Small.	Domestic.
103	Milo Gilbert	Sec. 24, T. 1 S., R. 4 W	1900	7-inch pipe	1,004	864	220	12 wind				
104	Riverside Trust Co	do	1898	10-inch pipe	1,077	1,077	506	Artesian			1.600	Irrigation.
105	do	do	1898	do	1,071	1,071	531	do			1.200	Do.
106	do	do	1898	do	1,065	1,065	517	do			1.400	Do.
107	do	Sec. 23, T. 1 S., R. 4 W	1899	do	1,045	1,045	675	do			1.500	Do.
108	do	Sec. 24, T. 1 S., R. 4 W	1899	do	1,076	1,076	568	do			2.040	Do.
109	do	Sec. 26, T. 1 S., R. 4 W	1899	do	1,019	1,019	554	do			.400	Do.
110	do	Sec. 13, T. 1 S., R. 4 W	1899	do	1,052	1,052	580	do				Do.
111	do	do	1899	do	1,061	1,061	537	do			2.600	Do.
112	do	do	1899	do	1,066	1,066	577	do			1.200	Do.
113	do	do	1899	do	1,069	1,069	505	do			1.040	Do.
114	do	do	1900	do	1,079	1,079	478	do			3.000	Do.
115	Gage Canal Co	Sec. 26, T. 1 S., R. 4 W	1891	do	1,033	1,033	656	do			.089	Do.
116	do	do	1891	do	1,034	1,034	534	do			.956	Do.
117	do	do	1891	do	1,034	1,034	582	do			.770	Do.
118	do	do	1891	do	1,034	1,034	482	do			1.026	Do.
119	do	do	1891	10¼-inch pipe	1,034	1,034	320	do			.064	Do.
120	do	do	1891	10-inch pipe	1,034	1,034	784	do			1.089	Do.

a Not finished.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
121	Gage Canal Co	Sec. 23, T. 1 S., R. 4 W.	1888	10¼-inch pipe	1,036	1,036	196	Artesian			.550	Irrigation.
122	do	do	1888	do	1,036	1,036	190	do			.979	Do.
123	do	do	1889	10-inch pipe	1,036	1,036	142	do			.188	Do.
124	do	do	1889	10¼-inch pipe	1,036	1,036	148	do			.121	Do.
125	do	Sec. 24, T. 1 S., R. 4 W.	1886	7-inch pipe	1,037	1,037	141	do			2.330	Do.
126	do	Sec. 13, T. 1 S., R. 4 W.	1886	do	1,037	1,037	181	do			1.928	Do.
127	do	do	1891	10-inch pipe	1,037	1,037	426	do			5.901	Do.
128	do	do	1891	do	1,037	1,037	472	do			1.874	Do.
129	do	do	1891	do	1,048	1,048	518	do			1.874	Do.
130	do	do	1891	do	1,049	1,049	338	do			1.264	Do.
131	do	do	1891	do	1,049	1,049	380	do			.770	Do.
132	do	do	1891	do	1,049	1,049	386	do			1.424	Do.
133	do	do	1891	do	1,052	1,052	198	do			5.314	Do.
134	do	do	1891	do	1,057	1,057	124	do			1.299	Do.
135	do	do	1891	do	1,055	1,055	116	do			2.746	Do.
136	do	do	1891	do	1,057	1,057	134	do			5.663	Do.
155	do	do	1892	do	1,051	1,051	193	do			8.239	Do.
156	do	do	1892	do	1,046	1,046	192	do			8.315	Do.
157	do	do	1892	10¼-inch pipe	1,044	1,044	390	do			4.835	Do.
158	do	do	1892	10-inch pipe	1,042	1,042	224	do			5.697	Do.
159	do	do	1885	7-inch pipe	1,045		123				1.923	Do.
160	do	do	1885	do	1,045		133				.473	Do.
161	do	do	1885	do	1,045		133				3.015	Do.
162	do	do	1885	5-inch pipe	1,048		139				8.217	Do.
163	do	do	1885	7-inch pipe	1,048		211				4.641	Do.
164	do	do	1885	do	1,046		100				.579	Do.

169	....do	....do	1890	10-inch pipe	1,037	1,037	300	Artesian			5.901	Do.
170	Riverside Trust Co	Sec. 23, T. 1 S., R. 4 W.	1900	....do	1,011	1,011	582	....do			6.131	Do.
171	Bloomington Land Co	Sec. 22, T. 1 S., R. 5 W.	1900	12-inch pipe	1,100	858	454	....do	$1,200			Not used.
172	D. Johnson	Sec. 8, T. 1 S., R. 4 W.		8-inch pipe	1,095	1,081	283		600			Do.
173	Fox, Archibald & Lantz	....do			1,089			Centrifugal; 10 gas			.414	Irrigation.
174	Jas. Lamb	....do	1894	8-inch pipe	1,097	1,083	102	....do	200	$1,800	.400	Do.
175	Jas. Barnhill	....do		....do	1,097			Centrifugal; 15 electric			.800	Do.
176	City of Colton	....do	1899	10-inch pipe	1,087	1,070	490	Centrifugal; electric			.834	Irrigation; domestic.
177	....do	....do	1899	8-inch pipe	1,084	1,068	90	....do			.200	Do.
178	G. W. Curtis	Sec. 24, T. 1 S., R. 4 W.	1895	7-inch pipe	1,088	1,063	85	8 wind	130	70	.002	Do.
179	J. J. Curtis	....do	1892	....do	1,088	1,063	90	....do	150	120	.003	Do.
180	A. C. Harvey	....do	1898	....do	1,088	1,088	600	Centrifugal; 12 gas	400	1,200	2.250	Irrigation.
181	W. A. Thomas	....do			1,078	1,076		Artesian				
182	L. S. Dart	Sec. 25, T. 1 S., R. 4 W.	1890	7-inch pipe	1,075	1,055	80	12 wind	150		.002	Domestic.
183	Anderson estate	....do		{8-inch pipe {4.5-inch pipe	1,093		450 150	Centrifugal; 25 gas		2,275	.250	Irrigation.
184	A. Hunt	Sec. 27, T. 1 S., R. 4 W.	1889	7-inch pipe	1,005	1,005	127	Artesian	200		.100	Irrigation; domestic.
185	....do	....do	1889	....do	1,001	1,001	57	....do	90		.800	Irrigation.
186	....do	....do	1895	9½-inch pipe	1,004	1,004	280	....do	1,100		.400	Do.
187	....do	....do	1894	7-inch pipe	1,007	1,007	200	....do	500			Do.
188	No record.											
189	E. M. Cooley	....do	1889	....do	1,019	959	86	12 wind	150	100		Irrigation; domestic.
190	H. L. Drew	Sec. 21, T. 1 S., R. 4 W.		3-inch pipe	980	980	200	Artesian			.010	Domestic.
191	C. C. Cooley	Sec. 27, T. 1 S., R. 4 W.	1885	7-inch pipe	993	928	85	12 wind	150	100		Do.
192	P. Filance	....do	1887	10-inch pipe	983	983	250	Artesian	1,000		1.200	Irrigation.
193	Filance estate	....do	1880	3-inch pipe (3)	984	984	75 85 90	....do			.900	Irrigation; domestic.
194	O. A. Byrne	Sec. 21, T. 1 S., R. 4 W.		2-inch pipe	984	980		Hand		5		Domestic.
195	Harry Whaley	Sec. 34, T. 1 S., R. 4 W.	1890	7-inch pipe	1,150	1,115	100	8 wind			.001	Do.
196	Thomas N. Hunt	....do	1890	Dug, 3-foot diameter.	1,117	1,000	123	16 wind	750	100		Do.
197	Mr. Blair	....do	1899	Dug, 5 by 5 foot	1,115	1,109	16	Never used				

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
198	Ignacio Reyes	Sec. 34, T. 1 S., R. 4 W.	1895	Dug	1,182	1,172	13		$15	$3		Domestic.
199	Washington School	Sec. 27, T. 1 S., R. 4 W.		7-inch pipe	1,043	966	129	8 wind		90		Do.
200	S. A. Pooles	Sec. 33, T. 1 S., R. 4 W.	1890	do	1,015	955	75	12 wind		500	.005	
201	Fred Pooles	do	1901	$8\frac{1}{4}$-inch pipe	955	907	98	8 wind				Do.
202	Mrs. C. A. Peake	do	1880	2-inch pipe	950	936	18	Hand	10			Do.
203	Chas. Green	do		3-inch pipe	944		3	Wind				Do.
204	J. D. Warner	Sec. 28, T. 1 S., R. 4 W.	1884	$1\frac{1}{2}$-inch pipe	938	927	13	Hand	10			Do.
205	do	do	1898	$1\frac{3}{4}$-inch pipe	926	916	13	do	8			Do.
206	do	do	1894	10-inch pipe	941	935	155		2,455			
207	Geo. Cooley, sr	Sec. 27, T. 1 S., R. 4 W.	1894	7-inch pipe	978	952	72	12 wind		125	.005	Irrigation; domestic.
208	C. A. Poole	do	1900	do	1,002	984	50	Hand	110			Domestic.
209	A. A. Warren	Sec. 33, T. 1 S., R. 4 W.	1885	2-inch pipe	936	929	25	12 wind	15	150	.002	Irrigation; domestic.
210	West Riverside Water Co.	Sec. 32, T. 1 S., R. 4 W.			950	944	112	30 compressor		1,275		Irrigation.
211	J. M. Snodgrass	Sec. 28, T. 1 S., R. 4 W.	1898	Dug, 10-foot diameter.	931	927	13	Bucket pump; engine	50	600	.500	Do.
212	do	do	1898	Dug, 2-foot diameter.	923	920	7.5	12 wind	10	50	.003	Do.
213	A. A. Warren	Sec. 33, T. 1 S., R. 4 W.	1897	2-inch pipe	943	936	15	Hand	15	5		Domestic
214	Southern Pacific R. R. Co.	Sec. 21, T. 1 S., R. 4 W.	1882	7-inch pipe	958	915	45	12 wind			.005	Do.
215	Frank Parody	Sec. 28, T. 1 S., R. 4 W.	1900	Dug	955	934	33	Hand		12		Do.
216	Martin Gahm	Sec. 21, T. 1 S., R. 4 W.	1888	Dug, 3 by 3 foot	964	927	41	8 wind	50	75	.005	Do.
217	W. H. Wells	do	1893	Dug, 2.5 by 2.5 foot.	966	928	44	Hand	6			Do.
218	C. G. Turner	do	1895	7-inch pipe	966		70	12 wind				
219	G. B. Kinyon	do	1888	Dug, 3 by 3 foot	948	934	25	Wind	25	500		Irrigation; domestic.
220	J. F. Stuchberry	do	1886	Dug, 3.5 by 3.5 foot.	952	933	22	8 wind	30	90	.007	Do.

221	J. H. Vaughan	....do	1886	Dug, 4-foot diameter.	955	934	27	12 wind	48	75	.009	Do.
222	Alfred Vaughan	....do	1900	....do	959	928	34	....do	62	155	......	Irrigation.
223	W. L. Vaughan	....do	1884	....do	965	......	......	....do	......	......	.009	Irrigation; domestic.
224	H. D. Young	....do	1890	Dug, 2-foot diameter.	963	931	40	Hand	40	......	......	Domestic.
225	J. H. Dodson	....do	1885	Dug, 4-foot diameter.	969	926	50	8 wind	......	105	.003	Irrigation; domestic.
226	Henry Kaiser	....do	1892	....do	964	922	43	12 wind	84	......	.006	Do.
227	H. C. Dodson	....do	1892	Dug, 2-foot diameter.	968	928	55	8 wind	......	212	......	Do.
228	John Benner	....do	1880	Dug, 4-foot diameter.	970	916	62	12 wind	......	......	.002	Do.
229	Tom Moran	....do	......	....do	974	921	54	Hand	......	......	Small.	Domestic.
230	T. Allen	....do	1880	....do	978	924	68	14 wind	......	155	.001	Do.
231	S. A. Woodard	....do	18ˢ2	Dug, 4.5-foot diameter.	984	928	69	12 wind	......	......	.009	Irrigation; domestic.
232	Los Angeles Building Co.	....do	......	Dug, 4 by 4 foot	1,000	Dry.	70	10 wind	......	......	......	
233	J. A. Coburn	Sec. 16, T. 1 S., R. 4 W.	1890	....do	1,000	934	80	12 wind	......	......	.005	Do.
234	Miss B. Top	....do	......	......	1,038	1,038	3	8 wind	5	65	.002	Do.
235	Byron Waters	....do	1893	Dug, 9.5 by 9.5 foot and 5 by 5 foot.	1,019	991	28	Centrifugal; 3 electric	300	376	.6	Do.
235a	....do	....do	1889	3-inch pipe	1,019	......	220	Artesian	700	......	.005	Do.
236	Doctor Rowl	......	......	Pipe	......	......	......	....do	......	......	......	
237	....do	......	......	....do	......	......	......	....do	......	......	......	
238	Homer Jones	Sec. 16, T. 1 S., R. 4 W.	1895	3-inch pipe	1,023	1,010	300	8 wind	......	......	.002	Do.
239	Mrs. M. G. Hammel	....do	......	......	1,008	1,000	83	....do	......	75	.002	Do.
240	Riverside Trust Co.	Sec. 23, T. 1 S., R. 4 W.	......	7-inch pipe	1,000	......	......	Hand	......	......	......	Domestic.
241	F. S. West	....do	1897	2-inch pipe	998	......	......	......	......	......	......	Irrigation; domestic.
242	Mrs. E. A. Paine	Sec. 22, T. 1 S., R. 4 W.	1896	3-inch pipe	1,000	1,000	109	Artesian	......	75	.04	Do.
243	M. B. Warren	....do	1885	4-inch pipe	996	996	125	....do	......	......	.01	Do.
243a	....do	50 feet southeast from 243.	1899	3-inch pipe	997	997	130	....do	......	......	.25	Irrigation.
244	....do	Sec. 22, T. 1 S., R. 4 W.	1880	2-inch pipe	998	998	125	....do	......	......	.041	Irrigation; domestic.

Wells in San Bernardino quadrangle—Continued.

No. of well	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
244*a*	M. B. Warren	20 feet southwest from 244.	1899	3-inch pipe	997	997		Artesian			.178	Irrigation; domestic.
245	C. E. Bishop	Sec. 23, T. 1 S., R. 4 W.	1882	....do	1,001	1,001	94	....do	$125		.02	Do.
245*a*	....do	....do	1888	7-inch pipe	1,004	1,004	94	....do			.02	Do.
246	Wm. E. Everett	Sec. 22, T. 1 S., R. 4 W.	1898	3-inch pipe	1,001	1,001	96	....do	100		.25	Do.
247	Bob Gomer	Sec. 15, T. 1 S., R. 4 W.	1890	....do	984							
248	John Welsh	Sec. 23, T. 1 S., R. 4 W.		....do	1,007	1,007	100	Artesian			.083	Do.
249	S. B. Parish	Sec. 14, T. 1 S., R. 4 W.	1892	10-inch pipe	1,019	1,019	540	....do	2,500		.40	Irrigation.
250	....do	....do	1885	6-inch pipe	1,017	1,015	104		300			
251	....do	....do	1889	2-inch pipe	1,016		100		150			
252	....do	....do	1870	1½-inch pipe	1,014	1,014	83	Artesian			.004	
253	Mrs. Elizabeth Case	....do	1898	3-inch pipe	1,007	1,007	91	....do	85		.115	Irrigation; domestic.
254	....do	....do	1892	7-inch pipe	1,009	1,009	260	....do	500		.2	Irrigation.
254*a*	W. G. Merrilees	....do	1893	....do	1,009	1,009	211	....do			.14	Do.
254*b*	....do	....do	1897	3-inch pipe	1,009	1,009	86	....do			Small.	Do.
255	Wm. Stewart	Sec. 15, T. 1 S., R. 4 W.	1898	8-inch pipe	1,004	1,004	315	....do			*a* 1.14	Do.
256	....do	....do	1898	9-inch pipe	1,005	1,005	85	....do			*b* .2	Do.
257	....do	....do		1½-inch pipe	1,004	1,004		....do			Small.	Domestic.
259	....do	....do		7-inch pipe	1,002							Irrigation.
260	John Sullivan	Sec. 14, T. 1 S., R. 4 W.	1874	2-inch pipe	1,021				100		(*c*)	Irrigation; domestic.
261	....do	....do	1893	3-inch pipe	1,024	1,024	210	Artesian	325		.062	
263	....do	....do	1884	7-inch pipe	1,025	1,023	84		80		(*d*)	
264	....do	....do	1871	2-inch pipe	1,037		90				(*d*)	
265		....do	1892	....do	1,022		92	Artesian			.002	Domestic.
266	Wm. Baker	....do	1870	1.5-inch pipe	1,022	1,022	96	....do	130		Small.	Do.

267	....do....	....do....	1899	3-inch pipe	1,024	1,024	271	....do....	435	....	.178	Domestic; irrigation.
268	P. J. Clevenger	....do....	......	2-inch pipe	1,030	......	......	10 electric; centrifugal	....	....	(c)	
269	....do....	....do....	1897	10-inch pipe	1,043	......	150	....	....	....	.5	Irrigation.
270	Henry Warren	....do....	1883	2-inch pipe	1,033	1,023	106	....	150	....	(d)	
271	....do....	....do....	1890	3-inch pipe	1,033	1,023	100	12 wind	100	$160	(d)	Domestic; irrigation.
272	John Sullivan	....do....	1898	....do....	1,024	1,024	214	Artesian	300	....	.178	Irrigation.
273	Henry Warren	....do....	1880	7-inch pipe	1,036	1,026	106	....	200	....	(e)	Not used.
274	....do....	....do....	1880	....do....	1,038	1,028	220	....	500	....	(f)	Do.
275	....do....	....do....	1893	10-inch pipe	1,039	1,039	640	Artesian	3,000	....	.386	Irrigation.
276	Frank Feri	....do....	......	2-inch pipe	1,034	......	......	Hand	....	....	(g)	Domestic.
277	G. Renwick	Sec. 8, T. 1 S., R. 4 W.	......	6-inch pipe	1,090	1,055	186	8 wind	....	....	Small.	Do.
278	Orange Land and Water Co.	....do....	......	7-inch pipe	1,089	1,069	225	Centrifugal; 20 compressor; 3 wells in group together.	....	....	1.64	Domestic; irrigation.
279	Callahan estate	Sec. 20, T. 1 S., R. 4 W.	1886	Dug, 4 by 4 foot	1,009	933	84	12 wind	....	....	....	
280	E. Memory	....do....	1886	....do....	982	927	60	....do....	....	....	Small.	Domestic.
281	F. A. Cleveland	Sec. 8, T. 1 S., R. 4 W.	1898	2-inch pipe	1,072	......	90	8 wind	47	40	Small.	Do.
282	C. H. Westmyer	....do....	1897	3-inch pipe	1,069	1,062	94	....do....	74	100	Small.	Domestic; irrigation.
283	W. W. Brison	Sec. 9, T. 1 S., R. 4 W.	1899	2-inch pipe	1,062	1,052	99	10 wind	100	200	Small.	Domestic.
284	G. F. Woods	....do....	1900	8-inch pipe	1,059	1,049	140	....do....	300	350	.008	Domestic; irrigation.
285	....do....	....do....	1887	7-inch pipe	1,060	1,060	300	....	....	....	None.	
286	City of Colton	Sec. 8, T. 1 S., R. 4 W.	......	{10-inch pipe (2) {7-inch pipe (2)	1,065	......	{200 {640	Centrifugal; 20 electric	....	2,000	2.500	Do.
287	Isaac Jameson	....do....	1898	8-inch pipe	1,070	1,050	90	12 wind	126	275	.015	Do.
288	J. Collins	....do....	1887	3-inch pipe	1,054	......	75	10 wind	....	....	Small.	Irrigation; domestic.
289	J. C. Ralphs	Sec. 9, T. 1 S., R. 4 W.	1899	10-inch pipe	1,047	1,016	202	12 wind	500	200	Small.	Do.
290	Los Angeles Building Co.	....do....	1893	....do....	1,052	......	160	8 gas; centrifugal	....	....	.8	Irrigation.
291	V. Herkelrath	Sec. 15, T. 1 S., R. 4 W.	1882	2-inch pipe	979	979	......	Artesian	70	....	.072	Domestic.
292	....do....	....do....	1880	....do....	980	980	......	....do....	175	....	.119	Irrigation.
293	Mrs. Nowland	....do....	1875	....do....	980	980	160	....do....	275	....	....	Do.

a 1899. b 1898. c Stopped flowing in 1895. d Stopped flowing in 1898. e Stopped flowing in 1889. f 1890. g May, 1900.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
294	M. H. Hurd	Sec. 15, T. 1 S., R. 4 W.	1887	2-inch pipe	983			Artesian				Domestic.
295	Mrs. N. H. Ball	do	1894	7-inch pipe	996	996	253	do	$500		.262	Irrigation.
296	Los Angeles Building Co.	Sec. 9, T. 1 S., R. 4 W.		10-inch pipe	1,051	1,049	446	do			.4	Do.
297	do	do		do	1,050	1,048	451	do			.4	Do.
298	Mrs. N. H. Ball	Sec. 15, T. 1 S., R. 4 W.	1886	3-inch pipe	992	992	107	do	250			Domestic.
299	W. Beck	do	1892	do	998	988	204	do				Irrigation.
300	H. Kleuter	Sec. 10, T. 1 S., R. 4 W.	1885	do	1,006	1,006	200	do	300		.074	Domestic; irrigation.
301	do	do	1887	do	1,005	1,005	206	do	328			Irrigation.
302	do	do	1887	do	1,005	1,005	132	do	159		.518	Do.
303	do	do	1897	do	1,003	1,003	135	do	125		.006	Do.
304	Stephen Wood	Sec. 11, T. 1 S., R. 4 W.	1894	do	1,010	1,010	160	do			Small.	Domestic.
305	W. B. Barton	Sec. 14, T. 1 S., R. 4 W.	1883	2-inch pipe	1,041		100	12 wind		$216	Small.	Do.
306	Stephen Wood	Sec. 11, T. 1 S., R. 4 W.	1880	3-inch pipe	1,022		164	8 wind			Small.	Stock.
307	F. M. Kellar	do	1882	do	1,024	1,024	267	Artesian	500		.02	Domestic.
308	W. B. Barton	Sec. 13, T. 1 S., R. 4 W.	1892	10-inch pipe	1,045	1,033	115	9 gas; centrifugal			.209	Irrigation.
309	A. J. Downer	do		3-inch pipe	1,045		190	12 wind	125	50	Small.	Domestic.
310	Edwin Martin	do		do	1,045	1,033	215	Hand			Small.	Do.
311	Lucas Hoagland	do	1897	2-inch pipe	1,049	1,039	80	do	75		Small.	Do.
312	do	do	1884	3-inch pipe	1,050	1,040	250	8 wind	250	75	Small.	Stock.
313	do	Sec. 12, T. 1 S., R. 4 W.	1884	2-inch pipe	1,047		100		100			Not used.
314	R. F. Garner	Sec. 10, T. 1 S., R. 4 W.	1888		1,019		200	Artesian			Small.	Domestic.
315		Sec. 12, T. 1 S., R. 4 W.		10-inch pipe	1,059	1,059	682+	do			.123	Stock.
316	Geo. M. Cooley	Sec. 36, T. 1 N., R. 4 W.	1892	7-inch pipe	1,150	1,108	66	12 wind		500		Irrigation; domestic.
317	do	do	1895	11-inch pipe	1,150	1,108	80	9 gas		1,500	.6	Irrigation.
317a	do	do	1895	10-inch pipe	1,150	1,108	80	9½ cylinder pumps				Do.

318	E. J. Stiles	Sec. 35, T. 1 N., R. 4 W.	1898	7-inch pipe	1,196	1,157	48	10 wind	40	160	Small.	Domestic; stock.
319	Jas. Dickson	....do	1888	10-inch pipe	1,179	1,145	44	12 wind		135	Small.	Domestic.
320	J. G. Wood	....do	1884	7-inch pipe	1,124	1,090	44	....do		200	Small.	Do.
321	....do	Sec. 36, T. 1 N., R. 4 W.	1885	11-inch pipe	1,140	1,092	64	Cylinder pump; 5 gas	240	600	.125	Irrigation.
322	M. E. Myers	Sec. 35, T. 1 N., R. 4 W.	1890	2-inch pipe	1,111	1,089	310	12 wind				Domestic; irrigation.
323	J. S. Bean	Sec. 3, T. 1 S., R. 4 W.	1889	3-inch pipe	1,108	1,108	210	Artesian	200		.1	Irrigation.
324	....do	....do	1898	10-inch pipe	1,108	1,108	524	....do	1,100		.9	Do.
325	J. F. Johnson	Sec. 34, T. 1 N., R. 4 W.	1890	7-inch pipe	1,098	1,076	39	Hand				Not used.
326	Oscar Perris	Sec. 26, T. 1 N., R. 4 W.			1,177		96	Steam; power				Irrigation.
327	S. G. Ramsey	Sec. 25, T. 1 N., R. 4 W.	1896	10-inch pipe	1,190	1,125	90	Power; 10 gas	160	1,200	.3	Do.
328	Saml. S. Ford	Sec. 26, T. 1 N., R. 4 W.	1898	Dug, 3-foot diameter.	1,185	(a)	58	Wind		225	None.	
329	Muscupiabe Land and Water Co.	Sec. 23, T. 1 N., R. 4 W.	1899	10-inch pipe	1,288	1,143	402	Power; 15 steam	1,200	2,000	.5	Domestic; irrigation; stock.
330	....do	Sec. 26, T. 1 N., R. 4 W.	1892	....do	1,222	(a)	102	Wind	300	250	None.	
331	Mrs. Anne C. Severance	....do	1895	....do	1,227	(a)	106	12 wind	300	900	None.	
332	Mrs. S. A. Smith	Sec. 27, T. 1 N., R. 4 W.	1894	....do	1,224	1,224	140	16 wind		800	.010	Irrigation; domestic.
333	F. M. Johnson	Sec. 34, T. 1 N., R. 4 W.	1899	10-inch pipe	1,117	1,095	600	10 gas; cylinder pump	1,160	800	.230	Irrigation.
334	....do	....do	1880	12-inch pipe	1,112	1,084	40	Wind			Small.	Stock; domestic.
335	H. H. Fitting	Sec. 35, T. 1 N., R. 4 W.	1885	7-inch pipe	1,124		44	....do			Small.	Do.
336	....do	....do	1888	Dug, 6 by 6 foot	1,135	(a)	47	4½ gas; cylinder pump	100			
337	....do	....do	1886	3-inch pipe	1,131		325		1,000		Dry.	
338	C. Hansen	....do	1895	7-inch pipe	1,127	1,090	39	8 wind		200	Small.	Do.
339	N. Hoien	....do	1895	....do	1,127	1,090	47				Small.	Do.
340	John Anderson	Sec. 34, T. 1 N., R. 4 W.	1885	....do	1,130		90	8 wind	114	100	Small.	Do.
341	H. N. Stones	....do	1884	....do	1,141	1,087	85	....do		125	Small.	Do.
342	M. F. Swing	....do	1891	....do	1,151		93	12 wind		220		Domestic; stock.
343	....do	....do	1894	....do	1,152		87	....do				Irrigation.
344	A. R. Togg	....do	1891	....do	1,160		100	....do			Small.	Irrigation; domestic.
345	F. L. Smith	....do	1897	....do	1,163		106	10 wind	105	135	.002	Do.
346	John W. Anderson	....do	1880	....do	1,165	1,103	70	....do	75	175	.002	Irrigation.

a No water.

Wells in San Bernardino quadrangle—Continued.

No of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
347	John W. Anderson	Sec. 34, T. 1 N., R. 4 W.	1900	7-inch pipe	1,166	1,103	113	16 wind	$125	$225	0.004	Irrigation.
348	S. E. Pearson	Sec. 27, T. 1 N., R. 4 W.	1899	do	1,182	1,107	104	12 wind	135	60	Small.	Irrigation; domestic.
349	R. Meacham	do	1900	do	1,183		110	do			Small.	Irrigation; stock.
350	do	do	1890	do	1,172	(a)	64	do			None.	
351	J. H. Taylor	do	1896	do	1,188	(a)	62	8 wind	50	100	None.	
352	W. G. Warner	do	1899	do	1,189	1,119	80	10 steam				Not used.
353	F. D. Olmstead	do	1895	do	1,190		101	12 wind		100	Small.	Irrigation; domestic.
354	S. F. Kelley	Sec. 28, T. 1 N., R. 4 W.	1897	do	1,170	1,121	115	8 wind			Small.	Do.
355	S. F. Kelley et al	do	1900	12-inch pipe	1,185	1,127	208	Electric; centrifugal (355 and 355a)	1,700	1,171	.9	Irrigation.
355a	do	do	1899	10-inch pipe	1,185	1,127	460					
356	H. C. Ward	do		7-inch pipe	1,177	1,118	120	12 wind			Small.	Do.
357	S. H. Johnson	do	1885	do	1,182	1,122	84	10 wind		250	Small.	Domestic.
358	H. Giddings	do	1898	do	1,205	1,148	73	15 wind		125		Do.
359	W. G. Rowland	do	1893	do	1,224	1,156	112	Geared pump; 3 gas	125	625	.1	Irrigation.
360	Fred Heilemann	Sec. 32, T. 1 N., R. 4 W.	1889	do	1,227	1,147	146	16 wind	200	750	.008	Irrigation; domestic.
361	do	do	1894	do	1,228	1,148	129	18 wind			.012	Do.
362	do	Sec. 29, T. 1 N., R. 4 W.	1890	10-inch, 8-inch, and 6⅝-inch pipes.	1,245	1,155	1,025		7,000		(b)	
363	B. E. Wheeler	do	1898	10-inch pipe	1,258	1,152	125	Plunger pump; 5 gas	300	800		Do.
364	F. Alvarado	Sec. 32, T. 1 N., R. 4 W.	1900	7-inch pipe	1,188	1,135	93					Not used.
365	A. B. Hancock	Sec. 5, T. 1 S., R. 4 W.	1896	do	1,170		56	12 wind	125	100	Small.	Domestic; irrigation; stock.
366	do	do	1882	do	1,169		56	do				Do.

367	D. W. White	Sec. 4, T. 1 S., R. 4 W	1871	....do	1,109	1,089	195	Gas; centrifugal; 8 wind.	1,200	200	.400	Irrigation; domestic.
368	W. F. Holcomb	Sec. 33, T. 1 N., R. 4 W		....do	1,115	1,089	37				Small.	Domestic.
369	Alex. Wixom	Sec. 4, T. 1 S., R. 4 W	1899	8-inch pipe	1,117		45	12 wind	50	148	Small.	Do.
370	F. L. Holcomb	Sec. 33, T. 1 N., R. 4 W	1885	7-inch pipe	1,128	1,100	47	....do	100	150	Small.	Do.
371	....do	....do	1885	....do	1,133	1,103	47	....do	100	150	Small.	Stock.
372	J. J. Whitney	Sec. 4, T. 1 S., R. 4 W	1884	Pipe	1,129	1,101	112	Wind		400	Small.	Domestic; stock.
373	P. B. Hockaday	....do	1887	7-inch pipe	1,133		110	12 wind		500	Small.	Domestic; irrigation.
374	J. J. Morris, sr.	Sec. 5, T. 1 S., R. 4 W	1890	8-inch pipe	1,137	1,109	53	10 wind		75	Small.	Do.
375	Dexter Field	....do	1870	6-inch pipe	1,147	1,112	45	....do			Small.	Domestic.
376	C. A. Muscott	Sec. 32, T. 1 N., R. 4 W	1886	8-inch pipe	1,158	1,115	78	12 wind	100	250		Domestic; irrigation.
377	J. W. Roberts	Sec. 27, T. 1 N., R. 4 W	1889	10-inch pipe	1,210	1,155	160	Plunger pump; 5 electric.	400	900	.24	Do.
378	T. C. Parker	Sec. 32, T. 1 N., R. 4 W	1886	7-inch pipe	1,205	1,110	98	12 wind; 3 gas		550		Do.
379	P. Oldecker	Sec. 33, T. 1 N., R. 4 W	1893	7-inch pipe	1,195		133	Geared pump; 2 gas		400	.10	Do.
380	A. Petersen	....do	1890	....do	1,192	1,134	76	12 wind	50	100	Small.	Do.
381	C. A. Bruckman	Sec. 32, T. 1 N., R. 4 W	1894	10-inch pipe	1,221	1,151	146	Geared pump; 16 gas	325	775	.36	Irrigation.
382	....do	....do	1892	7-inch pipe	1,215	1,145	84	12 wind	115	300		Do.
383	....do	....do	1892	....do	1,214	1,144	85	Geared pump; 5 gas.	115	625	.042	Do.
384	....do	....do	1890	....do	1,192	1,134	85	12 wind	115	250	Small.	Domestic.
385	Wilson & Wheat	....do	1890	....do	1,188	1,128	82	16 wind				Domestic; irrigation.
386	E. D. Palmer	Sec. 33, T. 1 N., R. 4 W	1894	....do	1,184		80	14 wind			Small.	Do.
387	C. G. Leonhardt	Sec. 32, T. 1 N., R. 4 W	1890	....do	1,182		85	12 wind	115	192	Small.	Do.
388	....do	....do	1899	8-inch pipe	1,197	1,133	90	....do	125	297	.006	Irrigation.
389	S. E. A. Palmer	Sec. 33, T. 1 N., R. 4 W	1887	7-inch pipe	1,176	1,124	92	14 wind	150	350	.003	Domestic; irrigation.
390	Fred F. Palmer	....do	1899	Dug, 4 by 6 foot; 7-inch pipe.	1,189	1,134	85	Duplex; steam	300	500	.036	Irrigation.
391	W. D. Wilson	Sec. 32, T. 1 N., R. 4 W	1893	8-inch pipe	1,203	1,138	94	12 wind				Do.
392	S. H. Harmon	....do	1893	10-inch pipe	1,191	1,132	133	Geared pump; 5 gas	1,300	(c)	.020	Do.
393	S. W. Harmon	....do	1882	7-inch pipe	1,181	1,128	83	12 wind	50	220		Domestic; irrigation.
394	J. O. Slatter	Sec. 33, T. 1 N., R. 4 W	1890	....do	1,155		100	....do		150	Small.	Domestic.
395	C. N Damron	....do		....do	1,120	1,093	47	8 wind			Small.	Do.

a No water. b Tools left in well. c Two wells.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	Feet.	Feet.				Sec.-ft.	
396	Mrs. Amy McCrary	Sec. 33, T. 1 N., R. 4 W.	1899		1,138	1,112	91	Hand			Small.	Domestic.
397	Thos. Webster	do	1898	7-inch pipe	1,134			12 wind				Do.
398	N. M. Swarthout	do	1885	do	1,142	1,115	75	8 wind	$150	$100	Small.	Do.
399	do	do	1895	10-inch pipe	1,169		80	Horse	100	35	Small.	Irrigation.
400	J. H. Lytle	do	1885	7-inch pipe	1,166	1,135	79	12 wind	75	50	Small.	Domestic; irrigation.
401	H. S. Davidson	do	1880	do	1,158		56	do		500		Do.
402	N. Swarthout	do	1885	do	1,142	1,108	55	8 wind			Small.	Domestic.
403	G. W. Evans	do	1887	6-inch pipe	1,128	1,096	75	do			Small.	Do.
404	R. M. Bradley	do	1884	7-inch pipe	1,101	1,082	90	12 wind			Small.	Do.
405	Mrs. Sarah Abel	do	1880	Dug, 3 foot diameter.	1,109	1,088	22	Bucket			Small.	Do.
406	R. Poppett	Sec. 34, T. 1 N., R. 4 W.	1885	7-inch pipe	1,109	1,085	45	12 wind	50	140	Small.	Domestic; irrigation.
407	G. Johnson	do	1890	do	1,114	1,087	47	8 wind	60	60	Small.	Do.
408	E. G. Fish	do	1889	2-inch pipe	1,133		425	do	1,000		Small.	Do.
409	C. Cohn	do		7-inch pipe	1,118	1,089		10 wind			Small.	Domestic.
410	O. B. Peck	do	1888	do	1,147		115	14 wind			Small.	Domestic; irrigation.
411	K. P. Stephens	do	1883	do	1,164	1,114	65	do			.003	Do.
412	Jno. Y. Anderson	do	1900	{8-inch pipe 12-inch pipe}	1,165	1,109	{150 460}		2,000			Not used.
413	Jno. Lawrence	do	1897	7-inch pipe	1,091	1,076	42	8 wind		160	Small.	Domestic.
414	J. C. Wees	do	1898	do	1,097	1,073	46	do				Do.
415	Thos. J. Rennous	do	1900	do	1,133	1,101	72	10 wind	72	150	Small.	Domestic; irrigation.
416	H. H. Ham	do	1888	do	1,121	1,090	52	8 wind	75	100	Small.	Do.
417	W. M. Jenkins	do	1884	do	1,118	1,088	52	12 wind			Small.	Do.

418	Oscar Wees	do	1885	do	1,108		48	8 wind			Small.	Domestic.
419	M. W. Davis	do	1898	do	1,100		42	do	40	90		Do.
420	P. W. Heap, jr	do	1894	do	1,128	1,088	58	12 wind	60	125	.002	Domestic; irrigation.
421	B. M. Wall	do	1897	3-inch pipe	1,100		137	8 wind			Small.	Do.
422	E. Case	Sec. 3, T. 1 S., R. 4 W	1899	8-inch pipe	1,086	1,073	50	Hand			Small.	Domestic.
423	Jno. E. Garner	Sec. 2, T. 1 S., R. 4 W	1900	do	1,087	1,073	334	Centrifugal; 8 gas	750	750	.800	Irrigation, etc.
424	do	Sec. 35, T. 1 N., R. 4 W	1888	10-inch pipe; 7-inch pipe.	1,164	1,108	420	Centrifugal; 20 electric	1,500	3,000	1.200	Irrigation.
425	Colton City Water Co	Sec. 31, T. 1 N., R. 4 W	1900	10-inch pipe	1,202		208	Centrifugal; 25 gas			1.480	Irrigation; domestic.
426	San Bernardino city waterworks.	Sec. 36, T. 1 N., R. 5 W	1895 1900	Two 11-inch pipes. 12-inch pipe	 1,239	 1,207	320 550 800	Centrifugal; 25 gas			1.400	City supply.
427	Riverside Highlands Water Co.	Sec. 31, T. 1 N., R. 4 W	1900	10-inch pipe	1,218	1,204	320					Not used.
428	do	Sec. 36, T. 1 N., R. 5 W	1892	do	1,246	1,211	650	Centrifugal; 22 gas	5,000	1,100	1.600	Irrigation; domestic.
429	do	Sec. 31, T. 1 N., R. 4 W	1893	Two 10-inch pipes.	1,250	1,201	350 300	Centrifugal; 30 electric	3,000	2,500	2.000	Do.
430	do	do		do	1,258	1,203	500– 600	do	3,000	2,500	2.800	Do.
431	Rialto irrigation district Citizens' Water Co.	Sec. 36, T. 1 N., R. 5 W	1891	do	1,255	1,204	450	Centrifugal; turbine	1,500		1.300	Do.
432	do	do	1894	10-inch pipe	1,260	1,207	460	Centrifugal; 20 gas	1,800	6,000	.720	Do.
433	F. E. Watkins	do	1888	do	1,266	1,210	621	Two 25 compressors			890	Irrigation.
434	Lytle Creek Water and Improvement Co.	do	1900	Three 12-inch pipes.	1,290	1,215	226	Duplex steam	3,661	3,500	2.200	Do.
435	Rialto irrigation district	Sec. 25, T. 1 N., R. 5 W	1897	10-inch pipe	1,333	1,303	520	Centrifugal; 30 electric	1,500	2,000	1.800	Irrigation; domestic.
436	do	do	1894	do	1,342	1,306	432	do	1,500	2,000	1.500	Do.
437	Anglo-American Canaigre Co.	do	1899	Dug, 7 by 9 foot (2).	1,337	1,307	45					Not used.
438	F. E. Watkins	do	1898	10-inch pipe	1,390	1,251	381		2,000			Do.
439	Riverside Highlands Water Co.	Sec. 31, T. 1 N., R. 4 W		20 wells	1,200–1,225						(a)	Irrigation.
440		Sec. 4, T. 1 S., R. 4 W		Dug, 4 by 4 foot	1,089	1,083	7	Hand				Stock.

a These 20 wells have nearly all ceased flowing.

Wells in San Bernardino quadrangle—Continued.

No. of well.	Owner.	Location.	Year completed.	Class of well.	Elevation of surface.	Elevation of water, 1900.	Depth of well.	Method of lift.	Cost of well.	Cost of machinery.	Quantity of water.	Use of water.
					Feet.	*Feet.*	*Feet.*				*Sec.-ft.*	
441	M. E. Brooks	Sec. 5, T. 1 S., R. 4 W	1886	3-inch pipe	1,102		132	8 wind				Domestic; stock; irrigation.
442	do	do		do	1,105		140	12 wind			Small.	Irrigation.
443	Mrs. Mary Bemis	do	1888	Pipe	1,113		132	Hand			Small.	Domestic.
444	A. W. Bemis	do	1890	8-inch pipe	1,118	1,101	48	12 wind			Small.	Do.
445	do	do	1894	10-inch pipe	1,114	1,104	50	Centrifugal; 3 gas		$250	0.014	Irrigation.
446	D. F. Probst	Sec. 4, T. 1 S., R. 4 W	1886	7-inch pipe	1,085	1,070	36	10 wind			Small.	Domestic.
447	Mrs. A. Tompkins	Sec. 5, T. 1 S., R. 4 W	1882	do	1,115		212	Wind	$1,000	175	Small.	Domestic; irrigation.
448	J. Hancock	do	1875	do	1,138	1,092	128	do			Small.	Do.
449	M. D. Reynolds	do	1900	10-inch pipe	1,136	1,106	146	Centrifugal; 25 gas	300	1,400	.027	Irrigation.
450	do	do	1898	7-inch pipe	1,116	1,094	40	8 wind	60	150	Small.	Domestic.
451	Mrs. M. Lord	Sec. 4, T. 1 S., R. 4 W	1888	3-inch pipe	1,125		150	10 wind			Small.	Do.
452	John Marshall	Sec. 5, T. 1 S., R. 4 W	1888	7-inch pipe	1,128	1,103	42	do			Small.	Do.
453	I. W. Hazlett	Sec. 4, T. 1 S., R. 4 W	1900	do	1,101	1,082	142	12 wind	233		.002	Do.
454	Mrs. Alice Wixom	do		do	1,067	1,055	22	do			Small.	Do.
455	Mrs. Irving	do		do	1,099	1,078	100	8 wind			Small.	Do.
456	J. B. Kitring and R. H. Hacker.	do	1895	2-inch pipe	1,085	(*a*)	152	do		260	Small.	Do.
457	J. F. Cadd	do	1888	7-inch pipe	1,068	1,057	40	Hand	40		Small.	Do.
458	H. E. Gardner	Sec. 5, T. 1 S., R. 4 W		3-inch pipe	1,089	1,075		8 wind			Small.	Do.
459	Mrs. Marilla Smith	do	1889	2-inch pipe	1,094	1,079	122	Wind	122	150	Small.	Do.
460	San Bernardino County Hospital.	Sec. 8, T. 1 S., R. 4 W	1898 1899	3-inch pipe 7-inch pipe 10-inch pipe	1,089	1,071	125 125 330	Centrifugal; 6 gas			.300	Irrigation.
461		do		2 wells	1,057			Electric				Do.

462	Riverside Trust Co	Sec. 26, T. 1 S., R. 4 W		9 wells	1,019	1,019		Artesian				Irrigation.
463	Riverside Water Co	Sec. 2, T. 1 S., R. 4 W			1,036	1,036		do			1.976	Do.
464	do	do			1,037	1,037		do			1.930	Do.
465	do	do	1900	10-inch pipe	1,040	1,040	544	do			2.896	Do.
466	do	do	1900	do	1,041	1,041	582	do			3.096	Do.
467	E. D. Meissner	Sec. 26, T. 1 S., R. 4 W	1899	10 and 8 inch pipes	1,200	1,120	500	Plunger pump; 20 gas	2,600	1,350	.200	Do.
468	G. G. Lathrop	do	1897	7-inch pipe	1,063	1,017	70	10 wind	105	130	.003	Domestic; irrigation.
469	R. L. Dewitt	do	1897	Dug	1,047	1,028	26	Hand				Domestic.
470	Charles Morris	do	1892	Dug, 12 by 12 foot, 10-inch pipe.	1,078	1,063	80	12 wind	400	140	.007	Irrigation.
471	do	do	1899	10, 8, and 7 inch pipes.	1,077		640	Artesian	1,500		.005	
472	No record.											
473	F. S. Waters	Sec. 23, T. 1 S., R. 4 W	1877	2-inch pipe	1,054	1,044	196	8 wind	200	145	.002	Domestic; irrigation.
474	J. H. Hatherley	do	1888	3-inch pipe	1,555		450	Artesian	1,700		.140	Irrigation.
475	J. H. Kelly	do	1890	8-inch pipe	1,089		382	do	2,000		.400	Domestic; irrigation.
476	do	do	1891	7-inch pipe	1,074	1,066	500	Hand		5		Domestic.
477	Mr. Meyers	Sec. 25, T. 1 S., R. 4 W	1890	do	1,060		400				(b)	
478	W. E. Pedley	Sec. 2, T. 1 S., R. 4 W	1899	10-inch pipe	1,042		510	Artesian	1,284		2.700	Irrigation.

a 1,070 feet in 1899.

b Stopped flowing in 1899.

INDEX.

O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 142.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

Most of the above publications may be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they may be obtained, free of charge (except classes 2, 7, and 8), on application.

2. A certain number are allotted to every member of Congress, from whom they may be obtained, free of charge, on application.

3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they may be had at prices slightly above cost.

4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the forty-fifth in Series O, the complete list of which follows (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper):

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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian well prospects in the Atlantic coastal plain region, by N. H. Darton, Bulletin No. 138.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

SEPTEMBER, 1905.

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Reference.

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