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Geology and Ground-Water Resources of the Santa Maria Valley Area, California

By G. F. WORTS, Jr.

With a section on Surface-water Resources *by* H. G. THOMASSON, Jr.

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GEOLOGY AND GROUND-WATER RESOURCES OF THE SANTA MARIA VALLEY AREA, SANTA BARBARA COUNTY, CALIF.

By G. F. WORTS, JR.

ABSTRACT

This report is the third in a series of interpretive reports on the several ground-water basins of Santa Barbara County, Calif., prepared by the United States Geological Survey, in cooperation with the county. It presents the pertinent results of an investigation of the geology and water resources of the Santa Maria Valley area. It deals with the valleys of the Santa Maria and lower Sisquoc Rivers situated principally in the northwestern part of the county, which together form one large agricultural district dependent for its water supply on irrigation from wells. The report presents data on runoff from the region tributary to the area, shows the extent to which ground water is replenished from the rivers, estimates total recharge to and total discharge from the one principal ground-water body, estimates the yield of that body, and discusses the possibility of sea-water encroachment.

The Santa Maria River, which is formed by the confluence of the Cuyama River and the Sisquoc River, flows generally westward to the Pacific Ocean. The Cuyama River, which enters the area from the north, and the Santa Maria River together form the boundary between San Luis Obispo and Santa Barbara Counties. Channels of the Santa Maria and lower Sisquoc Rivers overlie a large irregular structural downfold or syncline, which is bounded on the north by the northwest-trending San Rafael Mountains and on the south by the west-trending Solomon and Casmalia Hills. These ranges are composed of consolidated essentially non-water-bearing rocks, which include the Franciscan, Knoxville(?), Monterey, Sisquoc, and Foxen formations, ranging in age from Jurassic to upper Pliocene. These impermeable rocks underlie the ground-water basin and bound it on the north, east, and south.

The valley area between the bordering ranges consists mostly of broad terraced uplands and alluvial plains adjacent to the Santa Maria and Sisquoc Rivers. Beneath the uplands and plains and along the flanks of the ranges are the unconsolidated or water-bearing materials which have been deposited on the consolidated rocks, and which in part have been downfolded in the syncline. The unconsolidated deposits are of upper Tertiary and Quaternary age, and attain a maximum thickness of about 3,000 feet. From oldest to youngest they include seven units: The Careaga sand, Paso Robles formation, Orcutt formation, terrace deposits, alluvium, river-channel deposits, and dune sand. Of these the alluvium of Recent age is the most permeable and yields water to more than 500 wells at rates of more than 1,000 gallons per minute per well.

Contained within these deposits and extending over an area of about 110,000 acres is a single large ground-water body. Near the coast over an area of 30,000 acres it is confined beneath silt and clay composing the upper part of the alluvium; over the remaining 80,000 acres it is unconfined. All ground-water recharge takes place in the unconfined portion or intake area. The chemical quality of the

ground water is such that it can be used for most purposes, and further, analyses of well waters show that near the coast there has been no sea-water encroachment to date. During historic time there has always been a fresh-water head accompanied by ground-water outflow at the coast.

Recharge to ground water is derived from seepage losses from streams and infiltration of rain. Seepage losses from streams for the 16-year period 1930–45 was estimated from the records of surface-water runoff which occurs over the 1,800 square miles of the drainage basin. Eight gaging stations on the Cuyama and Sisquoc Rivers and their major tributaries record the surface-water inflow to the valley area, and one station on the Santa Maria River at Guadalupe measures the surface-water outflow from the area. Infiltration of rain has been estimated on the basis of type of land cover and character of underlying deposits, using estimates of deep penetration of rain derived from work done mostly in nearby Ventura County. Recharge from both sources has averaged about 70,000 acre-feet a year during the period 1930–45.

Discharge of ground water is by pumping and by natural means. Pumping for irrigation, which began in 1898, constituted nearly 80 percent of the total discharge in 1944 when about 35,000 acres of land were irrigated from 317 wells. Estimates of pumpage for the period 1929–44 were obtained largely from the kilowatt-hours used and electrical energy needed to pump 1 acre-foot of water. The total pumpage has increased from about 55,000 acre-feet in 1929 to nearly 80,000 acre-feet in 1944. However, the net pumpage is estimated to be about 20 percent less. Natural discharge during the period 1929–44 has been in the form of ground-water outflow to the sea from beneath the confining beds of the upper part of the alluvium. Outflow has ranged from about 9,500 acre-feet in 1936, when water levels and storage were the lowest of record, to nearly 13,000 acre-feet in 1944.

Increases and decreases in ground-water storage have been roughly proportional to periods of above-average and below-average rainfall, respectively, but have been modified considerably by pumping during the past 20 years. The period 1929–36 was one of below-average rainfall in which recharge averaged only about 34,000 acre-feet a year. By 1936 storage was depleted and water levels were lowered to the point where pumping lifts locally became economically infeasible. The net decrease in storage in this period is estimated to have been 160,000 to 200,000 acre-feet. The following period, 1936–45, was one of above-average rainfall in which recharge averaged nearly 100,000 acre-feet a year. In the heavily pumped area the average net rise in water levels amounted to nearly 30 feet, and the over-all net increase in ground-water storage was about 260,000 acre-feet.

The perennial yield of the ground-water basin for the period 1929–45 was estimated by two independent methods, as follows: It is equal to the total recharge less the total natural discharge divided by the 16 years of inventory, and it is equal to the total net pumpage plus the net increase in storage divided by the 16 year's inventory. The yield for the period is considered to be the average of the two, but because of somewhat greater than average rainfall it is probably slightly greater than the long-term average. Based on a comparison with rainfall for the period 1886–1945, the perennial yield is estimated to be about 53,000 acre-feet a year. Current net pumpage is about 65,000 acre-feet a year, and therefore, the perennial yield is being exceeded by about 12,000 acre-feet a year.

A program outlined by the Bureau of Reclamation to utilize more efficiently the surface-water resources of the Santa Maria River drainage system involves the construction of dams to detain the surface-water inflow, to transfer water from the reservoirs to the ground-water basin by natural spreading in the permeable channels, and so to salvage a considerable part of the estimated 33,000 acre-feet a year now wasting to the sea as surface-water outflow. Under such a program the perennial yield could be increased in nearly direct proportion to the quantity of outflow salvaged.

INTRODUCTION

LOCATION AND GENERAL FEATURES OF THE AREA

The Santa Maria Valley area is one of the larger coastal valleys of California, and is situated about 130 miles northwest of Los Angeles and 60 miles northwest of Santa Barbara. It occupies the northwestern part of Santa Barbara County and the extreme southwestern part of San Luis Obispo County (fig. 1). It lies approximately between 34°50′ and 35°5′ north latitude, and between 120°10′ and 120°40′ west longitude (pl. 1). It covers an area of about 260 square miles and has an east-west length of 28 miles and a maximum north-south width of 15 miles.

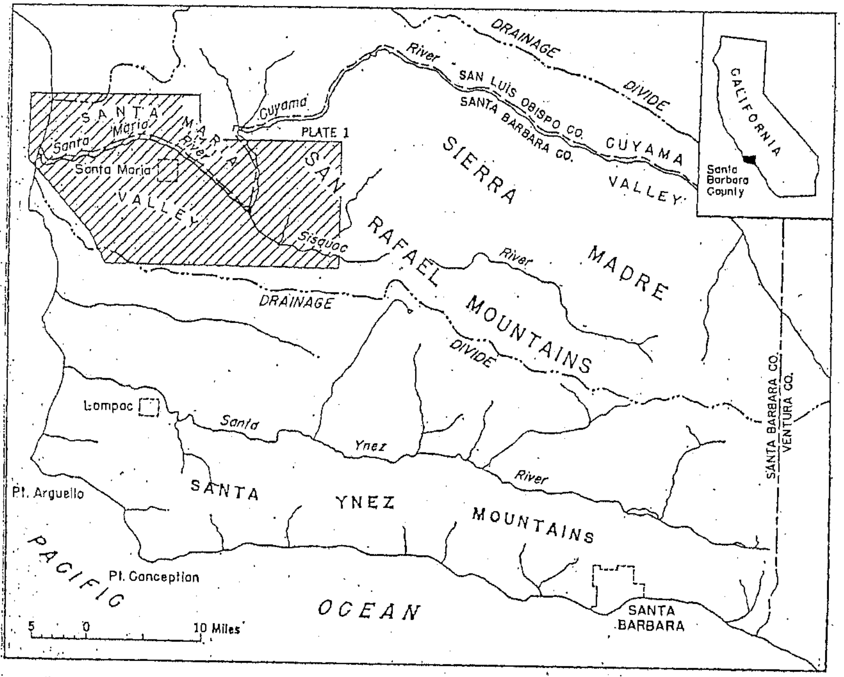

FIGURE 1.—Index map of Santa Barbara County, California, showing location of the Santa Maria River drainage system

This area comprises the alluvial plains and adjoining terraces, foothills, and mountain slopes of the Santa Maria Valley and of the lower valley of the Sisquoc River. The Santa Maria River is formed by the confluence of the Sisquoc and Cuyama Rivers at Fugler Point (pl. 1) and flows westward across a broad alluvial plain, called the Santa

Maria plain, to the Pacific Ocean. A small alluvial plain adjoins the Santa Maria plain at Fugler Point and extends up the Sisquoc River to La Brea Creek. The Cuyama River, though longer than the Sisquoc and draining a much larger area, has developed no appreciable alluvial plain within the area here considered. Bordering the Santa Maria plain on the north and south are relatively elevated terrace areas referred to as the Nipomo upland and the Orcutt upland, respectively. The Nipomo upland borders and rises gently northward to the westward extension of the San Rafael Mountains; the Orcutt upland borders and rises gently southward to the Solomon and Casmalia Hills. Most of the plains, and little of the upland areas, are extensively cultivated and represent the largest single agricultural district in Santa Barbara County.

Between the mountains, which are composed mainly of consolidated rocks, the uplands and alluvial plains as a whole are underlain by a large mass of unconsolidated deposits which contain a single, large, ground-water body. This body, herein designated the main water body, supplies water to more than 700 irrigation, public supply, and industrial wells whose aggregate net draft in 1944 was about 65,000 acre-feet.

HISTORY AND CULTURAL DEVELOPMENT

The principal community in the area is the city of Santa Maria (originally named Central City), founded in 1876, and situated on the Santa Maria plain 12 miles from the coast. It lies astride U. S. Highway 101 at its junctions with State Highway 166. Nine miles to the west is the town of Guadalupe, founded in 1872, and situated on State Highway 1 and on the coastal line of the Southern Pacific railroad, which was completed in 1901. The Santa Maria Valley Railroad connects Santa Maria and the sugar beet refinery at Betteravia with the Southern Pacific railroad at Guadalupe. About 5 miles south of Santa Maria is the small oil town of Orcutt on State Highway 1; and 6 miles north of Santa Maria is the small agricultural community of Nipomo on U. S. Highway 101. On the plain of the Sisquoc River 9 miles southeast of Santa Maria are the small towns of Garey and Sisquoc, both on State Highway 140.

The first settlers were the Spanish in about 1840. The large land grants established thereafter are shown on plate 1. Among the larger of these are the Ranchos Guadalupe, Nipomo, Punta de la Laguna, Tepusquet, and Sisquoc. American pioneers arrived in about 1865 and since then have purchased most of the land comprising the old Ranchos. The early Spanish settlers raised mostly cattle and feed, but during the drought of 1863–64 they lost heavily and the liquidation of the large grants began.

USE OF GROUND WATER

Essentially all the irrigated acreage, the major industries, and all public water-supply systems depend upon water from wells which tap the large ground-water reservoir, or main water body. By far the greatest demand upon this reservoir is made by truck farming. Over 300 irrigation wells supply water to about 35,000 acres of land. Upon this land one or two crops of lettuce, cauliflower, carrots, or other vegetables are raised each year. In addition, alfalfa, flowers for seed, and sugar beets are raised. The sugar beets are processed at the refinery at Betteravia, which is supplied with water from a battery of 10 wells along the north edge of Guadalupe Lake.

The city of Santa Maria derives its water supply from three wells about 4 miles south of the city. Also, the towns of Guadalupe, Orcutt, Betteravia, and Sisquoc derive their water supply from wells. The towns of Garey and Nipomo have no public water-supply systems and obtain their water from domestic wells, as do the numerous farms throughout the area.

There are several major oil fields in the area as follows: the Santa Maria Valley oil field, immediately south of and extending both east and west from the city of Santa Maria; the Orcutt oil field, on the crest of the Solomon Hills due south of the town of Orcutt; and the Cat Canyon oil fields about 2 miles south of the town of Sisquoc. Most of the oil produced by the major companies is transported out of the area in crude form by truck, rail, or pipeline. However, near the city of Santa Maria there are several small refineries that process a considerable quantity of oil. Water used in the refining process and in oil-field operations is furnished entirely from wells.

Other principal industries in the area that depend upon ground-water supply are the vegetable-packing plants and the ice-manufacturing plants at Guadalupe and at Santa Maria.

PURPOSE AND SCOPE OF THE INVESTIGATION AND REPORT

The investigations of which this report is the third were begun by the Geological Survey, United States Department of the Interior, in January 1941 in cooperation with Santa Barbara County. The first two parts deal with the Santa Ynez River valley and the south-coast basins, respectively, and results are embodied in two reports by Upson and Thomasson (Upson and Thomasson, 1951; and Upson, 1951). This report gives the results of the investigation in the Santa Maria Valley area. It has been carried on by the Geological Survey, United States Department of the Interior, under the direction of O. E. Meinzer, geologist in charge of the Ground Water Branch; and under the general supervision of A. M. Piper, district geologist in charge of ground-water investigations on the Pacific coast.

The investigation was begun in 1941 with the general objectives of estimating the yield of the ground-water basin supporting irrigation, and of evaluating the possibility or presence of sea-water contamination of the ground-water bodies. The investigation was also related to broad plans[1] for the county-wide utilization of water resources, under which it is proposed to construct reservoirs on the Cuyama and Sisquoc Rivers for purposes of controlling floods, and storing or detaining flood waters that can be released for replenishment of ground-water reservoirs downstream. Thus, the investigation was also directed toward the solution of problems pertaining to the amount and distribution of runoff in the two rivers and to replenishment of ground-water bodies from them.

Accordingly, the ground-water and surface-water phases of the work had somewhat different scopes. The detailed study of the geology, ground-water conditions and resources, and river-seepage losses was restricted to the Santa Maria Valley area, as here defined and shown on plate 1; whereas the study of runoff concerned the entire drainage basins of the Cuyama and Sisquoc Rivers, a total area of about 1,600 square miles, shown on plate 4.

Specifically, this report describes the geology of the Santa Maria Valley area as it pertains to the occurrence of ground water; the report summarizes the runoff from the Cuyama and Sisquoc River drainage basins, and estimates the seepage losses to ground water in the lower Sisquoc, Cuyama, and Santa Maria River channels; it describes the occurrence, source, movement, and natural discharge of ground water; it estimates the amount of discharge, both natural and artificial; it discusses the quality of the ground water and the possibility of sea-water contamination; and it estimates the perennial yield of the ground-water basin.

The collection of basic ground-water data was begun by the Geological Survey in the spring of 1941 and has been carried on to date. Records of stream flow were made in 1903–05, and from 1929 to date. The geologic field work was begun in January 1944 and carried on intermittently until September 1945.

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[1] Water resources and utilization, Santa Maria, Santa Ynez, and related basins, U. S. Dept. Interior, Bur. Reclamation, Harry W. Bashore, Commissioner, C. E. Carey, Director of region 2: Mimeographed project planning rept. No. 2-3.1-3, pp. 27-29, June 1945.

CLIMATE

The climate of the Santa Maria Valley area is characterized by a wet and a dry season. The average annual rainfall over the area varies considerably, but in general the lowland areas receive less rain than the surrounding mountains. About 95 percent of the rainfall occurs during the seven months from October through April, during which time the heaviest rainfall originates from storms moving in from the Pacific Ocean.

The temperature varies considerably between winter and summer, but the mean annual temperature is about 60° F. During the winter temperatures below freezing are infrequent and usually occur during the night. On the other hand, the summers are mild with temperatures usually in the 70's. Only on the rare occasions when hot winds sweep seaward from the valleys of central California does the temperature approach 100° F.

The prevailing winds are from the northwest, and during the summer months these winds bring heavy fogs which extend like long white fingers into the coastal valleys. The fog usually appears in the evening and lasts until about noon the following day, at which time it is "burned off" by the sun. Because the fog acts as an insulator against heat from the sun, it is beneficial to some types of crops.

Records of rainfall and of other detailed climatological data for Santa Barbara County have been presented in another report (Upson, Water-Supply Paper 1108, in preparation). However, there are presented in table 1 records of rainfall at six stations whose locations are shown on plate 4. The records show the seasonal distribution, the monthly quantities, and the variations in quantity of rainfall with altitude.

TABLE 1.—*Monthly and yearly precipitation, in inches, at 6 stations in the Santa Maria Valley area, California*

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Santa Maria (altitude 217 feet) [1]													
84–85	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.01	0.04	0.30	-----
85–86	0	8.80	1.60	1.83	0.97	2.55	3.37	0	0	0	0	0	19.12
86–87	.06	.59	.72	.50	5.95	.25	1.07	.22	T	0	0	.30	9.66
87–88	.40	1.09	2.69	4.62	.43	1.98	.12	.14	T	T	0	T	11.47
88–89	0	2.59	5.86	.42	1.35	4.20	.97	.60	.05	0	0	0	16.04
89–90	7.53	1.80	6.71	7.02	3.64	.88	.10	.13	0	.06	0	.55	28.42
90–91	.70	.70	3.40	.63	3.57	.71	1.58	.20	0	0	0	.03	11.52
91–92	0	.33	2.77	.56	2.18	2.36	.45	1.15	T	0	0	0	9.80
92–93	.35	1.95	2.52	2.08	3.10	6.84	.80	.05	0	0	0	0	17.69
93–94	.65	.22	2.95	1.16	1.78	.62	.25	.73	.16	.06	T	1.05	9.63
94–95	.68	.07	3.86	4.43	1.22	1.25	.53	.51	0	T	0	.01	12.56
95–96	.65	1.26	.60	4.60	0	2.59	1.77	.03	0	.11	.03	.02	11.66
96–97	.60	1.82	2.34	3.55	4.00	2.52	.14	.01	0	.03	0	.10	15.11
97–98	.67	.03	.55	1.44	1.06	.65	.02	1.14	0	0	0	.96	6.52
98–99	.30	.05	.64	3.49	.46	4.88	.99	.75	0	0	0	0	11.56
99–1900	1.86	1.21	.89	.87	.05	1.41	.97	1.97	T	T	T	T	9.23
00–01	.65	5.40	.35	4.51	3.17	.25	1.82	.13	T	0	0	.12	16.40
01–02	1.60	.56	.01	1.73	4.03	2.37	1.70	.20	T	0	0	0	12.20
02–03	1.02	2.59	.79	1.80	1.91	3.97	.71	T	0	0	0	0	12.79
03–04	T	.19	.16	.55	5.39	3.06	1.73	.10	0	0	.86	2.55	14.59
04–05	1.25	.03	1.55	1.85	5.83	4.46	.69	1.58	0	.02	T	.07	17.33
05–06	.15	1.37	.31	2.64	3.40	6.94	.55	2.39	.02	T	.01	.01	17.79
06–07	0	.63	4.35	7.78	1.02	3.95	.23	0	.04	0	0	.06	18.06
07–08	3.57	0	1.80	3.98	3.76	.35	.26	.18	0	0	0	1.03	14.93
08–09	.52	.97	.61	10.31	4.98	4.39	0	0	0	0	0	0	21.78
09–10	.75	2.14	5.89	3.47	.50	3.82	.01	0	0	T	0	.65	17.23
10–11	.72	.15	.45	6.42	3.80	6.68	1.82	0	0	T	0	T	20.04
11–12	0	0	1.77	1.34	.10	4.13	.69	1.60	0	0	0	0	9.63
12–13	0	.40	.20	2.20	1.27	.63	.42	0	.34	0	0	0	5.46
13–14	1.00	2.45	2.95	9.36	2.20	.90	0	0	0	0	0	0	18.85
14–15	0	0	5.40	4.05	6.31	.54	1.11	1.52	0	0	0	0	18.93
15–16	0	.60	3.31	8.95	2.12	1.49	.19	0	0	0	0	2.51	19.17
16–17	1.92	.52	4.15	2.53	2.01	.50	.11	.23	0	0	0	0	11.97
17–18	.09	0	.31	.53	9.39	5.87	0	0	0	0	0	0	16.19
18–19	.63	3.55	1.46	.68	2.36	1.57	0	.74	0	0	0	.41	11.40
19–20	0	.15	1.88	.24	1.78	4.02	1.12	0	0	0	0	0	9.19
20–21	.73	.94	1.24	3.13	1.65	1.57	.32	1.45	.01	0	0	.44	11.48
21–22	.05	.13	5.32	4.90	2.97	2.50	.22	.35	0	0	0	0	16.44
22–23	.32	1.34	3.59	1.91	1.06	.18	3.97	.05	.01	.01	0	.22	12.66
23–24	.30	0	.62	.64	.46	3.01	1.00	.01	0	0	.03	.04	6.11
24–25	.76	.78	1.85	2.56	1.67	3.28	2.34	1.71	.05	.02	.01	.01	15.04
25–26	.16	.12	1.81	1.72	2.99	.41	2.68	.11	.01	.02	.01	.04	10.08
26–27	.55	3.37	.91	1.88	5.21	2.10	1.26	.06	.20	.02	.01	.02	15.59
27–28	3.08	.81	3.80	.22	2.51	3.99	.19	.71	0	T	.01	.02	15.34
28–29	.04	2.31	2.16	2.28	1.22	1.61	.94	0	.16	T	T	.01	10. 7
29–30	.02	T	.15	3.42	1.18	2.70	.94	.68	.08	0	T	.16	9.33
30–31	.02	1.55	T	4.16	1.13	.28	.42	.94	.06	.01	0.31	.09	8.97
31–32	.04	2.46	6.56	4.25	2.14	.31	.31	.26	.04	.02	.02	.07	16.48
32–33	.09	.09	1.31	6.08	.30	.94	.18	.38	1.96	T	T	.02	11.35
33–34	.32	.03	2.91	1.11	1.52	.20	T	.26	1.30	.01	.01	.01	7.68
4–35	3.14	2.19	1.78	4.16	1.64	3.11	3.09	0	0	.01	.26	.17	19.55
5–36	.50	2.02	1.71	1.31	5.32	1.23	1.06	.13	.03	.02	.01	.14	13.48
6–37	1.83	T	5.69	3.59	4.83	4.65	.22	0	0	.01	0	0	20.82
7–38	.16	.26	2.88	4.72	7.39	4.09	2.01	.04	.02	T	.02	.59	22.18
8–39	.18	.23	1.53	3.25	2.18	2.39	.22	.03	0	0	0	1.50	11.51

See footnotes at end of table.

TABLE 1.—*Monthly and yearly precipitation, in inches, at 6 stations in the Santa Maria Valley area, California*—Continued

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Santa Maria (altitude 217 feet)—Continued													
39–40	0. 46	1. 03	1. 30	5. 41	2. 67	1. 98	1. 74	0	0	0	T	0. 02	14. 61
40–41	. 73	. 12	5. 25	5. 04	6. 83	8. 72	3. 86	. 07	T	. 09	. 03	. 01	30. 74
41–42	1. 04	. 32	7. 50	1. 78	1. 30	2. 04	2. 82	. 11	0	0	. 02	. 02	16. 95
42–43	. 82	. 84	2. 94	7. 23	1. 27	3. 04	1. 06	. 02	0	0	0	T	17. 22
43–44	1. 05	. 47	3. 09	1. 32	4. 69	1. 36	2. 46	. 11	. 01	0	0	0	14. 56
44–45	. 12	2. 26	1. 90	. 61	2. 87	3. 27	. 11	. 04	. 11	0	. 02	T	11. 31
60-year average	. 74	1. 13	2. 39	3. 15	2. 70	2. 54	. 99	. 40	. 08	. 01	. 03	. 24	14. 40
16-year average, 1930–45	------	------	------	------	------	------	------	------	------	------	------	------	15. 42
Betteravia (altitude 155 feet)[2]													
96–97	------	------	------	------	------	------	------	------	------	------	------	0. 10	------
97–98	0. 67	0. 03	0. 55	1. 44	1. 06	0. 65	0. 02	1. 14	0	0	0	. 96	6. 52
98–99	. 30	. 05	. 64	3. 49	. 52	3. 88	1. 02	. 44	0	0	0	0	10. 34
99–1900	1. 36	1. 02	. 73	. 83	. 13	1. 94	. 67	1. 10	0	0	0	0	7. 78
00–01	. 47	3. 53	. 11	3. 96	2. 75	. 31	1. 53	. 45	0	0	. 03	0	13. 14
01–02	1. 77	. 74	------	1. 47	4. 03	2. 34	1. 92	. 04	0	0	0	0	------
02–03	. 81	1. 75	1. 00	1. 76	1. 87	3. 36	. 87	0	0	0	0	0	11. 42
03–04	0	. 08	. 15	. 38	3. 84	2. 38	1. 20	. 10	0	0	. 18	2. 44	10. 75
04–05	1. 32	0	1. 30	1. 95	6. 12	4. 46	. 49	2. 00	0	. 03	0	. 10	17. 77
05–06	0	1. 36	. 29	3. 25	3. 21	6. 39	. 73	2. 30	0	0	0	. 12	17. 65
06–07	0	. 73	4. 59	8. 60	. 68	3. 82	. 19	. 10	0	0	0	. 11	18. 82
07–08	. 95	0	2. 33	4. 54	3. 86	. 23	. 24	. 18	0	0	0	1. 02	13. 35
08–09	. 40	. 98	. 66	13. 27	6. 73	5. 03	0	0	0	0	0	0	27. 07
09–10	. 54	1. 70	6. 72	2. 38	. 25	3. 52	. 15	0	0	. 08	0	. 49	15. 83
10–11	. 63	. 32	. 42	7. 47	4. 52	5. 89	1. 10	. 08	0	0	0	0	20. 43
11–12	0	. 19	1. 91	1. 44	. 14	3. 50	1. 18	1. 19	0	0	0	. 08	9. 63
12–13	. 02	. 42	. 25	2. 86	1. 66	. 60	. 48	. 15	. 36	0	. 97	0	7. 77
13–14	0	2. 32	3. 40	10. 30	3. 04	1. 06	. 24	0	. 10	T	0	T	20. 46
14–15	0	. 71	4. 85	4. 82	7. 08	. 20	1. 04	1. 35	0	0	0	0	20. 05
15–16	0	. 57	3. 74	7. 86	1. 20	1. 33	. 10	0	0	0	0	2. 09	16. 89
16–17	1. 78	4. 9	6. 06	1. 69	3. 29	. 37	. 07	. 26	0	0	0	0	14. 01
17–18	. 08	0	. 36	. 36	9. 44	7. 13	. 05	0	0	0	. 12	. 08	17. 62
18–19	. 63	1. 66	1. 94	. 54	3. 08	1. 62	. 15	. 47	0	0	0	. 21	10. 30
19–20	. 17	. 12	1. 99	. 18	1. 43	4. 16	. 76	0	0	0	0	0	8. 81
20–21	. 65	1. 08	1. 54	3. 11	1. 96	1. 60	. 32	1. 45	. 02	0	0	. 49	12. 22
21–22	. 12	. 17	3. 68	3. 62	3. 27	2. 54	. 31	. 47	0	0	0	0	14. 18
22–23	. 45	1. 16	3. 34	1. 87	1. 39	. 09	4. 66	0	. 07	0	0	. 18	13. 21
23–24	. 10	. 10	. 54	. 90	. 38	3. 21	1. 04	0	0	0	T	0	6. 27
24–25	. 69	. 56	1. 84	1. 73	1. 72	3. 79	2. 24	1. 36	. 11	0	0	0	14. 04
25–26	. 15	. 26	2. 06	2. 62	3. 08	. 64	2. 15	. 05	0	0	0	0	11. 01
26–27	. 63	3. 37	. 98	1. 75	5. 37	1. 99	. 46	. 03	. 06	0	0	0	14. 64
27–28	2. 14	1. 01	3. 88	. 19	2. 70	2. 28	. 16	. 61	0	0	0	0	12. 97
28–29	0	2. 26	2. 57	2. 02	1. 33	1. 67	. 74	0	. 16	0	0	0	10. 75
29–30	0	0	. 08	3. 86	1. 19	2. 80	. 94	. 49	. 07	0	T	. 28	9. 71
30–31	0	1. 55	T	4. 18	1. 43	. 16	. 56	. 57	0	0	. 67	0	9. 12
31–32	. 11	2. 24	6. 56	3. 25	3. 26	. 23	. 09	. 14	0	0	0	. 35	16. 23
32–33	0	. 06	1. 29	6. 16	. 39	. 93	. 20	. 25	1. 80	0	. 11	0	11. 19
33–34	. 30	0	2. 49	1. 07	1. 80	. 29	0	. 03	. 60	0	0	T	6. 58
34–35	1. 84	2. 18	1. 58	3. 92	1. 25	3. 23	2. 68	0	0	T	. 40	. 25	17. 33
35–36	. 35	2. 03	1. 44	1. 20	5. 20	1. 55	. 72	. 02	. 13	. 11	. 07	. 11	12. 93

See footnotes at end of table.

TABLE 1.—*Monthly and yearly precipitation, in inches, at 6 stations in the Santa Maria Valley area, California*—Continued

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Betteravia (altitude 155 feet)—Continued													
936–37	1. 31	0	5. 84	3. 28	3. 93	3. 76	0. 34	0	0	0	0	0	18. 46
937–38	. 33	. 41	2. 79	4. 38	6. 49	4. 01	1. 42	0	0	0	0	. 93	20. 76
938–39	. 31	. 31	1. 79	3. 56	1. 99	2. 77	. 40	. 04	T	T	0	2. 01	13. 18
939–40	. 53	. 86	1. 50	3. 96	2. 76	1. 89	. 54	0	0	0	T	0	12. 04
940–41	. 62	. 16	5. 16	5. 09	7. 48	7. 55	3. 03	. 07	0	. 04	. 09	0	29. 29
941–42	1. 04	. 32	6. 80	1. 93	1. 19	2. 16	2. 26	. 15	0	0	T	0	15. 85
942–43	1. 05	. 71	1. 68	6. 39	1. 24	2. 20	1. 08	T	0	0	0	0	14. 35
943–44	1. 05	. 22	3. 20	1. 29	5. 00	. 66	1. 59	. 09	0	0	0	0	13. 10
944–45	. 32	2. 03	1. 73	. 87	2. 43	3. 76	. 09	0	. 16	0	0	0	11. 39
47-year average	------	------	------	------	------	------	------	------	------	------	------	------	13. 98
16-year average, 1930–45	------	------	------	------	------	------	------	------	------	------	------	------	14. 47
Suey Ranch (altitude 500 feet) [2]													
908–09	------	------	------	------	------	------	------	------	------	0	0	0	------
909–10	0	2. 62	5. 11	4. 90	0. 75	3. 83	0. 53	0	0	0	0	. 80	18. 54
910–11	. 63	. 45	. 18	8. 55	4. 00	7. 25	1. 10	0	0	0	0	0	22. 16
911–12	0	. 24	2. 10	1. 90	0	4. 68	1. 12	1. 83	0	0	0	0	11. 87
912–13	0	. 87	0	2. 50	1. 54	. 90	. 25	. 13	. 10	. 15	1. 90	0	8. 34
913–14	0	3. 63	3. 05	11. 75	2. 15	1. 15	. 10	. 05	. 25	0	0	0	22. 13
914–15	0	0	5. 68	5. 72	6. 80	. 38	2. 40	1. 35	0	0	0	0	22. 33
915–16	0	. 22	3. 56	10. 65	1. 00	1. 72	0	0	0	0	0	2. 05	19. 20
916–17	1. 81	. 44	5. 75	1. 75	2. 27	0	. 63	. 18	0	0	0	0	12. 83
917–18	0	. 18	. 25	. 85	11. 98	4. 34	0	0	0	0	0	. 25	17. 85
918–19	. 40	2. 52	. 53	. 45	2. 77	1. 76	. 06	. 61	0	0	0	. 60	9. 70
919–20	. 01	. 37	2. 44	. 40	1. 84	3. 59	1. 16	0	0	0	0	0	9. 81
920–21	. 70	1. 15	1. 93	3. 19	2. 09	1. 46	. 27	1. 37	0	0	0	. 17	12. 33
921–22	. 26	0	4. 90	3. 95	2. 76	2. 57	. 21	. 44	0	0	0	0	15. 09
922–23	0	2. 08	3. 87	2. 55	1. 23	. 22	4. 42	0	0	0	0	. 51	14. 88
923–24	0	. 30	. 59	. 51	. 40	3. 51	. 78	0	0	0	0	0	6. 09
924–25	1. 08	1. 17	1. 68	1. 89	2. 24	2. 77	2. 86	1. 58	. 22	0	0	0	15. 49
925–26	. 30	1. 30	1. 05	1. 79	4. 26	. 27	2. 70	0	0	0	0	0	11. 67
926–27	. 53	2. 43	. 55	1. 79	5. 21	2. 17	1. 13	0	0	0	0	0	13. 81
927–28	2. 86	1. 00	3. 69	. 15	2. 22	4. 30	1. 75	0	0	0	0	0	15. 97
28–29	. 14	3. 10	1. 22	1. 90	1. 40	1. 54	. 75	0	. 22	0	0	0	10. 27
29–30	0	0	. 22	3. 58	1. 43	3. 01	. 55	1. 38	. 30	0	0	0	10. 47
30–31	0	1. 71	0	3. 96	1. 39	. 27	. 27	1. 28	0	0	0	0	8. 88
31–32	0	2. 99	6. 70	3. 07	3. 55	. 67	. 67	. 27	0	0	0	0	17. 92
32–33	0	. 22	1. 20	6. 07	. 20	. 80	. 19	. 09	2. 53	0	0	0	11. 30
33–34	0	0	3. 28	1. 09	2. 10	. 83	0	0	1. 44	9	0	0	8. 74
34–35	2. 17	4. 98	2. 01	3. 94	1. 39	3. 44	2. 62	0	0	0	0	0	20. 55
35–36	. 60	2. 28	1. 24	1. 13	5. 14	1. 32	1. 23	. 20	0	0	0	0	13. 14
36–37	1. 33	0	6. 30	3. 51	4. 62	4. 32	. 47	0	0	0	0	0	20. 55
37–38	. 17	. 26	3. 11	4. 40	7. 74	5. 36	2. 10	0	0	0	0	. 46	23. 60
38–39	. 19	. 20	1. 62	3. 38	2. 39	2. 25	. 32	. 02	0	0	0	. 88	11. 25
39–40	. 62	1. 06	1. 58	6. 18	3. 16	1. 64	1. 74	0	0	0	0	0	15. 98
40–41	. 72	. 04	5. 34	4. 37	8. 46	7. 36	3. 65	. 08	0	. 14	. 11	0	30. 27
41–42	. 86	. 28	7. 39	1. 69	1. 34	1. 46	4. 08	. 42	0	0	0	0	17. 52
42–43	. 64	1. 05	3. 55	7. 02	1. 26	3. 93	1. 62	0	0	0	0	0	19. 07
43–44	1. 14	. 31	3. 55	1. 77	5. 35	. 84	1. 49	. 15	0	0	0	0	14. 60
44–45	. 40	1. 99	1. 74	. 56	3. 47	3. 66	. 09	. 04	. 10	0	T	. 02	12. 07
36-year average	------	------	------	------	------	------	------	------	------	------	------	------	15. 17
16-year average, 1930–45	------	------	------	------	------	------	------	------	------	------	------	------	15. 99

See footnotes at end of table.

TABLE 1.—*Monthly and yearly precipitation, in inches, at 6 stations in the Santa Maria Valley area, California*—Continued

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Sisquoc Ranch (altitude 600 feet) [2]													
903–04	------	------	------	0.99	4.43	3.81	2.73	0.10	T	0	1.30	3.73	------
904–05	1.00	0.05	1.78	1.42	6.63	8.71	.75	2.10	0	0	0	.01	22.45
905–06	.27	1.10	0	2.70	5.02	8.76	.52	1.30	0	0	0	0	19.67
906–07	0	.25	4.86	11.79	1.48	3.48	0	0	.10	0	0	0	21.96
907–08	3.73	0	1.38	4.97	4.18	.34	.32	0	0	0	0	1.90	16.82
908–09	1.13	1.25	1.66	15.80	7.63	5.15	0	0	0	0	0	T	32.62
909–10	.95	2.09	8.42	2.15	.45	4.14	0	0	0	.10	0	1.09	19.39
910–11	.36	.10	.55	7.85	4.34	11.11	.48	0	0	0	0	T	24.79
911–12	0	.17	1.40	.80	0	5.46	1.92	.41	0	0	0	0	10.16
912–13	0	.36	.20	1.89	2.87	.74	0	0	.38	0	1.02	.10	7.56
913–14	0	2.28	2.37	11.06	4.02	.96	0	0	.41	0	0	0	21.10
914–15	0	T	4.77	4.33	8.60	.83	1.11	1.32	0	------	------	------	[3] 20.96
931–32	------	------	------	------	------	------	------	------	------	------	------	------	[3] 10.29
932–33	------	------	------	------	------	------	------	------	------	------	------	------	[3] 20.15
933–34	------	------	------	------	------	------	------	------	------	------	------	------	[3] 12.41
934–35	------	------	------	------	------	------	------	------	------	------	------	------	[3] 8.56
935–36	------	------	------	------	------	------	------	------	------	------	------	------	[3] 6.27
936–37	------	------	------	------	------	------	------	------	------	0	0	0	[3] 21.30
937–38	0	.42	3.08	4.59	8.43	4.89	1.60	0	0	0	0	1.17	24.18
938–39	0	0	2.82	0	2.41	0	0	0	0	0	0	1.70	6.93
939–40	0	.85	1.95	6.66	2.82	2.44	2.22	0	0	0	0	0	16.94
940–41	.94	.19	5.49	8.21	8.93	8.41	4.52	0	0	0	0	.20	36.89
941–42	1.01	.36	8.32	1.57	.56	2.13	3.62	0	0	0	0	0	17.57
942–43	.76	1.42	3.54	5.68	1.75	3.46	1.35	0	0	0	0	0	17.96
943–44	.93	.18	3.58	1.66	7.04	.80	1.48	.10	0	0	0	0	15.77
944–45	.41	3.64	1.73	0	4.05	3.75	.13	.05	0	0	0	0	13.76
25-year average													17.86
Guadalupe (altitude 100 feet) [2]													
919–20	------	------	------	------	------	------	------	------	------	0	0	0	------
920–21	0.43	0.54	1.59	1.38	2.33	0.64	0.32	1.46	0	0	0	.44	9.13
921–22	.05	.65	5.31	3.90	2.97	2.50	.22	.35	0	0	0	0	15.95
922–23	.33	1.66	3.58	1.91	1.06	.18	3.97	.05	0	0	0	.23	12.97
923–24	.12	.06	.62	.63	.50	3.14	1.00	.01	0	0	0	.06	6.14
924–25	.76	.78	1.85	2.56	1.34	3.61	2.09	1.71	.05	.02	.01	.01	14.79
925–26	.16	.07	1.81	1.72	2.99	.23	------	------	------	------	------	------	------
929–30	------	------	------	------	------	------	------	------	------	------	------	.36	------
930–31	0	1.13	0	4.26	1.33	.14	.36	.55	0	0	.51	0	8.28
931–32	.06	2.56	5.88	3.41	2.56	.05	.10	.30	.05	0	0	.05	15.02
932–33	0	.07	1.22	5.45	.45	.61	.10	.27	1.53	0	0	0	9.70
933–34	.41	0	3.20	0	1.75	.19	.05	.04	.94	0	0	.07	6.65
934–35	1.67	1.73	1.19	4.39	1.09	3.22	3.12	0	0	0	.31	.17	16.89
935–36	.33	1.83	1.31	1.10	5.39	1.47	.55	.70	.25	.13	0	.10	13.16
936–37	1.21	0	4.76	2.97	3.10	3.90	.27	0	0	0	0	0	16.21
937–38	.12	.27	2.24	4.24	6.17	3.26	1.28	.03	0	0	0	.58	18.19
938–39	.35	.32	1.38	3.08	1.61	2.07	.32	.05	0	0	0	1.27	10.45
939–40	.75	.90	1.19	3.39	2.00	1.39	.35	0	0	0	0	0	9.97
940–41	.39	.16	3.98	4.95	6.04	5.86	2.68	0	0	0	0	0	24.06
941–42	1.06	.20	6.75	1.20	.69	1.22	2.28	.08	0	0	.01	0	13.49
942–43	.72	.42	1.42	4.52	1.00	1.48	.97	0	0	0	0	0	10.53
943–44	.91	.32	2.70	1.13	3.92	.27	1.24	.09	0	0	0	0	10.58
944–45	.05	1.47	1.45	.40	3.44	2.46	0	0	0	0	.02	.39	9.68
20-year average													12.59
Nipomo (altitude 330 feet) [2]													
919–20	------	------	------	------	------	------	------	------	------	0	0	0	------
920–21	0.70	1.02	1.90	3.36	1.69	1.46	0.20	1.94	0	0	0	.51	12.78
921–22	.12	.05	4.73	3.69	3.47	3.21	.25	.42	0	0	0	0	15.94
922–23	.54	2.27	4.23	2.30	.95	.18	4.97	0	.09	0	0	.42	15.95
923–24	.11	.28	.31	.85	.50	3.45	.61	0	0	.14	0	0	6.25

See footnotes at end of table.

TABLE 1.—*Monthly and yearly precipitation, in inches, at 6 stations in the Santa Maria Valley area, California*—Continued

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Nipomo (altitude 330 feet) [2]—Continued													
924–25	1.25	0.82	1.87	2.63	2.44	2.13	2.00	2.32	0.17	0	0	0	15.63
925–26	.30	.20	2.69	1.76	3.84	.32	2.41	.08	0	0	0	0	11.60
926–27	.64	4.02	.92	1.85	5.41	1.39	1.50	.12	.26	0	0	0	16.11
927–28	2.62	1.55	4.01	.18	3.84	4.12	.15	.75	0	0	0	0	17.22
928–29	0	2.20	3.74	1.63	1.77	1.50	.81	0	.21	0	0	0	11.86
929–30	0	0	.17	3.95	1.78	2.63	.52	.44	0	0	0	.30	9.79
930–31	0	1.42	0	4.28	1.22	.47	.62	1.40	.07	0	.25	0	9.73
931–32	.36	2.95	7.63	2.91	3.43	.26	.40	.18	0	0	0	0	18.12
932–33	0	.05	1.08	6.38	.28	1.31	.08	.36	1.65	0	0	0	11.19
933–34	0	.30	2.69	1.06	3.11	0	0	0	.90	0	0	0	8.06
934–35	1.61	4.46	2.26	5.69	1.34	3.92	3.51	0	0	0	.65	0	23.44
935–36	.70	1.84	1.79	2.21	7.43	1.45	0	0	0	0	0	0	15.42
936–37	1.89	0	5.05	3.71	6.08	4.15	.14	0	0	0	0	0	21.02
937–38	0	.41	4.75	2.45	7.67	5.32	1.60	.03	0	0	0	.55	22.78
938–39	.15	.38	1.53	3.16	2.52	2.64	.41	0	0	0	0	.40	11.19
939–40	1.19	.96	1.75	6.53	4.35	1.12	1.59	0	0	0	0	0	17.49
940–41	.63	.23	6.45	5.41	7.25	7.45	3.67	0	0	0	0	0	31.09
941–42	.95	.30	8.57	1.97	1.16	1.63	3.91	.37	0	0	0	0	18.86
942–43	.62	1.24	2.86	6.91	1.40	4.37	.88	0	0	0	0	0	18.28
943–44	.99	.30	3.90	1.28	4.82	.61	1.52	0.15	0	0	0	0	13.57
944–45	0	3.09	1.76	.24	5.31	3.96	.10	.12	0	0	.58	0	15.16
25-year average	----	----	----	----	----	----	----	----	----	----	----	----	15.54
16-year average, 1930–45	----	----	----	----	----	----	----	----	----	----	----	----	16.57

[1] Data from publications of the U. S. Weather Bureau.
[2] Data from compilation by the U. S. Bureau of Reclamation.
[3] Total for season ending June 30.
T=.005 inch or less of rain or melted snow.

PREVIOUS INVESTIGATIONS

The geology of the Santa Maria Valley area was first observed casually in the early 1850's during the explorations and surveys for the Pacific Railroad. Other examinations of a reconnaissance type were made in the latter part of the 19th century. H. W. Fairbanks (1904) presented a comprehensive report on the geology of the San Luis quadrangle, and in his work touched upon the general geologic features of the Santa Maria Valley area. These general geologic features are shown on the California geologic map (Jenkins, 1938), and have been described by Reed (1933).

Arnold and Anderson (1907) were among the first men to study the geology to determine the oil resources of the area. In that, and in subsequent reports of a similar nature, particular emphasis was placed on the potential and proved oil-producing structures and the reservoir rocks near and beneath the Santa Maria Valley. These studies have been made in recent years by Frame (1938), Canfield (1939), and Woodring (Woodring, Bramlette, and Lohman, 1943). Also, summaries of the local oil fields have been presented in a report by the California Division of Mines (1943, pp. 235–238 and 430–442).

The only hydrologic report on the area is one the late J. B. Lippincott [2] submitted to the Santa Barbara County in 1931. In addition to the hydrologic study, the report deals with the feasibility of building dams across the Cuyama and Sisquoc Rivers for the dual purpose of flood control and water conservation.

ACKNOWLEDGMENTS

The writer is grateful for the cooperation and assistance given by many persons and several agencies in the Santa Maria Valley area. The Santa Maria Valley Water Conservation District made available records of water-level measurements, drillers' logs, and chemical analyses. In addition, this organization supplied the map of the area from which the base for plate 1 was compiled. Information on the subsurface geology of the area was obtained from numerous oil-well logs and other data supplied by Mr. L. N. Waterfall, Mr. A. W. Hughes, and Mr. Charles Manlove of the Union Oil Co. of California, and by Mr. S. G. Dolman of the California State Division of Oil and Gas. Mr. G. V. Footman, District Manager, and other officials of the San Joaquin Power Division of the Pacific Gas & Electric Co. gave freely of their time in supplying records of power consumption, pump tests, and water-level measurements. Dr. M. G. Edwards of the Shell Oil Co. of California furnished chemical analyses of well waters.

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[2] Lippincott, J. B., Report on water conservation and flood control of the Santa Maria River in Santa Barbara and San Luis Obispo Counties, Calif., March 1931 (unpublished report available to the public at the offices of the County Planning Commission, Santa Barbara, Calif.).

Mr. York Peterson, engineer of the city of Santa Maria, and Mr. A. A. Howard, water plant superintendent, furnished records of water-level measurements and of pumpage for the city pumping plant.

Valuable information and time were donated by Mr. C. J. Longwell, a water-well driller, and Mr. W. C. Matthews, Byron-Jackson pump dealer, both of whom supplied many water-well logs. The cooperation and support given by ranchers and residents were greatly appreciated.

The portion of the geology shown on plate 1 and lying south of the Santa Maria and Sisquoc Rivers is in large part after Woodring (Woodring, Bramlette, and Lohman). Much valuable information is presented in Lippincott's [3] report, and it has been of great value in analyzing the hydrologic conditions of the area.

The writers acknowledge the advice and criticism of their colleagues of the Geological Survey in the preparation of this report. The report as a whole was improved by J. F. Poland and J. E. Upson, the section on quality of water was amended by A. A. Garrett, and the section on pumpage was improved by Penn P. Livingston, all members of the Ground Water Branch. The section on surface-water resources was improved by H. M. Stafford of the Surface Water Branch.

GEOLOGY

LAND FORMS

The Santa Maria Valley area is primarily the topographic expression of underlying geologic structures modified by the action of streams and rivers. The valley area overlies a broad downfold, or syncline; the bordering hills and mountains are the surface expression of anticlines or regional uplifts. The northwest-trending extension of the San Rafael Mountains is chiefly an uplift and forms the north border of the valley area; the Solomon and Casmalia Hills are on the axes of upfolds and form the south border. Between these ranges is the broad lowland occupied by the valleys of the Sisquoc and Santa Maria Rivers. This is the agricultural district and has a somewhat varied topography, many of whose features reveal elements of the geologic history or affect the occurrence and utilization of ground water.

LOWLANDS

Alluvial plains.—There are two major alluvial plains in the area, one in the Santa Maria Valley and the other in the Sisquoc valley, and they are herein designated the Santa Maria plain and the Sisquoc plain, respectively (pl. 1). Along the Cuyama River, owing to its constriction in a relatively narrow consolidated rock gorge within the area, are only small remnants of an alluvial plain, which are relatively unimportant by comparison with those of the valleys of the Santa Maria and Sisquoc Rivers.

The Santa Maria plain extends from Fugler Point on the east to the sand dunes and the Pacific Ocean on the west—a distance of about 20 miles. It includes the wedge-shaped part of the alluvial plain lying northwest of the river in San Luis Obispo County, which is known locally as the Oso Flaco district. The plain attains a maximum width of more than 5 miles in the vicinity of Guadalupe and has an area of about 36,000 acres. It is a gently inclined, nearly level surface, which reaches a maximum elevation of 350 feet at Fugler Point and has an average westward gradient of about 17 feet per mile. It is the principal irrigated agricultural district in the area, and is supplied with water by nearly 300 irrigation wells.

Along the south side of the plain, and extending from U. S. Highway 101 to the mouth of the Santa Maria River, is an old channel of the river known as Green Canyon (pl. 1). Because it has been an inactive channel during historic time and, further, because it has been under cultivation for many years, it is herein considered as a part of the alluvial plain.

The Sisquoc plain begins at La Brea Creek, at an elevation of about 540 feet, and extends downstream along the south side of the river to Fugler Point—a distance of about 8 miles. It has a maximum width of about 3,500 feet in the vicinity of the town of Sisquoc, is a relatively flat surface which has a gradient of about 24 feet per mile, and slopes slightly both downstream and toward the river. The surface area is a little more than 2,000 acres, most of which is irrigated by 17 wells.

River channels.—The Sisquoc, Cuyama, and Santa Maria Rivers all maintain relatively wide and distinct channels within the limits of the area (pl. 1). The Sisquoc and Cuyama Rivers join at Fugler Point to form the Santa Maria River. Their channels are essentially dry washes supporting little or no vegetation; they have appreciable flow only during the wet winter months, and then mainly during floods.

The Santa Maria River channel is approximately 22 miles long and has an average seaward gradient of about 15½ feet per mile. The lower courses of the Cuyama and Sisquoc Rivers have gradients of about 19 and 24 feet per mile, respectively. The channels range in width from a minimum of 750 feet at the mouth of the Cuyama River to a maximum of 7,000 feet northwest of Santa Maria. The combined surface area of the Sisquoc and Santa Maria River channels is about 11,000 acres—about one-quarter of that of the adjacent alluvial plains.

The surface of the channels of the Sisquoc River and of most of the Santa Maria River is only 3 to 5 feet below the surface of the alluvial

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[3] Lippincott, J. B., op. cit., 1931.

plains, and in times of extreme flood the rivers extend laterally onto the plains, causing extensive property damage and depositing silt and sand over the arable land. For example, during the flood of February 9, 1915, the water extended into the city of Santa Maria. Near Guadalupe, however, the Santa Maria River has entrenched itself from 10 to 20 feet below the surface of the plain and is usually confined by its banks.

At the western end of the Santa Maria Valley, the river formerly had two outlets to the ocean through the dune sand deposits—one through Oso Flaco Lake along the north edge of the valley, which in recent years has been blocked; the other, farther south and west of Guadalupe. The abandoned channel leaves the present channel about 3 miles upstream from Guadalupe and follows the course of Oso Flaco Creek, which drains that portion of the Santa Maria plain lying in San Luis Obispo County, and which empties into Oso Flaco Lake (pl. 1). Because the creek has insufficient discharge to maintain an opening to the sea, drainage from the lake into the Pacific Ocean takes place by seepage through the sand deposits that separate them.

The present outlet of the Santa Maria River is blocked by beach sand during the summer months. The shallow lakes which form behind the beach bar are supplied with water by discharge from a minor water body (p. 74). Only during the winter months when the river is at a relatively high stage is there a direct connection between the river and the ocean.

Terrace surfaces.—The terrace surfaces occur between the alluvial plains and the bordering hills and mountains, and are often referred to locally as "mesas" or "uplands." These are stream-formed features quite distinct from but correlative with the numerous smaller remnants of marine terraces along the coast.

Inland from the ocean the terraces occur at two general levels, 40 feet and 100 feet above the adjoining alluvial plains, and they are hereafter referred to as the 40-foot terrace and the 100-foot terrace, respectively. Of the two, the 40-foot terrace is the younger, the better developed, and the more widespread. In the canyon of the Sisquoc River it is locally over 50 feet above the river channel. The 100-foot terrace is less extensive and is poorly developed; it is best observed southeast of Nipomo. However, west of Nipomo Creek it is covered by dune sand.

South of the Santa Maria plain the surfaces of the two terraces plus the large area of dune sand together form the Orcutt upland. North of the Santa Maria plain the large area of dune sand and the 100-foot terrace together form the Nipomo upland (pl. 1).

Fairbanks (1904, pp. 12 and 13) noted remnants of 10 marine terraces at heights of 10, 40, 60, 80, 100, 200, 350, 570, 700, and 750 feet above sea level. Of these the 40-foot and 100-foot terraces are probably the marine equivalents of the alluvial terraces in the Santa Maria Valley area.

Sand dunes.—The sand dunes on the Nipomo and Orcutt uplands and at the west end of the Santa Maria plain form another prominent topographic feature of the area. The sand dunes form a very irregular but typical topography. The prevailing northwest wind is and has been the controlling agent in their formation and has elongated them in a northwest-southeast pattern, with numerous narrow closed drainage basins lying parallel to and contained between the ridges. The dunes have gentle slopes on the northwest or windward side and steep slopes on the southeast side, where the drifting sand spills over onto the lee side of the dunes. When the wind is blowing hard the rate of sand spilling over the lee side of the active or modern dunes becomes rapid and the dunes are said to be "moving" or "drifting." In this manner the dunes have "moved" inland from the beach and are continuing to do so.

BORDERING HILLS AND MOUNTAINS

San Rafael Mountains.—The most prominent mountain range in Santa Barbara County is the San Rafael Mountains. Big Pine Mountain, which rises to an altitude of 6,828 feet, is the highest peak in the range and also the highest peak in the county. It is about 30 miles east-southeast of the area. From Big Pine Mountain the crest of the range decreases in altitude gradually northwestward. It forms the northern boundary of the Santa Maria Valley area, and there has an altitude of 1,700 to 3,000 feet.

The core of the range, which is composed of old and resistant rocks, is highly dissected and is characterized by deep ravines and knife-edge ridges jutting off at sharp angles to the axis of the range. This jagged topography is further emphasized by large fault escarpments. Adjacent to the area, however, the topography is less rugged for in general the rocks are younger and less resistant. Plate 1 shows four major streams heading in the range. From east to west they are La Brea and Tepusquet Creeks, which are tributaries of the lower Sisquoc River; and Suey and Nipomo Creeks, which are tributaries of the Santa Maria River.

The courses of the Sisquoc and Cuyama Rivers are outstanding physiographic anomalies. The Cuyama River, which flows in a westerly direction on the north side of the Sierra Madre and the San Rafael Mountains (pl. 4), turns southward immediately below its junction with Huasna Creek and crosses the axes of the ranges to join the Sisquoc River at Fugler Point. The Sisquoc River flowing westward heads between the two ranges and crosses the San Rafael Mountains at an oblique angle east of the area shown on plate 1. Consequently, the drainage area of the rivers covers parts of both the north and south sides of the Sierra Madre and the San Rafael Mountains. No part of the Sisquoc drainage area is north of the Sierra Madre.

Casmalia and Solomon Hills.—The Casmalia and Solomon Hills, whose crests form the southern drainage divide of the area, are essentially one continuous range of hills extending westward from their junction with the San Rafael Mountains near Foxen Canyon to the Pacific Ocean (pl. 4). These hills are separated by a low saddle at an altitude of 520 feet, known as Graciosa Divide.

The Solomon Hills reach a maximum altitude of about 1,620 feet south of the town of Sisquoc. The hills consist of a moderately resistant anticlinal core of Miocene and Pliocene shales whose topography is characterized by steep ravines and knife-edged ridges. The flanks are composed of relatively unconsolidated upper Pliocene and Pleistocene gravel, sand, and clay whose topography is characterized by rolling hills and moderate to deep gullies. Heads of many canyons and larger gullies are amphitheatric in shape—a feature brought about by landslides.

The Casmalia Hills are similar to the Solomon Hills in most physiographic respects. Mount Lospe is the highest peak and rises to an an altitude of about 1,640 feet—only 20 feet higher than the highest peak in the Solomon Hills. Northwest of Shuman Canyon, the Casmalia Hills veer to the northwest and older basement rocks crop out. Arnold and Anderson (1907, p. 19) describe this part of the hills as follows:

> The Casmalia Hills, particularly that portion north of Schumann [Shuman] Canyon, have a distinct individuality among the topographic features of the basin region, and may be regarded as a separate although small range allied in age and character with the bounding ranges. It is conformable in trend with the San Rafael Mountains and forms a prominent headland jutting out to sea.

This prominent headland, formed by the resistant core of the range, is Point Sal; its impressive cliffs rise as high as 1,000 feet above the sea. Both north and south of the point, wave action has eaten more rapidly into the less resistant rocks composing the flanks of the range, and cliffs are less pronounced and gradually merge with the valley plains. Although the headlands suggest a coast line of emergence the adjacent valley fills of Recent age indicate that the coast line in reality is one of submergence in Recent time.

From east to west the principal streams draining the north flanks of the Casmalia and Solomon Hills are in Foxen Canyon, Oat Canyon, *Stratigraphic units of the Santa Maria Valley area, California*

	Geologic age	Formation and symbol on plate 2	Thickness (feet)	General lithologic character	Water-bearing properties
Quaternary	Recent	Dune sand (Qs)	0–100+	Sand, coarse to fine, well rounded, and in part actively drifting.	Unconsolidated; locally yields water in very small quantity where it overlies clay or hardpan.
		------ Unconformity ------			
		River-channel deposits (Qrc)	0–25±	Coarse gravel, sand, and some silt in the channels of the Cuyama, Santa Maria, and Sisquoc Rivers. Generally finer-grained in the Santa Maria River than in the Sisquoc and Cuyama Rivers.	Unconsolidated and generally above the zone of water-table fluctuations; permeability 154 to 1,060 gallons per day per square foot determined by laboratory tests. Enormous seepage losses from Sisquoc and Santa Maria Rivers take place through these deposits.
		------ Unconformity ------			
		Alluvium (Qal)	0–230	Gravel, sand, silt, and clay of fluvial origin except locally near the coast where marine clays and sands interfinger; underlies Santa Maria and Sisquoc plains. Composed of two members which are indistinguishable in the eastern part of the area, but in the western part the upper member becomes extremely fine-grained.	Unconsolidated; yields water to wells in quantities up to 2,200 gallons per minute, but averages about 1,000. Permeability 2,000 to 4,500 gallons per day per square foot determined from well tests. Upper member confines main water body in western part of area, where it is not water yielding.
		------ Unconformity ------			
	Pleistocene	Terrace deposits (Qt)	0–75	Gravel, sand, silt, and clay of fluvial origin; occurs principally north of Sisquoc River, and on Nipomo and Orcutt uplands.	Unconsolidated, but mostly above zone of saturation of the main water body. Supplies small quantity of water to wells in Nipomo upland, where it rests on consolidated rock.
		------ Unconformity ------			
		Orcutt formation (Qc)	0–225	Gravel, sand, clay, and silt predominantly of fluvial origin. Locally has a coarse gravel and sand lower member, and a sand and clay upper member principally beneath the Orcutt upland.	Unconsolidated. Beneath the Orcutt upland the lower member is principal source of supply, and water is of the best quality in the area.
— ? —	------ ? ------	------ Unconformity ------			
Tertiary	Pliocene (upper)	Paso Robles formation (Tpr)	0–2,000±	Somewhat compacted gravel, sand, clay, and silt occurring in discontinuous, lenticular bodies underlying the alluvium and Orcutt formations throughout most of the area. Occasional thin beds of limestone near base.	Unconsolidated; yields water to wells in appreciable quantities. Permeability about 65 gallons per day per square foot near the coast, where finer-grained, but probably much more permeable in the eastern part of the area.
		---- Local unconformity ----			
		Careage sand (Tc)	100–650±	Somewhat compacted medium-grained to fine-grained, marine sand with some silt, indurated in surface exposures. Locally fossiliferous, and contains few gravel and sand lenses.	Unconsolidated; not tapped by wells, owing to caving or flowing characteristics and to depth beneath most of area. Permeability about 70 gallons per day per square foot.
	------------	---- Local unconformity ----			
	Pliocene (upper) to Miocene (lower)	Unconsolidated Tertiary rocks, undifferentiated (Tu). (Includes Foxen mudstone, Sisquoc formation and Monterey shale.)	0–10,000+	Predominantly porcelaneous and diatomaceous shale with considerable mudstone, siltstone, sandstone, siliceous shale, pyroclastic tuff, and ash, occasional basic intrusive rock, and some limestone.	Consolidated or highly compacted; essentially not water bearing except for joints or fractures. Probably supplies little water to the area. Not tapped by wells.
----	------------	---- Major unconformity ----			
Jurassic (?)		Franciscan and Knoxville (?) formation (Jfk)		Metamorphic and igneous rocks of serpentine, quartzite, glaucophane schist, and green-banded and red-banded chert associated with fine-grained green sandstone locally pyritiferous and altered, and green to black shale.	Consolidated or highly compacted; essentially not water bearing except for joints or fractures. Probably supplies little water to the area. Not tapped by wells.

Solomon, Graciosa, and Shuman Canyons. Owing to the relatively light rainfall on these hills, the runoff of the streams is ephemeral and extremely low.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

AGE AND DISTRIBUTION

For the purposes of this report, the geologic formations in the Santa Maria Valley area have been divided into two groups: Unconsolidated water-bearing deposits which are of uppermost Tertiary and Quaternary age; and consolidated and essentially non-water-bearing rocks, which underlie the unconsolidated deposits and which range in age from Jurassic to upper Tertiary. From oldest to youngest—that is, in succession upward—the unconsolidated deposits include the Careaga sand, the Paso Robles and Orcutt formations, the terrace deposits, alluvium, river-channel deposits, and dune sand. They consist largely of lenticular bodies of gravel, sand, silt, and clay. They occur in the central part, or heart of the area, in an asymmetric structural depression or synclinal trough extending from La Brea Creek to the ocean. Canfield (1939, p. 69) has designated the part of the syncline in the Santa Maria Valley as the Santa Maria Valley syncline; its axis is shown on plate 1. Along this axis, near Orcutt, the unconsolidated deposits attain a maximum thickness of about 3,000 feet and extend westward beneath and are in contact with the Pacific Ocean.

From oldest to youngest, the consolidated rocks include the Franciscan and Knoxville (?) formations, the Monterey shale and interbedded volcanics, the Sisquoc formation, and the Foxen mudstone. These consolidated rocks form the north, east, and south sides and the bottom of the ground-water basin.

Oil well logs show that the Tertiary and Quaternary rocks attain a maximum thickness of more than 10,000 feet along the axis of the Santa Maria Valley syncline near Orcutt, and that they thin with moderate rapidity up the flanks of the syncline to the north and south before cropping out in the surrounding hills and mountains.

Plate 1 shows the areal distribution of the various formations; plate 2 shows their stratigraphic and structural relations; and the following table of stratigraphic units summarizes their sequence, general characteristics, and water-bearing properties.

Because the consolidated rocks are essentially not water bearing and are important only in that they define the basal and lateral limits of the main water body and its containing deposits, they are distinguished on the geologic map and cross sections (pls. 1 and 2) only as consolidated Tertiary rocks undifferentiated, and as the Franciscan and Knoxville (?) formations. On the other hand, the unconsolidated deposits, or water-bearing formations, have been mapped carefully and the areal extent of each is shown in detail on all three plates. The more detailed stratigraphic and structural relations and the lithologic character of the water-bearing formations are shown on plate 3 which has been compiled from logs of water wells. The five geologic sections are along lines shown on plate 1.

CONSOLIDATED ROCKS

FRANCISCAN AND KNOXVILLE (?) FORMATIONS (JURASSIC?)

The oldest recognized rocks in the area are the metamorphosed igneous and sedimentary rocks of the Franciscan formation, which is of Jurassic(?) age. Closely associated with these are sedimentary and metamorphic rocks, which possibly are partly of the Knoxville formation of Jurassic(?) age. Where examined in the north-central part of the area, both formations have been moderately to intensely folded and faulted, and no effort was made to distinguish them in the field or on the geologic map (pl. 1). Woodring (Woodring, Bramlette, and Lohman, 1943, p. 1343), recognized both formations in a small area in the western part of the Casmalia Hills, and found the Franciscan formation to consist principally of altered basalt and gabbro with minor areas of peridotite and serpentine, and the Knoxville formation to consist of intercalated beds of sandstone, conglomerate, and dark-colored shale, which is locally altered to lustrous phyllite. Canfield (1939, pp. 67, 68) examined the cores from oil wells drilled in the Santa Maria oil field, and found the Knoxville formation to be composed of fractured calcite-veined hard greenish-gray pyritiferous medium-grained sandstone, highly faulted and slickensided clay-shale. A few foraminifera were found in these cores which suggest a possible Cretaceous age for a part of the rocks encountered.

Where the Franciscan and Knoxville(?) formations crop out along the north side of the Santa Maria River, they were found to consist principally of fine-grained green sandstone, thin-bedded dense greenish to red chert, and slickensided light-green to dark-green serpentine, with lesser amounts of hard gray glaucophane schist, quartzite, and green to black shale.

MONTEREY SHALE AND INTERBEDDED VOLCANIC ROCKS (MIOCENE)

The Monterey shale is separated from the underlying Franciscan and Knoxville(?) formations by a major unconformity, which at places may be a fault. No other formation is known to occur between the Monterey shale and the Franciscan and Knoxville(?) formations in the area covered by this report. However, in the western Casmalia Hills, Woodring (Woodring, Bramlette, and Lohman, 1943, 1343–1345) mapped two intervening formations, the Lospe formation of lower Miocene(?) age and the Point Sal formation of early middle Miocene age. Also, along the north edge of the valley there are possibly older rocks of Tertiary age.

The Monterey shale, which is of middle and upper Miocene age, is of marine origin, and is the principal source rock of petroleum. It attains a maximum thickness of about 7,000 feet in the structural trough beneath the town of Orcutt, but is considerably thinner elsewhere. It forms the core of the Casmalia and Solomon Hills, extends beneath the Santa Maria and lower Sisquoc valleys at considerable depth, and rises to the north to form the main part of the San Rafael Mountains shown within plate 1. It has been described by Woodring (Woodring, Bramlette, and Lohman, 1943, p. 1345) as follows:

> Three mapped members are recognized in the Monterey of the Santa Maria district. The lower member is characterized by phosphatic shale, silty shale, and somewhat porcelaneous shale; the middle member by chert, cherty shale, and porcelaneous shale; and the upper member by porcelaneous shale, or by porcelaneous shale and soft diatomaceous strata. The lower member is 200 to 900 feet thick in the western Casmalia Hills; the middle member has an average thickness of 200 feet; and the thickness of the upper member varies from 600 to 700 feet in the western Casmalia Hills and is about 1,000 feet in the eastern Purisima Hills. Limestone, doubtless more or less dolomitic and presumably not of primary origin, is found throughout the formation, being most abundant in the lower member. The chert of the middle member is characteristically contorted and forms generally conspicuous outcrops. Wherever the upper member includes both hard porcelaneous shale and soft distomaceous strata, the soft diatomaceous strata overlie the hard porcelaneous shale.

In exposures the Monterey shale characteristically occurs in thin beds, 1 inch to 3 inches thick, which are usually white to light yellow in color, and highly jointed and fractured.

The volcanic rocks associated with the Monterey shale differ widely in character from place to place, but in general fall into two classes—pyroclastic and intrusive rocks. At the mouth of the Cuyama River, Arnold and Anderson (1907, p. 34, 35 and pl. 3A) recognized the pyroclastic rocks, which were probably laid down under marine conditions. These deposits show distinct bedding, and are composed of resistant red and white agglomerate and yellow tuff beds with a few interbedded strata of sandstone and cherty limestone. They also crop out south and east of the town of Nipomo.

The other type of volcanic rock associated with the Monterey shale is intrusive andesite. Outcrops of this material can be seen in a road cut on State Highway 166, just east of Suey Road. It is dark green to black in color and has a pillowlike structure, indicating that it probably was erupted subaqueously into the plastic Monterey shale.

SISQUOC FORMATION (MIOCENE AND PLIOCENE)

The Sisquoc formation is exposed high along the north flank of the Solomon and Casmalia Hills. Also, it underlies the valleys of the Santa Maria and Sisquoc Rivers and crops out along the north flank of Sisquoc Valley, but it laps upon the Franciscan and Knoxville(?) formations beneath the Santa Maria Valley.

The Sisquoc formation, which is of upper Miocene and lower and middle Pliocene age, rests unconformably upon the Monterey shale. It is represented by a coarse-grained shallow-water facies in the Sisquoc River valley, and by a fine-grained deep-water facies in the western part of the area. The deep-water facies attains a maximum thickness of about 3,000 feet and is composed primarily of massive diatomaceous mudstone with some porcelaneous shale and claystone beds. The shallow-water facies is considerably coarser and thinner, and is composed of relatively hard beds of siltstone and some conglomerate. In surface exposures the Sisquoc formation resembles the Monterey shale to a marked degree, particularly where the deep-water facies of the formation is represented.

FOXEN MUDSTONE (PLIOCENE)

The Foxen mudstone crops out only along the north flank of the Casmalia Hills and extends beneath the Santa Maria Valley, where it attains a maximum thickness of about 3,000 feet near Betteravia. It laps upon the Franciscan and Knoxville(?) formations beneath the valley floor and does not crop out along the north side of the valley. The Foxen thins rapidly to the east and is missing beneath most of the Sisquoc valley.

The Foxen mudstone of this report corresponds to that designated by Woodring (Woodring, Bramlette, and Lohman, 1943, pp. 1353–1355). It includes only the mudstone, siltstone, and fine-grained silty sandstone of middle(?) and upper Pliocene age, which rests conformably upon the Sisquoc formation in the western part of the area, and unconformably upon it in the eastern part. The fine-grained to medium-grained soft sandstone resting upon the siltstone has been considered a part of the Foxen by Frame (1938, pp. 30, 31) and Canfield (1939, pp. 54–60), but it is now distinguished as the Careaga sand.

WATER-BEARING PROPERTIES OF THE CONSOLIDATED ROCKS

The consolidated rocks are essentially not water bearing. Their denseness and high degree of compaction render them incapable of transmitting water. However, most of the formations contain fractures, joints, and fissures induced by folding and faulting. Conceivably such openings may convey small quantities of water to the adjacent unconsolidated deposits. A few wells have been drilled into the consolidated rocks in search of water for domestic and stock use, particularly near the town of Nipomo, but it is reported that water encountered was of insufficient quantity to meet even these uses. However, some of the small springs in ravines along the south flank of the San Rafael Mountains issue from fractures in the older rocks. Therefore, it is believed that a relatively small quantity of water is transmitted to the main water body through such fractures in the consolidated rocks.

UNCONSOLIDATED WATER-BEARING DEPOSITS OF TERTIARY AGE

CAREAGA SAND (PLIOCENE)

Areal extent.—The Careaga sand crops out along the north flank of the Casmalia and Solomon Hills, extends northward beneath the valleys of the Santa Maria and the Sisquoc Rivers, and laps upon the consolidated rocks beneath the northern edge of the valley floors. (See geologic sections *A–A′* and *C–C′*, pl. 2.) An isolated outcrop of tar-impregnated Careaga forms the north end of Fugler Point (pl. 1).

Stratigraphy.—The Careaga sand, which is upper Pliocene in age, was formerly considered to be the uppermost member of the Foxen formation (p. 26), but is now generally distinguished as a separate formation. The Careaga rests conformably upon the Foxen mudstone in the central part of the Santa Maria Valley. Eastward, it laps unconformably upon the Sisquoc formation.

In most water wells the Careaga is logged as sand—rarely as sandstone, although in surface exposures it appears somewhat consolidated. The induration is apparently just a surface feature presumably due to cementation, and does not extend to any appreciable depth. Therefore, the name Carega sand is used in this report rather than Careaga sandstone, as the formation has been described by Woodring.

Woodring (Woodring, Bramlette, and Lohman, 1943, pp. 1355–1356) recognized two members of the Careaga, which he distinguished as the Cebada fine-grained member and the overlying Graciosa coarse-grained member. For the purpose of this report they are treated as a single unit, which is shown on the geologic map.

Lithology and thickness.—The Careaga sand is composed primarily of white to yellowish-brown loosely consolidated massive medium-grained to fine-grained sand with some silt and with numerous lenses or "reefs" of megafossils. It is predominantly of marine origin. In the upper part it contains some lenses of soft conglomerate, the pebbles of which are well rounded and composed primarily of porcelaneous shale.

The maximum thickness of the sand is about 650 feet and occurs along the axis of the Santa Maria Valley syncline. Locally beneath the north flank of the valley it thins to a minimum thickness of about 20 feet. Most oil wells in the Santa Maria Valley oil field pierce the Careaga, but in most of the area its top is several hundred feet below the depths penetrated by water wells (pl. 2). Along the north edge of the Santa Maria Valley a few wells penetrate the Careaga. The geologic section on plate 3 shows the position of the Careaga beneath the eastern part of this valley. Wells 10/33–18H1, 10/33–18H2, 10/33–21R1, and 10/33–27D1[4] are the only water wells that are known to have been drilled through the Careaga, which locally ranges in thickness from as little as 20 feet to 120 feet. (For complete logs of representative wells see table 16.)

Water-bearing properties.—The Careaga sand bears the distinction of being the oldest water-bearing formation in the area, but it is probably one of the least permeable, owing principally to the contained silt. The loosely consolidated sand is capable of transmitting water through the openings or pore spaces between the grain particles. However, because the overlying formations are more permeable and because the loose sand tends to "sand up" the wells, drillers do not perforate well casings in the Careaga sand. Although in this area its water-yielding capacity remains unknown, in the Santa Ynez basin yields of 150 gallons a minute or more have been obtained from the Careaga by use of gravel-envelope wells. Presumably yields of this magnitude could be obtained in the Santa Maria Valley area.

Laboratory tests of permeability made on samples of the Careaga sand in the Santa Ynez basin (Upson and Thomasson, 1951), where its lithologic properties are believed to be essentially the same as in the Santa Maria Valley area, showed coefficients of permeability which averaged about 70 gallons a day per square foot at 60° F (Wenzel, 1942, pp. 7–10). When compared with that of the alluvium this permeability is quite low.

PASO ROBLES FORMATION (PLIOCENE AND PLEISTOCENE?)

AREAL EXTENT

Like the Careaga sand, the Paso Robles formation crops out along the north flank of the Casmalia and Solomon Hills, it is folded downward in the synclinal trough of the Santa Maria and Sisquoc valleys, and the upper part is truncated on the north limb by younger deposits (pls. 1 and 2). Several minor isolated outcrops of the Paso Robles are found on the north side of the area.

STRATIGRAPHY

The Paso Robles formation,[5] which is upper Pliocene to lower Pleistocene (?) in age, was considered a part of the Fernando formation

by Arnold and Anderson (1907, pp. 52–60). The Fernando formation, however, included all unconsolidated and some consolidated deposits from upper Miocene to lower Pleistocene. Both Frame (1938, pp. 28, 30) and Canfield (1939, pp. 52–54) limited the Paso Robles formation to 200 to 500 feet of "blue gravels" resting upon the "Foxen sand," here called the Careaga sand, and underlying from 400 to 1,600 feet of stream gravels or "yellow gravels."

The Paso Robles formation as used in this report includes both the "blue" and "yellow gravels," as differentiated by Frame and Canfield, and so conforms with the more recent work done by Woodring (Woodring, Bramlette, and Lohman, 1943, 1358–1359). The formation lies conformably upon the Careaga sand except locally near some valley margins where it overlaps the Careaga, and extends unconformably over the older Tertiary rocks, notably west of Tepusquet Creek. It is overlain unconformably at one place or another by all the younger deposits.

A deposit of massive fine white sand, over 125 feet thick and probably of marine origin, occurs along the axis of the Santa Maria syncline near Orcutt. This body has been observed only in water-well logs. The sand is apparently overlain unconformably by the Orcutt formation (pl. 3), and may lie unconformably upon the Paso Robles formation. It may be a hitherto unrecognized and distinct stratigraphic unit older than the Orcutt formation and younger than the Paso Robles. However, because its relation to the Paso Robles remains uncertain and, further, because the sand is of limited extent, it is tentatively assigned to the Paso Robles formation.

LITHOLOGY AND THICKNESS

The Paso Robles formation is probably the oldest nonmarine deposit in the area. In general it is composed of stream-laid lenticular beds or lenses of coarse to fine gravel and clay, medium to fine sand and clay, silt, clay, and some lenses of gravel and sand. In the lower part discontinuous thin limestone beds occur. However, the fact that the deposits on the south limb of the syncline appear to be somewhat finer-grained and of different composition than those forming the north limb, suggests a separate source for each and an inferred overlapping along the axis.

The lithologic character and textural irregularity of the formation along the south side of the area are perhaps best shown by two relatively complete sections observed in the Santa Maria Valley and one partial section observed in the Sisquoc valley.

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[4] For description of the well-numbering system see p. 163.

[5] Sometimes "designated the Schumann formation."

Section of about the lower three-fourths of the Paso Robles formation, exposed in ravine in the E½ sec. 34, T. 10 N., R. 35 W.

	Feet
Sand, medium-grained, gray to brown intermixed	8
Clay, silty, brown to gray	46
Sand, coarse, gray; and some clay	22
Clay, silty, gray; and some sand	19
Sand, silty, brown	5
Clay, with some sand and silt	60
Silt, sandy, soft, brown, weathers gray	57
Clay, silty, compacted, buff	12
Clay, sandy, gray	54
Clay, silty, varved, brown	11
Sand, clayey, fine, brown	68
Sand, medium-grained, massive, buff; and some clay	64
Sand, clayey, coarse, gray; and pebbles	33
Sand, locally clayey, massive, medium gray	75
Clay, silty, massive, buff	53
Sand, hard, massive, fine, gray	48
Sand, massive, fine to medium, coarser near top, clean; considerable ferruginous stain	22
Clay, limey, white	20
Limestone, fossiliferous, punky to hard; and some sand	1
Sand, medium-grained to coarse, clean, gray	7
Sand, massive, fine to medium; ferruginous stain	14
Clay, gray; occasional lenses of medium-grained sand with ferruginous stain	28
Sand, clayey, gray-brown, but weathers gray	53
Silt, clayey, brown; and little sand	9
Clay, limey, soft, white	7
Clay, silty, brown	12
Sand, coarse, clayey; and some small pebbles	19
Clay, limey, soft with occasional hard spots; and some fine sand	6
Sand, fine, clayey, white to yellow	28
Sand, massive, clean, well-rounded grains, buff-colored, mostly quartz, feldspar, and shale; visible openings between grains	25
Sand, hard, coarse, clayey, with few pebbles and cobbles; brown, but weathers gray-white	60
Limestone, conglomeratic, hard; quartz sand, and porcelaneous shale cobbles as large as 3 inches	32
Sand, medium-grained, soft; and clay with a few small quartzite and porcelaneous shale pebbles	18
Concealed; probably same as above	90
Sand, medium-grained, soft; and some clay	30
Clay, limey; and sand, above which water seeps	3
Sand, fine-grained to medium-grained, clayey, brown; and small porcelaneous shale pebbles	9
Concealed; smooth surface, probably clayey sand	331
Limestone, basal; contains few white quartz sand grains	3
Total	1,462

Section of about the lower three-fourths of the Paso Robles formation, exposed in ravine in the W½ sec. 15, T. 9 N., R. 34 W.

	Feet
Gravel, coarse, brown sandstone, porcelaneous shale, metavolcanics; sand, and some clay	146
Sand, coarse, brown	10
Gravel, medium; sand, and clay	35
Concealed	39
Gravel, mostly porcelaneous shale, rounded; little sand	6
Concealed	214
Sand, coarse, brown; some gravel	18
Clay, silty, gray to brown	23
Clay and medium-grained gravel	19
Sand, massive, medium, brown	7
Sand and coarse gravel showing cross bedding	70
Clay, gray	5
Sand, coarse; and pebbles of brown sandstone, porcelaneous shale, and metavolcanics	23
Clay, sandy to silty, brown	30
Limestone, sandy, white	1
Sand, massive, brown	6
Sand, hard; and gravel	11
Clay and coarse gravel as large as 3 inches	13
Sand, clayey, brown	8
Sand, clay, and cobble gravel as large as 4 inches	10
Sand, brown; and cobble gravel	8
Concealed	25
Clay, gray, silty	4
Sand, fine; and small rounded pebbles	8
Concealed	141
Cobbles of porcelaneous shale and weathered-brown sandstone, rounded, as large as 3 inches	5
Concealed	81
Clay, gray	18
Concealed	31
Pebbles, rounded, sand, and clay; gray	22
Sand, massive, fine, clean, buff	27
Pebbles, rounded, sand, and clay; gray	44
Sand, massive, gray	4
Pebbles and cobbles of porcelaneous shale as large as 3 inches, and clay	22
Clay, gray	6
Sand, clayey, brown; and some pebbles	77
Clay, limey, gray	35
Concealed	12
Sand, medium-brown; and some silt	12
Clay and some sand; gray	88
Clay, silty, brown	6
Sand, clayey, medium, gray; and pebbles of porcelaneous shale	59
Sand, fine, clean, gray	6
Pebbles, porcelaneous shale; maximum 2 inches; and gray clay	30
Sand, clean, white	12
Concealed, probably clay, sand, and pebbles	115

Section of about the lower three-fourths of the Paso Robles formation, exposed in ravine in the W½ sec. 15, T. 9 N., R. 34 W.—Continued

	Feet
Clay, slightly limey, gray	24
Limestone, basal	5
Total	1, 621

Section of part of the Paso Robles formation, exposed in Cat Canyon in the SE¼SE¼ sec. 13, T. 9 N., R. 33 W.

	Feet
Soil mantle	2
Cobbles as large as 4 inches, sand, and clay	1
Sand, clayey, fine; and small rounded porcelaneous shale pebbles	4
Sand, coarse; and cobbles as large as 3 inches of metavolcanics and porcelaneous shale	2
Sand, medium-grained; and some small porcelaneous shale pebbles	2
Sand, massive, medium to fine, subangular, mostly quartz and feldspar with porcelaneous shale	3
Gravel, as large as 1 inch; sand, and some clay	1
Cobbles as large as 3 inches, mostly of porcelaneous shale, some brown sandstone and metavolcanics; coarse sand, and clay	2
Sand, coarse; well rounded, small porcelaneous shale pebbles, and little clay	2
Total	19

The lithologic character of the Paso Robles formation along the north limb of the syncline is known primarily from logs of wells. Beneath the Santa Maria and Sisquoc plains and the Orcutt upland water wells penetrate the Paso Robles formation for distances of from several feet to over 700 feet. Only those along the north edge of the Santa Maria plain pass through the formation, which in this area is represented by a truncated section. (See section *C–C′*, pl. 2.) The logs show that, except for a coarse basal gravel 10 to 30 feet in thickness encountered only by oil wells in the Santa Maria Valley oil field,[6] there is no correlation possible between beds from place to place in the formation, and that the deposits are lenticular. However, the logs show that in general the Paso Robles contains large quantities of boulders and gravel, chiefly in a matrix of clay but locally including some sand. Westward near the coast the formation is composed mostly of sand and clay, which locally may be of marine origin, and some gravel and few boulders. (See logs for wells 10/35–7G1, and 17D1, and 11/35–19E1, 20E1, and 29R1, table 16.)

This formation forms the thickest single water-bearing deposit in the area. Geologic section *C–C′* (pl. 2) shows that the formation reaches a thickness of about 2,000 feet near the town of Orcutt. This is believed to be the thickest section in the area. Elsewhere the thickness ranges widely. Water well 9/34–3N4 (table 16), which is the deepest well in the area (900 feet), is situated almost on the axis of this trough and penetrates the formation for a thickness of 716 feet—only about one-third the total thickness at this point.

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[6] Dolman, S. G., personal communication, 1946.

WATER-BEARING PROPERTIES

The coarse-grained lenses of the Paso Robles formation supply a considerable quantity of water to wells, but the finer-grained lenses probably supply very little. As a whole the formation is a good water-bearing deposit, probably about as productive as the Orcutt formation, but considerably less than the alluvium. Few wells have been perforated in the Paso Robles alone, but those show that the formation is capable of yielding water to wells at rates as great as 1,000 gallons per minute. However, to obtain this high production the casings are perforated throughout a considerable section of the formation, and the wells have relatively low specific capacity, ranging from 5 to 10 gallons a minute per foot of drawdown.

The permeability of the formation has been determined by a recovery test (Wenzel, 1942, 125–129) in one pumped well near the coast where the deposit is generally fine-grained. The test was run on well 11/35–20E1, which penetrates only a part of the Paso Robles but the results of which are believed to be representative of the formation in that area. They indicate that the deposits tested have an average permeability of about 65 gallons a day per square foot, or about the same magnitude as that obtained for the Careaga sand (p. 28).

It can be concluded that the grain size and probably the water-yielding capacity of the formation decreases toward the coast and from north to south. The numerous irrigation wells on the Santa Maria plain, therefore, probably tap the most productive part of the formation.

UNCONSOLIDATED WATER-BEARING DEPOSITS OF QUATERNARY AGE

ORCUTT FORMATION (PLEISTOCENE)

Areal extent.—The Orcutt formation extends along the south side of the Santa Maria and Sisquoc valleys, and is believed to be present along the north side of the Santa Maria River (pl. 1). It does not extend beneath the alluvium in the Sisquoc valley nor beneath the greater part of the Santa Maria Valley (pl. 2). However, beneath most of the Oso Flaco district (p. 19) it may be present where the lower part of the alluvium is absent (pl. 3).

Stratigraphy.—The Orcutt formation is an essentially nonmarine, slightly deformed, relatively thin deposit of upper Pleistocene age, which rests unconformably primarily upon the Paso Robles formation—the degree of unconformity becoming more pronounced on limbs of folds. Locally it rests unconformably upon the older rocks. According to Woodring (Woodring, Bramlette and Lohman, 1943, p. 1359), the type region is on the north flank of the Casmalia Hills west of Orcutt, where it attains a thickness of about 50 feet, and is primarily sand. However, the logs of wells indicate that only a small section of the Orcutt is represented in this locality, and that along the axis of the Santa Maria syncline it locally attains a maximum thickness of about 225 feet.

Furthermore, the logs indicate that the formation is composed of two conformable members—an upper fine-grained sand member which corresponds to that portion of the formation exposed at the type locality, and a lower coarse-grained member. Because the two members differ lithologically, the Orcutt in this report has been designated a formation rather than the "Orcutt sand," as named by Woodring. Woodring's term seems to apply only to the upper member. Parts of both members have been observed in exposures, and they are shown on plate 3. However, they are not distinguished on the geologic map (pl. 1).

In addition, the uppermost and partly deformed "terrace deposits" mapped by Woodring south of the Sisquoc valley are believed to be equivalent to the Orcutt formation, because of their physiographic and stratigraphic position and structural features. They have been assigned to the Orcutt formation in this report (pls. 1 and 2). Dips as great as 12° have been observed in the formation along the north flank of the Solomon Hills, which is perhaps unusual for deposits of upper Pleistocene age.

Lithology and thickness.—Because the entire formation cannot be observed at any one exposure in the area, the study of the lithology is based necessarily on both surface and well-log data. The upper member is mostly a loosely compacted massive medium-grained clean sand, stained reddish-brown by a ferruginous cement and interstratified with lenses of clay. Locally the sand beds themselves contain clay. Near the north edge of the Orcutt upland the upper member contains lenses of gravel (pl. 3). Where exposed the member usually stands in nearly vertical cliffs. It ranges in thickness from a feather edge to about 225 feet along the axis of the Santa Maria syncline.

The lower member is chiefly loosely compacted, coarse gray to white gravel and sand. Its contact with the upper member is sharp, and in surface exposures the lower member is usually intricately rilled and fluted. It is quite difficult to distinguish from the underlying Paso Robles formation, particularly where the unconformity between them is slight. It ranges in thickness from a feather edge to 65 feet.

Like the Paso Robles formation, the Orcutt is fine-grained near the coast, and well logs indicate that the deposits there are predominantly sand and clay throughout and in part may be of marine origin. In the Sisquoc valley the Orcutt is coarser in grain, and distinction between its two members is impossible.

Water-bearing properties.—The Orcutt formation supplies water to wells in appreciable quantities only beneath the Orcutt upland, where the lower member is one of the principal water-producing deposits. It supplies water of perhaps the best quality in the area to the city of Santa Maria and the town of Orcutt. These municipal wells are in secs. 3 and 10, T. 9 N., R. 34 W. However, in the years 1938–42 water levels in these wells fell below the top of the lower member; since then they have recovered (well 9/32–3N3, fig. 5). Toward and beyond the eastern end of the upland the member rises above the water table and is therefore useless as a source of supply. To the west it becomes less productive, until at the coast it is composed mostly of clay, silt, and fine sand, and is there considered a poor water-yielding deposit.

No tests of permeability have been made on either member of the Orcutt, but where the public-supply wells draw on the lower member, its permeability is probably considerably greater than that of the underlying Paso Robles. Also, because of its lithologic characteristics, the lower member here is probably considerably more productive than the upper member. Elsewhere the wide range in lithology obviously is accompanied by a corresponding range in productivity.

TERRACE DEPOSITS (PLEISTOCENE)

Areal extent.—Terrace deposits compose and underlie the 40-foot and 100-foot terrace surfaces previously described (p. 20). They are remnants of more extensive deposits but even now underlie the greater part of the Orcutt upland, the Nipomo upland, and numerous smaller areas along the Sisquoc and Santa Maria Rivers (pl. 1).

Stratigraphy and thickness.—The terrace deposits are the alluvial materials that were laid down by streams during the formation of the 40-foot and 100-foot terraces. They rest unconformably on the Orcutt formation, and locally on all older formations, and are in turn overlain locally by dune sand. They are older than the alluvium and are considered to be upper Pleistocene in age. They range in thickness from a feather edge to a maximum of at least 45 feet. (See log for well 9/32–7A1, table 16.) Beneath the extensive surface of the 40-foot terrace on the Orcutt upland the deposits are a thin veneer roughly 5 to 10 feet thick; but they are considerably thicker immediately south of Fugler Point where they fill an old channel.

Lithology.—The terrace deposits are composed essentially of unconsolidated boulders, gravel, sand, silt, and clay intermixed to varying degrees and occurring in poorly defined lenses. The coarse-grained portions are buff-colored. In general, the deposits are similar to the coarse-grained parts of the alluvium.

Water-bearing properties.—Near the rivers, and where they overlie unconsolidated deposits, the terrace deposits are mostly above the zone of saturation and hence supply little water to wells. However, near and southeast of Nipomo, the deposits rest on consolidated rock and there contain water in the lower part in quantities sufficient to meet domestic and stock requirements. The deposits are coarse-grained and porous, and hence readily absorb rain which they transmit to any underlying permeable formations.

ALLUVIUM (RECENT)

The alluvium, which is the most productive water-bearing deposit in the area, is unique in that it is almost completely concealed by its own surface. Because of this the extent, stratigraphy, thickness, lithology, and water-bearing properties of the alluvium all were determined entirely from well logs and pump tests. Over 350 water-well logs and numerous oil-test holes that pierce the alluvium were studied in detail. This study was considerably aided by a peg model, which presented a three-dimensional picture of all available well logs.

Stratigraphy.—The alluvium, as the name implies, is a body of alluvial deposits laid down by streams graded initially to a position of sea level about 230 feet below present level. It is believed to have been deposited as sea level rose during the retreat of the Wisconsin ice sheet, and is therefore considered to be Recent in age. The alluvium comprises two members—an upper fine-grained member, and a lower coarse-grained member. It is unconformable on all older deposits, but throughout the area rests chiefly on the Paso Robles formation (pl. 2). It is itself locally overlain by river-channel and dune sand deposits.

The stratigraphic units and position, physiographic expression, lithologic character, and thickness of the alluvium in the Santa Maria Valley area correspond to those of the alluvium found in other coastal valleys of southern California (Fairbanks, 1904, p. 13; Poland and Piper, in preparation; Upson, in preparation; Upson and Thomasson, in preparation.)

Areal extent.—The upper member of the alluvium underlies and forms the surfaces of the Santa Maria and Sisquoc plains, and the alluvial plains of tributary streams (pl. 1). It also extends beneath the channel deposits of all the major rivers and streams. The lower member has essentially the same extent as the upper member, with one major exception. It is missing beneath that portion of the Oso Flaco district lying roughly north of latitude 35°00′. (See pls. 1 and 2.)

Thickness.—In logs of wells the base of the alluvium is readily recognized beneath the Sisquoc River near La Brea Creek, and beneath the Santa Maria and Cuyama Rivers near Fugler Point where the deposit rests on consolidated rocks or the Careaga sand; but it is not easily recognized over the greater part of the area where it rests on the Paso Robles formation. However, by comparing logs where the base is doubtful with logs of nearby wells in which it can be recognized, and by projecting the slope of consolidated rock surfaces overlain by alluvium, the base can be fairly accurately determined everywhere.

As thus determined the alluvium ranges in thickness laterally from a feather edge at the north and south margins of the alluvial plains to maximum thicknesses beneath the central parts. These maximum thicknesses range from 50 feet at the upper end of the Sisquoc plain to 115 feet at Fugler Point (an average increase in thickness of 8 feet per mile in this reach); and to 230 feet at the coast (an average increase in thickness of 6 feet per mile for the reach below Fugler Point). Thus, the deposit thickens almost uniformly westward beneath the alluvial plains. (See pl. 3.)

At the coast the two members are each about 115 feet thick, and each thins eastward. However, the lower member thins more rapidly and near Fugler Point is about 40 feet thick, whereas the upper member there is about 75 feet thick.

Lithology.—The detailed lithologic character of the alluvium is shown by the logs of representative wells in table 16, and the two members are distinguished whenever possible. The logs show that the lower member of the alluvium is composed primarily of boulders, gravel, and sand, with minor lenses of clay interfingered near the coast. The basal part of the lower member is particularly coarse, and is usually denoted by well drillers simply as boulders, or gravel, or both. In general the grain size decreases slightly as the deposit thickens toward the coast.

The lithology of the upper member, like that of the lower member, is known primarily from logs of wells. Beneath the Sisquoc plain the upper member is practically indistinguishable from the lower member—both being composed of boulders and gravel and some sand. Beneath the eastern and central parts of the Santa Maria plain, the coarse gravel and boulders of the lower member are overlain by sand and gravel or sand in the upper member, and the contact between the two is distinguishable. From the city of Santa Maria to a point about halfway to Guadalupe, the sand and gravel of the upper member grade rapidly to sand and silt with progressively fewer beds of gravel. From this point westward to the coast it is composed of alternating beds predominately of clay and silt with some sand and a few gravel layers. Thus, the upper member decreases rapidly in grain size from east to west.

Near the coast the contact between the upper and lower members is sharp and is easily identified in well logs. The individual clay beds, which are compact and usually reported as blue, are relatively extensive, especially those commonly encountered near the surface. However, from the data at hand it cannot be definitely concluded that individual clay beds extend as one continuous unit entirely across the west end of the valley. It is thought that some of these clay beds are of marine origin and were deposited at times when the rise of sea level was faster than the accumulation of fluvial debris. Other clay beds, reported as yellow in drillers' logs, are possibly of fluvial origin, their color presumably resulting from surface exposure and oxidation of contained iron compounds. From one place to another the clay beds range in thickness from 1 foot to about 100 feet—almost the full thickness of the member.

Water-bearing properties.—The lower member of the alluvium, which at present is completely saturated, yields water readily to wells. For example, wells 10/33–21R1 and 10/33–36A1, which derive water solely from the alluvium, each have a yield of about 1,000 gallons a minute and a drawdown of about 45 feet; or a specific capacity of about 22 gallons a minute per foot of drawdown.

The upper member, on the other hand, has a wide range in ability to transmit and to yield water. In the eastern part of the area, where the deposits are similar to the lower member, the yield is high; but at the west end of the valley the fine-grained sediments, although saturated, are essentially not water yielding and are capable of transmitting water to wells only in small or negligible quantities. In the intervening area the yield is gradational. The fine-grained and irregular beds which compose the upper member at the west end of the area form a seal of varying tightness due to overlapping of one lens upon the other and there confine the water in the underlying deposits. (See pp. 72–73.)

Tests of permeability of the alluvium by use of the recovery method in a pumped well (Wenzel, 1943, pp. 125–129) were made on wells 9/32–24K1 and 10/33–21R1 (pl. 1). In both wells the alluvium rests on consolidated rocks. Results obtained from these tests showed permeability coefficients of 4,500 gallons a day per square foot for well 24K1 in the upper Sisquoc valley, and 3,500 gallons a day per square foot for well 21R1 in the upper Santa Maria valley. This indicates that the permeability of the alluvium is high and that it decreases in a downstream direction as the material becomes somewhat finer-grained.

Similar tests were run near the coast on wells 10/35–5J1, 8Q1, 17D1, 11/35–29D1, and 32R1, which are perforated in the lower member of the alluvium and in the upper part of the underlying less permeable Paso Robles formation. The average of the five tests, which in themselves were not entirely satisfactory owing to irregularities in the recovery curves, showed the composite permeability of both formations to be about 1,500 gallons a day per square foot. Obviously then, the permeability of the lower member of the alluvium alone is somewhat greater than 1,500. It has been indicated that the permeability of the alluvium at well 10/33–21R1 was 3,500 gallons a day per square foot, and that the permeability probably continues to decrease westward as the deposits become finer-grained. Hence, the permeability of the alluvium near the coast is probably considerably less than 3,500 gallons a day per square foot, but somewhat greater than 1,500. A coefficient of about 2,000 gallons a day per square foot is considered to be of the correct order of magnitude.

RIVER-CHANNEL DEPOSITS (RECENT)

Areal extent.—The river-channel deposits extend some 30 miles down the full length of the Sisquoc and Santa Maria plains. Along the Sisquoc plain and the upstream half of the Santa Maria plain they fringe the north edge of the plains, but downstream they cut diagonally across the plain to the southwest corner. In the lower course of Cuyama River the channel deposits occupy most of the surface area of the canyon floor (pl. 2).

Stratigraphy and thickness.—The river-channel deposits consist of the gravel, sand, and silt contained within the banks of the major rivers; these deposits extend downward to and rest unconformably upon the upper member of the alluvium. Because few wells are drilled in the channel deposits and because of the similarity between these deposits and the underlying alluvium, the maximum thickness is not definitely known but is not believed to exceed 25 feet.

Lithology.—The lithology of the channel deposits is known only from surface examination. In general these deposits are extremely coarse-grained in the Cuyama and Sisquoc River channels and relatively fine-grained in the lower reaches of the Santa Maria River channel. The deposits of the Sisquoc River channel are composed of boulders, gravel, and coarse sand intermixed in bars or lenses of varying coarseness. The boulders attain a maximum size of over 1 foot in diameter, but more commonly are smaller. The coarser constituents are composed primarily of hard sandstone and of metavolcanic rocks derived from the headwater area.

The deposits of the Cuyama River contain considerable silt which is derived from massive silt beds that crop out in the Cuyama Valley (pl. 4), intermixed with the coarser material. During high water and during the following recession the silt gives the water an orange color and a soupy appearance. Even during low flow considerable silt is carried by the river.

The deposits of the Santa Maria River channel are necessarily a combination of the materials carried by the Cuyama and Sisquoc Rivers. At Fugler Point, the deposits consist of coarse sand and silt with numerous pebbles. Westward the material becomes progressively finer, and near Guadalupe medium to fine sand and some silt with occasional pebbles form the main body of the deposits.

Water-bearing properties.—The water-bearing properties of the channel deposits are of particular importance because they transmit the large seepage losses that occur throughout the Sisquoc and the greater part of the Santa Maria channels whenever there is any runoff. Except along the Cuyama River, and possibly for some distance along the Sisquoc River below La Brea Creek, the major part of the channel deposits lie above the water table, and hence, transmit the seepage losses vertically downward.

TABLE 2.—*Results of permeability tests on samples of river-channel deposits in the Santa Maria, Cuyama, and Sisquoc Rivers*

Location (river miles from mouth)	General character	Permeability (gallons per day per square foot)
	Santa Maria River channel	
1.8	Medium to coarse sand with some silt	154
5.6 (State Highway 1)	Medium to coarse sand with some gravel.	256
8.9 (Bonita road)	do	266
13.3 (U. S. Highway 101)	Medium to coarse sand with some gravel and silt.	262
15.5 (Suey Creek bridge)	do	396
18.0	do	666
19.8	do	400
22.2 (Fugler Point)	Medium to coarse sand and coarse gravel.	602
	Cuyama River channel	
1.0	Cobbles, coarse gravel, sand, and silt	974
	Sisquoc River channel	
0.8 (Garey bridge)	Cobbles, coarse gravel, and sand	762
4.4 (Tepusquet Creek)	Cobbles, coarse gravel, and sand with some boulders.	994
7.8 (La Brea Creek)	Boulders, cobbles, coarse gravel, and sand.	1,060

The water-bearing properties of the unconsolidated and relatively coarse-grained channel deposits are perhaps best indicated by laboratory tests of permeability that were run on samples collected along the courses of the Santa Maria, Sisquoc, and Cuyama Rivers. The permeability coefficients were obtained by use of a variable-head appratus designed by S. F. Turner, United States Geological Survey, and similar to that described by Wenzel (1942, pp. 59–65). Two samples were taken on opposite sides of the active channel at 12 locations and the average permeability for each location is shown in table 2.

The table shows that the permeability of the deposits increases upstream and reaches a maximum value of 1,060 gallons a day per square foot in the upper part of the Sisquoc valley.

DUNE SAND (RECENT)

Areal extent.—The dune sand covers about 25 square miles of the Orcutt upland, about 15 square miles of the Nipomo upland, and about 10 square miles of the Santa Maria plain along the coast (pl. 1).

Stratigraphy, lithology, and thickness.—The dune sand deposits are Recent in age, and are found to be of two types: actively drifting dunes which are encroaching over the older deposits near the coast; and the old or inactive dunes which are anchored by vegetation and which in part have a well-developed soil mantle. They have not been differentiated on the geologic map. Both rest unconformably on older deposits. The dune sand is composed primarily of coarse to fine, well-rounded massive characteristically cross-bedded quartz sand, loosely to slightly compacted. The dunes range in thickness from a feather edge to more than 100 feet.

Water-bearing properties.—The dune sand lies above the surface of the main water body but contains several small perched or semiperched water bodies, which locally supply water to a few domestic wells in the Orcutt upland. Thus, the sands are known to transmit and to yield water. However, because no tests were made, the permeability of the sand is unknown.

GEOLOGIC STRUCTURE

GENERAL REGIONAL STRUCTURE

The regional structure surrounding and including the Santa Maria Valley area is extremely complex for it lies within the structural influence of both the California Coast Ranges and the so-called transverse ranges of southern California. Physiographically and structurally the San Rafael Mountains lie at the southern edge of the

California Coast Ranges; whereas the Santa Ynez Mountains to the south form the western part of the westward-trending transverse ranges (fig. 1). The region included between the two ranges is a structural depression, and the older rocks, which are exposed in the bordering ranges, here are concealed at considerable depth beneath Tertiary and Quaternary rocks. The tertiary rocks form a series of broad folds whose axes have a general westward trend. Of these the northernmost downfold forms the basin beneath the Santa Maria and Sisquoc valleys. The shape and extent of this major syncline and the faults which transect it, and their relation to the ground-water basin are discussed below.

MAJOR SYNCLINE

The major syncline that underlies the valley area is an asymmetric structural trough whose axis trends southeastward along the south side of the Santa Maria Valley, in the vicinity of Orcutt veers sharply northeastward toward Fugler Point, and finally turns southeastward near Garey into the Sisquoc valley. Its exact course and shape between Orcutt and Garey is not definitely known, and therefore, it is not shown on the geologic map (pl. 2). The offsets or bends in the axis are probably due to the regional stresses that exist between the Coast Ranges and transverse ranges. The shape and lateral extent of the syncline are shown on the geologic cross sections (pl. 3).

The south limb of the syncline, which is steeply dipping beneath the Santa Maria Valley and gently dipping beneath the Sisquoc valley, forms the north limb of the major anticlinal structure beneath the Casmalia and Solomon Hills. Minor en échelon folds having a northwest trend are prominent features of the south limb. In the Sisquoc valley the north limb rises steeply to form the south flank of the San Rafael Mountains, but in the Santa Maria Valley it rises gently and is cut out by the alluvium.

FAULTS

In the bordering hills which are underlain by consolidated rock the faults were observed only casually and for the most part their locations are taken from work of other geologists (Woodring, Bramlette, Lohman and Bryson, 1944).[7] In general these faults have a westward trend in the Solomon and Casmalia Hills and have a northwestward trend in the San Rafael Mountains. As such they bear little relation to the ground-water basin. However, several faults cut the water-bearing deposits of upper Pliocene and lower Pleistocene (?) age; namely, the Careaga sand and the Paso Robles formation. The faults

are in a position to affect the movement of ground water in those formations. They are concealed by the younger deposits and their existence has been determined primarily by studies of oil-well logs.

The faults are three in number and trend slightly west of north. It is thought that movement along all three is predominantly vertical. The fault extending southeastward from Santa Maria was encountered in oil wells drilled in the Santa Maria oil field; it has been plotted at the location shown by Canfield (1939, p. 48, fig. 2). It is a high-angle thrust fault and in this report is referred to as the Santa Maria fault. Uplift has taken place on the east side, and the fault cuts all formations up through the Paso Robles. The maximum amount of displacement in the Careaga sand and Paso Robles formation is about 150 feet, but displacement in the older rocks increases with depth. (See pl. 2 and geologic section *C–C′*, pl. 3).

East of the Santa Maria fault and roughly beneath Bradley Canyon is the second of the three faults, which is herein named the Bradley Canyon fault. The presence of this fault was determined primarily from oil-well logs, which indicate an offset in the older rocks. This faulting in Bradley Canyon is presumed to extend beneath the plain into a small fault of the same general trend observed on the north side of the Santa Maria River. Like the Santa Maria fault, it cuts the Careaga sand and Paso Robles formation, but, unlike the Santa Maria fault, the west side is believed to be uplifted and the amount of displacement is somewhat less. The straight-line appearance, the direction, and the location of Bradley Canyon possibly reflect topographically the existence of the fault.

A third fault having the same trend and age as the other two may cross the upper end of the Santa Maria Valley at Fugler Point. Because its existence is doubtful and because its location is uncertain, it is not shown on the geologic map nor on the cross sections. The existence of the fault was first suspected in the preliminary study of water-level contour maps, which show a sharp break in hydraulic gradient beneath the valley floor west of Garey (pl. 5). However, later studies show that the break could be caused equally well by other conditions (p. 75). Additional inconclusive evidence was the presence of small tar seeps in the Careaga sand at Fugler Point, suggesting a fracture zone along which the tar might be rising. The most likely evidence is a fault in the consolidated rocks on the north side of the river and trending generally toward the area in question. Considerably more evidence will be needed, however, before the presence and location of the fault can be established and its relation to the movement of ground water can be ascertained.

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[7] Also Greenwalt, W., personal communication.

RELATION OF STRUCTURE TO THE GROUND-WATER BASIN

The major synclinal trough is the structure which has determined the shape of the ground-water basin, whereas the faults have altered its shape but slightly. The shape of the contact between the unconsolidated water-bearing deposits and underlying consolidated rocks is an inherent part of the trough and, as such, limits the lateral and downward extent of the ground-water basin. Specifically, this contact as exposed on the northern and southern flanks of the Santa Maria and Sisquoc valleys marks the northern and southern limits or sides of the basin, and where the contact swings around the head of the Sisquoc plain it forms the eastern end. The concave upward surface of the contact forms the base or bottom of the basin.

On the other hand, at the west end of the valley the syncline, and hence the contact, passes out to sea. As a result the unconsolidated deposits and the contained water body extend out beneath and lie in contact with the Pacific Ocean. Thus there is no known structural or depositional barrier between the fresh water of the main water body and the salt water of the Pacific Ocean.

GEOLOGIC HISTORY

EARLY HISTORY

The early geologic history of the Santa Maria Valley area bears only an indirect relation to the present ground-water basin and the existing hydrologic problems, and it is therefore summarized very briefly. More complete accounts from which the summary has been drawn are presented principally by Woodring (Woodring, Bramlette, and Lohman, 1943, pp. 1338–1343) and Canfield (1939, pp. 79–81), and in the classic report by Arnold and Anderson (1907, pp. 66–71).

The erosional surface developed on the Jurassic rocks was submerged and covered by the sea with only minor fluctuations from late lower Miocene until upper Pliocene time. Deposition in this sea began with the accummulation of fine-grained materials composing the Monterey shale, which was followed in turn by the Sisquoc and Foxen formations and ended with the deposition of the Careaga sand. This period of marine deposition was accompanied by continued uplift and folding along and near the present San Rafael Mountains.

With deposition of the Careaga sand in upper Pliocene time, the basin was filled to sea level except along the axes of the synclinal troughs, which were still submerged. It was upon this surface that the continental Paso Robles formation was deposited. The lower and western parts of this formation, however, are locally of lagoonal or brackish-water origin because they were laid down in the still-submerged synclinal troughs. The deposition of the Paso Robles continued into the lower Pleistocene (?). The northern limit of Paso Robles deposition was probably the ancestral San Rafael Mountains, from which a considerable quantity of coarse material was derived; while on the south material of fine texture was probably derived from upland areas far to the southeast of the present Santa Maria Valley area. Minor warping accompanied the deposition of both the Careaga sand and the Paso Robles formation, thus accounting for the presence of the thickest sections in the troughs of synclines and the thinnest sections along the axes of anticlines.

HISTORY OF THE GROUND-WATER BASIN

Structural evolution.—Following the deposition of the Paso Robles formation, intense folding took place probably during middle Pleistocene time (Poland and Piper, in preparation) along established structural lines, and the existing limits of the ground-water basin were established. The Careaga sand and Paso Robles formation were arched over the Casmalia and Solomon Hills, were depressed into the large synclinal trough, and were cut by faults. It is believed that during the same period the Franciscan and Knoxville(?) rocks along the north side of the area were further uplifted. Thus, in middle Pleistocene time the lateral and downward limits or shape of the basin were defined broadly as they now exist.

Relatively stable conditions followed the intense folding of the middle Pleistocene and persisted into the upper Pleistocene (Woodring, Bramlette and Lohman, 1943, p. 1342). During this relatively long interval of time, stream erosion developed a gently seaward-sloping surface roughly between the San Rafael and Santa Ynez Mountains. Deposition of the Orcutt formation took place on this surface in upper Pleistocene time. Erosional activity in the ancestral headwater areas was probably vigorous at first and the coarse-grained lower member was deposited. Less active conditions prevailed during the deposition of the fine-grained upper member. Local coastal submergence is believed to account for the presence of the interfingered marine beds in the western extent of the Orcutt formation.

Folding and local minor faulting took place along the developed structural lines following the deposition of the Orcutt formation, but prior to that of the late Pleistocene terrace deposits. Thus, the post-Orcutt deformation marked the final phase in the structural evolution of the ground-water basin.

Erosional and depositional evolution.—The subsequent development of the basin took place almost entirely through erosion and deposition by streams in late Pleistocene and Recent time. It is believed that the ancestral rivers and streams were located approximately at their present positions and were developed on the surface of the deformed Orcutt formation. Thus, the Santa Maria and lower Sisquoc Rivers are essentially consequent and are situated in the structural trough formed between the Solomon and Casmalia Hills on the south and the San Rafael Mountains on the north. The courses of the lower Cuyama and upper Sisquoc Rivers, however, are antecedent, and transected the axis of the San Rafael Mountains at an earlier time.

The ancestral streams are believed to have cut the terrace floors and to have placed the deposits whose surfaces now remain at elevations of about 100 feet and 40 feet above the present river courses. The 100-foot terrace, which is the older of the two, was probably formed during a period of relative stability as the ancestral rivers were cutting down through the surface of the deformed Orcutt formation.

In general the history of the 40-foot terrace is fairly well preserved in the outcrops adjacent to the present channel courses. Following the formation of the 100-foot terrace the ancestral rivers cut down at least 100 feet, and possibly as much as 135 feet, below that surface probably in response to a lowering of sea level. (See log for well 9/32–7A1, table 16.) Their entrenched valleys occupied the full width of the present Sisquoc plain plus the terrace surface to the north, passed south of Fugler Point, and probably followed a course westward down the central part of the present Santa Maria plain to the coast. A subsequent rise in sea level of at least 40 feet, and possibly as much as 75 feet, caused the ancestral rivers to backfill their excavated courses to a height of about 40 feet above the present alluvial plains.

A period of relative quiescence followed the deposition, during which the rivers cut laterally into the adjacent deposits. During this time, the existing relatively extensive cut terrace was formed on the Orcutt upland, and the river cut northward into the consolidated rocks on the north side of Fugler Point. In geologic time this period may correspond to the interglacial period prior to the advance of the Wisconsin glacial sheet.

Sea level again began to decline, possibly coincident with the advance of the Wisconsin glacial sheet, and the rivers again began to down cut. This down cutting took place principally along the same course taken by the rivers during the previous down cutting, with one notable exception. The Santa Maria River, instead of reexcavating its channel south of Fugler Point, became established north of Fugler Point, about on its present course.

Down cutting continued until the rivers were graded to a sea level possibly as much as 300 feet below the present sea level and several miles west of the present shore line. During this process, terrace deposits were almost completely removed, and only small remnants now remain along the sides of plains and river channels (pl. 1). At the present coast the down cutting amounted to about 230 feet below current river grade, and at the eastern end of the Sisquoc valley the down cutting amounted to about 50 feet. (See geologic sections *E–F*, *F–G*, and *G–H*, pl. 3.) The trench thus excavated was a relatively flat featureless plain of about the same extent as the present alluvial plains, had a steeper surface gradient than the present plain (p. 37), and had one relatively large bench or terrace in the Oso Flaco district above the excavated floor, at a height about midway between the present alluvial plain and the bottom of the excavated trench (p. 36), or about 100 feet below present land surface. (See logs for wells 11/35–20E1 and 11/35–27H1, table 16, and pl. 3.) Although in this area there is no definite proof that this bench was formed as the river was down cutting, Poland (Poland and Piper, in preparation) has been able to show that the formation of similar terraces occurred during the down cutting in the vicinity of Long Beach, California.

Deposition in the excavated trough began and continued as long as sea level rose. Again the rise may be coincident with the retreat of a glacial ice sheet. If so and, further, if the ice sheet was the last or Wisconsin glacial sheet, then the initial deposit formed in the bottom of the trough marks the beginning of the Recent epoch. It has been estimated by Schuchert and Dunbar (1933, p. 479) that the retreat of this ice sheet, and hence the initial deposition, may have begun approximately 27,000 years ago.

The deposit formed during the initial stages was the lower member of the alluvium. Its coarseness can be attributed to vigorous erosional activity in the headwater areas caused by exceedingly wet climatic conditions, a large volume of river discharge, which transported considerable quantities of coarse material into and through the area, and an average land-surface gradient of about 24 feet per mile, compared to the present average of about 18 feet per mile, or about 30 percent steeper than the present gradient. Deposition of the coarse material comprising the lower member continued until it attained a maximum thickness of about 115 feet at the present coast line (pl. 3).

Following the deposition of the lower member, drier climatic conditions apparently prevailed and caused an abrupt decrease in erosional activity in the headwater areas and the deposition of the fine-grained sediments of the upper member within the plains.

The abrupt change in depositional activity is indicated by the sharp contact between the two members of the alluvium near the coast, as shown on cross sections *E–F* and *I–I′* (pl. 3). Deposition of the upper member by the ancestral Santa Maria River at times took place more slowly than the rise of sea level. Consequently, brackish water or lagoonal clays and beach sands are interfingered with the fluvial deposits near the coast.

Guadalupe Lake, which has a depth of as much as 25 feet, probably owes its existence to the fact that the alluvium was deposited at a more rapid rate by the Santa Maria River than by the creek entering the plain through the lake from the southeast. Consequently, a closed basin was formed in the lower course of the creek.

The Sisquoc and Santa Maria plains now form the surface of the upper member of the alluvium, and the present channel deposits of the Sisquoc and Santa Maria Rivers have been deposited on that surface. The Sisquoc River and the upper part of the Santa Maria River have maintained courses along the north side of the alluvial plains throughout historic time. The present relatively stable position of the channels is caused largely by man-made control in the form of jetties, which are built out into the river channels.

The sand of the relatively large area of dunes on the surface of the alluvial plain and adjacent upland areas has been brought along the shore of the Santa Maria Valley by waves and longshore currents from the headlands projecting into the Pacific Ocean northwest of San Luis Obispo. The prevailing northwest winds, occasionally of gale velocity, have blown the sand inland and are continuing to do so. The extent of the dunes on the plain is limited in part by the action of the Santa Maria River.

SURFACE-WATER RESOURCES

By H. G. Thomasson, Jr.

The over-all drainage system of the Santa Maria River basin encompasses about 1,800 square miles. This system embraces the drainage basins of two major rivers—the Cuyama and Sisquoc and their tributaries, an area of about 1,600 square miles—all above their confluence at Fugler Point; also, the drainage basin of the Santa Maria River proper, about 200 square miles, downstream from Fugler Point.

This drainage system is here divided into a mountainous headwater area underlain at shallow depth by older consolidated rocks, and a downstream segment or valley area underlain to substantial depth by unconsolidated and largely permeable deposits. The headwater area includes all of the 1,600 square miles of the drainage basins upstream from Fugler Point, except the Sisquoc plain and a part of the dissected upland to the south, as shown within the limits of plate 2. Thus, it is almost wholly outside the area for which the geology and ground-water conditions are appraised in this report.

In this treatment of surface-water resources, all stream flow is considered as originating in the headwater area and, because surface runoff from the valley area is relatively small, its contribution is included in the evaluation of rainfall infiltration (p. 80). The geographic distribution and extent of the several drainage basins are shown on plate 4.

The Cuyama and Sisquoc Rivers deliver large quantities of runoff to the valley area. In times of flood, much of this runoff is wasted to the ocean; during periods of low or moderate flow, all or most of the water entering the area is absorbed by the river-channel deposits and is contributed as recharge to the ground-water supply. Thus, determination of the total runoff from the headwater area, and of the seepage losses occurring within the valley area, is necessary in order to evaluate the natural recharge to ground water in the valley area. Accordingly, in the ensuing pages, data on surface-water resources are presented to show the estimated total amount and distribution of runoff in the Cuyama and Sisquoc Rivers and their tributaries at about the edge of the Santa Maria Valley area, the estimated amount of natural seepage loss that takes place from these rivers and from the Santa Maria River within the valley area of ground-water recharge, and the estimated amount of surface-water outflow to the sea.

GENERAL CHARACTERISTICS OF RUNOFF

Because the 1,600 square miles of the headwater area includes terrain ranging from the relatively wet Sisquoc and Huasna River drainage basins to the semiarid Cuyama Valley, and further, because rainfall occurs largely in a few storms during a rainy season that extends from about November to April, runoff varies considerably among the several stream drainage basins and fluctuates greatly from year to year. During the 16 years 1930–45, for which gaging-station records are available for the Cuyama and Huasna Rivers, the greatest yearly runoff in the Cuyama River was 21 times the least yearly runoff, the extremes occurring in 1940–41 and 1933–34, respectively; whereas in the Huasna River this ratio was 259, extremes occurring in 1940–41 and 1930–31, respectively. Maximum monthly measured discharge in the Cuyama River was 33,320 acre-feet (March 1938), and in the Huasna River was 24,150 acre-feet (February 1941). In years of low rainfall each of the streams has been observed to be dry for periods of several months. These figures are rather remarkable considering that the drainage area above the Cuyama River gaging station is 912 square miles, whereas the area above the Huasna station is only 119 square miles.

GAGING-STATION RECORDS AND SUMMARY OF MEASURED STREAM FLOW

The following table indentifies the gaging statons at which continuous records of stream flow have been obtained, the periods of those records, and water-supply papers in which they have been published. As shown on plate 4, the gages record the runoff from practically all the drainage area tributary to the Santa Maria Valley area upstream from Fugler Point. Within the valley area the station at Guadalupe measures essentially all surface-water outflow from the valley.

Available records of stream flow in the Santa Maria River drainage system

Station	Term of record
Santa Maria River near Santa Maria, Calif.[1]	November 1903 to December 1905.
Cuyama River near Santa Maria, Calif	December 1929 to September 1945.
Santa Maria River at Guadalupe, Calif	January 1941 to September 1945.
Alamo Creek near Santa Maria, Calif	October 1943 to September 1945.
Huasna River near Santa Maria, Calif	December 1929 to September 1945.
Sisquoc River near Sisquoc, Calif	December 1929 to September 1933. October 1943 to September 1945.
Sisquoc River near Garey, Calif	February 1941 to September 1945.
La Brea Creek near Sisquoc, Calif	October 1943 to September 1945.
Tepusquet Creek near Sisquoc, Calif	Do.

[1] Records collected on Cuyama River at mouth of Buckhorn Canyon, 6.5 miles upstream from present gaging station, Cuyama River near Santa Maria.

NOTE.—Records here listed have been published by the Geological Survey as follows:

Year ending Sept. 30	Water-Supply Paper	Year ending Sept. 30	Water-Supply Paper	Year ending Sept. 30	Water-Supply Paper
1904	447	1934	766	1940	901
1905	447	1935	791	1941	931
1906	447	1936	811	1942	961
1930	706	1937	831	1943	981
1931	721	1938	861	1944	1,011
1932	736	1939	881	1945	1,041
1933	751				

The gaging station on the upper Cuyama River near Ozena (pl. 4) was installed in October 1944. Insufficient records are available at that site to be of use in this report.

Only two gaging stations have been operated continuously since 1930—namely, the station on the Cuyama River near Santa Maria, 2½ miles above Alamo Creek, and the station on the Huasna River near Santa Maria, half a mile above the mouth. (See preceding table.) A gaging station was operated on the Sisquoc River near Sisquoc, about 2½ miles above La Brea Creek, from December 1929 to September 1933; and at the same site since October 1943. The station on the Sisquoc River near Garey, about half a mile below the mouth of Tepusquet Creek and within the valley area, has been operated since February 1941. The stations near the mouths of Alamo, La Brea, and Tepusquet Creeks have been operated since October 1943. The station on the Santa Maria River at Guadalupe, which measures surface water leaving the valley, has been operated since January 1941.

In the study of seepage losses from streams, numerous miscellaneous measurements and estimates of flow have been made at places along the Cuyama, Sisquoc, and Santa Maria Rivers and their tributaries. The records of measured discharge at all gaging stations are summarized in table 3 in terms of monthly and yearly runoff.

TABLE 3.—*Measured runoff, in acre-feet, at eight gaging stations in the Santa Maria River drainage system in the water years 1904–45*

[Data from Water-Supply Papers of the Geological Survey]

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Total
Santa Maria River near Santa Maria [1] (drainage area 912 square miles)													
1903–04	----	48	172	363	702	1,734	238	68	12	----	----	----	3,350
1904–05	6,702	637	1,064	1,384	20,050	35,290	863	953	352	307	166	96	67,900
1905–06	332	512	719	----	----	----	----	----	----	----	----	----	1,560
Cuyama River near Santa Maria (drainage area 912 square miles)													
1929–30	[2] 0	[2] 0	127	855	438	1,180	199	215	9	6	0	0	3,030
1930–31	0	112	341	953	1,290	497	411	236	74	7	0	0	3,920
1931–32	0	311	4,730	2,560	15,300	2,220	851	497	241	50	25	12	26,800
1932–33	26	89	582	3,810	1,280	928	643	461	326	43	18	12	7,720
1933–34	14	14	370	1,340	663	455	147	18	3	0	0	0	3,020
1934–35	6	510	792	2,160	815	1,470	2,700	473	139	42	50	27	9,180
1935–36	25	37	469	675	5,310	1,050	1,090	291	165	35	11	2	9,160
1936–37	205	195	1,060	2,560	21,750	12,140	4,130	1,130	396	132	48	19	43,770
1937–38	29	98	738	837	14,440	33,320	3,430	1,650	748	414	181	173	56,060
1938–39	283	437	1,670	1,590	1,500	1,460	711	461	157	69	42	854	9,230
1939–40	284	239	438	1,610	1,600	779	804	221	81	34	19	9	6,120
1940–41	8	10	2,580	2,030	11,330	26,210	16,740	3,190	934	390	217	100	63,740
1941–42	224	394	1,520	1,650	1,080	1,420	1,780	791	287	97	50	33	9,330
1942–43	34	114	494	9,140	2,730	10,840	2,510	990	534	237	77	38	27,740
1943–44	66	324	881	910	6,790	7,020	1,460	837	443	126	44	33	18,930
1944–45	34	857	799	809	3,030	2,130	1,130	562	322	74	31	73	9,850
Santa Maria River at Guadalupe (drainage area 1,763 square miles)													
1940–41	[2] 0	[2] 0	[2] 0	650	28,090	84,830	67,990	1,730	0	0	0	0	183,300
1941–42	0	0	311	69	1	35	664	5	0	0	0	0	1,090
1942–43	0	0	0	35,480	2,310	33,770	342	0	0	0	0	0	71,900
1943–44	0	0	20	13	7,910	5,610	6	0	0	0	0	0	13,560
1944–45	0	0	0	0	4,670	302	15	1	0	0	0	0	4,990
Alamo Creek near Santa Maria (drainage area 87.7 square miles)													
943–44	154	149	160	152	854	1,740	300	242	194	160	149	142	4,400
944–45	127	173	148	136	606	616	288	232	189	167	146	130	2,860
Huasna River near Santa Maria (drainage area 119 square miles)													
929–30	[2] 0	[2] 0	68	136	62	121	22	21	0	0	0	0	431
930–31	0	0	28	122	68	39	6	0	0	0	0	0	264
931–32	0	0	4,650	3,090	12,400	861	271	171	80	31	10	16	21,600
932–33	31	60	111	3,250	655	235	154	96	89	25	8	8	4,720
933–34	11	54	140	144	109	103	33	4	0	0	0	0	598
934–35	0	95	111	309	157	457	5,390	315	103	42	41	45	7,070
935–36	57	84	102	125	14,970	1,370	1,300	207	83	65	29	29	18,420
936–37	87	76	226	1,750	23,680	9,250	2,590	611	193	88	59	42	38,650
937–38	51	99	1,060	192	23,050	20,950	2,270	971	359	222	105	72	49,400
938–39	82	101	138	179	279	230	153	59	24	8	0	1	1,250
939–40	10	47	93	970	2,020	1,670	846	158	60	28	15	16	5,930
940–41	36	50	282	1,470	24,150	23,120	16,020	2,110	540	254	152	112	68,300
941–42	118	125	2,090	1,960	1,770	1,750	2,410	790	303	138	82	79	11,620
942–43	73	132	211	15,200	3,380	23,080	2,540	761	304	199	115	83	46,080
943–44	94	131	206	251	1,660	4,250	520	292	173	104	65	55	7,800
944–45	80	142	135	129	2,170	2,780	879	301	130	70	30	34	6,880
Sisquoc River near Sisquoc (drainage area 290 square miles)													
929–30	----	----	0	54	108	2,120	455	363	2	0	0	0	[3] 3,100
930–31	0	0	0	0	213	4	0	0	0	0	0	0	[3] 217
931–32	0	0	7,070	2,780	26,900	4,500	1,640	836	61	0	0	0	[3] 43,800
932–33	38	0	0	3,030	1,600	1,300	495	181	32	0	0	0	[3] 6,680
943–44	68	71	123	616	13,110	17,190	5,350	2,520	931	300	131	94	[4] 40,500
944–45	83	1,170	520	615	9,800	6,320	3,570	1,260	434	133	95	77	[4] 24,080

See footnotes at end of table.

ABLE 3.—*Measured runoff, in acre-feet, at eight gaging stations in the Santa Maria River drainage system in the water years 1904–45*—Con.

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Total
Sisquoc River near Garey (drainage area 442 square miles)													
0-41					25,160	61,610	44,440	9,540	2,240	246	0	0	143,200
1-42	0	0	2,050	3,360	1,500	2,420	4,850	1,430	38	0	0	0	15,650
2-43	0	0	0	21,430	8,280	29,270	5,790	1,460	85	0	0	0	66,320
3-44	0	0	0	0	13,390	18,150	4,480	1,640	142	0	0	0	37,800
4-45	0	357	0	0	7,600	6,130	2,680	212	0	0	0	0	16,980
La Brea Creek near Sisquoc (drainage area 86.7 square miles)													
3-44	0	0	0	0	3,800	2,700	286	76	0	0	0	0	6,860
4-45	0	0	0	0	1,030	1,520	382	33	0	0	0	0	2,960
Tepusquet Creek near Sisquoc (drainage area 28.9 square miles)													
3-44	37	42	43	41	488	451	133	98	73	53	37	25	1,520
4-45	20	23	30	33	118	303	136	86	56	33	16	13	867

[1] Records collected on Cuyama River at mouth of Buckhorn Canyon, 6.5 miles upstream from present gaging station Cuyama River near Santa Maria.
[2] Estimated on the basis of rainfall records and subsequent record of discharge.
[3] Low-water flow diverted by Sisquoc Ranch, above station.
[4] Above all diversions and areas of seepage loss.

RUNOFF IN THE SANTA MARIA RIVER DRAINAGE SYSTEM

GENERAL FEATURES OF THE DRAINAGE BASINS

For purposes of this report, the Santa Maria River drainage system is divided into nine subsidiary drainage areas tributary to the gaging stations, and an ungaged area immediately upstream from Fugler Point (pl. 4). The greater part of this drainage system is included in the drainage basins of the Cuyama and Sisquoc Rivers and their tributaries. Thus, with respect to runoff, the most important of these subareas are the eight above Fugler Point, from all but one of which the runoff has been gaged in recent years. The physical features of these drainage areas differ considerably; they are summarized briefly herewith.

The Cuyama River is the longest stream in the area. Above Ozena it drains a fan-shaped high, mountainous area, about 10 miles long from east to west, which is outside of Santa Barbara County. Below Ozena it flows northwest for about 50 miles across the broad Cuyama Valley, which is bordered on the south by the Sierra Madre and on the north by the Caliente Range. Runoff from these mountains is largely absorbed in the Cuyama Valley, and only in time of flood does the river flow across the full valley reach. Below Gypsum Canyon, however, the river flows southwesterly through a narrow rock gorge for about 20 miles, in a winding course across the axes of both the Sierra Madre and San Rafael Mountains. At the lower end of this reach it is joined by its principal tributaries, Alamo Creek and the Huasna River. These two streams are each between 19 and 20 miles long and, together with the adjacent reach of the Cuyama River, drain the northwestern extension of the San Rafael Mountains and the Sierra Madre. This is a fairly rugged well-watered terrain, which supplies most of the total Cuyama River runoff. Below the mouth of the Huasna, the Cuyama River flows generally south for about 8 miles to Fugler Point, where it leaves the consolidated rock canyon, enters the Santa Maria Valley area, and joins the Sisquoc River.

The Sisquoc River is about 40 miles in total length, the upper 25 miles of which is in the very rugged region between the San Rafael Mountains and the Sierra Madre. (See pl. 4.) It crosses the axis of the San Rafael Mountains about 8 miles above La Brea Creek, and thence flows through lower and less rugged terrane to its confluence with the Cuyama River at Fugler Point. The principal downstream tributary is La Brea Creek, which heads in the Sierra Madre and crosses the northwest extension of the San Rafael Mountains.

The Santa Maria River proper extends from the confluence of the Cuyama and Sisquoc Rivers, at Fugler Point, to the Pacific Ocean and traverses the full length of the Santa Maria plain. That plain is primarily an area of water absorption characterized by low altitude, gentle land-surface slopes, and relatively light rainfall. Runoff resulting from rainfall on the local drainage area tributary to the Santa Maria River proper forms an insignificant part of the total flow of that stream and thus contributes little to ground-water replenishment.

On the other hand, runoff from the area drained by the Cuyama and Sisquoc Rivers supplies at least three-quarters of the recharge to ground water in the valley area. (See tables 5 and 7.) Therefore, it is one of the basic elements in the hydrologic equation of the valley. In the ensuing paragraphs, only the drainage area above Fugler Point is considered in the discussion of rainfall and runoff.

DISTRIBUTION OF RAINFALL ON THE HEADWATER AREA

Quantities and intensities of rainfall on the headwater area are for the most part unknown. Prior to 1946 (p. 58) there was no known rain gage in the drainage basin of the Sisquoc River above the mouth of La Brea Creek, in the La Brea Creek basin, or in the Alamo Creek basin. Also, in the Huasna River basin rainfall records were not available to provide adequate information for that area. In the Cuyama Valley a long record at Ozena and four short records furnished some information regarding quantities of rainfall in that semiarid region.

In this study, therefore, rainfall distribution among the several stream drainage basins is considered only qualitatively. Suggested distribution is based on the relation of orographic features to storm paths, type and luxuriance of vegetation, and size and condition of stream channels as related to drainage areas of the respective streams.

The general topographic pattern, as it affects precipitation, is as follows: The westward-trending San Rafael Mountains form the south watershed of the Sisquoc River basin at altitudes ranging from 4,000 to 6,000 feet. The northwestward extension of the San Rafael Mountains, which is crossed by the Sisquoc River and extends toward the Santa Lucia Mountains near San Luis Obispo, forms the west watershed of the Huasna River basin at altitudes ranging from 1,000 to 3,000 feet. Making an acute angle with the San Rafael Mountains, the northwestward-trending Sierra Madre separates the Sisquoc River basin from the Cuyama River basin; the altitude of its crest ranges from 3,000 to 5,000 feet, with a few peaks higher than 5,000 feet. The Cuyama Valley is a long alluvial valley, whose floor ranges from 1,500 to 3,000 feet above sea level. The Caliente Range north and northeast of that valley is not high enough to have any appreciable effect on precipitation.

Storms along the coast of Santa Barbara County usually move inland from the southwest, west, or northwest. Moist air moving from the south and east acrosses the Santa Ynez Mountains, the San Rafael Mountains, and the Sierra Madre. On the other hand, moist air moving from the west and northwest crosses the mountains drained by the Huasna River and Alamo Creek but with a path almost parallel to the crest of the San Rafael Mountains and the Sierra Madre. Thus, under the first condition of air movement, relatively large amounts of precipitation may be produced on the Sisquoc drainage basin, whereas under the second condition relatively large amounts of precipitation may be produced on the drainage basins of the Huasna River and Alamo Creek.

Vegetation is heaviest on the north flank of the San Rafael Mountains and is moderately heavy in the Huasna River basin and on the the north flank of the extreme eastern part of the Sierra Madre. Moderate growths of brush and grass cover the south flank of the Sierra Madre, but very little native vegetation is present in the Cuyama Valley and in the hills north and northeast of that valley. Although factors other than rainfall necessarily affect the type and quantity of vegetation, nevertheless the vegetative pattern closely follows the rainfall-distribution pattern suggested by the relation of the orographic features to storm paths.

Based on these studies, it appears that average yearly rainfall is heaviest on the southern and western parts of the drainage area, becoming progressively lighter toward the north and east. Specifically, some of the heaviest rainfall probably occurs on the north flank of the San Rafael Mountains within the south half of the upper Sisquoc River drainage basin. Here, moist air moving in from the south is forced upward over the 4,000- to 6,000-foot crest of the San Rafael Mountains, with resulting precipitation. It is true that the parallel Santa Ynez Mountains to the south, which rise to altitudes of 3,000 to 4,000 feet, have already exacted their toll of precipitation as discussed in the companion report on the Santa Ynez River valley. (Upson and Thomasson, 1951). However, the greater altitude of the San Rafael Mountains may reasonably produce secondary precipitation. Rainfall may be fairly uniform from the Sisquoc River northward to the crest of the Sierra Madre, whence it decreases rapidly down the north flank of that range. Although in places the Sierra Madre is almost as high as the San Rafael Mountains, it apparently has less effect on precipitation.

The Cuyama Valley and lower hills north and east of that valley are very dry, moisture available for precipitation apparently having been intercepted by the mountain ranges to the south. However, considerable rain and snow fall on the high mountains surrounding the extreme eastern part of the Cuyama Valley. For example, Mount Pinos, about 2 miles outside of the basin, is 8,826 feet above sea level and snow collects there in sufficient quantities to provide some runoff. In this area, intense thunderstorms of small extent and of short duration occasionally produce small amounts of flash runoff in the tributary streams. This runoff, however, usually is absorbed in the Cuyama Valley. The Cuyama River is perennial in most years as far downstream as Ozena, but all except large flash flood flows sink before traversing the Cuyama Valley completely.

The northwest part of the Cuyama River drainage system also has considerable rainfall, which probably decreases toward the east. In the absence of any distinct mountain barrier, it may be presumed that average rainfall on the Alamo Creek drainage basin is less than that on the Huasna River basin, and that the average rainfall on the adjacent small part of the Cuyama drainage basin is in turn less than that on the Alamo Creek drainage basin, but greater than that on the Cuyama Valley proper.

In an effort to relieve the deficiency in basic precipitation data for the mountainous areas of Santa Barbara County, several public agencies are now cooperating in the installation and operation of precipitation stations in those areas. Included among these agencies are Santa Barbara County, the city of Santa Barbara, Corps of Engineers of the United States Army, United States Forest Service, United States Weather Bureau, and the United States Geological Survey. During the winter of 1945–46, 6 recording rain gages and 10 storage-type gages were installed. In addition, three snow-rain recording gages were installed in 1946. Of the total number, seven recorders and four storage gages are within the Santa Maria River drainage system. The data obtained from these gages should furnish valuable additional information concerning the principal water-producing area of the county.

RUNOFF AS A FUNCTION OF RAINFALL

The distribution of rainfall on the whole drainage basin of the Santa Maria Valley is known only in a general way, and its relation to runoff is exceedingly complex, probably even more so than in the Santa Ynez River basin (Upson and Thomasson, 1951). Furthermore, runoff in the Cuyama and Sisquoc Rivers has no direct relation to runoff in the Santa Ynez River. For example, within the periods of concurrent gaging-station records, storms of sufficient magnitude to produce material runoff have occurred in the Huasna River and Alamo Creek drainage basins at the same time that light precipitation fell on the Santa Ynez River valley. The opposite condition has also been observed.

Because of this and other factors that influence the rainfall-runoff relation, estimates of runoff based on rainfall measured outside the area here under consideration are subject to question.

RUNOFF FROM THE HEADWATER AREA

ESTIMATES OF YEARLY RUNOFF

For the purpose of studying water-supply characteristics, the headwater area was subdivided into main stream and tributary stream drainage basins, as previously indicated. For all these basins, except the one immediately upstream from Fugler Point, some gaging-station records were available (pl. 4). Estimates of runoff from the various basins were made in order to supplement the available records.

The water supplies originating in the headwater area include not only the surface flow in the streams but also the underflow, or water percolating through the channel deposits at the gaging stations. However, the only gaging station at which underflow was important was the lower station on the Sisquoc River. Estimates of seepage loss above that station were made for years in which a record for that station was available. At the other main stem stations underflow was considered to be negligible. For example, between Gypsum Canyon and Fugler Point the Cuyama River flows in a narrow rock canyon on bedrock or on a thin veneer of channel deposits. Underflow in that canyon was estimated not to exceed a few hundred acre-feet per year—a quantity so small as to be disregarded in the estimated total yearly runoff. Also, in the Sisquoc channel deposits above the upper gaging station underflow which does not exceed a small fraction of a second-foot is probably all intercepted about 1,000 feet upstream from that gage by a low concrete dam reportedly built to bedrock.

As brought out in the discussion of gaging-station records (p. 50), the periods of record on the several streams were so intermittent that in every year except the two water years 1943–44 and 1944–45 one or more of the tributary drainage basins was not gaged. Thus, in all but these two years computations of total yearly runoff in the two river systems involved estimates of runoff from sizable ungaged areas. Such estimates were based largely on comparison with adjacent gaged drainage areas, modified in some instances by miscellaneous low-water discharge measurements. Runoff was not estimated for any year during which less than two stream-gaging stations were operated within the area. The estimates therefore span only the 16 years ending September 30, 1930–45, the longest continuous period in which two or more gaging stations were operated.

The ungaged part of the total drainage area was not the same in all of the 16 years. For example, during the water-years 1930–33, the ungaged drainage area included the Cuyama River drainage downstream from the main-stem gage, except that of the Huasna River, and the drainage area of the Sisquoc River downstream from the upper gage, except the narrow valley floor. During the water-years 1934–40, the ungaged area included the same area along the Cuyama River and all of the Sisquoc drainage basin. During the water years 1941–43, the ungaged area included the same area along the Cuyama River but only the small hilly part of the Sisquoc drainage area downstream from the lower gaging station. Since October 1943, the only ungaged part of the headwater area was the drainage area downstream from the gaging stations for the Cuyama and Huasna Rivers and Alamo Creek and that downstream from the lower Sisquoc gaging station.

Also, it was found that low-flow characteristics among the several basins varied so widely that runoff relations based on yearly totals for gaged areas were not satisfactory for estimating runoff from ungaged areas. For example, the Huasna River has a high storm runoff but a low summer and autumn flow, whereas the adjacent Alamo Creek has a relatively low storm runoff but a considerable low-water flow. Thus, the normal yearly runoff from Alamo Creek may be about half of the Huasna River runoff, yet in the dry year ending September 30, 1934, the total estimated runoff from Alamo Creek, obtained by adding monthly quantities based on miscellaneous measurements, was almost double the measured runoff of the Huasna River. Accordingly, the runoff figures in table 4 were obtained by adding measured monthly runoff from the gaged areas and estimated monthly runoff from ungaged areas.

TABLE 4.—*Measured and estimated yearly runoff, in acre-feet, from the headwater area of the Santa Maria River drainage system in the water years 1930–45*

Water year	Cuyama River above Alamo Creek	Alamo Creek	Huasna River	Sisquoc River above gage near Sisquoc	Sisquoc River above gage near Garey [1]	Seepage loss above Garey gage	Unmeasured balance of drainage area	Total runoff
1929–30	3,030	[2] 200	431	[3] 3,100	----------	----------	[2] 400	7,200
1930–31	3,920	[2] 200	264	[3] 217	----------	----------	[2] 200	4,800
1931–32	26,800	[2] 10,000	21,600	[3] 43,800	----------	----------	[2] 12,100	114,000
1932–33	7,720	[2] 2,900	4,720	[2] 6,680	----------	----------	[2] 4,200	26,200
1933–34	3,020	[2] 1,000	598	[2] 12,600	----------	----------	[2] 500	17,700
1934–35	9,180	[2] 3,600	7,070	[2] 20,000	----------	----------	[2] 3,300	43,200
1935–36	9,160	[2] 9,000	18,420	[2] 14,000	----------	----------	[2] 5,000	55,500
1936–37	43,770	[2] 18,000	38,650	[2] 65,000	----------	----------	[2] 24,000	190,000
1937–38	56,060	[2] 25,000	49,400	[2] 97,000	----------	----------	[2] 35,000	262,000
1938–39	9,230	[2] 1,600	1,250	[2] 11,400	----------	----------	[2] 1,100	24,600
1939–40	6,120	[2] 2,600	5,930	[2] 7,800	----------	----------	[2] 5,300	27,700
1940–41	63,740	[2] 34,000	68,300	----------	143,200	[2] 15,000	[2] 8,500	333,000
1941–42	9,330	[2] 4,500	11,620	----------	15,650	[2] 10,000	[2] 1,500	52,600
1942–43	27,740	[2] 22,000	46,080	----------	66,320	[2] 10,000	[2] 6,000	178,000
1943–44	18,930	4,400	7,800	----------	37,800	12,600	[2] 1,500	83,000
1944–45	9,850	2,860	6,880	----------	16,980	11,800	[2] 880	49,250

[1] Includes measured runoff of La Brea and Tepusquet Creeks.
[2] Estimated.
[3] Does not include small diversion above gage.

The yearly totals of the preceding table are subject to considerable error, owing largely to inherent differences between runoff characteristics of the gaged and ungaged drainage areas; also because on the Sisquoc River poorly controlled estimates of large seepage losses had to be made in some years. For example, during the years 1941–43 when the Sisquoc River was gaged only near Garey, the estimated yearly seepage loss upstream from that station ranged between 10,000 and 15,000 acre-feet, or between 10 and 64 percent of the total yearly discharge at the station. Although the estimates of runoff from ungaged areas may be considerably in error for individual months or even years, the average yearly runoff for the 16-year period—91,800 acre-feet—is believed to be reasonably accurate.

The runoff characteristics of the separate gaged drainage areas, together with the basis for comparing runoff of one area with that of another, are given in following paragraphs.

RUNOFF CHARACTERISTICS OF THE INDIVIDUAL DRAINAGE BASINS

Cuyama River above Alamo Creek.—Records of measured discharge at the gaging station on the Cuyama River, 3 miles upstream from Alamo Creek, have been obtained since December 1929 and published as "Cuyama River near Santa Maria." No estimates of discharge were necessary because the period of analysis was covered by factual records.

The drainage area above the gaging station is 912 square miles. However, the effective drainage area above the station varied widely from year to year. For example, during normal and dry years little water left the valley above Gypsum Canyon, and for those years runoff past the station was essentially that from the intervening small mountainous area. On the other hand, during wet years some runoff may have been contributed from the full drainage area above the station. Because of this variation in effective drainage area, the records of runoff at this gaging station did not plot consistently with records at gaging stations on nearby streams. Accordingly, estimates of runoff from ungaged areas were not based on records of Cuyama River runoff. Those records were used, however, as a guide in limiting the estimates which were based on the records for other nearby streams.

Alamo Creek.—A continuous gaging station has been operated on Alamo Creek, 1.2 miles above its mouth since October 1943, and the records have been published as "Alamo Creek near Santa Maria." Between 1930 and 1943, numerous miscellaneous measurements of discharge were made at the same site in all years except 1932 and 1940. Monthly quantities of runoff during the two years 1944 and 1945 were plotted against concurrent data for the station on the adjacent

Huasna River and a relation between the two drainage basins was obtained, as follows: During months of high flow the runoff from the Alamo Creek basin appeared to be about half of that from the Huasna River basin. Runoff was about equal when the monthly total was about 200 acre-feet, but during months of low discharge flow in Alamo Creek was consistently greater than that in the Huasna River. Because there was no reported surface diversion in either basin, the difference must have been due to natural conditions.

During the water years 1930–43, monthly runoff from the Alamo Creek drainage basin was estimated on the basis of the Huasna River record and the runoff relationship that existed between the two streams during the 2 years of concurrent records. Results so obtained were adjusted for periods of low flow on the basis of available low-water measurements of discharge, but no adjustment was made for months in which floods occurred in the Huasna River. It was found that minor rises in the Huasna River early in the rainy season usually were not accompanied by similar rises in Alamo Creek. On the other hand, fairly heavy rainfall on the Alamo Creek drainage basin was necessary to produce an appreciable rise at any time. Yearly estimates of runoff from the Alamo Creek drainage basin are considered reasonably accurate.

The characteristics of the basin relative to the headwater area as a whole may be summed up as follows: Flood peaks are not great and high flows are of short duration. The stream is clear except for a few days following heavy rainfall. It is reported never to have ceased flowing in the driest years, and in most years flow does not drop below 1 second-foot. In the late summer and autumn of most years flow in the Alamo Creek may equal or exceed the combined flow in the Cuyama and Huasna Rivers. As a tributary of the Cuyama River the Alamo Creek is second in importance only to the Huasna River.

Huasna River.—A continuous gaging station has been operated since December 1929 on the Huasna River, 0.5 mile above its mouth, and the records have been published as "Huasna River near Santa Maria" The period of study was covered by that record. The drainage area above the gage, 119 square miles, is largely mountainous with a small farmed area in the middle part. Storm runoff is flashy and is followed by rapid recession to medium rates of flow. The stream is clear except during floods and is perennial at the gage except in the summer and autumn of consecutive dry years. It is the most important tributary of the Cuyama River.

Records at this site were used as the basis for estimating runoff from the Alamo Creek drainage basin and from the ungaged area to the south, which includes tributaries of the Sisquoc River between the

upper gage and Fugler Point and, also, the Cuyama River between the gage and Fugler Point.

Sisquoc River above upper gage.—Records of discharge of the Sisquoc River at the upper gaging station (pl. 4) were collected during the period December 1929 to September 1933 and were published as "Sisquoc River near Sisquoc." These records did not include diversions that may have been made at a site about 500 feet upstream. Such diversions probably were small but they may account for the periods of no flow during the summer and autumn of those years. Miscellaneous measurements made at the site and on intervening tributaries during 1943 indicated considerable seepage loss from the channel between this site and the gaging station below Tepusquet Creek. The gaging station therefore was reestablished as of October 1943, using the same structures as in the earlier years. The recent records, however, include diversions and therefore represent the total runoff above this site.

In estimating runoff during years of no gaging-station record, it was considered desirable to separate the drainage area above the upper gage from that below because the rainfall and runoff characteristics of the two parts were quite different. Quantities of monthly runoff, measured at the upper gaging station, therefore, were plotted against corresponding quantities of runoff of the Santa Ynez River above Gibraltar Dam, which were corrected for the operation of Jameson Lake. That drainage area is immediately adjacent to the Sisquoc on the south. The comparison indicated that the runoff at the Sisquoc station was about 80 percent of the corresponding runoff above Gibraltar Dam. Accordingly, quantities of monthly runoff of the Sisquoc above the upper gage during the period from October 1933 to September 1940 were estimated on the basis of records at Gibraltar Dam by the use of this relation. Yearly runoff, obtained by adding the estimated monthly quantities, is considered reasonably accurate.

The part of the Sisquoc River drainage basin above the upper gage is probably the wettest of all the drainage areas here considered. In some years runoff from the 290 square miles apparently equals that from the remaining 1,300 square miles in the headwater area. This is not true in all years, however, because of the variation in rainfall distribution from year to year, but in all years this 290 square miles of drainage area is a very important contributor to the Santa Maria Valley area.

Sisquoc River above lower gage.—A gaging station has been operated since February 1941 on the Sisquoc River, about 0.5 mile downstream from Tepusquet Creek. The records of runoff, published under the heading "Sisquoc River near Garey," represent runoff from all the drainage area of the Sisquoc River except the small area to the west, between the gage and Fugler Point. However, the records did not include considerable quantities of seepage loss from the channel between the upper and lower gages. Miscellaneous discharge measurements made in 1943 and subsequent gaging-station records on the main stem and tributaries indicated that seepage loss above the gaging station near Garey was about 15 second-feet late in the runoff season. It may have been much greater than this early in the season and also during high flows when considerable areas of the channel were flooded.

Because the seepage loss was substantial, and because it varied from year to year depending on the duration and quantities of total yearly flows, no estimates of prior runoff at this gaging station were prepared. Records at the Garey station were used in the computations of total inflow to the Santa Maria Valley area only during the water years 1941–45. For earlier years estimates of runoff from the area above the upper station on the Sisquoc River plus runoff from the intervening area between the two stations were considered more reliable than estimates at the lower station plus estimates of seepage loss above it.

La Brea Creek.—Records of discharge have been collected since October 1943 on La Brea Creek, 0.4 mile above the mouth, and published as "La Brea Creek near Sisquoc." In addition, one miscellaneous measurement was made near this site in 1942 and six were made in 1943. The gaging station is on the valley fill about 0.3 mile downstream from the consolidated rock channel and some small seepage loss above the station was not included in the records of runoff.

Records of measured runoff from the La Brea Creek drainage basin do not appear directly in table 4 because the concurrent records on the Sisquoc River near Garey include runoff from this basin. The records were used, however, in computing seepage loss above Garey during the 2 years ending September 30, 1945, and in setting up rates of seepage loss above Garey for use in earlier years. The records were also combined with records of runoff from the Tepusquet Creek drainage basin to derive runoff relations which were used in estimates for years predating the period of record for these basins, as discussed on page 66.

La Brea Creek drainage basin is uninhabited except for a few small stock ranches, which require little water. The basin is mountainous throughout and is characterized by flash runoff, accompanying heavy rainfall, followed by rapid recession to small flows. A small perennial flow is present in most years in the lower reaches of the rock canyon but that flow sinks into the valley fill so that the stream is dry at the mouth during each summer and autumn. During the 2 years of record

the basin contributed 6 or 7 percent of the total inflow from streams to the valley area.

Tepusquet Creek.—Records of discharge have been collected since October 1943 on Tepusquet Creek, 1.1 miles above the mouth, and published as "Tepusquet Creek near Sisquoc." Prior to the establishment of the gage miscellaneous measurements were made as follows: one in 1941, one in 1942, and eleven in 1943. The gaging station is in a narrow rock-walled canyon and underflow is negligible. The stream is perennial at the gaging station in most years. Low flows are absorbed within a few hundred feet after reaching the Sisquoc channel. As with the La Brea Creek record, the records of runoff from the Tepusquet Creek drainage basin do not appear in table 4. They were used in conjunction with the La Brea Creek records, as discussed on pages 64 and 66.

Tepusquet Creek drainage basin is mainly one long canyon with fan-like tributaries in the mountainous headwaters. Storm runoff is very small—the basin absorbs all but the heaviest rains. Flow is uniform in winter and holds up until well into the summer, when it slowly recedes to the autumn low. Any diversions above the gage are too small to be detected by diurnal fluctuations in flow at the gaging station.

Ungaged area above Fugler Point.—The preceding discussion has dealt with records and estimates of runoff from the several drainage basins in the headwater area for which records were available in some years. No records of runoff were available for the remainder of the headwater area, which includes downstream segments of both the Cuyama and Sisquoc River drainage basins between the gaging stations and Fugler Point. In order to complete the estimates of total runoff reaching the Santa Maria Valley area from the headwater area, it was necessary to estimate the runoff from this downstream area for all years.

The characteristics of this part of the headwater area are somewhat different from those of the Alamo Creek drainage basin and the Sisquoc River drainage basin, so that it was not feasible to combine it with either of the others in preparing estimates of runoff. The area consists largely of foothills and mountains of relatively low altitude, having lighter average rainfall than either the Alamo or Sisquoc basins.

Because of the staggered periods of record at the various gaging stations, the downstream ungaged area was not constant throughout the period of analysis. During the period prior to October 1940 it included the drainage area downstream from the gaging station on the Cuyama River, excluding the Huasna River and Alamo Creek basins, and the drainage area downstream from the upper gage on the Sisquoc River, excluding that part previously described as being in the valley area. Since October 1940 it has included the same area downstream from the Cuyama gage and the small hilly part of the area north of the Sisquoc River, and downstream from the lower Sisquoc gage.

The procedure used for estimating runoff from this area prior to October 1940 was as follows: Monthly runoff during the 2 years 1943–44 and 1944–45 was gaged at the stations on La Brea and Tepusquet Creeks. Runoff during those 2 years from the ungaged area adjacent to the Cuyama River and from the ungaged area adjacent to the Sisquoc River valley floor downstream from the upper gage (mostly Foxen Canyon) were each assumed to be about equal to runoff from Tepusquet Creek drainage basin. Thus, runoff during those 2 years from the total area below the Cuyama and upper Sisquoc gages was estimated as the sum of the runoff of La Brea Creek plus three times the runoff of Tepusquet Creek. Total quantities of monthly runoff so derived were plotted with corresponding quantities of measured runoff of the Huasna River. Although the plotted points scattered considerably, estimated runoff from the area under study seemed to be about 90 percent of that from the Huasna River drainage basin. This relation was applied to the records of runoff of the Huasna River prior to October 1940, to estimate quantities of runoff from the ungaged area above Fugler Point for the equivalent period. The runoff computed by this procedure was found to be unreasonably high for several months as compared to estimated runoff in the adjacent drainage basin of the upper Sisquoc River, which had been computed from records for the Santa Ynez River. The runoff was adjusted arbitrarily for those months so as not to exceed 50 percent of the estimated runoff from the upper Sisquoc drainage basin. This adjustment was made on the basis of the relation between runoff of the two areas during the last 2 years when gaging station records were available, probable rainfall distribution on the two areas, and the fact that the estimates of runoff for the Sisquoc were based on more and better factual data.

For the water years 1941–45, the ungaged balance of the headwater area included the area downstream from the Cuyama gage and the small hilly area downstream from the lower Sisquoc gage and north of the river. For the period October 1940 to September 1943, runoff from the ungaged balance was arbitrarily estimated on the basis of unit runoff from adjacent areas. For the period October 1943 to September 1945, runoff from this area was assumed to have been about the same as the measured runoff from the Tepusquet Creek drainage basin.

Estimates of runoff in all years from the ungaged area immediately upstream from Fugler Point are considered poor. However, the quantities represent only about 10 percent of the total inflow to the Santa Maria Valley area during the period prior to October 1940 and only 2 or 3 percent of the total during the later years. The inaccuracies in the estimates, therefore, do not introduce very material errors into the estimates of total inflow.

SEEPAGE LOSSES FROM STREAMS

At the start of this investigation it was known that water was lost by seepage from stream channels in the Santa Maria Valley area. The evaluation of such losses was an integral part of this study of the water resources of the valley. The difference between the total inflow from the headwater area, which has been summarized in the foregoing paragraphs, and the total surface-water outflow to the sea was considered to be approximately equal to the total seepage losses within the valley. The runoff from the valley area proper was quite small and no allowance was made for it in the seepage studies.

Numerous miscellaneous measurements and estimates of stream discharge indicated that principal losses occurred in the reach between the upper gage on the Sisquoc River and the inland edge of the artesian area on the Santa Maria River (pl. 5). Minor losses were noted downstream from the Cuyama River gage to its confluence with the Sisquoc River at Fugler Point. These reaches of stream channel are within the recharge area as defined in this report (p. 73). In the western part of the valley area the Santa Maria River is separated from the main ground-water body by confining beds, and very little permanent seepage loss occurs. Stream flow reaching the area of confined ground water is largely wasted to the ocean.

Surface-water outflow was largely measured at a gaging station installed on the Santa Maria River at Guadalupe in January 1941 (table 3), well within the artesian area (pl. 5). Considerable difficulty has been experienced in the operation of this station. During periods when the river was flowing, the stream has continually shifted back and forth across the wide sand channel so that gage heights have been uncertain, when recorded at all. In some recorded years the flow at the station was so small it never registered on the gage. Discharge records during those periods when the stream was away from the gage were computed largely on the basis of the composite inflow hydrograph adjusted to discharge measurements made at Guadalupe.

Even though the discharge records at Guadalupe were rated no better than "poor," nevertheless they furnished considerable valuable information regarding rates and quantities of seepage loss above that station. For example, in the year ending September 30, 1942, the measured and estimated total inflow to the valley was 52,600 acre-feet, but the outflow in that year as measured at Guadalupe was only 1,090 acre-feet; or the loss from stream channels above Guadalupe was about 51,500 acre-feet. Similarly, during several months the total inflow was more than 15,000 acre-feet, whereas the outflow was from zero to a few hundred acre-feet. Thus, sizable errors in the Guadalupe record would have made no material change in the estimates of total seepage losses for those periods.

A study of several storm periods indicated that seepage loss from streams exceeded 1,000 acre-feet per day for moderate flows and that it probably exceeded 2,000 acre-feet per day during major floods when large areas of channel were flooded. In view of the large and variable rates of seepage loss above Guadalupe, it was concluded that for years prior to the period of record reliable estimates of stream flow at that station could not be based on flow at the upstream gaging stations; rather, it appeared that direct estimates of seepage loss during those years would be more accurate.

Accordingly, monthly estimated quantities of seepage loss during the water-years 1941–45 were plotted against corresponding estimated quantities of total inflow to the valley floor from the headwater area. The following significant relations were established from this study: For all months with less than 10,000 acre-feet of total inflow there was no outflow at Guadalupe, indicating that (neglecting evapotranspiration; see p. 71) all inflow sank into the ground. For months in which flow was uniform, with no major floods, the amount of inflow might be as much as 20,000 acre-feet without any outflow at Guadalupe. A good example was March 1944, during which month a moderate flow was sustained and no large flood occurred. Estimated total inflow for the month was 34,200 acre-feet, but, because it was well distributed with respect to time, only 5,610 acre-feet passed Guadalupe, or 28,600 acre-feet seeped out of the channel. Rises occurring late in some months caused scattering of the plotted points, owing to channel storage, and because flash floods may have exceeded the capacity of the channel to absorb water. For example, in 1943, when all streams were low until January 21, the sudden flood beginning that day was great enough to bring the estimated total inflow for the month up to 55,600 acre-feet. Probably more than 90 percent of the total inflow occurred during the latter third of the month, and the high peak flows from that storm greatly exceeded the maximum absorption capacity of the channel. Consequently the excess water was wasted to the ocean, and the estimated total seepage loss for this month was only 20,100 acre-feet.

Just as the monthly quantities of seepage loss depend on the distribution of inflow with respect to time as well as on its total monthly amount, so also the yearly quantities of seepage loss depend on the monthly distribution of inflow as well as on the total yearly amount of inflow. During years in which rainfall was well distributed and no major floods occurred, seepage losses were considerably greater

than during years in which the total inflow was about the same but in which most of the inflow was concentrated in one or two major floods.

On the basis of these principles, quantities of monthly seepage loss for the years ending September 30, 1930–40, were estimated as follows: For all months in which total inflow was less than 10,000 acre-feet, the entire inflow was considered to have seeped from the channel. For months in which total inflow exceeded 10,000 acre-feet, the daily records of flow at available gaging stations in the area, and also in adjacent stream basins, were studied to determine the presence or absence of floods and the distribution of flow with resepct to time. Seepage losses for those months were adjusted for excessive floods and for floods occurring near the end of the months. Estimated yearly seepage loss was then obtained by adding the monthly estimates.

Table 5 presents estimated yearly inflow to, outflow from, and seepage losses within the Santa Maria Valley area in the 16 years ending September 30, 1945. Quantities of estimated yearly inflow were obtained from table 4. Outflow was measured beginning in 1940–41 (table 3). The quantities of estimated yearly outflow during the years prior to 1940–41, as given in table 5, represent the residual difference between estimated inflow and estimated seepage loss during the respective years. Yearly seepage losses during the years prior to

TABLE 5.—*Estimated seepage loss, in acre-feet, from stream channels in the Santa Maria Valley area in the water years 1930–45*

Year	Inflow	Outflow	Seepage loss
1929–30	7, 200	0	7, 200
1930–31	4, 800	0	4, 800
1931–32	114, 000	42, 000	72, 000
1932–33	26, 200	3, 700	22, 500
1933–34	17, 700	0	17, 700
1934–35	43, 200	3, 600	39, 600
1935–36	55, 500	19, 300	36, 200
1936–37	190, 000	88, 000	102, 000
1937–38	262, 000	135, 000	127, 000
1938–39	24, 600	0	24, 600
1939–40	27, 700	0	27, 700
1940–41	333, 000	[1] 183, 300	150, 000
1941–42	52, 600	[1] 1, 090	51, 500
1942–43	178, 000	[1] 71, 900	106, 000
1943–44	83, 000	[1] 13, 560	69, 400
1944–45	49, 250	[1] 4, 990	44, 300
Total	1, 468, 750	566, 440	902, 500
16-year average	91, 800	35, 400	56, 400

[1] Outflow measured at Guadalupe.

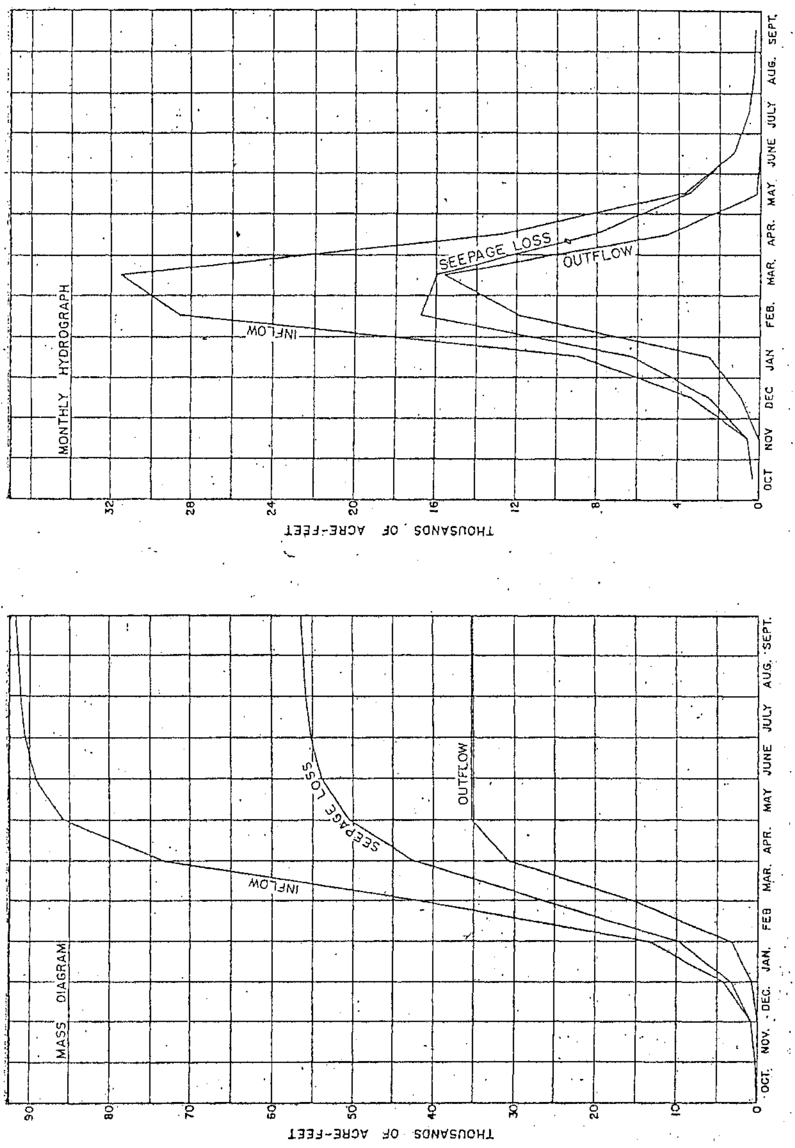

FIGURE 2.—Estimated average monthly inflow, seepage loss, and surface-water outflow for the Santa Maria Valley area in the 16 water years 1930–45.

1940–41 were estimated directly, as described in the preceding paragraphs. For the years beginning 1940–41 seepage loss is the residual difference between estimated inflow and measured outflow.

Figure 2 presents in graphic form the estimated average monthly quantities of inflow, seepage loss, and surface-water outflow for the Santa Maria Valley area during the 16-year period analyzed in this report. The two graphs on that plate are based on the same data. The monthly hydrograph shows the distribution of quantities with respect to time but the mass diagram, or cumulative monthly hydrograph, shows more clearly the division of inflow into seepage loss and surface-water outflow.

Estimated seepage losses during months of low and moderate flow are as accurate as the estimated quantities of total inflow. Estimated losses during floods are subject to question but are as accurate as available data permit. Future records of discharge at the present gaging stations will furnish data which will either confirm these estimates or establish a factual basis for their revision.

The over-all difference between surface-water inflow and outflow was classified as seepage loss in table 5. Actually some water evaporated from the water surface in the streams and from the channel sands, and transpired through riparian vegetation, and so did not reach the main water body of the Santa Maria Valley area. Such losses by evapotranspiration are believed not to have exceeded a few hundred acre-feet a year, however, and so were not deducted from the over-all difference.

Under natural conditions of stream regimen that prevailed during the period of current analysis, most of the runoff and seepage loss took place during the winter and early spring months, when evapotranspiration losses were at a minimum. However, the disturbance of the natural regimen, in which flood waters might be detained in surface reservoirs and later released during the summer, would result in disproportionately large losses by evaporation from the reservoir surfaces and from stream channels. For example, in the headwaters of the Santa Ynez River, about 50 miles southeast of the Santa Maria Valley, the 14-year average evaporation at two stations, as measured by class A land pans, was 1.10 and 1.28 inches, respectively, during the month of January, and 8.08 and 9.80 inches, respectively, during the month of July (Upson and Thomasson, in preparation). Furthermore, the conservation of flood waters through the use of storage reservoirs would probably produce large additional losses by transpiration. Water-loving plants around the edges of the reservoirs would take their toll and, also, many acres of riparian vegetation could be expected to spring up and flourish along the stream channels, which now are mostly barren, if furnished an adequate supply of water during the growing season.

Although evapotranspiration losses might be increased manyfold by the regulation of the stream regimen, such losses could be minimized by releasing the stored flood waters as rapidly as the stream channels could be made to absorb them. The increased evapotranspiration losses resulting from reservoir storage undoubtedly would be far more than offset by the reduction in peak flows and hence the salvage of water that otherwise would waste to the ocean. The stream system appears to be well suited to the development of dual-purpose reservoirs for the control of floods and the conservation of water supplies.

GROUND-WATER RESOURCES

This evaluation of the ground-water resources of the Santa Maria Valley area is developed through successive treatment of the occurrence of ground water essentially in a single main water body, its magnitude and its containing formations, and conditions which cause its partial confinement; the source and movement of water through the deposits, with a critical analysis of the controlling factors; the nature and quantity of recharge; the nature and quantity of discharge; water-level fluctuations and their relation to net changes in ground-water storage; estimates of perennial yield of the basin; and finally the general chemical quality of water and possibilities of sea-water encroachment. The quantitative hydrologic studies are limited to the period 1929–45 by the availability of records on water levels, rainfall, runoff, and pumpage.

OCCURRENCE OF GROUND WATER

MAIN WATER BODY

The main water body of the Santa Maria Valley area extends continuously from the head of the Sisquoc plain on the east to the Pacific Ocean on the west and is contained within the unconsolidated deposits that fill the major syncline, described on page 42. Minor arms extend up the tributary tongues of alluvial material, principally those along the Cuyama and Sisquoc Rivers. The containing formations include the alluvium, the Orcutt and Paso Robles formations, and the Careaga sand; also, locally, the terrace and channel deposits (pl. 1). The bottom of the water body is considered to be at the base of the Careaga sand. In the deeper parts of the basin the water may be of poor chemical quality.

This main water body is as much as 8½ miles wide and underlies an area of about 110,000 acres. Its maximum thickness is about 1,300 feet beneath the Sisquoc plain near Sisquoc and 2,800 feet beneath the Orcutt upland near Orcutt; however, the average thickness is roughly 1,000 feet. Thus, the total volume of saturated deposits is roughly 100,000,000 acre-feet. Unfortunately, only a very small part of the total volume of water in the containing deposits can be withdrawn for use without exceeding the perennial yielding (p. 123).

Most wells penetrate only from 200 to 400 feet into the main water body; they disclose no marked differences in head of the water within that range of penetration. With respect to the land surface, in general the head in wells ranges from about 500 feet below in the southeast part of the Orcutt upland to about 10 feet above near the coast. Any minor differences of head which may exist between the several formations tapped probably are largely equalized within the casings of wells which tap more than one formation. In the few deep wells perforated only in the Paso Robles formation, the head is a few feet higher than in shallower wells tapping only the overlying formations. This slight increase of head with depth probably is due to local confinement of water beneath clay lenses in the Paso Robles. Plate 5 shows contours on the water table or pressure surface of the main body.

Beneath the eastern and larger part of the area about 80,000 acres of the main water body is unconfined; however, beneath the western part of the Santa Maria plain about 30,000 acres is confined beneath the upper member of the alluvium. In turn, the area of confined water has two parts—an eastern part where the head of water is below the land surface, and a western part where the head is above the land surface and where there are flowing wells. The extent of the area of flowing wells has varied considerably during the past 27 years, as is shown on plate 5.

The eastern boundary of confined water is somewhat irregular and intangible, but in general, it is roughly along the line between Rs. 34 and 35 W. (See pls. 1 and 5.) This position is deduced chiefly from physical and lithologic features of the upper member of the alluvium, from differences in the fluctuation of water levels in wells, and from the reported areas of ground-water discharge as of 1918.

The area of unconfined water is one of potential recharge, and is called the intake area because there water is able to infiltrate from the land surface down to the water table of the main water body. On the other hand, in the area of confined water, there is essentially no infiltration from the land surface because of the low permeability of the confining beds.

MINOR WATER BODIES

In the Santa Maria Valley area there are three known minor water bodies, as follows:

1. A thin and possibly discontinuous body beneath the central part of the Orcutt upland, contained in dune sand. It is perched above the

main water body on fine-grained deposits or old soils of the Orcutt formation, and it supplies water in small quantities to a few domestic wells. Recharge is wholly by infiltration of rain and water not withdrawn or retained in storage eventually reaches the main water body below.

2. A relatively thin body beneath the Nipomo upland, contained in the terrace deposits and upheld by consolidated rocks. Wells tapping this body yield water in quantities sufficient only for domestic and stock needs. Recharge is principally from rain but partly from minor streams. South of the drainage divide water that is not extracted moves southwest through the deposits and eventually reaches the main water body. (See pl. 2, sec. *D–D′*.)

3. A shallow body in the uppermost part of the alluvium and in the channel deposits in the area of main-body confinement, and extending into the dune sand at the west end of the Santa Maria plain. Recharge is chiefly by seepage from streams, and infiltration of rain and irrigation water. Discharge, which takes place by drainage westward toward the ocean, sustains the perennial dry-season flow in the lower reaches of the Santa Maria River and Oso Flaco Creek. No wells tap this body.

SOURCE AND MOVEMENT OF GROUND WATER

GENERAL FEATURES SHOWN BY WATER-LEVEL CONTOURS

The sources of ground-water recharge are indicated by the direction of movement of water in the main water body. Water moves away from areas of replenishment toward points of discharge. Specifically, provided impermeable barriers do not exist, movement is indicated by differences of head between any two points because water always moves from a point of high head to a point of low head. Contour lines drawn on the surface of a water body connect points of equal head.

Plate 5 shows by contours the head of water throughout the main water body, based on measurements of "static" (nonpumping) levels in wells made in February to May of 1936 and 1942. Those for 1942 are based on measurements made and compiled by the Geological Survey, and those for 1936 were supplied by several agencies in the Santa Maria Valley. Altitudes of wells were determined by spirit leveling or aneroid barometer, or were interpolated from topographic maps. Within the area of confined water the contours are drawn on the pressure surface of the main water body, and elsewhere on the water table.

The contours for 1942 show the head of water during a period of relatively high water levels, and those for 1936 show the head during the lowest period of record. The map also shows the approximate eastern limit of the area of flowing wells in 1918, 1936, and 1942, and the reported areas of ground-water overflow in 1918.

With respect to source, both sets of contours show that within the intake area water moves generally westward away from the Sisquoc and Santa Maria Rivers; water moves northward away from the Casmalia and Solomon Hills, and southward from the western part of the Nipomo upland; and water moves down the lower course of the Cuyama River. Similar movement down the canyon of the Sisquoc is indicated by maps not here reproduced. In other words, the contours show that substantial recharge to the main water body is accomplished by seepage from streams, infiltration of rain on the bordering hills, and underflow in the alluvium and channel deposits along the rivers. Considerable recharge also is accomplished by infiltration of rain on the intake area, but this is so thoroughly dispersed that it is not shown by the contours.

Although the shape of the contours on plate 5 is influenced chiefly by recharge, it is modified also by conditions within the main water body, such as changes in permeability of the containing deposits and changes in cross-sectional area of the deposits, and by fault barriers. The variations in the movement of water through the area as caused by these structural and lithologic features, and hence the changes in the configuration of the contours, are discussed separately as follows:

MOVEMENT IN THE SISQUOC VALLEY

The contour map (pl. 5) shows that beneath the Sisquoc plain water is moving with a fairly uniform hydraulic gradient in a westerly direction. The direction is established by the natural westward drainage and the withdrawals for irrigation farther west. Along the north and south sides of the plain few data are available concerning the movement, but it is presumed to be towards the plain.

PERCOLATION FROM THE SISQUOC VALLEY TO THE SANTA MARIA VALLEY

The movement of water from the Sisquoc valley to the Santa Maria Valley takes place through the Careaga sand, the Paso Robles formation, and possibly the terrace deposits on the south side of Fugler Point, and principally through the alluvium on the north side. At Fugler point the main water body is split longitudinally by the outcropping tar-impregnated Careaga sand, which forms an impermeable "island" at the north end of the Point, (See geologic sec. *B–B′*, pl. 2.)

The water-level contour map shows that south of Fugler Point, a rapid steepening of gradient occurs immediately west of Garey from about 25 feet per mile to about 100 feet per mile. There are several possible explanations for this feature, and among the most likely are the following: a large decrease in the permeability of the saturated deposits as water moves from the highly permeable alluvium to the less permeable older formations—thus, in order to transmit the same quantity of water through the less permeable deposits a steeper hydraulic gradient would be required; the inferred westward plunge of the base of the permeable beds west of Garey which might cause a steepening of hydraulic gradient; and the presence of the postulated Fugler Point fault (p. 43) which might retard the movement by a reduction in effective cross-sectional area through displacement of beds, through cementation, or through impregnation by tar seepage. Until more data are available on the existence of the fault, the first two explanations together are believed to be the most reasonable.

In the alluvium on the north side of Fugler Point, on the other hand, the water table has approximately the same gradient as established in the Sisquoc valley but steepens rapidly below. Thus, there exists relatively free hydraulic continuity between the Sisquoc and Santa Maria valleys through the alluvium.

The quantity of water moving as underflow from the Sisquoc valley to the Santa Maria Valley through the alluvium is of particular interest, especially in view of possible future water-spreading operations in the channels, and the subsequent transmission of water stored in the deposits of the Sisquoc valley. The amounts of underflow for the two years 1936 and 1944 are used to show the extremes of maximum and minimum values, respectively, and are determined by the use of Darcy's law, which may be expressed by the formula

$$Q=PIA,$$

in which Q is the quantity of water in gallons per day, P is the permeability coefficient in gallons per day per square foot, I is the hydraulic gradient in feet per mile, and A is the cross-sectional area in square feet (Wenzel, 1942, pp. 3–4). The permeability coefficient used is 3,500 gallons a day per square foot, obtained from the test on well 10/33–21R1 (p. 38). Obviously, at best this value is only an estimate because it was determined in an area 2 miles downstream, and further it may not apply strictly to both years when the deposits were saturated to different depths.

In 1936, the hydraulic gradient was about 15 feet per mile. (See pls. 5 and 6.) The width of the saturated deposits was about 3,000 feet and the thickness about 60 feet, giving a total saturated cross-sectional area of about 180,000 square feet. The quantity of water moving through these deposits in 1936 is computed to have been about 1,800,000 gallons a day—about 2.8 second-feet, or 2,000 acre-feet a year.

Similarly, in 1944 the hydraulic gradient was about 20 feet per mile. The width was the same, 3,000 feet, and the saturated thickness was about 100 feet, giving a total saturated cross-sectional area of 300,000 square feet. The quantity of water moving through the deposits then was about 4,000,000 gallons a day, about 6.2 second-feet, or 4,500 acre-feet a year. Thus the natural limits of underflow have ranged from about 2,000 to 4,500 acre-feet a year.

MOVEMENT IN THE SANTA MARIA VALLEY

The water-level contour maps (pl. 5) show three main features in regard to the movement of ground water in the Santa Maria Valley, as follows: a striking longitudinal break or flattening of hydraulic gradient near the central part of the valley; a wide lateral shifting of the trough, or low, down the middle of the valley between 1936 and 1942; and a seaward gradient to and at the coast.

The longitudinal break in hydraulic gradient near the central part of the valley, which in 1942 was from about 40 feet per mile on the east to less than 10 feet per mile on the west, is evident as far back as 1907 when there was little pumping in the area. This is clearly shown by the profiles of water levels for selected years (pl. 6). Consequently, the break is a natural phenomenon and not the result of pumping. Furthermore, the break is not the result of displacement of beds along the Santa Maria fault, because the fault does not cut the upper part of the main water body contained in the Orcutt formation nor in the highly permeable alluvium; because the displacement of the older unconsolidated deposits is small and does not materially alter the cross-sectional area; and further because the change in gradient is just the reverse of that which would be produced by a fault barrier.

The flattening is believed to be due primarily to a line of hydraulic balance established at the intersection of two independently controlled gradients: the western gentle gradient, which is controlled largely by the rate of discharge at the coast, and the eastern steep gradient, which is determined largely by the rate of recharge from the Santa Maria River and from underflow out of the Sisquoc valley; in conjunction with considerable widening and thickening of the water-bearing deposits from the Sisquoc valley westward to the central part of the Santa Maria Valley. (See geologic sec. *B–B′*, *C–C′*, and *D–D′*, pl. 2.) The water-level profiles (pl. 6) show that the line of balance has shifted only slightly eastward or westward since 1907, depending upon the controlling altitudes of the water surface at either end of the valley. From the edge of the area of confined water westward the gradient steepens slightly, probably owing to a decrease in cross-sectional area of the water-bearing deposits.

The second feature of water movement in the Santa Maria Valley is the lateral shifting of the trough on the surface of the water body shown by two sets of contours on plate 5. In 1936 the trough extended roughly up the central part of the Santa Maria plain, crossed beneath the Orcutt upland southeast of Santa Maria, and probably entered the Sisquoc valley near Garey. In 1942 the trough had moved southward a maximum distance of about 5 miles and extended along the south side of the Orcutt upland, entering the Sisquoc valley near Garey. Thus at present the trough lies about 3 miles south from the Santa Maria plain in an area where only about 5 percent of the withdrawals occur, and hence is not simply a pumping depression.

Its position is probably determined primarily by the relation between recharge from the Santa Maria River and discharge by pumping from beneath the Santa Maria plain. In the long series of dry years ending in 1936, there was relatively small recharge from the river. Consequently, pumpage exceeded recharge and the trough shifted northward from beneath the Orcutt upland toward the center of pumping. On the other hand, in 1942, following a period of wet years, recharge from the river exceeded withdrawals on the plain, and the excess water moved southward beneath the Orcutt upland, causing the trough to shift in that direction. Thus, the source and movement of water in the heavily pumped area may vary over a period of years. During wet years recharge from the Santa Maria River supplies more water than is pumped, but during dry years water supplied by the river is inadequate and the water beneath the Orcutt upland, which is supplied by infiltration of rain, is more heavily drawn upon.

The third feature, the seaward hydraulic gradient of the main water body to and at the coast, is extremely important because it means that water is moving toward and is being discharged into the Pacific Ocean at some point off the coast, and it is thereby preventing the landward encroachment of sea water. The water-level profiles (pl. 6) show the hydraulic gradients for the various years projected to the coast line. If extended seaward, they indicate that the point of discharge is somewhere between 2 and 4 miles off shore. The profiles also indicate that there has always been escape at the coast.

RECHARGE TO THE MAIN WATER BODY

In some areas, such as those in the Midwestern States, recharge to water-bearing formations from rain and streams may take place in remote districts hundreds of miles from the points of withdrawal. In such areas the evaluation of quantities of annual or long-term recharge involves chiefly computations of the amount of ground water transmitted into the areas through the aquifers. In the Santa Maria Valley area, on the other hand, practically all the recharge takes place within the boundaries of the area shown on the geologic map (pl. 1). Therefore, in order to determine total recharge it is necessary to estimate recharge to the main water body by appraising seepage loss from streams, infiltration of rain and underflow along principal streams.

SEEPAGE FROM STREAMS

As indicated on pages 67 and 73, stream losses take place in the lower course of the Cuyama River, in the Sisquoc River below the upper gage, and in the Santa Maria River downstream to the area of confined water. Within this area there are no extensive impermeable beds, and water seeping from the streams is able to reach the main water body. Large losses are possible because of the relatively high permeability of the channel deposits, which ranges from 266 to over 1,000 gallons a day per square foot (table 2), and the large areas from which the losses can take place—about 2,700 acres in the Sisquoc valley and about 6,300 acres in the Santa Maria Valley, or a total of about 9,000 acres. However, the entire acreage is covered only during infrequent major floods and then for relatively short periods of time. Seepage at most times is from much smaller areas.

Throughout most of the reach in which seepage losses from streams occur, measurements of water levels in wells adjacent to the channels show that the water table lies at considerable depth below the river channels. In the Sisquoc valley the depth has ranged from a minimum of less than a foot at the upper and lower ends to a maximum of 90 feet near Sisquoc. Similarly, in the Santa Maria Valley the depth has ranged from less than a foot at Fugler Point to a maximum of 130 feet north of Santa Maria (pl. 6). Therefore, except near Fugler Point and probably in part of the Sisquoc valley, river water has not been in hydraulic continuity with the main water body. Water from the river, then, seeps vertically downward through the permeable channel deposits and through the greater part of the upper member of the alluvium before reaching the main water body as recharge.

The methods used to estimate seepage losses have been presented in the section on surface-water resources, and yearly estimates therein derived for the 16-year period 1930–45 are shown in table 5. The magnitude of the losses involved with respect to time are discussed on pages 67 to 79. Because there are but very few water-loving plants along the channel courses, and because evaporation losses during the winter months are at a minimum, for all practical purposes the total yearly estimated seepage losses reach the main water body as recharge in the manner described above. Thus, estimated yearly recharge by seepage from streams has ranged from 4,800 acre-feet in 1930–31 to 150,000 acre-feet in 1940–41, and has averaged 56,400 acre-feet for the period 1930–45. Recharge from this source constitutes about 80 percent of the total recharge to the main water body. Even so, the average surface-water outflow, or the water forever lost from the basin, has averaged about 35,000 acre-feet a year during the past 16 years. Therefore, it is obvious that any future plan devised to utilize fully the surface-water resources should consider the advantages of salvaging this wasted water insofar as possible and of spreading it on the appropriate portions of the Sisquoc, Cuyama, and Santa Maria River channels.

In the area of confined water, seepage loss cannot penetrate below the contact between the channel deposits and the relatively impermeable upper member of the alluvium. Water lost here is stored temporarily in the surficial sediments adjacent to the river during high flows, and returns to the stream channels when the floods subside.

INFILTRATION OF RAIN

AREAS OF INFILTRATION

The area of rain infiltration encompasses the greater part of the area shown on plate 1, and hence is nearly wholly outside the headwater area for which estimates of runoff have been made. It is estimated to be about 140,000 acres in extent, and receives relatively little rainfall and essentially no runoff from minor tributaries except during infrequent heavy storms. Because the quantity of infiltration is governed principally by the character of the underlying deposits and the type of vegetative cover, the total area of infiltration is divided into a primary area, which is coextensive with the intake area and which includes about 80,000 acres whose cover consists of grass and irrigated lands; and a secondary area, which includes about 60,000 acres characterized by thick growths of brush, scrub oak, and some grass, and underlain principally by consolidated rocks.

METHODS USED TO ESTIMATE INFILTRATION

Precise field determinations of that part of the total rainfall that infiltrates below the root zone and reaches the main water body were beyond the scope of this investigation, and to be of value they would have to be made under a variety of conditions over a series of years. Therefore, the estimates of infiltration are based primarily on field studies made in Ventura County, principally by Blaney. (Blaney, 1933; Blaney and Sopp, 1929). Although conditions are not exactly the same in the Santa Maria Valley as in Ventura County, it is believed that they are sufficiently similar for the estimates to be valid.

The primary area is divided into two subareas according to type of land cover: 60,000 acres of grass land and 20,000 acres of irrigated land. Infiltration of rain on these lands was determined by plotting a curve of infiltration against rainfall for each type of cover, derived from data of Blaney, who found that in general there is no infiltration when yearly rainfall is less than 15 inches on grass land or less than 12 inches on irrigated land. From the curve for any given yearly rainfall the infiltration of rain in inches can be estimated. In this way the infiltration of rain on each type of land has been estimated for the years 1930–45.

The secondary area is underlain locally by relatively thin terrace deposits and nearly everywhere has a soil mantle that ranges in thickness from 1 foot to 4 feet and which supports relatively thick growths of brush, scrub oak, and some grass. Because it is underlain mostly by consolidated rock, the principles governing the infiltration of rain are believed not to be the same as in the primary area; rather, the infiltrate must move laterally toward the basin through the soil zone and through fractures near the surface of the consolidated rock, and by so doing it is subject to use by vegetation. Accordingly, the amount reaching the basin is believed to be quite small. The water-level contour map (pl. 5) shows water moving northward from the Casmalia and Solomon Hills, indicating that some infiltrate is reaching the primary area by lateral movement.

Blaney has indicated that in general when yearly rainfall on brush land is less than 18 inches no deep infiltration occurs. It is thought that in the secondary area about 10 percent of the rainfall in excess of 18 inches might be a reasonable estimate for recharge. Accordingly, infiltration each year from this area is taken as 10 percent of the excess over 18 inches when the yearly rainfall is more than 18 inches, and zero when it is less. Thus, during the period 1930–45, recharge from the area is estimated to have occurred only in 4 years—1935, 1937, 1938, and 1941 (table 6). For these years, the infiltration is estimated to have ranged from a minimum of about 800 acre-feet in 1935 to a maximum of about 6,400 acre-feet in 1941, which is only a small part of the totals for those 2 years. Also, the estimated infiltration includes any recharge that might be supplied by local runoff or by percolation through fractures in the consolidated rocks (p. 27).

It should be pointed out that with years having the same total rainfall there is likely to be a difference in the amount infiltrating to storage, due to variations in storm intensities, in soil moisture at the beginning of and during the rainy season, and in other related characteristics. Thus, rigid use of the method is subject to some error in any one year. However, over a series of years these errors would tend to balance each other, and so are used without adjustment.

ESTIMATES OF INFILTRATION

Infiltration to the main water body in any one year, then, is the sum of the values for each of the three types of land cover obtained by the method outlined. The yearly rainfall at Santa Maria is used for all three areas because it is believed to represent about the average for them. At Santa Maria the long-term average rainfall is 14.40 inches (table 1). This is less than that required for infiltration on grass and brush lands, but somewhat greater than that required for irrigated land. Table 6 shows the total recharge thus derived for the years ending September 30, 1930–45.

Table 6.—*Estimates of yearly recharge to the main water body by infiltration of rain in the water years 1930–45*

Year ending Sept. 30—	Rainfall at Santa Maria [1] (inches)	Recharge to the main water body (acre-feet)	Year ending Sept. 30—	Rainfall at Santa Maria [1] (inches)	Recharge to the main waterbody (acre-feet)
1930	9. 33	0	1940	14. 61	2, 000
1931	8. 97	0	1941	30. 75	80, 000
1932	16. 48	9, 000	1942	16. 95	12, 000
1933	11. 35	0	1943	17. 22	13, 000
1934	7. 68	0	1944	14. 56	2, 000
1935	19. 55	25, 000	1945	11. 31	0
1936	13. 48	1, 000			
1937	20. 82	35, 000	Total	246. 75	219, 000
1938	22. 18	40, 000			
1939	11. 51	0	16-year average	15. 42	13, 700

[1] From table 1.

The table suggests that there was no infiltration of rain during years of low rainfall, and that infiltration was about 80,000 acre-feet in 1941, the wettest year of record. The estimated average yearly infiltration was nearly 14,000 acre-feet and suggests that about 2 inches per year or about 13 percent of the average rainfall for the 16-year period, infiltrated to storage. However, it is apparent that the average is raised appreciably by the large infiltration that occurred during 1941. For the 60-year period 1886–1945, by the procedure outlined above, it was estimated that the average yearly infiltration was 10,000 acre-feet or 1.5 inches—about 10 percent of the average rainfall for that period. This is about 25 percent less than the average yearly infiltration during the 16-year period 1930–45.

UNDERFLOW ALONG PRINCIPAL STREAMS

The continuous unseen flow of ground water into the main water body, principally through the alluvium at the mouths of the Cuyama and Sisquoc Rivers and major tributaries, is designated as recharge by underflow. Essentially all the underflow at the mouths of these rivers is measured as surface flow at stream-gaging stations a considerable distance upstream, where the deposits are thin or missing entirely, and where the underflow is estimated to be only a few hundred acre-feet a year (p. 59). This rough estimate of underflow is well within the limits of error involved in the estimates of yearly runoff and seepage loss. Consequently, for all practical purposes the recharge by underflow is accounted for in the measured and estimated seepage losses from streams (table 5), and hence is not separately estimated.

ESTIMATE OF TOTAL RECHARGE

The total quantity of recharge to the main water body is the sum of the seepage loss from streams and the infiltration of rain (tables 5 and 6). Table 7 shows the estimates of total yearly recharge for the years ending September 30, 1930–45.

Table 7.—*Estimates of total yearly recharge to the main water body in the water years 1930–45*

Year ending Sept. 30—	Total recharge to main water body (acre-feet)	Year ending Sept. 30—	Total recharge to main water body (acre-feet)
1930	7, 200	1940	29, 700
1931	4, 800	1941	230, 000
1932	81, 000	1942	63, 500
1933	22, 500	1943	119, 000
1934	17, 700	1944	71, 400
1935	64, 600	1945	44, 300
1936	37, 200		
1937	137, 000	Total	1, 121, 500
1938	167, 000	16-year average	70, 000
1939	24, 600		

The table shows that estimated total yearly recharge has ranged from about 4,800 acre-feet in 1931 to 230,000 acre-feet in 1941, and has averaged about 70,000 acre-feet. Thus, any one year's recharge may be as much as 330 percent of the 16-year average, as in 1941, or as little as 7 percent, as in 1931. Obviously, the large increment in 1941 has raised the average considerably. With respect to long-term average recharge to the main water body based on comparative rainfall, it is about 93 percent of that for the period 1930–45 (p. 128), or is estimated to be about 65,000 acre-feet a year.

For short periods, too, the recharge is roughly proportional to rainfall. For example, the average yearly recharge during the 7-year period 1930–36 was about 34,000 acre-feet, in contrast to an average during the 9-year period 1937–45 of about 98,000 acre-feet. The wide range in average recharge between these two periods can be traced directly to rainfall. For the two periods, the average yearly rainfall was 12.41 inches and 17.77 inches, respectively. Thus, there exists a general relationship between rainfall and total recharge, but because of the relatively wide variation in distribution and intensity of rainfall (p. 58) no attempt is made to construct total yearly recharge from rainfall alone. The relationship is used, however, in the estimation of long-term average recharge above and of perennial yield (p. 128).

DISCHARGE FROM THE MAIN WATER BODY

Discharge of ground water from the main water body occurs in two ways: by natural means, and by withdrawals from wells, which include the discharge from uncapped flowing wells. Essentially all discharge of ground water occurred by natural processes prior to the introduction of large-capacity pumps near the turn of the century. Since then pumpage has increased steadily, until in recent years it has constituted about 85 percent of the total discharge. During the past 20 years natural discharge has been only in the form of ground-water outflow to the sea, but in earlier years ground water overflowed at the eastern edge of the area of confined water, and considerable discharge took place above ground.

PUMPAGE

HISTORY AND DEVELOPMENT

The first recorded well in the area was a dug domestic well constructed in 1868 by a Mr. B. Wiley, who was one of the first settlers (Mason, 1883, p. 313). From then to 1898 only domestic and stock wells were constructed. Pumping for irrigation started in 1898 with the inception of the sugar-beet industry, and the first irrigation wells were at about the sites now occupied by wells 10/35-25K1-10 (pl. 1). Shortly thereafter large steam-driven centrifugal pumps, which reportedly had discharges of about 3,000 gallons a minute, were installed on batteries of closely-spaced wells near present wells 10/33-35B1, 10/34-8R1, 10/34-19A1, 10/35-12H1, and 11/35-33C1. In order to raise the water with centrifugal pumps in the intake area, pits were dug to the water table where necessary and the pumps set on the bottom. Drifts were run out from the bottom of the pits to intercept wells drilled from the surface, and the multiple suction pipes installed were connected to a single pump. Usually 5 to 10 wells were connected in this manner. Surface distribution was accomplished through open ditches and flumes, and each battery of wells supplied irrigation water to areas which were often miles away. Consequently, large "ditch-losses" resulted.

Diversion of surface water for irrigation was attempted about 1900, when water was brought through flumes and pipes from the Cuyama River to the Santa Maria plain. However, about 1908, floods reportedly destroyed the installation, and diversion from that source has not again been attempted. On the Sisquoc River similar diversion works were installed about 1910 and are still in use (p. 63).

Until about 1920 the development of irrigation supply and increase of irrigated acreage proceeded slowly, and then in the early twenties vegetable farming was introduced. During the next 10 years the acreage under irrigation expanded rapidly, but from 1930 to 1944 the expansion has been somewhat slower. An intensive well-drilling program kept pace with the rapid expansion of irrigated acreage. Table 8 shows the number of irrigation wells and the approximate acreage under irrigation for the years 1920–44. The figures for years prior to 1931 were obtained from the report by Lippincott,[8] and for the years 1931–44 were from estimates made and factual data collected by the Geological Survey.

TABLE 8.—*Number of irrigation wells and approximate acreage irrigated in the Santa Maria Valley area, 1920–44*

Year	Number of active irrigation wells	Acres irrigated	Year	Number of active irrigation wells	Acres irrigated
1920	11	--------	1933	256	28,000
1921	16	--------	1934	260	28,000
1922	31	10,700	1935	264	29,000
1923	61	--------	1936	271	30,000
1924	101	17,300	1937	278	30,000
1925	122	--------	1938	284	31,000
1926	163	--------	1939	288	32,000
1927	175	--------	1940	298	33,000
1928	206	--------	1941	[2] 305	33,000
1929	231	25,000	1942	[2] 311	34,000
1930	[1] 242	[1] 26,600	1943	[2] 313	34,000
1931	248	27,000	1944	[2] 317	35,000
1932	253	28,000			

[1] From field canvass by Lippincott.
[2] From field canvass by Geological Survey.

The table shows that in the years 1920–44 the rapid expansion of irrigated acreage went forward hand in hand with the well-drilling program. In the year 1930 and during the years 1941–44 the average number of acres irrigated by a single well was about 110. This figure was applied to the known number of irrigation wells during the period 1931–40 to obtain estimates of acreage irrigated for those years.

The 35,000 acres under irrigation in 1944 include approximately the entire surface areas of the Santa Maria and Sisquoc plains. Of this total, about 33,000 acres, which are irrigated by nearly 300 wells, are on the Santa Maria plain; the remaining 2,000 acres, which are supplied by 17 wells, are on the Sisquoc plain. Therefore, any future development must necessarily take place on the bordering upland areas, where there are high pumping lifts, sandy soils (Watson and Smith, 1916), and somewhat less productive underlying water-bearing formations.

The yields of the irrigation wells on the plains are relatively high. Tests run on 18 selected wells by the Geological Survey showed dis-

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[8] Lippincott, J. B. Report on water conservation and flood control of the Santa Maria River in Santa Barbara and San Luis Obispo Counties, Calif., March 1931, pp. 10–11 (unpublished report available to the public at the offices of the County Planning Commission, Santa Barbara, Calif.).

charges ranging from 400 to 1,900 gallons a minute. Similarly, tests run on 180 irrigation wells by the San Joaquin Power Division of the Pacific Gas & Electric Co. showed discharges ranging from 300 to 2,200 gallons a minute. The average discharge for the 198 wells was slightly less than 1,000 gallons a minute. The high and low yields were about equally distributed throughout the Santa Maria and Sisquoc plains. The wide range in discharge is due to differences in depth, perforation, and condition of the wells, and to the capacity and condition of the pumps.

The agricultural growth of the area was accompanied by an increase in allied industries and in population. In addition, there was an expansion of the oil industry following the discovery of the Santa Maria oil field in 1934. The demand upon ground water for the cattle and dairy industries, however, has remained about constant for the past 25 years.

Lippincott[9] estimated that in 1930 about 500 wells supplied water for irrigation, public-supply, industrial, domestic, and stock use. In 1942 there were 311 irrigation wells, 22 public-supply wells, 20 industrial wells, and about 350 domestic and stock wells, most of which are shown on plate 1 and have been described in another report (La Rocque, Upson, and Worts, 1950). Thus in 1942 there was a grand total of about 700 wells that supplied water for all uses throughout the Santa Maria Valley area.

Most of the wells penetrate the main water body for relatively short distances. Approximately 80 percent of the 700 wells are less than 300 feet in depth, and of the remaining deeper wells only 10 are more than 500 feet in depth. Beneath the Sisquoc plain and the greater part of the Santa Maria plain wells derive water principally from the lower member of the alluvium, but partly from the upper part of the underlying Paso Robles formation. The few wells on the Orcutt upland derive most of their water from the lower member of the Orcutt formation, but partly from the upper part of the Paso Robles formation.

Thus, the wells "skim" water from the upper part of the main water body leaving the thicker lower portion untapped. However, because water in the main body is presumed to be in hydraulic continuity throughout both its vertical and horizontal limits, it is believed there would be no particular advantage in searching for water at greater depth. Rather, the disadvantages would doubtless outweigh the advantages for the following reasons: Drilling costs would be greater, available data indicate that the most productive water-yielding deposits are the alluvium and locally the Orcutt formation, which now are tapped, and it is possible that in the deepest portions of the main water body the chemical quality of the water would be poor. The only possible advantage would be the increased yield and increased specific capacity if greater thicknesses were tapped. This would permit operation of larger pumping units which might conceivably be operated at greater efficiency than smaller units, both with respect to plant efficiency and application of water to an irrigated area or to industrial use. Doubtless this advantage would be greatest at places where the permeability of the unconsolidated deposits is only moderate.

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[9] Lippincott, J. B., op. cit., p. 23.

ESTIMATES OF PUMPAGE FOR IRRIGATION

METHODS FOR ESTIMATING PUMPAGE

The methods used for estimating quantities of water pumped for irrigation are necessarily indirect because there are no water meters attached to the wells to determine directly the quantity pumped. Approximately 95 percent of the irrigation pumps in the Santa Maria Valley area are electrically operated—the remaining 5 percent are run either by tractors or stationary internal-combustion engines. Under these conditions the most accurate method of determining the pumpage was to calculate, for each of as many electrically operated plants as possible, the number of kilowatt-hours required to pump one acre-foot of water, and to divide the average value, or energy factor, so obtained into yearly totals of kilowatt-hours consumed.

The San Joaquin Power Division of the Pacific Gas & Electric Co. kindly furnished data on more than 500 pump-efficiency tests and yearly totals of kilowatt-hours consumed for the years 1932–44. The area was divided into five subareas because of the wide range in energy factors, which was due chiefly to the range in pumping lift. Actually, the variations in pumping lift during the period 1932–44 did not result in appreciably different average energy factors in different years. The established average energy factors range from a minimum of 130 kilowatt-hours per acre-foot in the area of lowest lifts nears the coast to a maximum of 300 kilowatt-hours per acre-foot in the area of highest lifts on the Orcutt upland.

The yearly quantity pumped in acre-feet was determined by dividing the total yearly kilowatt-hours consumed in each of the five subareas by the appropriate average energy factor; and the sum of the five quantities thus derived is the total amount of water pumped each year from the entire area by electrically operated pumps. This total was then increased by 5 percent, to allow for the quantity pumped by nonelectrically operated pumps, to obtain the yearly total pumped for irrigation by both classes of pumps for the period 1932–44.

The quantity pumped each year prior to 1932 had to be determined by a second method which is based on the yearly totals derived above.

It was found that during the period 1932–44 the average yearly depth of water pumped onto the irrigated land, or the duty of water, varied approximately in accordance with rainfall. During years of above-average rainfall the duty of water was about 1.7 acre-feet per acre, whereas during years of below-average rainfall the duty of water was about 2.1 acre-feet per acre; thus, the average duty was about 1.9 acre-feet per acre for the whole period. Yearly rainfall was plotted against the duty of water for the years 1932–44, and a smooth curve was drawn through the points. For years prior to 1932 values of rainfall were then plotted on this curve and corresponding values for duty of water obtained. These values in turn were multiplied by the known or estimated irrigated acreage to determine yearly pumpage. In this manner it was possible to estimate the pumpage by years as far back as the acreage irrigated was known (table 8). The total quantity pumped for irrigation for the years 1929–44 is shown in table 9.

RETURN OF IRRIGATION WATER

The total quantity of water pumped for irrigation as computed above is not the quantity permanently removed from storage. In the intake area a part of the total quantity pumped each year for irrigation seeps below the root zone and returns to storage in much the same manner as does the infiltration of rain. The greater part, however, is lost by transpiration and evaporation.

The quantity of irrigation water which returns to storage each year varies considerably from one part of the area to another, depending primarily on type of soil, type of crop, irrigation practice, and climatic conditions. It is probably greatest in the Sisquoc and upper Santa Maria valleys where the soil is sandy. Westward, down the Santa Maria Valley the soil is heavier and less water returns to storage. In the area of confinement (pl. 5), which includes approximately one-third of the irrigated area, little or no return occurs, and essentially all water in excess of that transpired or evaporated eventually discharges from the shallow water body into the sea (p. 74).

The amount of irrigation water which returns to storage each year in the intake area (about two-thirds of the irrigated area) ranges from essentially no return along the inland boundary of the area of confined water to possibly as much as 50 to 60 percent of the yearly pumpage in the eastern part.[10] Thus, the average return in the intake area is estimated to be about 30 percent of the pumpage, and for the entire area, including the area of confinement in which there is little or no return, about 20 percent of the total pumpage. Therefore, of the total quantity of water pumped for irrigation each year, an estimated 80 percent is permanently removed from storage. This

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[10] Based on data compiled for other coastal areas of California by Harold Conkling.

quantity is designated the total net pumpage. Table 9 shows both the total pumpage and the total net pumpage for irrigation for the 16-year period 1929–44.

TABLE 9.—*Estimates of pumpage for irrigation from the main water body, 1929-44*

Year	Total pumpage for irrigation (acre-feet)	Total net pumpage for irrigation (acre-feet)
1929	50, 000	40, 000
1930	52, 000	42, 000
1931	54, 000	43, 000
1932	50, 800	41, 000
1933	45, 000	36, 000
1934	48, 000	38, 000
1935	51, 000	41, 000
1936	60, 000	48, 000
1937	58, 900	47, 000
1938	59, 000	47, 000
1939	65, 500	52, 000
1940	75, 400	60, 000
1941	60, 400	48, 000
1942	61, 400	49, 000
1943	67, 900	54, 000
1944	70, 900	57, 000
Total	930, 200	743, 000
16-year average	58, 100	46, 400

Pumpage during 1940 was the greatest on record and was due in large part to the relatively low and poorly distributed rainfall during that year. Pumpage declined in the early thirties, probably owing mainly to the economic conditions which prevailed at that time, but has increased steadily since then. Presumably additional lands will be placed under irrigation in the future. Lippincott[11] has estimated that there are 50,000 acres of irrigable land in the area—an excess of 15,000 acres or 40 percent above that now in use. If all this land were placed under irrigation, or if more double-cropping were practiced on the present acreage, and the pumpage were increased proportionately, the total net pumpage for irrigation alone would be more than 80,000 acre-feet a year.

ESTIMATES OF DISCHARGE FOR USES OTHER THAN IRRIGATION

Pumpage for uses other than irrigation includes withdrawal for public-supply, industrial, domestic, and stock uses. Also included is the flow from artesian wells, which is artificial discharge. The methods used for estimating each differ according to the available data, and are discussed separately below.

PUBLIC SUPPLY AND DOMESTIC USES

The largest single use for public supply is that for the city of Santa Maria from three wells on the Orcutt upland. Fortunately, the water pumped from these wells is metered and the yearly pumpage

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[11] Lippincott, J. B., op. cit., p. 16, 1931.

can be obtained directly. Records of municipal use have been made available by the City Water Department. In 1944 the pumpage was about 1,700 acre-feet.

As nearly as can be determined, the population of the outlying towns and rural areas was about 4,500 in 1930, and about 5,100 in 1940 (Bureau of the Census 1940).[12] The quantity consumed in these areas is based on an estimated per capita use of 125 gallons a day. This quantity allows for gardening, for use by small-business establishments in the smaller towns, etc. Thus, the quantity pumped for the rural population is estimated to have been about 670 acre-feet in 1930, and about 760 acre-feet in 1940. For the intervening and subsequent years the average yearly increase is apportioned.

INDUSTRIAL USE

The estimate of pumpage for industrial use is based on the reported and inferred capacities of the pumps and their operating schedules. The principal industrial uses are for ice plants, packing sheds (excluding those in Santa Maria, which are supplied by the city wells), and oil refineries. Most of these plants operate only during the day. A total of 20 industrial wells were active in 1942. Each of these wells was visited and from the data gathered at that time it is estimated that the average daily schedule was about 5 continuous pumping hours, and that the average yield of each well was approximately 500 gallons a minute. Thus, in 1942 the yearly pumpage by the 20 wells for industrial use is estimated to have been about 3,500 acre-feet.

For years prior to and after 1942 no data are available on the exact number of pumping plants in use by industries. However, it is believed that the pumpage has increased steadily since 1929. Because no reliable data are available, and further because the estimate of pumpage in 1942 is only approximate, it is assumed that the pumpage has increased at a rate of about 100 acre-feet a year. Thus, in 1929 the pumpage for industrial use may have been about 2,000 acre-feet.

STOCK USE

It was reported[13] that for the past 25 years there has been an average of about 7,000 head of dairy cattle in the Santa Maria Valley area, and the quantity of water required per head is ordinarily estimated as 15 gallons a day. In addition, 15 gallons a day per head is required for dairy operation and maintenance. Thus, the average pumpage for stock use has been about 200,000 gallons a day, or roughly 250 acre-feet a year.

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[12] Also data from Santa Maria Valley Chamber of Commerce.

[13] Eriksen, H. C., personal communication, Nov. 1945.

FLOW FROM WELLS

Ground-water discharge by flow from wells is considered artificial discharge. Most of these wells are allowed to flow unchecked, and in that sense the water discharged is a needless waste of ground water. During the 4-year period 1942–45, the discharge from artesian wells amounted to nearly 2 percent of the total discharge by pumpage. Although relatively small, this amount is worth conserving.

In 1942, there were 20 flowing wells distributed over about 5 square miles of the arable part of the area of confinement (pls. 1 and 5). The quantity of flow from each was estimated in the spring of that year by the Geological Survey, and it was found that the total discharge amounted to approximately 1,250 gallons a minute. Most of these wells were revisited at various seasons of the year during the 4-year period 1942–45, and it was found that the flow decreased substantially during the summer pumping season, but increased to about the same discharge each spring. The average flow is estimated to have been about 700 gallons a minute, or 1,200 acre-feet a year.

Lippincott[14] reported that the area of flow was 23 square miles in 1918 and extended eastward almost 1 mile from Guadalupe (pl. 5), but in 1930 the area of flow has decreased to 1.5 square miles. Records of water levels indicate that by 1936 the area of flow was even less. During this time the discharge by flow from wells varied according to the head and to the number of wells permitted to flow unchecked. It is estimated that the flow decreased from an unknown maximum in 1918 to a minimum in 1936 of about 300 gallons a minute, or 500 acre-feet a year, and that in the years 1937–42 the flow increased steadily with the increase in head. The yearly quantities of flow during the years 1929–44 are apportioned according to the rough estimates derived above.

ESTIMATE OF TOTAL DISCHARGE FOR OTHER USES

The total discharge for nonirrigation uses (as described in preceding pages) amounts to only about 10 percent of the total net pumpage for all uses. In view of this relatively small percentage, the estimates may be in error without affecting appreciably the estimate of total discharge from the main water body. Accordingly, more refined estimates of pumpage for minor uses are not considered justifiable at this time.

Table 10 shows the total yearly pumpage for public-supply, industrial, domestic, and stock uses, and includes the discharge by flow from wells—all of which are designated discharge for use other than irrigation.

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[14] Lippincott, J. B., op. cit., p. 28, 1931.

TABLE 10.—*Estimates of total yearly discharge from the main water body for use other than irrigation,* 1929–44

Year	Total pumpage (acre-feet)	Year	Total pumpage (acre-feet)
1929	5, 000	1939	6, 100
1930	5, 100	1940	6, 400
1931	5, 200	1941	6, 600
1932	5, 200	1942	7, 200
1933	5, 100	1943	8, 000
1934	5, 200	1944	8, 200
1935	5, 200		
1936	5, 300	Total	95, 200
1937	5, 600	16-year average	6, 000
1938	5, 800		

This discharge for nonirrigation uses remained about constant during the early and middle thirties, probably owing to economic conditions and to the decrease in flow from wells. In the later years, and during the war years 1941–44 in particular, pumpage increased rapidly to keep pace with the wartime population. It is not believed that the increase will continue at the present rate in postwar years, but there is every indication that pumpage will remain above its prewar level.

NATURAL DISCHARGE

FORMS AND AREAS OF DISCHARGE

Natural discharge of ground water is all discharge other than pumpage and artesian flow from wells. It includes outflow or submarine discharge into the sea, overflow into streams at the eastern edge of the area of confinement and thence to the sea, and evapotranspiration by native vegetation where the water table is close to the land surface. Prior to the drilling of wells, all recharge to the main water body in excess of that retained in storage was dissipated by natural discharge.

Water moving seaward beneath the confining beds at the west end of the Santa Maria Valley is discharged from the main water body into the Pacific Ocean through the unconsolidated deposits exposed on the ocean floor. The confining beds composing the upper member of the alluvium extend off shore for a distance of about 2 to 4 miles, causing water to be discharged west of that boundary (p. 78). Water thus discharged from the main water body is designated as natural discharge by ground-water outflow. Since the mid-twenties natural discharge has taken place only in this form.

During consecutive years of excessive recharge prior to the advent of heavy pumpage in the mid-twenties, outflow could not dispose of the large ground-water increment. Consequently, the water table rose in the intake area until water flowed over the eastern edge of the confining beds (pl. 5). It is reported by several residents that from about 1914 to the mid-twenties perennial surface flows occurred in Green Canyon, starting near well 10/35–13J1; and in the Santa Maria River, starting several miles east of the railroad bridge. Water thus discharged from the main water body is designated as natural discharge by ground-water overflow.

Evaporation and transpiration losses occurred only at times when and in the areas where overflow was taking place. It is reported that there were heavy growths of water-loving plants in the channels downstream from the areas of overflow in the late teens and early twenties. Doubtless, fairly large evapotranspiration losses took place in these reaches. Elsewhere, the water table has remained below the reach of water-loving plants. The absence of plants and trees of this type in the intake area along the Sisquoc and Santa Maria Rivers bears evidence to this fact. Furthermore, it is reported by residents that the Santa Maria and Sisquoc plains and river channels have always been barren of this type of vegetation. Thus, losses from the main water body by evaporation and transpiration are practically nonexistent, although a shallow water body (p. 74) supports plant growth at the west end of the valley.

ESTIMATES OF DISCHARGE BY GROUND-WATER OUTFLOW

The method used to compute the quantity of ground-water discharge by outflow to the sea is based on Darcy's law (p. 76). Therefore, it is necessary to know the saturated cross-sectional area of the water-bearing formations at or near the coast, the permeability of each, and the slope of the pressure surface, or hydraulic gradient.

Geologic section *D–D′* (pl. 2) shows the cross-sectional area of the deposits through which the water being discharged at the coast must move. These formations are the Careaga sand, the Paso Robles formation, the lower part of the Orcutt formation, and the lower member of the alluvium. The cross-sectional area of the lower member of the alluvium is determined from numerous water-well logs and, therefore, is fairly accurate. The cross-sectional areas of the other formations are only roughly defined by a few data from oil tests. Furthermore, the area of outflow is limited on the north by the ground-water divide, as water moving north of that divide is not part of the Santa Maria Valley area discharge.

With respect to the saturated cross section along line *D–D′*, it may be noted that beneath the Santa Maria plain all water-bearing deposits are confined beneath the upper member of the alluvium and their entire section is saturated—including the lower member of the alluvium, the Orcutt (?) and Paso Robles formations, and the Careaga sand; also, in the relatively small areas of unconfined water north and south of the plain, the water table fluctuates from year to year and so changes the saturated cross section. Because these fluctuations are negligible when compared to the very large saturated section, the saturated section throughout the length of section *D–D′* is considered to be constant.

As thus defined, the cross-sectional area of the saturated portion of the Careaga sand is approximately 11,800,000 square feet, of the Paso Robles and Orcutt formations about 29,200,000 square feet, and of the lower member of the alluvium about 2,238,000 square feet; or a total saturated cross-sectional area of somewhat more than 43,000,000 square feet.

The permeabilities of the various formations, which are in part estimated, have been discussed elsewhere, and the coefficients applied to this cross section are as follows: for the Careaga sand about 75 gallons per day per square foot—the laboratory permeability of 70 at 60° F. (p. 28) adjusted to field temperature of 64° F. by dividing by the conversion factor 0.95 (Wenzel, 1942, p. 62); for the Paso Robles and the Orcutt formations about 65 gallons per day per square foot (p. 33); and for the lower member of the alluvium about 2,000 gallons per day per square foot (p. 39).

The hydraulic gradient, although relatively slight at the line of section, has varied considerably from 1918 to 1944. Plate 6 shows water-level profiles for the main water body for 1907, 1918, 1936, and 1944. The profiles for 1907 and 1918 were obtained from the report by Lippincott,[15] and those for 1936 and 1944 were compiled from data collected by the Geological Survey. The profile for 1936 is the lowest of record and that for 1918 is the highest. The profiles in 1907 and 1944 are intermediate and are nearly coincident. All four have been projected to the coast line to show roughly how the head of water has varied at that place. A maximum head about 55 feet above sea level occurred in 1918, and a minimum head of about 20 feet in 1936. On plate 6 the hydraulic gradients at the crossing of section *D–D′* appear to have varied only slightly in the 4 years. However, on profiles of larger scale it was found that in the 3 years 1918, 1936, and 1944 the hydraulic gradients were 10, 6, and 8 feet per mile, respectively. Owing to the irregularity in the gradient in 1907 near the line of section, this year is omitted from the outflow computations. However, outflow was probably of about the same magnitude as in 1944.

Because the water in the main water body is considered to be essentially confluent throughout, the hydraulic gradients then, are applicable to the full cross-sectional area. Thus, the total ground-water outflow to the sea for the 3 years, 1918, 1936, and 1944, or for other years when the hydraulic gradient is known, can be estimated as follows: The rate of ground-water outflow in gallons per day is equal to the product of the cross-sectional area times the permeability times the hydraulic gradient. The rate times 365 gives the total quantity for any 1 year. The quantities thus derived are shown in table 11 for the maximum discharge in 1918, for the minimum discharge in 1936, and for the discharge in 1944.

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[15] Lippincott, J. B., op. cit., diagram 3, 1931.

TABLE 11.—*Estimates of ground-water outflow from the main water body in 1918, 1936, and 1944*

Formation	Permeability (gallons per day per square foot)	Saturated cross-sectional area (foot-miles)	Hydraulic gradient (feet per mile)	Outflow	
				Million gallons per day	Acre-feet per year
1918					
Alluvium (lower member)	2, 000	450	10	9. 0	10, 100
Paso Robles and Orcutt formations	65	5, 500	10	3. 6	4, 000
Careaga sand	75	2, 200	10	1. 7	1, 900
Total				14. 3	16, 000
1936					
Alluvium (lower member)	2, 000	450	6	5. 4	6, 000
Paso Robles and Orcutt formations	65	5, 500	6	2. 1	2, 400
Careaga sand	75	2, 200	6	1. 0	1, 100
Total				8. 5	9, 500
1944					
Alluvium (lower member)	2, 000	450	8	7. 2	8, 100
Paso Robles and Orcutt formations	65	5, 500	8	2. 9	3, 200
Careaga sand	75	2, 200	8	1. 3	1, 500
Total				11. 4	12, 800

The table shows that there has been a fairly wide range in ground-water outflow to the sea. Furthermore, approximately two-thirds of the total outflow takes place through the lower member of the alluvium, which constitutes only about 6 percent of the total cross-sectional area.

It is believed that in the years around 1918, when water levels were the highest of record and when ground water was discharging along the edge of the area of confinement as overflow in Green Canyon and the Santa Maria River, approximately the maximum possible hydraulic gradient was established across the area of confined water. Hence, the discharge of 16,000 acre-feet a year is also the maximum possible ground-water outflow. This is believed to be true because any further increase in gradient in the intake area would produce an increased overflow, but it would increase only slightly the hydraulic gradient in the area of confinement. Hence, the outflow could not be increased appreciably.

In 1936, on the other hand, when the minimum known hydraulic gradient of 6 feet per mile occurred, the outflow also was at a minimum, or 9,500 acre-feet. The overflow had long since ceased, and water levels along the edge of the area of confined water had declined 55 feet. The pressure head at the coast had also declined from a projected high in 1918 of about 55 feet above sea level to a projected low in 1936 of about 20 feet (pl. 6). Thus, if the water levels had continued to decline after 1936, the hydraulic gradient would have decreased accordingly. Ultimately, when the hydraulic gradient approached zero outflow would also approach zero. In order for this to happen, the water levels along the eastern edge of the area of confined water would have to be reduced nearly to sea level, or about 80 feet below the 1936 levels; however, this possibility was averted when water levels began to rise in 1937.

Thus, ground-water outflow has ranged from a maximum of about 16,000 acre-feet in 1918 to a minimum of about 9,500 acre-feet in 1936. With the subsequent rise in water levels and increase in hydraulic gradient from 1936 to 1944 it has increased to nearly 13,000 acre-feet a year. For the intervening years not shown in the table, outflow has been estimated for years when there were sufficient water-level data and interpolated for the remaining years. The total outflow for the 16-year period 1929–44 is estimated to have been about 180,000 acre-feet, or to have averaged slightly more than 11,000 acre-feet a year.

ESTIMATES OF DISCHARGE BY GROUND-WATER OVERFLOW AND EVAPOTRANSPIRATION

Discharge by ground-water overflow can be very roughly estimated for the years around 1918. These estimates include any evapotranspiration losses that may have occurred at that time. During the 14-year period 1905–18, rainfall was above average, and as a result a considerable quantity of recharge was supplied to the main water body. Recharge undoubtedly was greater than during the years of below-average rainfall, 1929–36, but probably was less than that in the extremely wet years, 1937–44 (p. 83). If an average yearly recharge of about 80,000 acre-feet is assumed as reasonable for the period 1905–18 (p. 126), then the distribution of discharge for the years around 1918 can be roughly approximated as follows: Discharge by

outflow amounted to about 16,000 acre-feet a year (table 11), and pumpage was possibly about 20,000 to 30,000 acre-feet a year. Thus, discharge by overflow and evapotranspiration losses must have made up the difference and would have been about 30,000 to 40,000 acre-feet a year.

Perennial flows in Green Canyon and in the Santa Maria River totaling approximately 40 to 50 second-feet would have been necessary to dispose of the excess recharge. As was mentioned, flows in both channels were reported by residents, but unfortunately the magnitude of the flows was not known by them. If such large yearly flows were discharged at the surface, a considerable portion would have been lost by evaporation and transpiration (p. 93). However, the discharge by overflow and evapotranspiration cannot be divided.

Overflow and evapotranspiration losses have not taken place since the depression of the water table in the mid-twenties. Therefore, no estimates are included in table 12. It is certain that neither form of discharge will recur as long as the water table remains at or near the levels induced by the heavy pumpage of the past 20 years. Thus, in effect, pumpage has salvaged a large amount of natural discharge for agricultural and other uses which otherwise would have been lost.

ESTIMATE OF TOTAL DISCHARGE

The estimate of total discharge from the main water body includes the discharges by net pumpage for irrigation, discharge for other uses, and ground-water outflow to the sea (tables 9, 10, and 11, and p. 96). These data have been assembled for the 16-year period 1929–44, and are shown in table 12.

TABLE 12.—*Estimates of total yearly discharge from the main water body, 1929–44*

Year	Total discharge (acre-feet)	Year	Total discharge (acre-feet)
1929	57, 500	1939	69, 800
1930	58, 900	1940	77, 800
1931	59, 400	1941	65, 300
1932	56, 900	1942	68, 600
1933	51, 600	1943	74, 500
1934	53, 600	1944	78, 000
1935	56, 100		
1936	62, 800	Total	1, 016, 200
1937	62, 100	16-year average	63, 500
1938	63, 300		

Total yearly discharge, which probably increased steadily during the twenties, reached a peak in 1931, decreased slightly to 1933, then generally increased steadily to 1944. Thus, the minimum of record was about 51,600 acre-feet, the maximum was about 78,000 acre-feet and the 16-year average was about 63,500 acre-feet. The relatively high discharges in 1939 and 1940 were due in part to the relatively low rainfall and consequent increase in net pumpage for irrigation. Because the net pumpage for irrigation has composed about 75 percent of the total discharge in recent years, the variations in pumpage have been the principal cause of the variations in the total discharge.

WATER-LEVEL FLUCTUATIONS IN THE MAIN WATER BODY

SCOPE AND UTILITY OF THE RECORDS

In the Santa Maria Valley area six agencies have made over 4,500 depth-to-water measurements in 71 observation wells. The agencies and their span of record to date are the city of Santa Maria, beginning September 1917; the Union Oil Co. of California, beginning March 1920; the San Joaquin Power Division of the Pacific Gas and Electric Co., beginning August 1929; J. B. Lippincott, a single set of measurements in September and October 1930; the Santa Maria Valley Water Conservation District, beginning April 1938; and the United States Geological Survey, beginning May 1941. In addition, there are fragmentary records by owners, well drillers, and pump agents. All these records have been assembled and released to the public in published reports by the Geological Survey (La Rocque, Upson and Worts, 1950. Meinzer, Wenzel, and others, 1943, pp. 147–153; 1944, pp. 228–237; 1945, pp. 177–183. Sayre, A. N., and others, 1947, pp. 156–163; 1949, pp. 168–175).

In any area, records of water-level fluctuations in wells are of inestimable value to the hydrologist for the interpretation of the past and present hydrologic conditions. The records collected in the Santa Maria Valley area showed several types of fluctuations pertaining to the conditions or forces at work in the main water body, as follows: recharge from streams, recharge from rain, pumping, and moving load on the land surface. The first three types may be cyclic and commonly produce a yearly or seasonal effect—differences among which, in part, serve to identify the cause. The fourth operates momentarily and has no large effects. The several types of fluctuations are discussed in the ensuing pages.

Figures 3, 4, 5, and 6 show fluctuations of water level in 13 selected wells in the Santa Maria Valley area. The hydrographs of the wells shown on figures 3, 4, and 5 are in the intake area, and those on figure 6 are in the area of confined water. The locations of these wells are shown on plate 1.

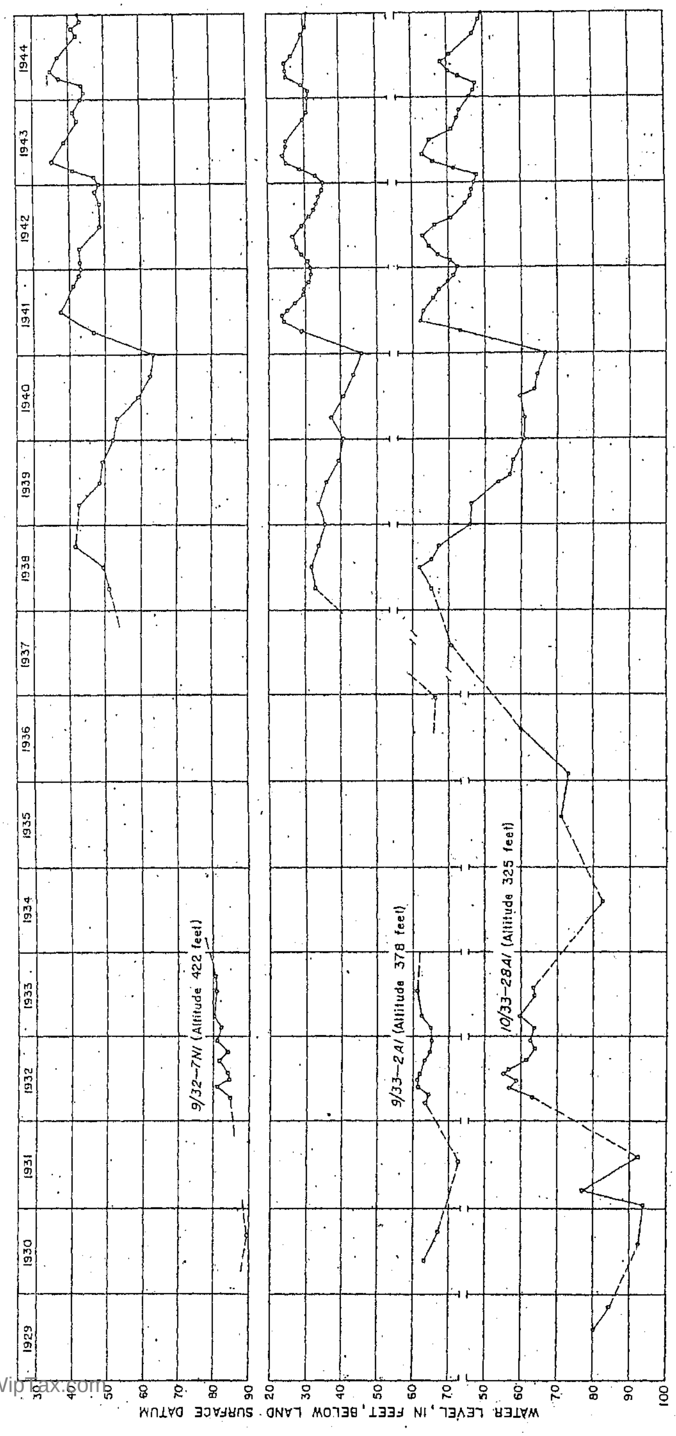

FIGURE 3.—Fluctuations of water levels in three wells adjacent to streams in the intake area, 1929–44.

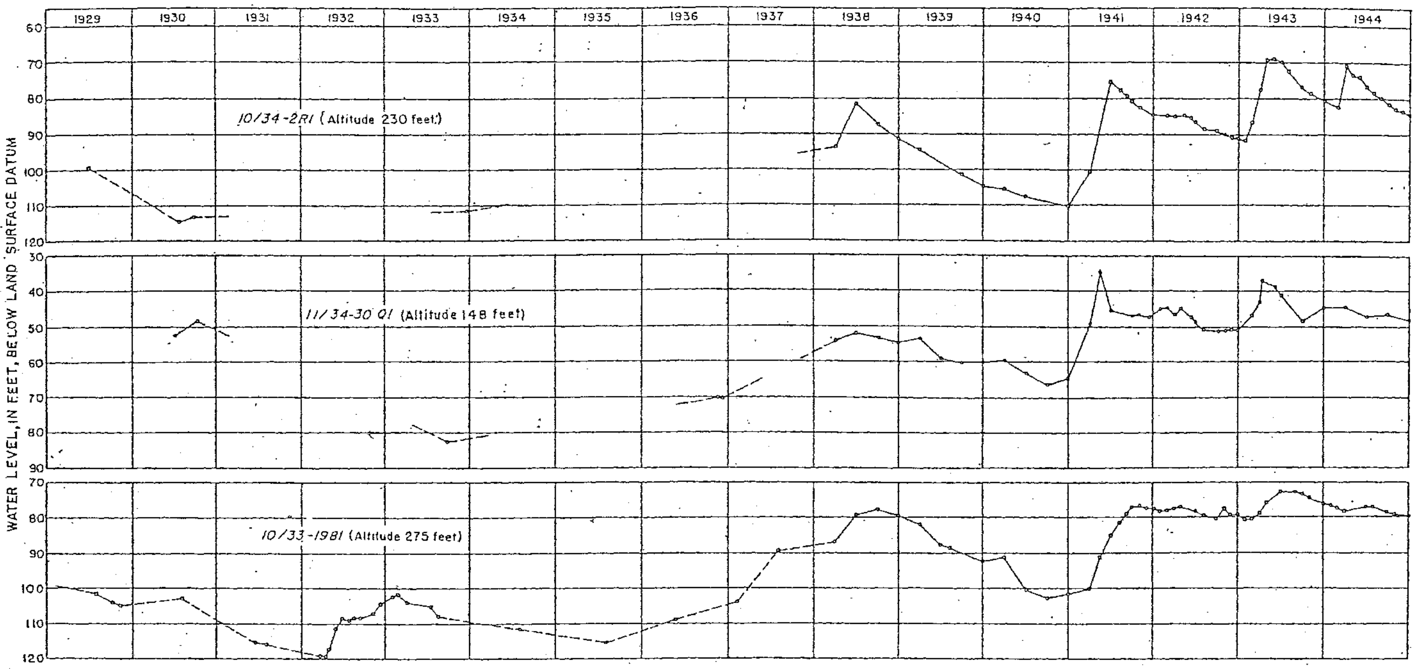

FIGURE 4.—Fluctuations of water levels in three wells in the intake area, 1929–44.

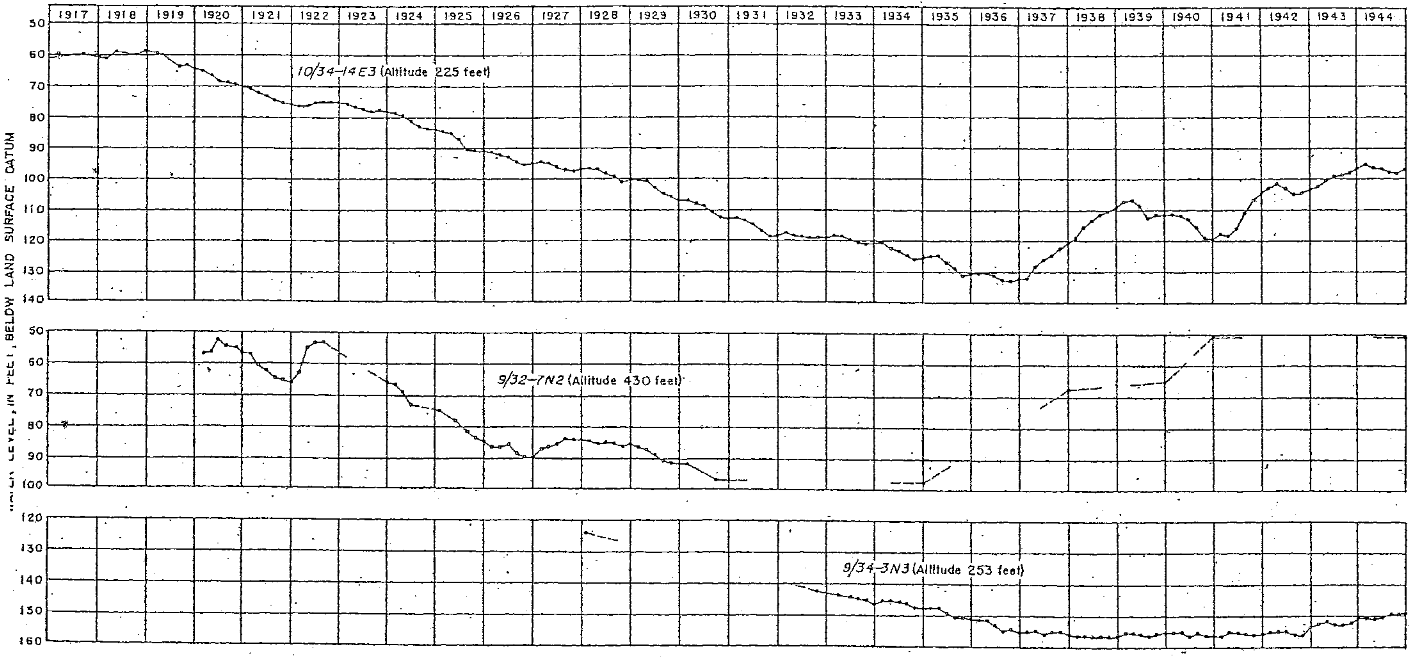

FIGURE 5.—Fluctuations of water levels in three wells in the intake area, 1917–44.

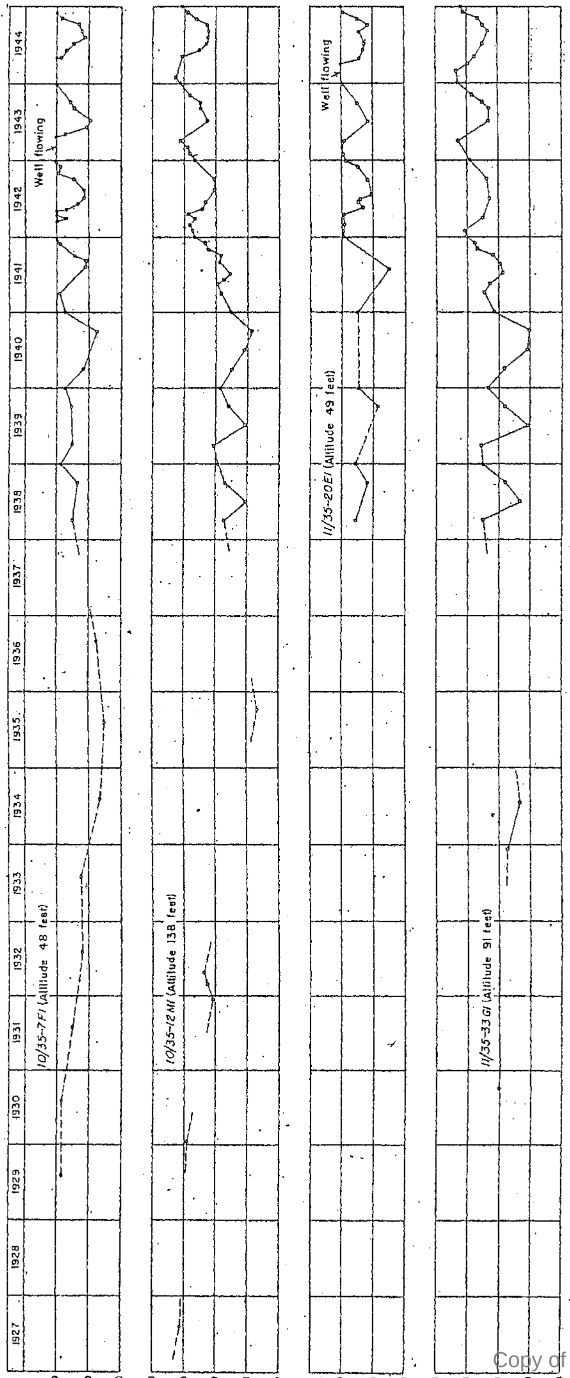

FIGURE 6.—Fluctuations of water levels in four wells in the area of confined water, 1927–44.

FLUCTUATIONS CAUSED BY RECHARGE FROM STREAMS

Because the water table nearly everywhere is far below the channels of the Sisquoc and Santa Maria Rivers, seldom, if ever, is there any hydraulic continuity between water in the channels and the main water body (p. 79). Thus, the levels in wells always rise in response to recharge from the two rivers but have never been known to fluctuate in accord with river stage.

Stream flow, and hence recharge from the rivers, commonly is limited to the 6-month period November through April each year; and during the remaining 6 months channels of both the Santa Maria and lower Sisquoc Rivers are usually dry. Accordingly, the response of water levels to stream recharge is cyclic in nature. Furthermore, the magnitude of the rise each year is dependent upon the quantity of recharge. During years of low recharge small rises occur and, of course, the converse is also true.

In the intake area the rise is due directly to the increase in stored water and represents actual saturation of the deposits, whereas in the area of confinement the rise is due solely to the increase in head in the adjacent intake area. Also, both in the intake area at some distance from streams and in the area of confinement there is a considerable time lag in the response of water levels to river recharge. Hence, the fluctuations in each are discussed separately.

Fluctuations in the intake area.—Wells along the river in the intake area are the first to respond to each year's recharge, and without exception they have larger rises than those in any other part of the area. The hydrographs of wells 9/32–7N1, 9/33–2A1, 10/33–28A1, 10/34–2R1, and 11/34–30Q1 (figs. 3 and 4) show the character of the rises. They show that during years of substantial recharge there is a steady, uninterrupted rise of water levels during the winter months of each year, and that the net rise is roughly proportional to the quantity of recharge. For example, in 1941, the year of greatest recorded recharge (table 7), the hydrographs of wells 9/32–7N1, 9/33–2A1, 10/33–28A1, 10/34–2R1, and 11/34–30Q1 show net rises of about 25, 20, 35, 35, and 30 feet, respectively. A relatively small and indeterminate part of these rises was due to infiltration of rain and recovery of water levels at the close of the summer pumping season. On the other hand, in 1940, a year of relatively small recharge, the hydrographs of wells 2A1, 28A1, and 11/39–30Q1 show net rises of only about 3 feet, and wells 9/32–7N1 and 10/34–2R1 show slight net declines. The net declines were due either to the fact that the depletion of storage by natural drainage exceeded the recharge, or to local pumpage, or both.

In wells progressively farther away from the river, the water levels respond to recharge from streams in much the same manner, but the rises are progressively smaller in magnitude, occur at slower rates, and are interrupted or partially masked by summer pumpage. These features are shown most clearly by wells 10/33–19B1 and 10/34–14E3 (figs. 4 and 5), which are more than a mile from the river. In 1941 the water levels in these wells rose 24 and 18 feet, respectively, which was somewhat less than those near the river; did not reach their peaks until 6 to 12 months after the levels in wells near the river; and rose at rates of 3 and 2 feet per month, respectively, for 8 months compared to an average rate of rise of 8 feet per month for 4 months in wells near the river.

Thus, each year's recharge travels away from the river as a mound. The mound probably registers in large part the transmission of head rather than the actual movement of water (Tolman, 1937, p. 241). However, in this report it is referred to simply as the recharge mound because in either case the effect on water levels is essentially the same. Water-level contour maps for 1941 and 1942, drawn for study purposes, show that the recharge mound which developed from river seepage loss in 1941 moved southwestward away from the Santa Maria River and decreased in height as it traveled. The mound took from 6 to more than 12 months to reach the southern edge of the Santa Maria plain. It decreased considerably in height and in volume by the time it reached wells 3 or 4 miles from the river, but ultimately it may have extended as far south as the axis of the ground-water trough beneath the southern part of Orcutt upland, as shown for the spring 1942 (pl. 5). However, its effect on water levels in this area was probably masked by infiltration of rain.

During years of average recharge from streams the mound probably does not extend far beyond the southern edge of the plain, and during years of below-average recharge it probably does not move even that far south.

Fluctuations in the area of confined water.—An increase in ground-water storage by recharge from streams in the intake area, as was explained above, results in a rise of water levels. This rise increases the head of water in the underlying formations, which farther west are confined beneath the upper member of the alluvium. This increase in head, in turn, is reflected by a rise of the water levels in wells. However, because the boundary between the two areas is gradational, and because, as was indicated previously, there is a considerable time lag in the movement of the stream-recharge mound southward across the plain, this transmission of head is a slow process.

These relationships are best illustrated by a comparison of the hydrographs of wells 11/34–30Q1 (fig. 4) in the intake area and 10/35–12M1 (fig. 6) about a mile within the area of confined water. In well 10/35–12M1 the principal rise after the 1941 recharge did not culminate until the winter of 1942, and thereafter the annual peaks rose slightly to 1944; whereas in well 11/34–30Q1 the peaks declined slightly from that of 1941.

The lack of pronounced rise in well 10/35–12M1 in 1941, in response to the large recharge of that year, is probably explained by the fact that the recharge mound moving southward from the river in the intake area did not reach the inland edge of confinement east of this well until mid-summer, and that it was dampened by summer pumpage.

The rise in well 10/35–12M1 from October 1941 to April 1942, which amounted to over 10 feet, cannot be traced to recharge in the winter of 1941–42, because the hydrograph of well 11/34–30Q1 shows no appreciable rise in the spring of 1942. Thus, the rise of water level in well 10/35–12M1 in 1942 must have been due primarily to the general rise in the water table in the intake area resulting from the large recharge in 1941. In well 11/34–30Q1 even the summer levels in 1942 and in later years were about 15 feet higher than in preceding years; and this rise is somewhat greater than but similar to the rise in the range of fluctuations in well 12M1. The hydrographs of wells 10/35–7F1, 11/35–20E1, and 11/35–33G1 (fig. 6) all show the same features. The peaks to which the water levels might have risen in wells 7F1 and 20E1 could not be ascertained because both flowed for several months in the winters of 1942–44 and measurements of static head were not made. The peaks were probably somewhat lower than in well 12M1.

Therefore, it is concluded that a recharge mound leaving the river in the intake area does not affect the head of water in the area of confinement until it has produced a general rise in water levels along the greater part of the inland boundary of confinement. The time lag involved is from 6 months to a year, and again the amplitude of rise is directly proportional to the quantity of recharge. Thus, even in the area of confinement the effect of river recharge decreases as the distance of the wells from the area of river recharge increases.

FLUCTUATIONS RELATED TO RECHARGE FROM RAIN

The relatively small quantities of recharge by infiltration of rain usually cannot be identified in the hydrographs of wells in most of the intake area because the response of water levels to rain is overshadowed by other larger responses, such as those to recharge from streams and to recovery from pumping. Nevertheless, in each season's rise of water levels in years when the rainfall is greater than about 12 inches, there must be some small increment that is due solely to rain. In areas remote from heavy pumping and from river recharge it is believed that recharge from rain can be recognized. Furthermore, there appears to be some time lag involved between the time of rainfall and the time the recharge reaches the main water body. For example, in the year 1942 the water level in well 9/34–3N3 (fig. 5) rose about 6 feet. Assuming a specific yield of about 16 percent (p. 119), and recharge from rain in 1941 as about 1 acre-foot per acre (table 6), the rise of water level from that recharge alone would have been about 6 feet. Thus, it is believed that the rise was due largely to rainfall and perhaps partly to the decrease in pumping rate. Conceivably, a part of the rise may have been due to river recharge in 1941. The quality of water in this area indicates, however, that recharge is primarily from the infiltration of rain (p. 137).

Isolated measurements in wells 9/33–15D1 and 11/34–19R1 show net rises from the mid-thirties to 1944 of about 15 and 6 feet, respectively—a rise which is believed to be due primarily to recharge from rain. In the minor water bodies in the Orcutt and Nipomo uplands (p. 74) water levels are reported to rise in years of above-average rainfall and to show little or no rise in years of below-average rainfall.

FLUCTUATIONS INDUCED BY PUMPING

Pumping of ground water for all uses in the Santa Maria Valley area has a considerable diurnal as well as seasonal fluctuation—most pumping being in the daytime, and most of it in the summer. The resulting variations in draft on ground water produce daily and seasonal fluctuations of water levels in wells. Because pumpage for irrigation constitutes the bulk of the draft its effect is the most pronounced. The length of the pumping season is dependent to a large degree upon the distribution and intensity of rainfall, but in general about 90 percent of the pumping occurs during the 7-month period April through October; the remaining 10 percent takes place during the winter months.[15]

Seasonal fluctuations.—In contrast to the general seasonal rise of water levels in wells due to recharge each year, there is a corresponding seasonal decline of water levels due mostly to discharge by pumpage during the late spring, summer, and early autumn months. However, an undetermined part of each year's decline is due to the continuous process of natural depletion of storage by the westward drainage of ground water. As a result of the staggered periods of yearly recharge and discharge the hydrographs of wells show an oscillation somewhat analogous to a sine curve. Late each spring water levels in most wells begin to decline abruptly as pumping for irrigation begins, generally at about the same time throughout the area. Naturally, the response is most noticeable in wells in the heavily pumped areas of the Sisquoc and Santa Maria plains. Elsewhere the response varies principally with the distance of wells from these heavily pumped areas.

In the intake area water levels in wells adjacent to the rivers usually closely approach or occasionally reach their peaks before pumping for irrigation begins each year. Consequently, in these wells the decline of water levels due to pumping is not appreciably masked by river recharge as in the case of water levels in wells farther away. During the 4-year period 1941–44, when monthly measurements were made in most observation wells, the hydrographs of wells 9/32–7N1, 9/33–2A1, 10/33–28A1, 10/34–2R1, and 11/34–30Q1 (figs. 3 and 4) showed declines each year which averaged about 7, 8, 13, 11, and 9 feet, respectively. Most of these wells show that the water levels reach their lowest stages near the end of each year and sometimes not until January or February of the following year. In years of small recharge, such as 1939, the hydrographs show that in general water levels continued to decline after February and throughout the remainder of the year.

In the intake area away from the river the decline of water levels each year in response to pumpage is greatly dampened or is even nullified by the delayed recharge mound from the river. The hydrographs of wells 10/33–19B1 and 10/34–14E3 (figs. 4 and 5) show that in 1941, instead of declining, water levels rose rapidly from about April throughout the period of concentrated pumping. This same characteristic was noted in other wells in the same area, and also for other years of large recharge, such as 1938. In fact, water levels in some wells in this area are occasionally at their lowest stage in February and March, when wells along the river are approaching their peaks. This is shown by a comparison of the hydrographs of wells 1033–19B1 and 10/34–2R1 in the years 1943 and 1944. Wells along the south side of the plain show normal spring rises and summer declines only because the recharge mounds reach this area almost 1 year late and, therefore, do not mask the pumping decline.

In the heavily pumped portion of the Orcutt upland fluctuations of water levels in response to pumping are different from those elsewhere in the area. This is due to the fact that wells 9/34–3N1, 9/34–3N2, 9/34–3N3, 9/34–3N4, 9/34–10M1, and 9/34–10M2 are all public-supply wells and are necessarily operated during the entire year. Because summer pumpage is greater than winter pumpage, water levels show some variation. The fluctuations induced by pumping are best illustrated by the hydrograph of well 9/34–3N3 (fig. 5) which, except during winters of large recharge, shows exceedingly small variations in water levels between winter and summer, amounting to only 1 to 3 feet.

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[15] Lippincott, J. B., Report on water conservation and flood control of the Santa Maria River in Santa Barbara and San Luis Obispo Counties, Calif., March 1931 (unpublished report available to the public at the offices of the County Planning Commission, Santa Barbara, Calif.).

In the area of confined water, on the other hand, water levels start to decline instantly when pumping begins, usually in April, reach their lowest stages at the height of the pumping season in July, August, or September, and start to rise rapidly thereafter as pumping decreases. The immediate rise or decline of water levels in response to pumping conditions is due primarily to the fact that the fluctuations largely represent changes in head, and not the unwatering of deposits as is the case in the intake area. When the pressure is reduced at the start of the pumping season, the loss of head throughout the artesian system is rapid, and water levels drop. At the close of the pumping season just the reverse takes place.

The close correlation between pumping schedules and water-level fluctuations in the area of confinement is best shown by the hydrographs of wells 10/35–7F1, 10/35–12M1, 11/35–20E1, and 11/35–33G1 (fig. 6). These hydrographs show clearly the start, height, and termination of the pumping season as outlined above. During the 4-year period 1941–44 the seasonal drop in water levels has averaged about 8 feet each year. This uniform amount of seasonal decline may be due to the fact that pumpage during each of these four years has been of about the same intensity and duration.

Diurnal fluctuations.—The diurnal fluctuations of water levels in response to pumping in the intake area differ considerably from those in the area of confinement. The records from recorder charts and float gages of well 10/33–27K1 in the intake area and of well 10/35–7G3 in the area of confinement are compared to show the effects of pumping in the two areas on the daily fluctuations.

Well 10/33–27K1 is about 300 feet from irrigation well 10/33–27K2. During each day of a 150-day period from April 27 to September 24, 1942, the water level in well 27K1 dropped almost consistently about 0.15 foot in response to pumping in well 27K2, and recovered about 0.05 foot during the night after the pump shut down, for a total net decline of 12.61 feet during the entire period. Furthermore, there was a lag of several hours between the time pumping started and stopped in well 27K2 and the time when the water level in well 27K1 responded.

In the area of confinement, on the other hand, the record of well 10/35–7G3 shows an entirely different response to daily pumping in irrigation well 10/35–7G1, which is only 250 feet distant. Well 7G3 shows a daily decline of over 6 feet and a nocturnal recovery of almost the same magnitude. From May through September 1942, the net decline was only 7 feet, indicating that diurnal fluctuations due to pumping were often as great as the total seasonal fluctuation. Also, when irrigation well 10/35–7G1 was started and stopped the response in observation well 7G3 was abrupt and almost instantaneous.

Another feature illustrated by comparing hydrographs for wells in these two areas are the diurnal fluctuations produced in the observation wells by pumping in distant wells. In well 10/33–27K1 only a barely perceptible diurnal fluctuation, usually less than 0.02 foot, was noted when either of the irrigation wells 10/33–27L1 and 10/33–27G1, which are both about 800 feet distant, was pumping. In contrast, diurnal fluctuations of over 2 feet were observed in well 10/35–7G3 when irrigation well 10/35–7F1, which is over 1,400 feet distant, was pumping.

These marked differences in response of water levels to pumping in these two areas support the inference that the seasonal fluctuations in the intake area are due to the composite effect of recharge mounds, which tend to give high levels in winter, and withdrawals by pumping augmented by natural depletion, which tend to produce low levels in summer. These fluctuations represent changes in the amount of water in storage. On the other hand, the fluctuations in the area of confinement represent pressure changes but essentially no unwatering of the deposits or changes in storage. In the area of confinement some small changes in storage actually do take place (Wenzel, 1942, p. 99), but they are so insignificant when compared to the changes in the intake area that they are not considered in this report.

FLUCTUATIONS CAUSED BY A MOVING LOAD ON THE LAND SURFACE

Momentary rises and declines of water levels of 0.02 to 0.05 foot caused by passing trains have been observed in wells in the area of confinement in the lower Santa Ynez Valley during the course of the ground-water investigation in Santa Barbara County. Similarly, Stearns (Stearns, Robinson, and Taylor, 1930, pp. 148–150, figs. 20, 21) observed rises of between 0.01 and 0.03 foot in certain wells in Mokelumne area, California; and Jacob (1939, pp. 666–674) made an intensive study of this type of fluctuation on Long Island, New York.

In the Santa Maria Valley area fluctuations caused by passing trains were observed in well 11/35–33G1, which is in the area of confined water and 58 feet from the Southern Pacific railroad. The well penetrates the full thickness of confining material, constituting the upper member of the alluvium, and is reported to penetrate the main water body for a depth of over 30 feet. Figure 7 shows the fluctuations of water level before, during, and after each of two trains passed on March 7, 1946. The general decline of water level in well 11/35–33G1 during the period of observation is due to pumping from a nearby irrigation well.

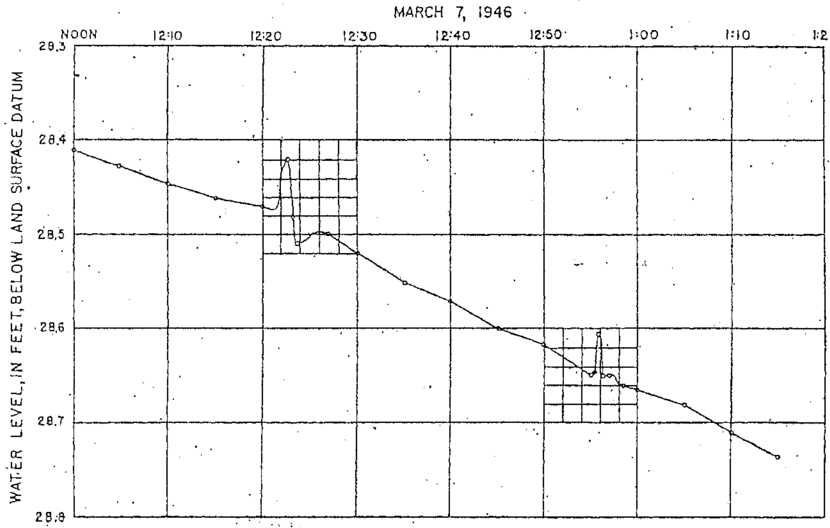

FIGURE 7.—Hydrograph of well 11/35-33G1, showing the effect of a moving load on the land surface.

The first train to pass was a slow-moving freight, and the second, about 30 minutes later, was a fast-moving passenger train. The effect on the water level in the well, as determined by individual tape measurements, seems not to have been the same in each case, but might have been found to be essentially the same had measurements been spaced more closely. The fluctuations of water level caused by the passing of the freight train seem to fit closely the explanation given by Jacob (1939, pp. 672–673, fig. 6) for the fluctuations in certain wells on Long Island.

The water tapped by well 11/35-33G1 is confined, and the aquifer is assumed to be elastic. Under these conditions, and in accord with Jacob's explanation, the fluctuations can be explained as follows. As the train approached the vicinity of the well the extra load on the confining bed caused an increase of pressure in the aquifer, resulting in a rise of water level in the well. With the passing of the train the load remained about constant for a time, but as the aquifer was compressed under the extra load, water was driven laterally and most of the train's load ultimately was supported almost entirely by the aquifer. Hydrostatic pressure then returned toward normal, and the water level in the well approached normal level. As soon as the train had passed the vicinity of the well, the excess load decreased, the aquifer, being elastic, expanded; and for a time the hydrostatic pressure in the aquifer was negative, resulting in a decline of water level in the well below normal level. As the water returned with

the expansion of the aquifer to its original shape, the hydrostatic head approached normal and the water level in the well returned to its normal position.

THE RELATION OF NET CHANGES OF WATER LEVEL TO NET CHANGES IN STORAGE

In the foregoing paragraphs the types of water-level fluctuations have been discussed from the standpoint of their causes, such as recharge and pumpage, which produce rises or declines most readily apparent over short periods of a few days or months. Because these causes also operate intermittently or continuously, they produce a composite effect which may result in a net rise, net decline, or no change in water levels over any particular period. In the intake area these net changes represent net changes in the amount of water in storage in the main water body. For example, over a given period if the total recharge is greater than the total discharge the difference goes into storage in the basin, and water levels show a net rise; if recharge is less than discharge the difference is taken from storage and water levels decline; and if recharge and discharge are equal, water levels show no net change. Because there have been relatively long periods of both above-average and below-average recharge, these net changes have been most pronounced over long-term periods.

Figure 8 shows fluctuations of water levels in the two wells having the longest record in the area and their relation to rainfall at Santa Maria. The continuous record of fluctuations in well 10/34-14E3 began in 1917, and in well 9/32-7N2 in 1920. Prior to 1918 few recorded data are available, but enough reports and records were obtained from owners and well drillers in the course of the investigation to determine in a general way the major fluctuations that took place in well 14E3 from 1903 to 1917. For example, the measurement for the year 1903 is based on a reported water level in a nearby well; and those for the years 1906 and 1907 are also based on levels in nearby wells given in Lippincott's report.[16]

The indicated decline of water level between 1890 and 1903 is based partly on reports of early water levels and partly on the remainder of the recorded fluctuations. Prior to 1883, according to Mason (1883, pp. 312–313), flowing water was obtained at a depth of 110 feet in and near Guadalupe, and in about 1880 water was obtained on the Rancho Punta de la Laguna (pl. 1) at depths of 20 to 60 feet. Thus, there must have been a net decline between 1880 and 1907 of at least 20 feet at Guadalupe and possibly of more than 30 feet in the Rancho Punta de la Laguna. (See pl. 6.) From these data, and from the general parallelism of the hydrograph with the curve for

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[16] Lippincott, J. B., op. cit., diagram No. 3, 1931.

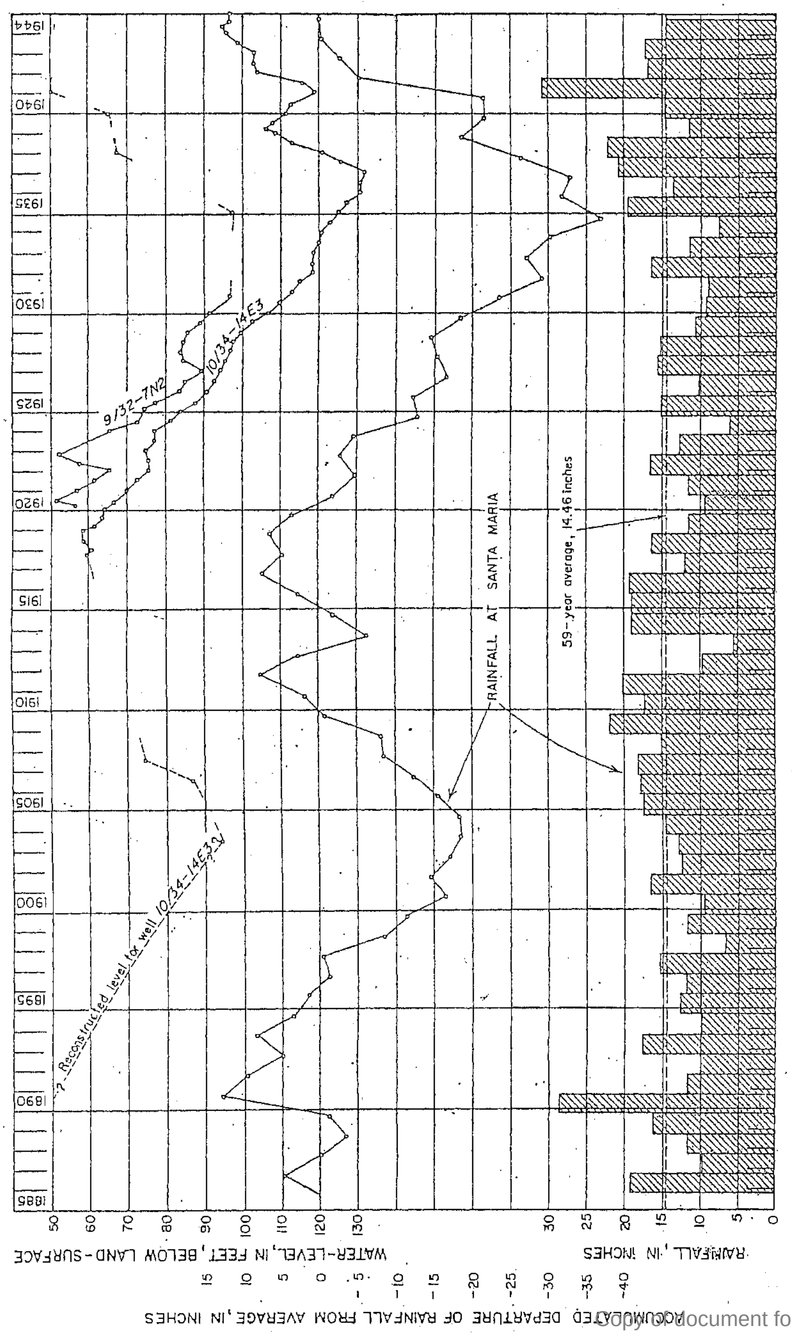

FIGURE 8.—Fluctuations of water levels in wells 9/32-7N2 and 10/34-14E3, 1903-44, and yearly rainfall at Santa Maria and accumulated departure of rainfall from average for the water years 1886-1944.

accumulated departure of rainfall, the hydrograph of 14E3 is extended back to an estimated depth to water of 50 feet in 1890. Not only is this partly reconstructed record the longest available, but also the well is near the middle of the Santa Maria plain and within the pumped area. Although the records show that fluctuations in wells near the central part of the Santa Maria plain have had a wider range in amplitude than wells either near the coast or in the Sisquoc valley, the fluctuations are probably fairly representative of fluctuations within the valley area as a whole.

Study of the fluctuations of water level in well 10/34-14E3 and comparison with the rainfall as a measure of the recharge reveal several pertinent features with regard to changes in storage. First, there have been two periods of rising water level, indicating increase in storage, and two periods of declining water level, indicating decrease in storage. Second, the long-period changes of water level, and hence storage, have been generally proportional to the natural fluctuation of rainfall. Third, the water level in 1944, which probably is close to a long-term peak, was about 35 feet lower than the peak of 1918. Thus, during the period 1918-44, pumpage has apparently been sufficient to modify considerably the natural fluctuations of water level. In ensuing paragraphs the long-term fluctuations are discussed according to four main periods of water-level change; namely, the period 1890-1904, of declining water level; the period 1905-18, of rising water level; the period 1919-36, of declining water level; and the period 1937-44, of rising water level.

Net decline during the period 1890-1904.—The period 1890-1904 was one of below-average rainfall (fig. 8), and hence below-average recharge. During the first 8 years of the period essentially all ground-water discharge was by natural processes. Doubtless there was not only maximum discharge by ground-water outflow (p. 96), but also a considerable quantity of discharge by ground-water overflow. After 1898, pumpage began to extract limited quantities of ground water. This pumpage, together with deficient rainfall, evidently caused a decrease in storage during this period. The net decline of water level may have amounted to as much as 45 feet at well 10/34-14E3. Had there been no pumping during the latter 7 years of the period, the decline would have been somewhat less, but the exact amount cannot be ascertained.

Net rise during the period 1905-18.—The above-average rainfall from 1905 to 1918, which is best illustrated by the graph of accumulated departure from average rainfall for that period (fig. 8), produced above-average quantities of runoff in the Santa Maria and Sisquoc Rivers. Consequently, storage increased during this period because recharge from all sources exceeded natural and artificial discharge.

The increase caused a net rise in water levels which amounted to about 40 feet in well 14E3. On December 22, 1918, the water level in well 14E3 stood only 58.67 feet below the land surface—the highest on record. It is reported that water levels in other wells also reached their highest stages in this year.

The area of flowing wells at the west end of the plain extended farthest eastward in 1918 (pl. 5). Increased pumpage and ground-water outflow together, however, apparently were insufficient to prevent the natural increase in ground-water storage and the accompanying rise of water levels. Consequently, along the eastern boundary of confinement the water level in 1918 stood only about 15 feet below the surface of the Santa Maria plain, and ground-water overflow into the streams occurred. The pits which had been constructed for the early pump installations (p. 84) were inundated by the rise of water levels, and the pumps had to be raised in those wells not already abandoned. For example, it is reported that in 1916 or 1917 a pump near well 14E3 was covered by the rising ground water. It was necessary to send a diver down to unbolt the submerged pump and to raise it above the water level in the pit.

Net decline during the period 1919–36.—The favorable period of increased storage which reached a peak in 1918 was followed by an 18-year period in which water levels declined rapidly, and storage reached its historic low in 1936. The general area-wide conditions are best shown by the water-level contours for that year (pl. 5). The water level in well 10/34–14E3 declined from the highest recorded level of 58.67 feet below land surface on December 22, 1918, to the lowest recorded level of 132.69 feet on October 18, 1936—a total net decline of 74.02 feet. In the Sisquoc valley the water level in well 9/32–7N2 declined from 52.7 feet below the land surface on May 11, 1920, to the lowest of record of 99.7 feet in January 1935—a total decline of 47 feet. In those wells which have shorter records (figs. 3–6) the water levels all showed similar declines in the latter part of this period.

The relatively rapid decline of water levels during the 18-year period can be directly attributed to two major causes. First, rainfall was considerably below average (fig. 8) and therefore recharge was small (table 7). Second, the introduction of vegetable farming in the early twenties greatly increased the withdrawals from storage by pumping for irrigation (tables 8 and 9). Thus, from 1919 to 1936 natural discharge plus the increased artificial discharge were considerably in excess of the below-average recharge. Consequently, a steady depletion of storage occurred, accompanied by a lowering of water levels throughout the area. In well 10/34–14E3 the rate of decline averaged over 4 feet per year.

The economic effects of the decline in water levels were widespread. In 1918, when there was a relatively large area of artesian flow from wells, most wells at the west end of the valley were equipped with centrifugal pumps. As the area of flow contracted owing to the decrease in head, pumping levels fell below the physical reach of suction pipes, and deep-well turbine pumps had to be installed. In the intake area, where most wells were equipped with deep-well turbine pumps, pumping levels locally fell below the bottom of suction pipes—a condition which necessitated the lengthening of most pump columns. A few wells were ultimately deepened to obtain a sufficient quantity of water. However, by far the greatest economic effect was the increased cost of pumping due to the area-wide increase in pumping lifts.

In the area of confinement water levels were depressed considerably by 1936, but there was always a favorable seaward gradient and thus a movement of ground water in that direction (pl. 6). The hydrograph of well 10/35–7F1 (pl. 6) also shows that the water levels near the coast during this critical period were above sea level. Therefore, even during this period of lowest water levels, there was sufficient fresh-water head to prevent encroachment of sea water into the range of thickness penetrated by wells. However, there theoretically was encroachment into the basin at depth (p. 138).

Net rise during the period 1937–44.—Following the 18-year period of below-average rainfall and the consequent depletion of storage, water levels throughout the area rose from the historic low of 1936 to relatively high elevations in 1944 in response to a period of above-average rainfall and recharge. The rise took place even though there was a steady increase of pumpage (tables 9 and 10). The water level in well 10/34–14E3 rose from 132.69 feet below the land surface (lowest level of record) to 95.40 feet on March 12, 1944—a total net rise of 37.29 feet. However, the water level in March 1944 was still 36.73 feet below that of December 22, 1918, and was about the same as the reported level in 1903. Similarly, the water level in well 9/32–7N2 in the Sisquoc valley showed a net rise of 49.5 feet, from 99.7 feet below the land surface in January 1935 to 50.2 feet at the end of 1940, slightly above the previous high level of 1920. The hydrographs of other wells (figs. 3–6) whose records are considerably shorter than those of wells 9/32–7N2 and 10/34–14E3 show declines of water levels to about 1936 and a subsequent rise into 1944. In most of these wells the levels in the years 1941–44 are the highest of record simply because their records do not extend back far enough to indicate the early conditions.

Plate 5 shows water-level contours for the main water body during the period of low water levels in 1936 and in the spring of 1942. The net rise of water levels is clearly indicated by the comparison of contour lines in these two years. Furthermore, the plate shows that the area of flowing wells increased substantially from about 1 square mile in 1936 to more than 5 square miles in 1944 but was considerably less than the maximum area of flow in 1918.

Thus, the net rise in water levels during the period 1937–44 indicates an over-all net increase in storage in the intake area during this period. Storage beneath the Santa Maria plain may have been about equal to that of 1903 or 1907 (pl. 6) but was considerably below that of 1918; and in the Sisquoc valley, where pumpage is small, the water levels indicate a net increase in storage about equal to the net depletion in the years 1920–36.

The stage of Guadalupe Lake apparently has varied considerably during the past 3 decades. It is reported that in 1918 the lake surface was relatively high, and that thereafter the level fell progressively until the lake went completely dry in 1934—at no time before had the lake ever been known to be dry. From 1934 into 1937 the lake bottom was farmed, but in 1938, with the rise of water levels, the lake was reestablished. In 1942 it was observed that the elevation of the lake surface corresponded roughly to the elevation of water levels in levels in wells 10/35–26K1–10, situated on the lake shore, thus indicating a hydraulic continuity with the main water body. Examination of old shore lines showed that the lake at some time had been about 5 to 10 feet above the level of 1942. Thus the reported stage of Guadalupe Lake has corresponded in general to the major fluctuations of ground-water levels throughout the area.

Significance of long-term net changes.—Thus, it is believed that under natural conditions there has been a fairly delicate balance between recharge and natural discharge. The large fluctuations of water levels in the intake area, in the early years before any appreciable pumpage, indicate this relationship. During years of high natural recharge there was an increase in ground-water storage, and during years of low recharge, storage decreased. Pumpage in years prior to 1920 probably was not large enough to affect appreciably the amount of water in storage at any time. However, after 1920 the rapid increase in pumpage affected storage considerably. Coupled with and augmented by deficient rainfall, the increased discharge caused a progressive and large decrease of storage into 1936. In the period 1936–44, one of above average rainfall, although discharge was not great enough to exceed the recharge, it was great enough to prevent the restoration of water levels to the peaks reached in 1918.

Thus, at least by 1936, and probably earlier, the dynamic balance established between natural recharge and total discharge was such that water levels ever since have fluctuated at levels considerably below those that would have prevailed under natural conditions. Consequently, it is believed that water levels will continue to fluctuate in accord with protracted wet and dry periods, but that the amplitude of the fluctuations will be greatly modified by the pumpage at that time. With an expected increase in pumpage, during protracted periods of below-average recharge, water levels may decline to or even below the levels of 1936; and during periods of above-average recharge they will undoubtedly rise, but probably never again will they reach peaks such as the levels attained in 1918.

Thus, the long-term net rises or declines of water levels within the intake area indicate net increases or decreases of ground-water storage, respectively. Because the amount of water-level change is directly proportional to the corresponding change in storage, the actual amounts of storage change can be determined when the specific yield of the water-bearing deposits within the zone of water-table fluctuations is known. This concept is developed in the following pages.

NET CHANGES IN STORAGE IN THE MAIN WATER BODY

METHODS FOR ESTIMATING STORAGE CHANGES

It has been shown in the preceding section that over periods of years net changes in water levels accompany net changes in ground-water storage in the intake area. These changes in storage are converted to actual quantitative estimates by two methods. During the years 1929–45, the quantities can be estimated for any period simply by taking the difference between total recharge and discharge for the period. However, because these totals themselves are in part estimated, it is desirable to derive estimates of net change by another method in order to verify the totals. The other method employed is the use of the specific yield of the deposits within the zone of water-table fluctuations, applied to the net change in water levels.

USE OF SPECIFIC YIELD

ESTIMATE OF SPECIFIC YIELD

The specific yield of a rock or soil with respect to water is usually expressed as a percentage derived by dividing (1) the volume of water which a rock or soil, after being saturated, will yield by gravity by (2) the volume of the rock or soil (Meinzer, 1923, p. 28). In the field, the specific yield is derived by dividing the increase or decrease in stored water in a given area by the average rise or decline of the water table in the same area.

The method used for estimating the specific yield of the water-bearing deposits in the zone of water-table fluctuations in the Santa Maria Valley area is patterned after that used by Piper (Piper, Robinson, and Park, 1939, pp. 74–76) in the Harney Basin, Oregon, and by Eckis (1934, p. 109, table 5) in southern California. It is based on the relative volumes of gravel, sand, and clay that lie within the zone of water-table fluctuations, taken in conjunction with adjusted values of specific yield for each type of material as determined in other areas. This method was selected primarily because of the wide lithologic variations that exist between the different water-bearing formations and within each formation itself. Ultimately, if desired, the estimates could be refined by extensive pumping and laboratory methods which, however, are beyond the scope of this investigation.

The formations underlying the Santa Maria Valley area and in which the water-level fluctuations have occurred primarily are: the coarse-grained lower member and the lower part of the upper member of the alluvium beneath the Sisquoc plain and the intake area of the Santa Maria plain; the Orcutt and Paso Robles formations and locally the Careaga sand beneath the upland areas, and the relatively coarse grained terrace deposits along the north side of the Sisquoc valley. For these deposits there are seven terms commonly used by well drillers to designate the various lithologic types of material encountered in well-drilling operations. These are: gravel, sand, silt, clay, gravel and sand, gravel and clay, and sand and clay. Well drillers questioned during the investigation all maintained that such terms as "gravel and sand" mean about half sand and half gravel; and the term is therefore evaluated accordingly. However, material described as "gravel and clay" and "sand and clay" are both considered as "clay" because it is believed that the pore spaces between the sand grains or pebbles are largely filled by clay, and hence the specific yield of these two types of material would approach that of clay. Because the term "silt" is commonly used to designate very fine sand and clay, material thus designated is also classed as clay. Therefore, the seven types of material as distinguished by well drillers are in this report divided into three main classes: gravel, sand, and clay.

Naturally, there is a considerable range in the specific yield of the gravel, sand, and clay, depending on grain size, degree of sorting, and the terminology of the individual driller. Nevertheless, owing to the large number of well logs which were analyzed it is believed that a mean value for specific yield can be applied satisfactorily. The values used for specific yield are: for gravel, 30 percent; for sand, 20 percent; and for clay, 5 percent. These values are slightly lower for gravel and higher for clay than those used in the Harney Basin, because the term "gravel" as used by drillers usually contains some sand; and the term "clay," some sand and silt.

To obtain the relative volume of the three types of material over 250 well logs were carefully examined, and for each log the footage of gravel, sand, and clay in the zone of water-table fluctuations was determined. Owing to the wide range in footage of each type of material from one part of the area to another and, furthermore, because the footage of each type varied, in general, according to the areal distribution of the water-bearing formations, it was found advisable to divide the area into three subareas, each containing generally the same types of material. The three subareas are as follows: the Sisquoc plain and the terrace to the north and that part of the Santa Maria plain from 0 to 10 miles west of Fugler Point; that part of Santa Maria plain from 10 to 13 miles west of Fugler Point, or to the edge of the artesian area; and the Orcutt upland, the southwestern part of the Nipomo upland, and the dissected upland area south of the Sisquoc plain. Within each subarea the logs showed approximately the same percentages of gravel, sand, and clay. The percentages thus derived are believed to be representative of the total quantities of the three principal classes of material distinguished in the zone of water-table fluctuations in each subarea.

The following table shows the extent of each subarea, the number of well logs, the percentage volume of each class of material, and the calculated specific yield of the material in the zone of water-table fluctuations. For each subarea the figure for specific yield of the material is the sum of the products of the specific yield of gravel, sand, and clay times, the percentage volume of each. The average specific yield for the whole area is weighted in proportion to the relative areal extent of each subarea.

Estimates of the specific yield of water-bearing materials within the zone of water-table fluctuations in the Santa Maria Valley area

Subarea	Area (acres)	Number of well logs	Percentage volume			Specific yield (percent)
			Gravel	Sand	Clay	
1. Sisquoc plain, terrace to the north, and part of Santa Maria plain 0 to 10 miles west of Fugler Point	21, 900	136	44	39	17	21. 8
2. Part of Santa Maria plain 10 to 13 miles west of Fugler Point	9, 600	65	23	41	36	15. 3
3. Orcutt, Nipomo, and minor upland areas	50, 900	80	30	21	49	15. 6
Total for area	82, 400	281	Weighted average			17. 2

The specific yield differs considerably from one subarea to another. It is high when the percentage of gravel is high and that of clay is low, and vice versa. In general, the weighted average specific yield for the area is relatively high because, in all subareas, the percentage volume of clay is less than 50 percent of the total.

APPLICATION TO WATER-LEVEL CHANGES TO OBTAIN STORAGE CHANGES

If water levels change uniformly throughout the intake area, the net changes in storage could be determined simply by multiplying the specific yield times the area in acres times the net change of water level in feet. For example, a net rise of 1 foot throughout the 80,000 acres of the intake area would represent an increase in storage of about 14,000 acre-feet. However, it has been shown that the water table does not rise or decline uniformly. Hence, the figure for specific yield of 17.2 percent for the total area is not strictly applicable. Consequently, changes in storage have to be computed separately for each of the three subareas, then totaled.

In order to obtain the net change in water level, contour maps spanning desired periods were drawn from peak water levels in the spring months of the 2 years being compared. One was then superimposed over the other, a grid of half-inch squares was laid over the two, and the net change in water level determined in each square of the grid. The figures in the squares in each subarea were averaged separately to obtain the average net change of water level for each. Thus, the average net change in storage in acre-feet for the intake area over any desired period of time for which sufficient water-level data are available can be obtained by adding the products for each subarea of: the average net change of water level in feet, the area in acres, and the specific yield.

The accuracy of the results obtained by the use of this method is dependent not only on the validity of the figures for specific yield, but also on the detail of the contour maps. Owing to the irregularities and ever-changing shape of the water table, due primarily to pumpage and recharge, numerous nearly simultaneous measurements in wells are necessary to obtain an accurate, detailed contour map. Even now there are too few wells in which measurements can be made around the margins of the main water body to control the contours accurately (pl. 5). In the past, and for a particular time desired, even fewer measurements were available. Consequently, the computations of storage change by use of the specific yield method are somewhat in error, probably largely owing to this cause.

USE OF RECHARGE AND DISCHARGE

The second method by which net changes in ground-water storage can be estimated is by use of the estimates of total recharge and discharge which have been computed for the years 1929–45 (tables 7 and 12). The difference between recharge and discharge over any

desired period of time within the years 1929–45, then, will give the net change in storage. However, estimates of storage change derived by this method are subject to considerable error because a small percentage error in estimating recharge will result in a very large percentage error in the amount of storage change computed.

For simplicity of treatment in the following sections, the recharge for any one water year, such as 1930–31, is listed as recharge in the second year indicated, in this case 1931. This is because the second year includes most of the water year, and because most of the recharge occurs after the beginning of the second year.

ESTIMATES OF STORAGE CHANGES, 1929–45

Estimates of net change in ground-water storage by use of specific yield and recharge and discharge have been made for three periods: for 1929–36, to show the net decrease in storage during the latter part of the dry period which began in 1919; for 1936–45, to show the net increase in storage in the current wet period; and for 1929–45, which spans the entire period for which estimates of recharge and discharge have been made.

In order to compare the net changes in storage determined by use of the two methods, both strictly should span identical periods. They do not, but the difference between them is relatively small. In the computations based on specific yield, contour maps were drawn for the spring peaks of 1929, 1936, and 1945, and net changes in storage for the three periods were computed between the spring peaks of the first and last years of each period (p. 119). On the other hand, the use of the estimates of total recharge and discharge is limited to water and calendar years, respectively, and net changes in storage for the three periods are computed by the differences of total recharge and discharge over an equal number of water years (ending September 30) and calendar years, respectively.

Figure 9 shows the time intervals that correspond to the three elements, net-change year, recharge year, and discharge year; and their chronologic relationship to each other for the period 1929–36. As shown, the time intervals are not exactly coincident, and hence the total net changes in storage computed are not strictly comparable. For example, the net water-level changes are taken from the spring peaks of 1929 to those of 1936, and the change in storage computed from these by the specific yield method are for that period. The net change in storage computed from total recharge and discharge is actually for the over-all period January 1, 1929, through September 30, 1936, and utilizes the difference between total discharge in the calendar years 1929–35 and total recharge in the water years 1930–36. Thus, the net change in storage for the period 1929–36 determined

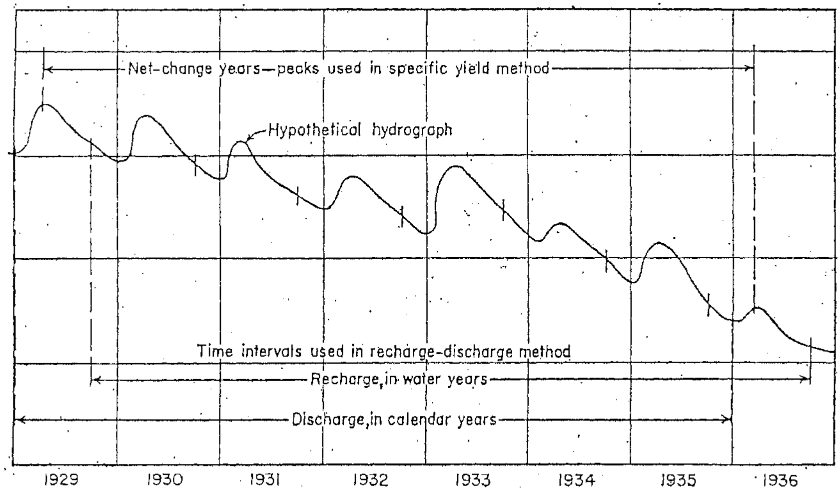

FIGURE 9.—Diagram showing chronologic relationship of net-change, recharge, and discharge years for the period 1929–36.

by use of total recharge and discharge incorporates the small amount of discharge in 1929 prior to the spring peaks, and that part of the recharge in 1936 after the peaks had passed, neither of which is included in the net change for the period as computed by use of specific yield.

Accordingly, not only does the computation by recharge and discharge differ somewhat within itself in regard to time interval, but it also differs slightly from that spanned in the specific yield method. Therefore, in estimates for periods of only a year or two considerable error may be introduced; but for longer periods, such as those considered in table 13, the error is reduced to a minimum and is probably well within the limits of the errors involved in the estimates themselves.

The same principles apply to the remaining two periods. The net change in storage for the period 1936–45 computed by use of specific yield is best compared with the difference between total recharge for the water years 1937–45 and total discharge for the calendar years 1936–44; and similarly, for the period 1929–45, it is best compared with the difference between total recharge for the water years 1930–45, and total discharge for the calendar years 1929–44.

Table 13 shows estimates of net change in ground-water storage for the three periods 1929–36, 1936–45, and 1929–45 as determined by use of the specific yield method and by the use of the totals for recharge and discharge; it also shows the difference between the results obtained by the two methods.

TABLE 13.—*Estimates of recharge, discharge, and net change in storage in the main water body during the periods 1929–36, 1936–45, and 1929–45*

	Period		
	1929–36	1936–45	1929–45
By use of specific yield method:			
Average net rise (+) or decline (−) of water levels, in feet:			
Subarea 1	−16	+30	+14
Subarea 2	−20	+25	+5
Subarea 3	−12	+10	−2
Net increase (+) or decrease (−) in storage, in acre-feet:			
Subarea 1	−76, 000	+143, 000	+67, 000
Subarea 2	−29, 000	+37, 000	+8, 000
Subarea 3	−95, 000	+80, 000	−15, 000
Total for area	−200, 000	+260, 000	+60, 000
By use of recharge and discharge method (tables 7 and 12):			
Total recharge, in acre-feet	235, 000	886, 500	1, 121, 500
Total discharge, in acre-feet	394, 000	622, 200	1, 016, 200
Net increase (+) or decrease (−) in storage, in acre-feet	−159, 000	+264, 300	+105, 300
Difference between methods, in acre-feet	41, 000	4, 300	45, 300

The table shows that the results obtained by the two methods differ by 2 to 25 percent of the total quantities involved in each period. However, discrepancies between these results are believed to be reasonable, considering the available data. Accordingly, the quantities obtained by the two methods are sufficiently in agreement not only to verify the general order of magnitude of values derived, but also to substantiate the methods used.

PERENNIAL YIELD OF THE WATER-BEARING DEPOSITS

The perennial yield of the water-bearing deposits in a coastal area is the rate at which water can be pumped from wells year after year without decreasing the storage to the point where the rate becomes economically infeasible, the rate becomes physically impossible to maintain, or the rate causes the landward migration of sea water into the deposits and thus renders the water chemically unfit for use. In the Santa Maria Valley area only the first condition was approached and that only locally during the mid-thirties, when pumping lifts were relatively high. Fortunately there has been at all times an appreciable seaward hydraulic gradient at the coast (pl. 6), and thus the danger of landward migration of sea water has never become serious. Similarly, the second condition has not been approached because the water body is so thick that under conditions of excessive pumpage and low recharge the first or third condition would be realized long before the second. The yearly pumpage in recent years has been large enough to exceed the perennial yield, and with an expected increase in ground-water development, and especially during a series of dry years, pumpage may far exceed the perennial yield in the future.

In terms of water available for pumpage, the perennial yield may be expressed in a different way. Originally, under natural conditions and without any pumping the long-term recharge necessarily was equal to long-term discharge. However, for shorter periods of time recharge was greater or less than discharge, depending directly on climatic conditions; and the differences, as discussed on pages 111–117, caused either an increase or decrease in storage which was reflected in a net rise or decline of water levels throughout the area (fig. 8). Even with the subsequent development of pumpage, storage changes continued to be governed largely by climatic conditions, and hence, by recharge. Thus, it follows that during periods of large recharge more water can be pumped without decreasing storage, and during periods of low recharge less water can be pumped without decreasing storage.

Specifically, for any of these short periods the short-term yield is the total recharge less the total natural discharge plus whatever water there is in storage above the limiting factors for safe withdrawal. However, if little or no water is available in storage above the limiting amount for the period, the short-term yield is merely the difference between average yearly recharge and average yearly natural discharge. The long-term or perennial yield, on the other hand, is intermediate between the short-term yields of periods of above-average and below-average recharge, but it is not dependent on the available water in storage, whose fluctuations affect only the short-term yields. For all practical purposes perennial yield is the difference between long-term average yearly recharge and the average yearly natural discharge.

In the ensuing pages, these principles are applied to the Santa Maria Valley area, and quantitative estimates of short-term yield are made for the period of below-average recharge 1929–36, and for the period of above-average recharge, 1936–45. Also, an estimate of the perennial yield is made. The estimates are based principally on the estimates previously derived for recharge, discharge, and storage changes. (See tables 7, 12, and 13.) As discussed elsewhere (pp. 121–123), the estimates for recharge, discharge, and storage changes are for periods that are slightly out of phase with each other, and they are treated accordingly.

SHORT-TERM YIELD DURING THE PERIOD 1929–36

The period 1929–36 was one of below-average recharge, when total discharge exceeded total recharge, and it marked the end of a long period of storage depletion that began in 1919. Although there was a progressive depletion of storage during this period, the short-term yield as defined was not actually exceeded because there had been a large amount of water in storage at the beginning. However, the short-term yield was approximately reached near the end of the period, when storage had been depleted to the point where pumping for irrigation locally exceeded economic limits. At that time the yield was approximately the difference between yearly recharge and the natural discharge by ground-water outflow to the sea. It probably would have been exceeded, all other factors remaining constant, had the pumping rate been continued long after 1936, and had recharge remained low.

These conditions can be expressed quantitatively as follows: The average yearly recharge for the period was about 34,000 acre-feet (p. 83), and the ground-water outflow in 1936 was about 9,500 acre-feet (table 11). Thus, at the end of the period the short-term yield was the difference between the two, or about 25,000 acre-feet a year. However, during the period the total net pumpage for irrigation plus the total pumpage for other use amounted to about 317,000 acre-feet (tables 9 and 10), or averaged about 45,000 acre-feet a year. This rate of pumpage was within the short-term yield because there was considerable excess water in storage that was being drawn upon. However, if these conditions had been maintained beyond 1936 the yield would have been exceeded by about 20,000 acre-feet per year.

The total net depletion in storage during the period 1929–36 amounted to between 159,000 and 200,000 acre-feet (table 13), or averaged about 26,000 acre-feet per year. The relatively uniform rate of decline of the water level in well 10/34–14E3 (fig. 5) throughout the 18-year period 1919–36 of below-average rainfall suggests that the rate of decrease in stored water was about constant. Accordingly, the rate of storage depletion of about 26,000 acre-feet a year for the period 1929–36 may be applicable uniformly to the entire period. If so, the total depletion of storage from 1919 into 1936 must have been roughly 500,000 acre-feet.

Obviously, had the average yearly recharge remained only 34,000 acre-feet, then the yield of the deposits would have continued to be exceeded beyond 1936, water levels would have continued to decline, and ground-water outflow to decrease. Ultimately, under such conditions pumping lifts would have been extremely high and perhaps in most of the area economically infeasible; landward encroachment of sea water into the water-bearing deposits eventually would have occurred. Furthermore, a large part of the highly productive lower member of the alluvium would have been unwatered, and wells would have been drawing from the less permeable Paso Robles formation—a condition which probably would have increased considerably the pumping lifts and hence the operational costs.

Quite possibly the average yearly recharge of 34,000 acre-feet is representative of periods of below-average rainfall. If so, the short-term yield of about 25,000 acre-feet a year is on the order of magnitude to be expected near the end of future similar periods of below-average recharge. With present withdrawals approaching 65,000 acre-feet a year and total discharge approaching 80,000 acre-feet a year, it is obvious that during future dry periods storage will be depleted at a rate greater than that which took place in the years 1929–36.

SHORT-TERM YIELD DURING THE PERIOD 1936–45

Fortunately, the periods of below-average recharge have been compensated for by complementary periods of above-average recharge, such as that for 1936–45. Total recharge during this period was far greater than total discharge. Consequently, there was a considerable net increase in storage and the short-term yield for the period was never approached.

These conditions are expressed quantitatively in much the same manner as for the period 1929–36, as follows: The average yearly recharge for the period was about 98,000 acre-feet (p. 83), and the average yearly ground-water outflow was about 11,000 acre-feet (table 11). Thus, the short-term yield was the difference between the two, or about 87,000 acre-feet a year. During the period the total net pumpage for irrigation plus the total pumpage for other use amounted to about 521,000 acre-feet (tables 9 and 10), or averaged about 58,000 acre-feet a year. Thus, pumpage averaged about 29,000 acre-feet a year less than the short-term yield.

The total net increase in storage for the period 1936–45 amounted to between 260,000 and 264,000 acre-feet (table 13), or averaged about 29,000 acre-feet a year. Thus, in contrast to the preceding period, storage increased considerably, and water levels rose accordingly throughout the area (figs 3–6). In fact, the storage was enabled to regain about one-half of the estimated over-all depletion of about 500,000 acre-feet incurred during the period 1919–36.

The unusually large recharge in 1941, which was about 230,000 acre-feet, was nearly double the quantity supplied in most wet years (table 7). Consequently, the short-term yield of about 87,000 acre-feet a year for the relatively short period 1936–45 is probably greater than that for other longer wet periods such as 1905–18 (see fig. 8), and probably is above the general average that might be expected in future wet periods. The average yearly recharge for the years 1937–45, exclusive of that for 1941, was about 82,000 acre-feet a year. Thus, by subtracting the average yearly ground-water outflow of 11,000 acre-feet a year, it is believed that the short-term yield for average wet periods would be on the order of 70,000 acre-feet a year.

ESTIMATE OF PERENNIAL YIELD UNDER NATURAL CONDITIONS

Obviously, the perennial or long-term yield of the water-bearing deposits in the Santa Maria Valley area is a quantity greater than the short-term yields during periods of below-average recharge, but less than the short-term yields for periods of above-average recharge. To obtain the maximum perennial yield, it is desirable to reduce to a minimum the natural discharge by ground-water outflow, but not to the point where either the water levels are below practical limits, or the danger of salt-water encroachment becomes imminent. On the other hand, it is undesirable to permit storage to increase to the point where losses by ground-water overflow and evapotranspiration occur as they did around 1918. In addition, it is desirable to stop the loss by flow from wells.

The perennial yield is estimated by equating certain of the quantities derived in preceding sections of this report based on the somewhat above-average period 1929–45. The estimates obtained are then modified on the basis of rainfall to the long term. Two independent methods are used commonly for estimating perennial yield which can be applied to the Santa Maria Valley area for this period, as follows: Perennial yield is equal to the total recharge (table 7) less the total natural discharge by ground-water outflow (p. 96) divided by the number of years of inventory; and it is equal to the total net pumping draft (tables 9 and 10) plus the net increase in storage (determined by specific yield method, table 13) divided by the number of years of inventory. These may be expressed in equations, respectively, as follows:

$$\text{Perennial yield} = \frac{1{,}121{,}500 - 180{,}000}{16} = 58{,}800 \qquad (1)$$

and

$$\text{Perennial yield} = \frac{743{,}000 + 95{,}200 + 60{,}000}{16} = 56{,}100 \qquad (2)$$

Because these two quantities agree very closely, the perennial yield, based on the relatively short period 1929–45, is considered to be the average of the two, or is estimated to be about 57,000 acre-feet a year.

However, because rainfall during the period 1930–45 compared to that of the long term is above average, this estimate of perennial yield is modified accordingly. The basis for the modification rests solely upon the rough correlation that exists between rainfall and recharge, and hence perennial yield. At Santa Maria the average rainfall for the 16-year period 1930–45 was 15.42 inches, whereas for the 60-year period 1886–1945 it was 14.40 inches (table 1); that is, the long-term average rainfall was about 93 percent of that for the shorter period. Although it is almost a certainty that the perennial yield during the 60-year period was not also exactly 93 percent of that for the shorter period, nevertheless, in the absence of other data this percentage is used. The estimated perennial yield of about 57,000 acre-feet a year for the period 1929–45, then, is adjusted to the long term by multiplying by 93 percent. Thus, under natural conditions the perennial yield of the water-bearing deposits in the Santa Maria Valley area is estimated to be about 53,000 acre-feet a year.

The validity of this figure is dependent on two critical factors. First, the adjusted value applies specifically to the 60-year period 1886–1945; and for it to apply in the future it must be assumed that the future climatic cycles, or periods of above-average and below-average rainfall and, hence, recharge, will continue to operate in the same manner and will be on the same order of magnitude as they have in the past. With regard to the expectable future recharge, there eventually may be some reduction due to the development of irrigation with ground water in the Cuyama Valley (pl. 4). Withdrawals, which started in 1939, have increased to about 17,000 acre-feet in 1946, and probably will continue to increase. Because in the Cuyama Valley recharge to ground-water bodies by seepage loss from the Cuyama River is limited by the rate of vertical downward percolation to the deep-lying water table, it is believed that the relatively small amount of runoff which ordinarily passes the area of withdrawals will not be reduced appreciably. However, it is believed that increased pumpage may reduce substantially the natural ground-water discharge into the Cuyama River below the area of withdrawals. The amount so discharged at present is estimated to be about 5 second-feet. If it is assumed that because of evapotranspiration losses and diversions only 50 percent of this flow reaches the Santa Maria Valley area, and further that increased pumpage in the Cuyama Valley will eventually cause the flow to stop entirely, then the future recharge, and hence the perennial yield of the Santa Maria Valley area would be reduced by about 2,000 acre-feet a year. A more accurate estimate of this loss can be made only when more low-flow measurements are available below the area of ground-water discharge.

Second, the yield derived was based on a minimum practicable average ground-water outflow of 11,000 acre-feet a year. To salvage much more outflow would necessitate a lowering of water levels and, hence, costly pumping lifts. It is believed that the range of water levels between 1929 and 1945 is probably the most efficient from the standpoint of both maximum salvage and nominal pumping lifts.

With respect to the current net pumpage of about 65,000 acre-feet a year (tables 9 and 10), it is apparent that the perennial yield is being exceeded by about 12,000 acre-feet, which in years of average recharge would result in a yearly average net decline of water levels amounting to slightly less than 1 foot (p. 120). However, because there was in 1945 about 260,000 acre-feet in storage above the estimated minimum levels, the yearly depletion of 12,000 acre-feet can be tolerated for a limited time. Obviously, if this yearly overdraft is continued or should be increased with no additional supply of water, the result will be a depletion of storage and a decline of water levels to stages far below those of 1936.

Two measures should be considered immediately to conserve ground water: Reduce or stop entirely the flow from wells when not in use because with adequate control the current discharge could be reduced by over 1,000 acre-feet a year (p. 91); and adopt more efficient methods of irrigation. For example, decrease to a minimum the unduly large quantities of "tail waste," space irrigation periods at the maximum practicable intervals, and eliminate wherever possible the long open-ditch conveyance of irrigation water from pumps to the land being irrigated. If these measures were adopted it might be possible to keep the pumpage within the limits of the perennial yield, or at about 53,000 acre-feet per year and, at the same time, maintain the present agricultural development.

ESTIMATE OF INCREASED PERENNIAL YIELD BY SALVAGE OF SURFACE-WATER OUTFLOW

A program for a more efficient utilization of the surface-water resources of the Santa Maria River drainage system has been largely outlined by the Bureau of Reclamation, United States Department of the Interior.[17] In general, this program involves the construction of two dams for surface-water storage or detention. One of the sites is on the Cuyama River about 5 miles above the mouth—a location known locally as the Vaquero Dam site. In conjunction with this structure, a silt-debris dam is to be constructed upstream. The other dam contemplated is on the Sisquoc River about 10 miles above its confluence with the Cuyama River, at a location known locally as the Round Corral Dam site.

One of the fundamental purposes of this program is to salvage each year a substantial part of the surface-water outflow which is wasted to the sea, and so to provide a means of increasing ground-water recharge. During the 16-year period 1930–45 this loss was estimated

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[17] Water requirement, water supply and flood control, Santa Maria Basin comprehensive plan, Santa Barbara County project, California; U. S. Bur. Reclamation Rept., appendix 8, 67 pp., March, 1946. [Mimeographed.]

to total about 566,000 acre-feet, or to average about 35,000 acre-feet a year—about 40 percent of the total runoff (table 5). The reason for the waste is that most runoff occurs during storms and at rates too large for complete absorption through the channel deposits and, hence, transference to the main water body. Thus, as in many ground-water basins under natural conditions, the available surface-water resources have not been utilized fully in replenishing ground-water supply. However, if the winter flow can be largely detained and released over a longer period of time, much of the waste could be salvaged as additional recharge. Thus, by increasing the recharge, and hence the perennial yield of the basin, the program would be of considerable importance to future ground-water development in the area.

Under the program, two features are critical with respect to the amount of increase of perennial yield from salvage of surface-water outflow, as follows:

1. Because water levels indicate that at present there is ample room between the land surface and the water table beneath the Sisquoc and Santa Maria River channels and adjacent areas to accommodate a large increase in storage, the rate at which water could be transferred from surface reservoirs to the main water body would be dependent solely upon the absorptive capacity of the channel deposits. Existing data show that the channels are dry or nearly so throughout more than half of each year, are quite permeable (table 2), and therefore provide excellent natural spreading grounds for the transference of water stored in reservoirs.

2. The perennial yield could be increased by about the amount of surface-water outflow salvaged by the reservoirs, less evapotranspiration losses incurred from spreading operations and from the reservoirs themselves, and less any loss incurred from development in the Cuyama Valley (p. 128).

Under one plan presented by the Bureau of Reclamation,[18] roughly 50 percent of the average yearly surface-water outflow could be salvaged. Assuming the long-term average yearly outflow to be 93 percent of the 35,000 acre-feet a year estimated for the period 1930–45 (p. 128), it would amount to 33,000 acre-feet a year. If the perennial yield were to be increased by about one-half that amount, or by about 16,000 acre-feet a year (neglecting evapotranspiration losses), the estimated perennial yield of 53,000 acre-feet a year under natural conditions would be increased to about 65,000 to 70,000 acre-feet under this particular plan.

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[18] U. S. Bureau of Reclamation, op. cit., tables 5A and 5P, 1946.

The net pumpage in 1944 was about 65,000 acre-feet a year. Even if the ground-water conservation measures suggested on page 129 were to be adopted, the current draft would approach the perennial yield as increased under this particular plan of the Bureau of Reclamation. Therefore, this plan would correct the present deficiency, but it would not provide much if any margin for future development. On the other hand, the steady increase in pumpage during the 4 years 1941 to 1944 strongly suggests that further development will occur.[19] A sustained rate of pumpage materially greater than the 1944 rate would have to be supplied by an increase in salvage of surface waters because nearby sources of water for importation are not available. Thus, it would appear desirable to plan now to salvage the largest amount of surface-water outflow that is economically practicable, and so to increase the yield accordingly; also, to limit ground-water development so as not to exceed the increased yield. Such a program, if accomplished, not only would provide for the maximum utilization of the water resources of the Santa Maria Valley area, but also would prevent a serious overdevelopment that would be detrimental to the economy of the entire valley area.

CHEMICAL QUALITY OF WATER

GENERAL FEATURES

In 1941 and 1942, in connection with the field canvass of wells, the Geological Survey collected 152 samples of water from 116 wells for chemical analysis. Of these, 7 were analyzed for all constituents and the remainder were analyzed only for chloride and hardness in parts per million and for specific electrical conductance in reciprocal ohms$\times 10^6$ ($K \times 10^6$ at 77° F.), which is a measure of the total dissolved solids. In addition, two complete analyses were obtained of river water during low-flow conditions—one from the Cuyama River at its mouth and one from the Sisquoc River above its confluence with La Brea Creek. Numerous other agencies have made available for study over 350 analyses, mostly from water wells but in part from streams, lakes, and ponds. Records of representative partial analyses are included in table 14; and records of selected "complete" analyses are shown in table 15. The locations of all wells are shown on plate 1 and of all streams outside the area on plate 4.

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[19] Since the completion of this report, estimated net pumpage for the 5 years 1945 to 1949 has been 75,000, 85,000, 100,000, 90,000, and 100,000 acre-feet, respectively.

TABLE 14.—*Selected partial chemical analyses of well waters in the Santa Maria Valley area*

[Analyses by A. A. Garrett, Geological Survey]

Well	Date	Chloride (Cl), parts per million	Soap hardness, as $CaCO_3$, parts per million	Specific conductance $K \times 10^5$ at 25° C.	Temperature, °F.
9/32–7N1	June 2, 1942	24	590	107	62
16L1	do	23	575	102	61
17G1	do	26	575	102	------
18A1	do	28	550	106	62
9/33–1L1	do	33	615	101.8	62
2A1	do	22	525	97.7	62
5B1	July 1, 1946	21	515	94.8	------
6C1	do	36	490	92.9	------
8K1	do	29	425	89.4	------
15D1	do	51	450	92.6	------
9/34–2M1	Apr. 1, 1942	46	100	32.7	------
3N3	Apr. 15, 1942	51	100	36.2	------
4M1	Apr. 1, 1942	74	90	39.9	------
6K1	do	95	130	52.9	------
8H3	do	122	125	57.3	------
15B1	do	54	365	93.1	------
10/33–7R1	June 2, 1942	35	600	107	61
18H1	do	67	590	122	65
19E1	do	55	825	155	62
20L1	do	47	600	129	60
27G1	Oct. 1, 1941	75	700	171	60
28J1	June 2, 1942	57	725	152	62
33H1	July 1, 1946	28	500	95.9	------
34N1	do	34	525	100	------
35R1	do	26	465	99.3	------
36Q1	do	28	500	102	------
10/34–2P1	June 2, 1942	40	590	108	59
4P1	June 9, 1942	44	625	120	60
6K1	do	50	550	115	60
8E3	do	56	725	138	61
10E1	do	37	500	109	61
12L1	June 2, 1942	31	540	100	60
13P1	do	56	840	148	62
16F1	June 9, 1942	79	1,125	192	62
18D1	do	103	775	167	62
22L1	do	65	850	166	64
24L1	June 2, 1942	65	890	167	64
26A1	June 9, 1942	71	775	154	63
29D1	Apr. 1, 1942	37	415	95.5	------
32F1	do	49	150	47.0	------
33H1	do	37	350	84.1	------
34J1	do	37	350	84.3	------

TABLE 14.—*Selected partial chemical analyses of well waters in the Santa Maria Valley area*—Continued

[Analyses by A. A. Garrett, Geological Survey]

Well	Date	Chloride (Cl), parts per million	Soap hardness, as $CaCO_3$, parts per million	Specific conductance $K \times 10^5$ at 25° C.	Temperature, °F.
10/35–1N1	June 9, 1942	72	575	126	61
4C1	June 1, 1942	58	650	137	61
7E1	Oct. 1, 1941	54	550	120	63
9F1	June 1, 1942	159	825	182	62
11J1	June 9, 1942	127	750	163	62
12G1	do	71	750	151	62
15D1	June 8, 1942	68	600	135	64
17N1	do	101	575	115	64
18F1	do	91	750	143	63
21B1	June 16, 1942	86	600	133	63
23P1	July 1, 1946	52	320	80.6	------
24B2	June 22, 1942	67	600	131	64
10/36–12P1	July 1, 1946	44	440	99.5	------
11/34–19R1	do	63	150	54.9	------
29P2	Apr. 15, 1942	70	515	117	64
11/35–19E1	Aug. 27, 1942	48	315	136	63
22C2	July 1, 1946	46	550	120	------
25P1	Aug. 27, 1942	50	400	101	61
27H1	June 1, 1942	41	315	77.3	62
28M1	June 29, 1942	36	600	124	62
33F1	Oct. 1, 1941	47	525	118	60
35A2	June 16, 1942	33	465	106	60
11/36–13R1	Aug. 27, 1942	46	490	119	------

TABLE 15.—*Selected chemical analyses of well and stream waters of the Santa Maria Valley area*

Well or location symbol [1]	Source	Date of collection	Temperature (°F.)	Parts per million													
				Dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
9/32–2A1	Santa Maria Realty Co. Drilled irrigation well 168 feet deep. Sample taken by U. S. Geological Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geological Survey (No. 26552)	Oct. 22, 1941	62	628	28	0.02	80	45	49	3.7	0	261	241	18	0	4.6	384
9/33–5B1	Bradley Land Co. Drilled domestic well 301 feet deep	Oct. 13, 1927	------	774	7	------	93	46	54	------	0	244	293	25	------	Trace	421
9/34–3N3	City of Santa Maria, well 3. Drilled public supply well 226 feet deep. Sample taken by U. S. Geological Survey; analysis by G. J. Petretic, U. S. Geological Survey (No. 27407)	Apr. 15, 1942	------	234	40	.09	19	9	35	2.2	0	48	23	52	.1	14	86
0/33–21F2	M. J. Santos. Drilled irrigation well 361 feet deep—now abandoned	Oct. 11, 1927	------	1,186	3	------	146	67	101	------	0	238	566	42	------	18	640
35R1	A. F. Fugler. Drilled irrigation well 275 feet deep	Oct. 20, 1927	------	1,170	8	------	139	80	79	------	0	268	515	55	------	18	676
10/34–5P1	La Brea Securities Co. Drilled irrigation well 172 feet deep	Oct. 24, 1927	------	991	10	------	117	57	81	------	0	232	391	49	------	44	526
12B1	County of Santa Barbara. Drilled public-supply well 193 feet deep	Nov. 3, 1927	------	1,092	7	------	141	55	96	------	0	214	494	55	------	22	578
27H3	York Oil Co. Drilled industrial and domestic well 268 feet deep. Sample taken by U. S. Geological Survey; analysis by G. J. Petretic, U. S. Geological Survey (No. 27417)	Apr. 15, 1942	64	1,019	30	.31	138	69	67	9.6	0	237	488	44	.3	1.0	628
10/35–3N1	Bank of America. Drilled irrigation well 239 feet deep	Oct. 10, 1927	------	1,264	10	------	156	67	115	------	0	275	463	122	------	44	665
7F1	M. J. Ellis. Drilled irrigation well 249 feet deep. Sample taken by U. S. Geologic Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geologic Survey (No. 26556)	Oct. 17, 1941	63	896	32	.02	126	53	69	3.7	0	247	398	48	0.0	3.3	532
10/35–7P1,2	Union Sugar Co. Drilled irrigation wells 235 and 206 feet deep connected to single pump	Oct. 19, 1927	------	882	8	------	113	48	68	------	0	226	342	48	------	22	479
24B2	A. N. Silva. Drilled irrigation well 296 feet deep. Sample taken by U. S. Geological Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geological Survey (No. 26557)	Oct. 17, 1941	63	1,140	26	.02	154	66	103	4.6	0	285	477	90	.4	33	656
1/34–29P2	Alfred Guerra. Drilled irrigation well 201 feet deep. Sample taken by U. S. Geological Survey; analysis by G. J. Petretic, U. S. Geological Survey (No. 27414)	Apr. 15, 1942	64	863	38	1.1	123	51	65	3.0	0	215	368	68	.3	1.6	516
/35–18M1	Union Sugar Co. Drilled domestic well 200 feet deep	Oct. 19, 1927	------	1,136	10	------	162	56	94	------	0	232	529	51	------	Trace	635
28Q1	E. and G. LeRoy. Drilled irrigation, domestic, and stock well 373 feet deep. Sample taken by U. S. Geological Survey; analysis by G. J. Petretic, U. S. Geological Survey (No. 27416)	Apr. 15, 1942	61	968	30	1.0	140	56	64	4.0	0	209	481	35	.5	.8	580
9/31–19R	Sisquoc River, at upper gaging station. Sample taken by U. S. Bureau of Reclamation (No. 46): analysis by National Bureau of Standards, San Francisco Laboratory	June 3, 1943	------	770	------	------	87	58	51	1.6	1.9	230	340	16	------	.4	455
9/32–13P	La Brea Creek, above junction with Sisquoc River. Sample taken by U. S. Bureau of Reclamation (No. 13); analysis by National Bureau of Standards, San Francisco Laboratory	Feb. 18, 1943	------	1,000	------	------	100	71	94	1.9	5.2	340	380	44	------	0	541
17A	Sisquoc River, near lower gaging station. Sample taken by U. S. Bureau of Reclamation (No. 26): analysis by National Bureau of Standards, San Francisco Laboratory	Mar. 5, 1943	------	420	------	------	58	29	26	3.2	0	180	150	8.8	------	0	264
24E	Sisquoc River, above junction with La Brea Creek. Discharge estimated 30 cubic feet per second. Sample taken by U. S. Geological Survey; analysis by G. J. Petretic, U. S. Geological Survey (No. 27409)	Apr. 15, 1942	67	473	15	1.0	64	35	28	2.5	0	180	198	9.0	.4	.2	304
1/33–36B	Cuyama River, above confluence with Sisquoc River. Discharge estimated 10 cubic feet per second. Sample taken by U. S. Geological Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geological Survey (No. 26605)	Oct. 22, 1941	62	1,275	21	0	158	77	111	8.8	0	298	593	69	1.3	.2	711
	Cuyama River, above Alamo Creek, about 10 miles northeast of Santa Maria. Sample taken by U. S. Bureau of Reclamation (No. 27); analysis by National Bureau of Standards, San Francisco Laboratory	Mar. 5, 1943	------	3,200	------	------	520	120	150	5.7	0	130	1,800	45	------	.4	1,792
1/35–4E	Santa Maria River, at Guadalupe. Sample taken by U. S. Bureau of Reclamation (No. 19); analysis by National Bureau of Standards, San Francisco Laboratory	Feb. 18, 1943	------	1,600	------	------	230	87	120	5.3	0	420	680	86	------	0	932
	Huasna River, above junction with Cuyama River, about 8 miles northeast of Santa Maria. Sample taken by U. S. Bureau of Reclamation (No. 18); analysis by National Bureau of Standards, San Francisco Laboratory	do	------	480	------	------	76	24	44	1.2	0	260	120	36	------	.4	288
	Alamo Creek, above junction with Cuyama River, about 9 miles northeast of Santa Maria. Sample taken by U. S. Bureau of Reclamation (No. 17); analysis by National Bureau of Standards, San Francisco Laboratory	do	------	530	------	------	81	33	42	0.8	0	260	160	31	------	.7	338

[1] Symbol is well number as described in text or a location symbol only where applied to a stream locality. No location symbol assigned to stream locality outside of pl. —.

The analyses show a considerable range in the chemical quality of the main water body from one part of the area to another. However, the range in quality appears to bear little relation to range in depth of the wells—a fact which indicates that the water throughout the tapped limits of the main water body is at liberty to mix freely. It is believed, therefore, that the range in quality is due primarily to differences in the sources of water and to its subsequent alteration as it circulates underground and mingles with water from other sources. Accordingly, the quality of water in general is briefly discussed as it appears in the Sisquoc valley where the principal source is the Sisquoc River, in the Santa Maria plain where the principal source is the Santa Maria River, and in the Orcutt and Nipomo uplands were the source is rain. In addition, the change in quality from place to place is also discussed. Chloride contents of waters from wells near the coast are examined with specific references to the fresh water-salt water contact.

In the Sisquoc valley, the total solids content of the ground water is somewhat less than that of the upper range of concentration of the water in the Sisquoc River, based on three analyses of river water sampled in 1942 and in 1943. In the three samples analyzed, the total solids content ranged from 420 to 770 parts; that of the ground waters adjacent to the river ranged about from 610 to 640 parts, computed from electrical conductivity. The river and ground waters range in chloride content from 9 to 23 parts and 23 to 28 parts, respectively. The ground water is definitely higher in hardness than the river water, ranging from 400 to 750 parts.

Well 10/33–35R1, also in the Sisquoc valley, yields water similar to the water in the Cuyama River. Both these are calcium, sodium sulfate waters in which the total solids contents are over 1,100 parts per million. Of the two, the river water is somewhat more concentrated. The similarity indicates that waters percolating from the Cuyama River, extend southward beneath the Sisquoc River at least to well 35R1, where they are only slightly diluted by the less concentrated waters of the Sisquoc.

In the Santa Maria Valley, the quality of ground-water is similar to that in the Santa Maria River. During periods of flow the quality of the water in the river is necessarily a blend of the qualities of the water in the Cuyama and Sisquoc Rivers, depending on the quantity of each. Hence, the quality of water in wells varies accordingly. The Cuyama River in its upper course traverses formations which contain large amounts of gypsum, hence the water would be expected to be high in total solids, owing to solution of calcium and sulfate. The analysis of water from the Cuyama River above Alamo Creek (table 15) is confirmatory and represents essentially a calcium sulfate water, in which calcium and sulfate contents are 520 parts and 1,800 parts, respectively. The water in wells along the Santa Maria River has a chloride content ranging between 30 and 60 parts per million, a hardness between 500 and 700 parts, and total solids between 1,000 and 1,600 parts.

Southward across the Santa Maria plain the chloride content, hardness, and total solids increase somewhat. However, there is a relatively rapid decrease in the concentration of all three southward beneath the Orcutt upland. Toward the coast the quality improves, except in a local area along the south edge of the plain in T. 10 N., R. 35 W., and extending up along the creek southeast to Guadalupe Lake, nearly to the town of Orcutt. In this area the chloride content is over 100 parts per million, and in one well it reaches the maximum in the area of 175 parts. The cause of this increase is not definitely known, but it may be due in part to seepage of contaminated water from surface sumps or waste ponds. Because the base of the water-bearing deposits lies at least 1,000 feet below the bottoms of these wells, the higher chloride content is not believed to originate from below. However, it may be said that the condition has not changed materially since 1927 in those wells for which data are available.

Beneath the Orcutt upland and particularly in the vicinity of the city of Santa Maria wells (9/34–3N1–3), the waters range from 46 to 94 parts per million in chloride content, from 90 to 130 parts in hardness, and from 200 to 320 parts in total solids. Despite the comparatively high concentration in chloride the quality here is considered to be the best in the area. The water beneath the Nipomo upland has similar chemical composition.

The mingling of waters from the various sources occurs principally beneath the Orcutt upland, where waters moving southward from the Santa Maria plain and westward from the Sisquoc Valley mix with the waters derived from rainfall along the south side of the area. The concentrations of all three constituents decrease towards the center of the Orcutt upland where they reach a minimum, but westward appear to increase again. Furthermore, the concentrations are believed to increase with depth. Water moving southward from the Nipomo upland mingles with that originally derived from the Santa Maria River. As a result, in this locality there is a southward increase in chloride content, in hardness, and in total solids.

POSSIBILITY OF SEA-WATER ENCROACHMENT

The chloride content of the water is of specific importance in wells near the coast where, although there has always been a favorable seaward gradient, some alarm has been expressed with respect to sea-water encroachment. Analyses of samples collected from the wells at the extreme west end of the valley, both in the vicinity of Oso Flaco Lake and in the area west of Guadalupe, show that in 1941 and 1942 the chloride content was between 30 and 60 parts per million. Furthermore, analyses made in 1927 show about the same range. These chloride concentrations are far within the limits of safe use, and do not indicate any sea-water encroachment. Furthermore, as discussed below, hydraulic conditions at the coast are such that sea-water encroachment presents no immediate threat to water pumped by wells.

In order to determine where the contact between the fresh water and salt water in the permeable deposits along the coast might be at the present time it is necessary to apply the so-called Ghyben-Herzberg theory as used by Brown (1925) in ground-water investigations along the Connecticut coast. Fundamentally the principal involved deals with the density differential between fresh and salt water. In proportion to the slightly greater density of sea water the contact between the two will be depressed about 40 feet below sea level for each foot of fresh-water head above sea level, assuming the specific gravity of the sea water to be 1.025.

It has been shown that in 1944 the fresh-water head at the coast, as projected westward from the gradient determined by water levels in wells, was about 30 feet above sea level (pl. 6). Therefore, it can be calculated that the contact between fresh water and salt water is theoretically about 1,200 feet below sea level at the shore line. Because the deposits at the coast attain a maximum thickness of roughly 1,500 feet along the axis of the Santa Maria syncline, the salt water theoretically extends inland about 2 miles in the form of a narrow tongue, and its contact with the overlying fresh water plunges downward inland until it intersects the surface of the consolidated rocks at a depth of about 1,600 feet below sea level.

In 1936, when the head was the minimum of record, or about 20 feet, the salt-water contact may have been about 800 feet below sea level at the coast, and theoretically intersected the surface of the consolidated rocks along the axis of the syncline approximately 4 miles inland and at a depth of about 1,800 feet. At any time the theoretical computations would represent about the true conditions if the water-bearing materials were homogeneous throughout, and if movement were instantaneous. Each of these factors, however, is important in controlling the actual position of the contact between fresh water and salt water.

Owing to the lenticular nature of the deposits forming the Paso Robles formation, water is enabled to move more freely along lines parallel to the lenses than vertically across the lenses. Thus, throughout the lower and by far the greater part of the cross-sectional area (section *D–D′*, pl. 2), the natural seaward movement of ground water has probably established the contact at a point farther westward than it would be in homogenous material. No way is now available to determine the amount by which the contact is adjusted within these deposits, but it is obvious that this natural adjustment is favorable to the fresh-water supply.

Also, in deposits such as those at the coastal edge of the Santa Maria Valley the rate of movement of ground water is commonly not more than a few hundred feet a year. Thus, it seems obvious that, following a lowering of water level similar to the one culminating in 1936, a period of many years would elapse before inland and upward movement of the saline contact could bring salt water to its theoretical position under the head relationship. For this reason the inland advance that was developing into 1936 as a result of lowered water levels must have been reversed by the rising water levels of the years following 1936 long before sea water could have far invaded the area. Since 1936, seaward retreat of the salt-water contact doubtless has occurred but probably has not achieved balance with the higher water levels.

The following can be concluded with respect to sea-water encroachment: The salt-water contact lies at considerable depth beneath and west of the bottom of the deepest water wells. Specifically, within the range of the deposits tapped by wells the contact probably lies off shore, which would be several miles from the westermost irrigation well. The head at the coast can be reduced to or even somewhat below that of 1936 without creating a hazard to the fresh-water supply. A considerable depletion of storage would be necessary in order to bring the salt-water contact into the westermost wells. Finally, at the present time the head at the coast and the quantity of outflow are more than sufficient to maintain the salt-water contact at a safe distance from wells.

SELECTED WELL LOGS

Table 16 contains 100 logs of water wells—about one-fifth of the total available in the Santa Maria Valley area. They have been selected to give as complete an areal coverage as possible, to show the range in depth of wells, and to indicate the lithologic character of the stratigraphic units penetrated by the wells.

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*

[Stratigraphic correlations by G. F. Worts, Jr. Altitudes approximate and with respect to sea-level datum of 1929]

9/32–7A1. Ellen Elliot. On alluvial terrace. Altitude 470 feet

[Casing perforated 107 to 115, 154 to 189, 235 to 238, 282 to 290, 410 to 416, and 428 to 436 feet]

	Thickness (feet)	Depth (feet)
Terrace deposits:		
Soil	8	8
Boulders and gravel	37	45
Paso Robles (?) formation:		
Clay, sandy	10	55
Sand and gravel	18	73
Paso Robles formation:		
Clay	31	104
Sand and gravel	11	115
Sand	5	120
Clay and sand	31	151
Clay and gravel	3	154
Gravel and sand	6	160
Clay and gravel	7	167
Gravel	20	187
Clay, tough	10	197
Clay and sand	25	222
Sand and some small gravel	13	235
Paso Robles formation—Con.		
Sand and gravel	3	238
Clay	7	245
Sand and some gravel	30	275
Clay and sand	7	282
Sand and gravel	8	290
Clay, hard	5	295
Gravel, sand, and clay	16	311
Clay	49	360
Sand and streaks of clay	10	370
Gravel, sand, and clay	9	379
Sand, hard, and clay	31	410
Sand and gravel	6	416
Clay	12	428
Sand and gravel	8	436
Sand and clay	15	451
Clay	1	452

9/32–7N1. Valerio Tognazzini. On the Sisquoc plain. Altiude 422 feet

[Casing perforated 82 to 97, 105 to 145, and 162 to 185 feet]

Alluvium:		
Upper member:		
Wash, sandy, gray	20	20
Sand	14	34
Gravel, tight	11	45
Gravel, sand, and clay	10	55
Gravel, small, tight	10	65
Gravel, good	5	70
Lower (?) member:		
Clay, brown	3	73
Alluvium—Continued		
Lower (?) member—Con.		
Clay (?), hard	3	76
Gravel, good	19	95
Paso Robles formation:		
Sand and clay	10	105
Gravel, good	35	140
Sand and clay	22	162
Clay	42	204

9/32–17K1. E. C. Lyman. On Sisquoc plain. Altitude 454 feet

[Casing perforated 51 to 58, 269 to 279, 317 to 318, 365 to 370, 392 to 402, 410 to 415, and 423 to 426 feet]

Alluvium:		
Upper member:		
Soil	7	7
Gravel and boulders	51	58
Lower (?) member:		
Sand and some gravel	21	79
Gravel	1	80
Paso Robles formation:		
Clay and gravel	10	90
Clay, hard	14	104
Sand	9	113
Sand, clay, and some gravel	30	143
Clay, hard	4	147
Sand	5	152
Clay, hard	8	160
Sand and clay	17	177
Clay, sandy, hard	5	182
Sand, solid	23	205
Clay, sandy, and streaks of clay	22	227
Gravel, sand and hard clay	23	250
Clay and streaks of sand	19	269
Sand and gravel, water-bearing	1	270
Paso Robles formation—Con.		
Gravel, sand and clay	4	274
Gravel and sand	5	279
Clay and streaks of sand	16	295
Clay, hard	15	310
Sand	5	315
Clay	2	317
Sand and gravel	1	318
Clay and sand	5	323
Clay, hard	4	327
Clay and sand	35	362
Sand and gravel, water-bearing	5	367
Clay, hard	5	372
Sand and clay	8	380
Clay, hard	3	383
Gravel, sand, and clay	5	388
Sand and some gravel	20	408
Clay and sand	2	410
Sand and gravel	5	415
"Solid streak"	8	423
Gravel and sand	3	426
Sand	14	440
Clay, sandy, hard, and streaks of fine sand	30	470

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

9/32–18A1. Maria Dutra. On Sisquoc plain. Altitude 433 feet

[Casing perforated 50 to 60, 78 to 81, 90 to 95, 160 to 162, 206 to 208, 330 to 360, and 388 to 406 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	6	6
Gravel and boulders	54	60
Lower member:		
Sand	6	66
Clay and gravel	4	70
Sand and some gravel	6	76
Gravel and sand	5	81
Paso Robles formation:		
Clay, sandy	9	90
Gravel	5	95
Clay and sand	14	109
Sand, fine, and some gravel	15	124
Clay, sandy	8	132
Sand and some gravel	11	143
Clay and gravel	7	150
Sand	5	155
Sand and some gravel	4	159
Gravel and sand	3	162
Clay	44	206
Gravel	2	208
Clay	7	215
Paso Robles formation—Con.		
Sand	7	222
Clay	2	224
Gravel and sand	2	226
Clay	6	232
Gravel, not water-bearing	9	241
Clay	11	252
Sand, water-bearing	6	258
Clay, hard	12	270
Clay, sandy	12	282
Clay	8	290
Sand and gravel, water-bearing	16	306
Clay	24	330
Gravel and sand, water-bearing	30	360
Clay, hard	12	372
Sand, fine	8	380
Sand and some gravel	8	388
Gravel and sand	4	392
Clay	2	394
Gravel and sand	12	406
Clay	2	408

9/32–24E1. Sisquoc Investment Co. On Sisquoc plain. Altitude 545 feet

[Casing perforated 15 to 46 feet]

Alluvium:		
Soil	6	6
Gravel and boulders	40	46
Shale (?) and some gravel	6	52
Consolidated Tertiary rocks; undifferentiated:		
Shale	(?)	52+

9/33–1L1. M. V. Diaz. On Sisquoc plain. Altitude 391 feet

[Casing perforated 90 to 115, 125 to 132, 175 to 180, 200 to 230, and 244 to 288]

Alluvium:		
Upper member:		
Soil	4	4
Gravel and sand	61	65
Lower member:		
Gravel and boulders	19	84
Paso Robles formation:		
Clay and gravel	10	94
Gravel	21	115
Clay and gravel	5	120
Clay	5	125
Gravel	7	132
Paso Robles formation—Con.		
Clay	24	156
Sand	14	170
Clay	2	172
Gravel	5	177
Clay	15	192
Gravel and sand	8	200
Gravel	30	230
Clay	4	234
Gravel and sand	52	286
Clay	2	288

9/33–2A1. Santa Maria Realty Co. On Sisquoc plain. Altitude 379 feet

Alluvium:		
Upper member:		
No record	26	26
Sand	8	34
Gravel, water-bearing	14	48
Sand	16	64
Lower member:		
Sand, boulders, and gravel	28	92
Paso Robles formation:		
Clay and small pebbles	17	109
Gumbo and small pebbles	6	115
Clay, sandy	40	155
Gumbo	13	168
Clay	(?)	168+

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

9/33-5B1. Bradley Land Co. On Orcutt upland. Altitude 453 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Dune sand:			Paso Robles formation:		
Soil	2	2	Clay	42	182
Hard pan	2	4	Sand	38	220
Sand	31	35	Clay and gravel	7	227
Sand, fine, water-bearing	9	44	Clay and streaks of gravel	29	256
Orcutt formation:			Sand	9	265
Upper member:			Clay	10	275
Sand and streaks of hard pan	76	120	Sand, water-bearing	23	298
Lower member:			Clay	3	301
Boulders, gravel, and streaks of clay	20	140	Gravel	(?)	301+

9/33-8K1. K. B. Norswing. On Orcutt upland. Altitude 697 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Dune sand:			Paso Robles formation—Con.		
Soil	2	2	Clay	15	355
Sand	42	44	Sand, hard	5	360
Orcutt formation:			Clay and gravel	3	363
Upper member:			Clay	12	375
Hard pan	21	65	Clay and gravel	9	384
Clay and sand	6	71	Sand, hard	5	389
Sand, white	48	119	Clay and gravel	51	440
Clay and sand	6	125	Clay	10	450
Sand, white	52	177	Clay and gravel	15	465
Clay and sand	3	180	"Hard rock" (?)	5	470
Sand, white	23	203	Clay and gravel	10	480
Clay and sand	12	215	Clay	5	485
Lower member:			Gravel	7	492
Sand	22	237	Sand, hard	2	494
Clay and gravel	8	245	Sand	8	502
Gravel and boulders	25	270	Clay	8	510
Paso Robles formation:			Sand	10	520
Clay	12	282	Gravel, cemented	6	526
Clay and gravel	13	295	Gravel and sand	7	533
Gravel	7	302	Clay and gravel	10	543
Conglomerate	38	340			

9/33-12B1. Frank Gonsalves. On Sisquoc plain. Altitude 400 feet

[Casing perforated 58 to 88, 165 to 175, and 180 to 195 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation—Con.		
Upper member:			Clay, red	10	150
Soil	5	5	Clay, yellow	15	165
Sand and gravel	53	58	Gravel	10	175
Lower member:			Clay, yellow	5	180
Gravel	30	88	Gravel, coarse	18	198
Paso Robles formation:					
Clay, yellow	52	140			

9/33-15D1. South Basin Oil Co. In Bradley Canyon. Altitude 584 feet

[Casing perforated 348 to 350 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Orcutt formation:			Paso Robles formation:		
Upper member:			Clay and gravel	38	258
Soil	2	2	Clay	4	262
Hard pan	3	5	Clay and gravel	13	275
Sand and clay	65	70	Conglomerate	18	293
Sand, fine, white, water-bearing	15	85	Sand rock	7	300
Sand and streaks of clay	65	150	Clay	3	303
Lower member:			Clay and sand	40	343
Clay and gravel	40	190	Gravel and sand	10	353
Paso Robles (?) formation:			Gravel and clay	19	372
Gravel and boulders	30	220	Sand, hard	2	374

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

9/34-3A2. War Department, Santa Maria Army Air Base. On Orcutt upland. Altitude 271 feet

[Casing perforated 247 to 251, 258 to 271, and 284 to 331 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Orcutt formation:			Paso Robles formation—Con.		
Upper member:			Clay, (gumbo), hard, gray	10	236
Top soil	3	3	Gravel and clay	1	237
Hard pan, sandy	38	41	Clay, sandy, and gravel	10	247
Sand	8	49	Gravel, loose	4	251
Hard pan, sandy	17	66	Clay	7	258
Gravel, not water-bearing	40	106	Gravel and clay	2	260
No record	13	119	Gravel and sand	11	271
Lower member:			Clay, yellow	13	284
Gravel, large and boulders	46	165	Clay and gravel	9	293
Paso Robles (?) formation:			Gravel, loose	9	302
Sand, coarse, water-bearing	12	177	Sand and gravel	12	314
Sand, fine, solid, white	35	212	Clay and gravel	9	323
Paso Robles formation:			Sand and gravel	8	331
Clay, gravel, and sand	8	220	Clay, yellow	19	350
"Hard pan" and clay, sandy, white	6	226			

9/34-3N4. City of Santa Maria. On Orcutt upland. Altitude 255 feet

[Casing perforated 481 to 483, 580 to 595, 681 to 684, 701 to 719, 780 to 786, 801 to 804, and 874 to 880 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Dune sand:			Paso Robles formation—Con.		
Sand	2	2	Gravel, water-bearing	2	483
Orcutt formation:			Clay and gravel	13	496
Upper member:			Conglomerate	9	505
"Hard pan"	23	25	Clay and gravel	75	580
Sand, fine	10	35	Gravel and sand, water-bearing	15	595
Clay	15	50	Clay and gravel	17	612
Sand, hard	42	92	Conglomerate	13	625
Clay and sand	14	106	Boulders and clay	56	681
Sand and some gravel	6	112	Sand and some gravel	3	684
Clay and sand	33	145	Clay and gravel, hard	17	701
Clay	9	154	Sand and gravel, water-bearing	18	719
Lower member:			Clay	29	748
Clay, hard; sand, and some gravel	13	167	Clay and gravel	32	780
Gravel and sand	17	184	Clay and gravel, water-bearing	6	786
Paso Robles (?) formation:			Clay	15	801
Sand, white	101	285	Clay and gravel, water-bearing	3	804
Sand, hard, white	13	298	Clay and gravel	70	874
Paso Robles formation:			Sand and gravel	6	880
Clay and gravel	4	302	Clay and some gravel	20	900
Sand, yellow	6	308			
Clay and gravel	10	318			
Clay, yellow	50	368			
Clay and gravel	113	481			

9/34-4F1. War Department, Santa Maria Army Air Base. On Orcutt upland. Altitude 225 feet

[Casing perforated 259 to 267, 310 to 328, and 337 to 375 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Orcutt formation:			Paso Robles formation—Con.		
Upper member:			Gravel and clay, sandy	8	267
Soil, sandy	3	3	Clay, sticky, yellow	14	281
"Hard pan," sandy	39	42	Clay, sandy, yellow	29	310
Clay, yellow, and gravel	38	80	Clay and gravel	12	322
Clay, sandy, yellow	35	115	Gravel, clean	4	326
Lower member:			Clay and some gravel	2	328
Sand and gravel	39	154	Clay, yellow	9	337
Paso Robles (?) formation:			Gravel, good	26	363
Sand, white	98	252	Clay, sandy, and gravel	12	375
Paso Robles formation:			Clay	2	377
Clay, yellow	7	259	Gravel and clay	4	381

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

9/34-10J3. Ida A. Twitchell. On Orcutt upland. Altitude 361 feet

[Casing perforated 378 to 391 feet]

	Thickness (feet)	Depth (feet)
Dune sand:		
Sand	9	9
Sand, hard	20	29
Orcutt formation:		
Upper member:		
Sand	22	51
Clay	7	58
Sand	44	102
Clay	41	143
Sand	37	180
Clay	3	183
Sand	9	192
Clay	2	194
Sand	16	210
Clay	3	213
Sand	30	243
Orcutt formation—Continued		
Lower member:		
Clay and gravel	19	262
Paso Robles (?) formation:		
Sand, white	90	352
Paso Robles formation:		
Clay	4	356
Sand	5	361
Sand and gravel	7	368
Gravel and sand	6	374
Gravel	17	391
Clay	1	392
Sand and some gravel	7	399
Clay	1	400

9/34-15B1. County of Santa Barbara, Orcutt Union School District. On Orcutt upland. Altitude 355 feet

	Thickness (feet)	Depth (feet)
Orcutt formation:		
Upper member:		
Soil	2	2
"Hard pan"	10	12
Gravel and sand	3	15
Sand and streaks of clay	135	150
Clay	6	156
Sand	9	165
Clay	5	170
Lower member:		
Sand and streaks of clay	30	200
Paso Robles (?) formation:		
Sand, yellow	45	245
Sand, white	88	333
Paso Robles formation:		
Clay	7	340
Gravel	2	342
Clay	8	350
Sand and gravel	12	362

10/33-18C1. La Brea Securities Co. On Santa Maria plain. Altitude 267 feet

[Casing perforated 115 to 140, 300 to 338, 341 to 363, and 395 to 415 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	5	5
Sand	66	71
Lower (?) member:		
Boulders, gravel and sand	44	115
Lower member:		
Sand and boulders	25	140
Paso Robles formation:		
Clay	3	143
Clay and gravel	99	242
Clay, blue	18	260
Paso Robles formation—Con.		
"Quicksand," blue	8	268
Clay, blue	10	278
"Quicksand"	7	285
Gravel	53	338
Clay, blue	3	341
Gravel and clay	22	363
"Quicksand"	14	377
Clay	18	395
Gravel and clay	25	420
Careaga sand:		
Sand and shells	20	440

10/33-18G1. La Brea Securities Co. On Santa Maria plain. Altitude 273 feet

[Casing perforated 132 to 142, 288 to 320, 336 to 340, and 408 to 422 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	4	4
Sand and some gravel	95	99
Lower member:		
Gravel and boulders	6	105
Clay and sand	19	124
Sand, clay, and some gravel	6	130
Gravel and boulders	10	140
Paso Robles formation:		
Clay, hard	60	200
Clay, blue	28	228
Clay and gravel	52	280
Clay, blue	8	288
Gravel	4	292
Paso Robles formation—Con.		
Clay and gravel	4	296
Gravel	4	300
Clay and gravel	13	313
Gravel, solid	5	318
Gravel, loose	2	320
Clay and gravel	18	338
Gravel	8	340
Clay and gravel	25	365
Clay, blue	4	369
Sand, hard	23	392
Clay, hard	16	408
Careaga (?) sand:		
Gravel and sand	15	423
Careaga sand:		
Sand	13	436

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/33-18H1. La Brea Securities Co. On Santa Maria plain. Altitude 276 feet

[Casing perforated 135 to 145, 230 to 245, 242 to 248, 255 to 260, 285 to 305, and 395 to 414 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	5	5
Sand and some gravel	75	80
Sand and gravel	16	96
Lower member:		
Clay and gravel	14	110
Clay and sand	18	128
Clay and gravel	7	135
Gravel and boulders	6	141
Paso Robles formation:		
Clay, hard	59	200
Clay, blue	33	233
Gravel, small, and sand	2	235
Clay and gravel	9	244
Sand and gravel	2	246
Clay and gravel	9	255
Sand and gravel	2	257
Clay and gravel	2	259
Sand and gravel	1	260
Clay and gravel	11	271
Clay, sandy	4	275
Clay, blue, hard	10	285
Gravel	7	292
Clay and gravel	2	294
Paso Robles formation—Con.		
Gravel	2	296
Clay and gravel	3	299
Gravel	3	302
Clay and gravel	53	355
Clay, sandy	13	368
Sand, hard	11	379
Clay, blue, hard	20	399
Gravel	2	401
Clay and gravel	5	406
Gravel	3	409
Clay and gravel	1	410
Gravel	4	414
Clay	2	416
Careaga sand:		
Sand and strata of sand and clay	124	540
Consolidated Tertiary rocks, undifferentiated:		
Clay, dark, hard	45	585
Shale, brown (gas)	40	625
Franciscan and Knoxville (?) formations:		
Sandstone, hard	8	633

10/33-18H2. La Brea Securities Co. On Santa Maria plain. Altitude 272 feet

[Casing perforated 126 to 150, and 310 to 317 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	4	4
Sand	4	8
Soil	1	9
Sand and some gravel	89	98
Lower member:		
Gravel and sand	12	110
Sand	15	125
Gravel	14	139
Paso Robles formation:		
Clay, brown	50	189
Clay, blue	3	192
Sand (sulphur water)	2	194
Clay, blue	6	200
Clay, sandy, blue	10	210
Clay, blue	40	250
Clay, blue	19	269
Sand	2	271
Clay, blue	14	285
Sand	9	294
Paso Robles formation—Con.		
Clay, blue	9	303
Sand	6	309
Clay and gravel	1	310
Gravel	3	313
Clay and gravel	1	314
Gravel	3	317
Clay	3	320
Careaga sand:		
Sand	12	332
Sand and some gravel	7	339
"Quicksand"	44	383
Sand, hard	6	389
Gravel and "quicksand"	3	392
Sand, hard	4	396
Sand and gravel	3	399
Sand clay	16	415
Consolidated Tertiary (?) rocks, undifferentiated:		
Clay, hard (shale?)	25	440

10/33-19B1. O. T. Rice. On Santa Maria plain. Altitude 275 feet

[Casing perforated 92 to 97, 116 to 125; 190 to 215, and 238 to 248 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	4	4
Sand and gravel	81	85
Boulders and gravel	13	98
Lower member:		
Sand	16	114
Gravel and sand	11	125
Boulders and sand	7	132
Paso Robles formation:		
Clay and gravel	18	150
Paso Robles formation—Con.		
Clay and sand	14	164
Clay	26	190
Clay and gravel	10	200
Gravel	11	211
Clay, tough	19	230
Clay, blue	8	238
Clay and gravel	48	286
Clay, tough, and gravel	21	307

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/33-21F2. M. J. Santos. On Santa Maria plain. Altitude 312 feet

[Casing perforated 90 to 140, 170 to 203, 243 to 254, 274 to 310, and 320 to 337 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation—Con.		
Upper member:			Clay, blue	2	220
Soil	4	4	Sand and clay, loose sulphur	6	226
Sand and boulders	16	20	Clay, blue	20	246
Clay	1	21	Gravel	5	251
Sand and some gravel	64	85	Clay, blue, and gravel	27	278
Gravel and sand	12	97	Gravel	1	279
Lower member:			Clay	3	282
Clay and boulders	3	100	Gravel	2	284
Gravel and boulders	6	106	Clay, tough	6	290
Clay and boulders	16	122	Clay and streaks of gravel	10	300
Gravel	2	124	Clay	3	303
Clay and gravel	4	128	Clay, sandy	4	307
Gravel	7	135	Sand	3	310
Clay and gravel	4	139	Gravel and clay	15	325
Paso Robles formation:			Gravel and clay, loose	7	332
Clay, blue, and gravel	31	170	Gravel and clay	2	334
Clay, sulphur	2	172	Gravel	3	337
Clay, blue, and gravel	16	188	Careaga sand:		
Clay, sulphur	2	190	Clay	16	353
Clay and gravel	13	203	Sandstone, hard	3	356
Clay, sticky	11	214	Sand	4	360
Gravel and clay	4	218	Sandstone, hard	1	361

10/33-21R1. L. H. Adam. On Santa Maria plain. Altitude 323 feet

[Casing perforated 95 to 104, and 116 to 150 feet]

Alluvium:			Paso Robles (?) formation;		
Upper member:			Clay, hard	8	144
Soil	2	2	Clay; blue	14	158
Sand and some gravel	83	85	Careaga (?) sand:		
Lower member:					
Gravel and sand, solid	15	100	Sand, blue, fine, and a little gravel	10	168
Gravel	4	104	Clay, blue, and shells	8	176
Clay and sand	10	114	Franciscan and Knoxville (?) formations:		
Gravel, tight, and clay	9	123			
Gravel, loose	7	130	Sandstone, hard, blue	64	240
Gravel, tight	6	136			

10/33-27R1. Newhall Land and Farming Co. On Santa Maria plain. Altitude 353 feet

[Casing perforated 130 to 224 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Clay and gravel	14	160
Soil	5	5	Clay	5	165
Sand and gravel	43	48	Gravel	10	175
Gravel, cemented	10	58	Clay	5	180
Sand	37	95	Gravel	10	190
Lower member:			Clay and boulders	10	200
Gravel	3	98	Gravel	13	213
Sand	31	129	Clay and boulders	3	216
Gravel, coarse	12	141	Gravel	8	224
Paso Robles formation:			Clay, tough, and sand	13	237
Gravel, cemented	5	146	Clay (?) and some gravel	18	255

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/33-28A1. Joe Soares. On Santa Maria plain. Altitude 325 feet

[Casing perforated 100 to 215, and 242 to 335 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation—Con.		
Upper member:			Clay, sandy, blue	10	243
Soil	5	5	Gravel	17	260
Sand	45	50	Gravel and sand, water-bearing	20	280
Sand and small gravel	40	90	Gravel	12	292
Sand, hard	5	95	No record	1	293
Lower member:			Gravel	7	300
Gravel	9	104	Clay, tough, blue	3	303
Gravel, cemented	41	145	Gravel	11	314
Paso Robles formation:			Clay	2	316
Clay and streaks of gravel	13	158	Gravel	4	320
Clay and boulders	3	161	Clay	5	325
Clay and streaks of gravel	31	192	Gravel	10	335
Clay, tough, blue	10	202	Clay and boulders	7	342
Clay, blue, streaks of sand	13	215	Careaga (?) sand:		
Sand, soft, blue	12	227	Sand and small gravel	32	374
Clay, sticky, blue	3	230			
Sand	3	233			

10/33-30L1. R. R. Bush Oil Co. On Orcutt upland. Altitude 310 feet

[Casing perforated 190 to 210, 218 to 244, 268 to 286, 310 to 315, 327 to 342, 385 to 418, and 450 to 485 feet]

Dune sand:			Paso Robles formation—Con.		
Sand	20	20	Sand, gravel, and boulders	18	286
Orcutt formation:			Clay and boulders	24	310
"Hardpan"	34	54	Gravel and boulders	5	315
Clay, boulders, and gravel	81	135	Clay and boulders	12	327
Paso Robles formation:			Gravel and boulders, water-bearing	15	342
Clay	5	140	Gravel and boulders	76	418
Clay and boulders	54	194	Clay and boulders	32	450
Gravel, water-bearing	5	199	Sand, gravel, and boulders	25	475
Gravel and boulders	11	210	Sand and gravel	10	480
Clay and gravel	8	218	Clay and gravel, hard	15	500
Gravel and sand	26	244			
Clay and gravel	24	268			

10/33-33H1. E. L. Sargent. On Orcutt upland. Altitude 402 feet

[Casing perforated 204 to 232, 245 to 250, and 270 to 280 feet]

Terrace deposits:			Paso Robles formation:		
Soil	2	2	Clay and sand	8	140
Orcutt formation:			Clay and gravel	38	178
Upper member:			Gravel	3	181
Hardpan	14	16	Clay and gravel	15	196
Clay and streaks of sand	39	55	Clay	8	204
Clay and gravel	10	65	Gravel, water-bearing	28	232
Hardpan	8	73	Clay, yellow	14	246
Clay and gravel	17	90	Gravel	3	249
Gravel	12	102	Clay and gravel	23	272
Clay and gravel	7	109	Gravel	6	278
Lower (?) member:			Clay	10	288
Gravel	23	132	Gravel	2	290

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/33-34H1. Dan Donovan. On Santa Maria plain. Altitude 352 feet

[Casing perforated 70 to 80, 86 to 145, 160 to 191, 220 to 234, 237 to 238, 257 to 265, 275 to 282, and 293 to 300 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	10	10
Sand and streaks of clay	35	45
Gravel and boulders	5	50
Clay	20	70
Gravel	11	81
Clay	5	86
Gravel, coarse	2	88
Paso Robles formation:		
Gravel and streaks of clay	7	95
Gravel and clay	50	145
Clay	5	150
Sand and some small gravel	5	155
Gravel and clay	15	170
Gravel, muddy	6	176
Clay and gravel	13	189
Gravel	2	191
Sand, clay, and gravel	16	207
Sand and some gravel	11	218
Clay	2	220
Gravel, cemented	13	233
Gravel	1	234
Paso Robles formation—Con.		
Clay, sand, and gravel	3	237
Gravel	1	238
Clay, hard, sandy	19	257
Gravel	2	259
Clay and gravel	6	265
Clay, sandy, and some gravel	10	275
Gravel, tight	7	282
Clay	11	293
Gravel	7	300
Sand, bard	10	310
Clay, hard	10	320
Clay, bard, and streaks of fine sand	50	370
Clay	5	375
Sand and some gravel	4	379
Sand, hard	5	384
Clay, bard, and gravel	11	395
Clay and gravel	5	400
Sand, fine, and streaks of clay	16	416
Clay	(?)	416+

10/33-35J2. A. F. Fugler. On Sisquoc plain. Altitude 366 feet

[Well abandoned]

Alluvium:		
Upper member:		
Soil	4	4
Clay and gravel	19	23
Sand	17	40
Careaga sand:		
Clay, sandy, brown	35	75
Clay, sandy, blue, and clam shells	65	140

10/33-35R1. A. F. Fugler. On Sisquoc plain. Altitude 370 feet

[Casing perforated 62 to 74, 141 to 170, 182 to 195, 200 to 206, and 216 to 266 feet]

Alluvium:		
Upper member:		
Soil	4	4
Gravel	16	20
Clay	3	23
Boulders and clay	7	30
Boulders, water-bearing	10	40
Clay and boulders	7	47
Clay	15	62
Gravel and sand	10	72
Paso Robles formation:		
Clay	13	85
Sand	2	87
Clay	46	133
Gumbo	2	135
Sand and small gravel	5	140
Clay	1	141
Paso Robles formation—Con.		
Gravel	5	146
Clay and gravel	2	148
Gravel	6	154
Clay and gravel	6	160
Gravel	3	163
Clay	4	167
Gravel	3	170
Clay, sandy	12	182
Gravel and sand	9	191
Gumbo	6	197
Clay	6	203
Sand and small gravel	6	209
No record	7	216
Sand and gravel	34	250
Gravel, boulders, and sand	25	275

10/33-36A1. La Brea Securities Co. On alluvial plain. Altitude 367 feet

[Casing perforated 30 to 76 feet]

Alluvium:		
Silt	6	6
Gravel	4	10
Sand and gravel	10	20
Sand, coarse	10	30
Gravel	35	65
Clay and gravel	3	68
Alluvium—Continued		
Gravel	8	76
Consolidated Tertiary rocks, undifferentiated		
Clay	6	82
Clay, blue, sulphurous	68	150
Rock, blue	12	162

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-2R1. Gracio Apalatequi. On Santa Maria plain. Altitude 230 feet

[Casing perforated 106 to 130, 180 to 190, and 221 to 226 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	4	4
Sand and gravel	96	100
Lower member:		
Gravel	29	129
Paso Robles formation:		
Clay	46	175
Clay and gravel	7	182
Gravel	5	187
Clay and gravel	8	195
Clay and sand	26	221
Paso Robles formation—Con.		
Gravel	1	222
Clay and gravel	2	224
Gravel	2	226
Clay and sand	10	236
Sand and some gravel	4	240
Careaga (?) sand:		
Sand, blue	15	255
Clay, blue	20	275
Sand	3	278
Clay	14	292
Sand	2	294

10/34-5R1. La Brea Securities Co. On Santa Maria plain. Altitude 175 feet

[Casing perforated 125 to 158, and 192 to 238 feet]

Alluvium:		
Upper member:		
Soil	10	10
Sand, fine, and clay	52	62
Sand, coarse, and gravel	24	86
Clay	4	90
Clay and gravel	5	95
Lower member:		
Gravel	5	100
Sand	16	116
Alluvium—Continued		
Lower member—Continued		
Sand, hard	2	118
Gravel	41	159
Paso Robles formation:		
Clay and sand	19	178
Sand and a little gravel	12	190
Gravel and boulders	48	238
Sand	12	250

10/34-7F1. Antone Souza. On Santa Maria plain. Altitude 161 feet

[Casing perforated 104 to 108, 121 to 168, and 195 to 198 feet]

Alluvium:		
Upper member:		
Loam, sandy	6	6
Sand and clay	52	58
"Hardpan"	3	61
Sand and clay	28	89
"Quicksand"	8	97
Clay	4	101
Lower member:		
Gravel and clay	9	110
Clay, yellow	10	120
Alluvium—Continued		
Lower member—Continued		
Gravel, coarse	33	153
Clay	1	154
Gravel	14	168
Paso Robles formation:		
Gravel and clay	2	170
Clay	28	198
Boulders and clay	2	200
"Quicksand"	19	219
Clay, yellow	1	220

10/34-8H1. Mrs. Virgil Alexander. On Santa Maria plain. Altitude 176 feet

[Casing perforated 103 to 152 and 183 to 200 feet]

Alluvium:		
Upper member:		
Loam	10	10
Sand	30	40
Clay	10	50
Sand	20	70
"Quicksand"	17	87
Clay, sandy	3	90
Clay and gravel	4	94
Lower member:		
Gravel, coarse	6	100
Alluvium—Continued		
Lower member—Continued		
"Hardpan"	3	103
Gravel, coarse, water-bearing	49	152
Paso Robles formation:		
Clay, yellow, soft	28	180
Sand, hard	3	183
Gravel	17	200
Clay	2	202

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-9D1. J. Rembush. On Santa Maria plain. Altitude 183 feet.

[Casing perforated 110 to 151 and 180 to 230 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	5	5	Gravel and boulders	43	151
Silt	5	10	Paso Robles formation:		
Sand and gravel	20	30	Clay	3	154
Clay and sand	47	77	Sand	21	175
Gravel and sand	5	82	Gravel	61	236
Gravel, hard	14	96	Gravel, hard	2	238
Lower member:					
Sand	12	108			

10/34-10E1. L. C. Donati. On Santa Maria plain. Altitude 198 feet

[Casing perforated 136 to 221 feet]

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued	22	120
Soil	4	4	Clay	3	123
Sand	26	30	Sand, compact	2	125
Clay	4	34	Clay and gravel	16	141
Sand	31	65	Gravel		
"Hardpan"	8	73	Paso Robles formation:		
Gravel	6	79	Clay and gravel	13	154
Clay	11	90	Gravel	26	180
Sand, compact	5	95	Clay	2	182
"Hardpan"	2	97	Gravel	42	224
Lower member:			Clay	1	225
Gravel	1	98			

10/34-12E1. C. C. Mitchell. On Santa Maria plain. Altitude 230 feet

[Casing perforated 130 to 147 feet]

Alluvium:			Alluvium—Continued		
Upper member:			Lower member:		
Soil	4	4	Gravel	49	147
Sand	30	34	Paso Robles formation:		
Clay	8	42	Clay and gravel	47	194
Sand	40	82	Sand, hard, and gravel	6	200
Sand and gravel	16	98			

10/34-12J1. F. N. Silva. On Santa Maria plain. Altitude 255 feet

[Casing perforated 110 to 114, 125 to 155, 192 to 206, 224 to 228, and 233 to 237 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Sand and some gravel	12	190
Soil	5	5	Sand and gravel	15	205
Sand and gravel	85	90	Gravel, hard	23	228
Gravel and sand	10	100	Clay, blue	5	233
Lower member:			Gravel	4	237
Gravel	14	114	Gravel, hard	7	244
Sand	8	122	Clay, blue	6	250
Gravel	33	155	Sand	6	256
Paso Robles formation:			Clay, blue	1	257
Clay	23	178			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-13G1. La Brea Securities Co. On Santa Maria plain. Altitude 253 feet

[Casing perforated 136 to 160, 165 to 170, 344 to 350, 363 to 373, and 390 to 395 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation—Con.		
Upper member:			Sand, clay, and gravel	10	230
Soil	5	5	Clay	33	263
Sand and gravel	55	60	Gravel, not water-bearing	15	278
Gravel and boulders	40	100	Clay, hard	42	320
Lower member:			Clay, hard, and gravel	22	342
Sand	17	117	Clay, blue	2	344
Gravel	11	128	Gravel	2	346
Sand, hard, and gravel	8	136	Clay and gravel	9	355
Gravel	12	148	Gravel	5	360
Clay and gravel	4	152	Clay and gravel	3	363
Gravel	6	158	Gravel and sand, loose	10	373
Paso Robles formation:			Clay and gravel	19	392
Clay and gravel	7	165	Gravel	2	394
Gravel	3	168	Clay, gravel, and sand	30	424
Clay and gravel	6	174	Sand and some gravel	6	430
Clay	40	214	Clay, hard	20	450
Sand	6	220			

10/34-14E3. City of Santa Maria. On Santa Maria plain. Altitude 225 feet

[Casing perforated 87 to 109 and 164 to 181 feet]

Alluvium:			Alluvium—Continued		
Upper member:			Lower member:		
Soil	1	1	Clay	19	109
Sand	5	6	Sand	1	110
Clay, sandy	35	42	Sand and gravel	7	117
Sand	2	44	Clay, sandy	19	136
Gravel	10	54	Gravel and sandy clay	21	157
Clay	4	58	Gravel, clean	7	164
Gravel	8	66	Paso Robles formation:		
Clay	3	69	Sand and some pebbles	2	166
Gravel, cemented	2	71	Gravel	16	182
Sand and gravel	16	87			
Gravel, clean	3	90			

10/34-16N1. E. and G. LeRoy. On Santa Maria plain. Altitude 187 feet

[Casing perforated 89 to 119, 135 to 160, and 175 to 206 feet]

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Clay	6	6	Clay and gravel	17	152
Sand	71	77	Gravel and boulders	8	160
Clay and gravel	12	89	Paso Robles formation:		
Lower member:			Clay	15	175
Gravel and boulders	30	119	Gravel and boulders	35	210
Sand	16	135			

10/34-18D1. Dan Donovan. On Santa Maria plain. Altitlude 147 feet

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil, sandy	3	3	Clay	2	108
Sand	5	8	Gravel	14	122
Clay	2	10	"Quicksand"	10	132
Sand	22	32	Gravel	9	141
Clay	42	74	Paso Robles formation:		
Clay, sandy	16	90	Clay	31	172
Lower member:			Gravel, cemented	2	174
Gravel and sand	6	96	Gravel	18	192
Clay	6	102	Clay	12	204
Gravel	4	106			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-18P1. Olga Giacomini. On Santa Maria plain. Altitude 154 feet

[Casing perforated 95 to 120, 155 to 180, and 188 to 234 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil, sandy	8	8	Silt	3	148
Sand	38	46	Clay	1	149
Clay	3	49	Gravel, coarse	8	157
"Quicksand"	31	80	Paso Robles formation:		
"Hardpan"	8	88	Clay, yellow	5	162
Lower member:			Gravel, coarse	14	176
Gravel, coarse, water-bearing	19	107	Clay and gravel	10	186
"Hardpan"	2	109	Gravel, coarse	2	188
Clay and gravel	12	121	"Hardpan"	5	193
Gravel, fine, dirty	15	136	Gravel, coarse	41	234
Clay, yellow	9	145	Clay	3	237

10/34-20F1. Ulisse Tognazzini. On Santa Maria plain. Altitude 172 feet

[Casing perforated 90 to 130, 140 to 176, and 196 to 238 feet]

Alluvium:			Paso Robles formation:		
Upper member:			Clay	10	140
Soil	6	6	Gravel and boulders	36	176
Sand	24	30	Clay	20	196
Sand and streaks of clay	45	75	Gravel and boulders	42	238
Lower member:			Clay	8	246
Gravel	33	108			
Clay and gravel	3	111			
Gravel	19	130			

10/34-21G1. J. Moretti. On Santa Maria plain. Altitude 196 feet]

[Casing perforated 150 to 160 and 168 to 218 feet

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	7	7	Gravel and boulders	25	160
Sand	33	40	Paso Robles formation:		
Gravel and sand	45	85	Clay	8	168
Lower member:			Gravel and boulders	50	218
Clay and boulders	15	100	Clay	24	242
Sand, gravel, and boulders	35	135	Sand, gravel, and boulders	6	248

10/34-22R1. G. J. Wheat. On Santa Maria plain. Altitude 217 feet

[Casing perforated 118 to 242 feet]

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil, sandy	6	6	Gravel	6	114
Sand	27	33	Gravel, not water-bearing	4	118
"Hardpan," clayey	11	44	Gravel	6	124
Gravel	5	49	Gravel and streaks of clay	12	136
Clay and gravel	6	55	Gravel	4	140
Gravel	14	69	Clay	2	142
Clay and gravel	15	84	Gravel	4	146
Sand	8	92	Paso Robles formation:		
Lower member:			Gravel and clay	103	249
Clay and gravel	2	94	Clay and sand	3	252
Sand and gravel	14	108			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-23L2. F. A. Newlove. On Santa Maria plain. Altitude 232 feet

[Casing perforated 158 to 214 and 226 to 266 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	5	5	Gravel and sand	8	158
Sand	31	36	Paso Robles formation:		
Clay and gravel	4	40	Gravel and boulders, cemented	42	200
Gravel	40	80	Clay and gravel	14	214
Lower (?) member:			Clay	10	224
Sand and gravel	20	100	Clay and gravel	4	228
Lower member:			Gravel	38	266
Clay, hard, and boulders	20	120	Clay	4	270
Gravel	6	126			
Clay and gravel	24	150			

10/34-24K1. Union Oil Company of California. On Santa Maria plain. Altitude 254 feet

[Casing perforated 650 to 657 and 692 to 710 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Gravel	4	421
Soil	5	5	Clay, hard	43	464
Sand and gravel	25	30	Gravel and clay	4	468
Gravel and boulders	30	60	Gravel	30	498
Sand and gravel	14	74	Sand	15	513
Lower (?) member:			Clay and gravel	3	516
Gravel and boulders	41	115	Gravel and sand	10	526
Lower member:			Gravel and clay	11	537
Gravel and sand	5	120	Sand and gravel	2	539
Clay	6	126	Gravel and clay	11	550
Gravel, sand and clay	19	145	Gravel, sand, and blue clay	58	608
Gravel, water-bearing	9	154	Sand, clayey	8	616
Paso Robles formation:			Gravel, hard, and sand	21	637
Gravel, water-bearing	20	174	Sand and clay, soft	13	650
Clay	10	184	Sand and gravel, water-bearing	7	657
Sand, silty	14	198	Sand, hard, and clay	4	661
Clay	10	208	Gravel, hard	8	669
Clay and boulders	10	218	Clay	5	674
Clay	12	230	Sand and some gravel, loose	10	684
Sand and gravel	10	240	Clay and gravel	8	692
Clay	28	268	Sand and gravel, water-bearing	18	710
Gravel	30	298	Gravel, packed	4	714
Boulders, gravel and clay	16	314	Conglomerate	(?)	714+
Clay	5	319			
Gravel	19	338			
Clay and gravel	63	401			
Clay, hard	16	417			

10/34-27J1. J. Morrison. On Orcutt upland. Altitude 246 feet

Dune sand:			Paso Robles formation:		
Sand	2	2	Gravel	25	135
Orcutt formation:			Clay and gravel	10	145
Upper member:			Gravel	20	165
"Hardpan"	1	3	Clay, sandy	11	176
Sand	72	75	Gravel	4	180
Lower member:					
Clay and gravel	35	110			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/34-28C1. Stephen Nicholai. On Orcutt upland. Altitude 215 feet

[Casing perforated 188 to 191 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Orcutt formation:			Paso Robles formation:		
Upper member:			Clay	8	122
Sand	3	3	Sand and gravel	29	151
"Hardpan"	35	38	Clay	12	163
Clay, yellow	12	50	Gravel	6	169
Sand	17	67	Clay	9	178
Clay and gravel	10	77	Sand and gravel	7	185
Sand	11	88	Gravel and sand	7	192
Lower member:					
Clay and gravel	14	102			
Sand and gravel	12	114			

10/34-30C1. Union Sugar Co. On Orcutt upland. Altitude 182 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Orcutt formation:			Orcutt formation—Continued		
Upper member:			Upper member—Continued		
Sand	2	2	Sand, fine	4	87
Sand, hard	1	3	Gravel	16	103
Clay, hard, yellow	17	20	Sand, fine	13	116
Sand	15	35	Lower member:		
Clay	10	45	Gravel, "good"	47	163
Sand, water-bearing	15	60	Sand and clay	½	163½
Sand	21	81	Sand, fine	1½	165
Clay, yellow	2	83			

10/34-34K2. War Department, Santa Maria Army Air Base. On Orcutt upland. Altitude 242 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Dune sand:			Paso Robles (?) formation:		
Soil, sandy	10	10	Sand, white (?)	14	150
Sand, hard	10	20	Clay, yellow	12	162
Orcutt formation:			Sand	11	173
Upper member:			Paso Robles formation:		
Sand	50	70	Clay, dark	4	177
"Hardpan", sandy	10	80	Gravel	7	184
Sand	15	95	Clay and gravel	6	190
Lower member:			Clay	5	195
Gravel	41	136	Gravel	15	210

10/35-4P1. Campodonico Water Co. On Santa Maria plain. Altitude 85 feet

[Casing perforated 165 to 194, 212 to 226, and 232 to 246 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	6	6	Sand and gravel	9	174
Clay	41	47	Gravel and some sand	20	194
Clay, sandy	17	64	Paso Robles formation:		
Clay, yellow	10	74	Clay, sandy	18	212
Sand	33	107	Clay, sandy, and gravel	8	220
Lower member:			Gravel and clay	6	226
Sand and gravel	3	110	Clay, yellow	6	232
Gravel	2	112	Clay, blue	10	242
Clay, yellow	5	117	Gravel	4	246
Clay, blue	11	128	Clay, yellow	2	248
Clay, sandy	9	137	Clay, blue	8	256
Clay, blue	13	150	Sand, solid	2	258
Sand	13	163	Sand	8	266
Clay, yellow	2	165	Sand and gravel	21	287

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/35-5J1. Union Sugar Co. On Santa Maria plain. Altitude 79 feet

[Casing perforated 137 to 144, 176 to 188, 225 to 230, and 250 to 280 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	4	4	Clay, yellow	9	176
Clay, sandy, yellow	6	10	Gravel	12	188
Clay, yellow	22	32	Paso Robles formation:		
Clay, blue	35	67	Sand and clay	12	200
Sand, blue	31	98	Sand, yellow	15	215
Lower member:			Gravel	15	230
Clay, blue	39	137	Clay, yellow	3	233
Gravel	7	144	Sand, yellow	12	245
Sand, yellow	20	164	Gravel	35	280
Gravel	3	167	Clay, blue	11	291

10/35-7F1. M. J. Ellis. On Santa Maria plain. Altitude 48 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	6	6	Clay and gravel	18	210
"Quicksand"	94	100	Gravel, clean	15	225
Lower (?) member:			Paso Robles formation:		
Sand and streaks of clay	40	140	Clay	1	226
Lower member:			Sand	19	245
Gravel, small	5	145	Clay	4	249
Sand and clay	47	192			

10/35-7G1. John Jenkins. On Santa Maria plain. Altitude 55 feet

[Casing perforated 138 to 160, 191 to 194, 202 to 208, 268 to 281, 320 to 357, 361 to 365, and 375 to 387 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:					
Upper member:			Paso Robles formation:		
Soil	4	4	Sand and clay, solid	7	215
Silt	6	10	Clay and gravel	15	230
Sand	6	16	Sand	8	238
Clay	4	20	Sand, clay, and some gravel	11	249
Sand and streaks of clay	30	50	Clay, brown, sticky	11	260
Clay	12	62	Clay, blue	4	264
Clay and sand	10	72	Clay, hard, sandy	4	268
Clay, sticky	2	74	Gravel	6	274
Clay and sand	14	88	Clay and streaks of gravel	7	281
Sand, brown	9	97	Clay, light	9	290
Lower (?) member:			Clay, blue	17	307
Sand, gray, and clay	21	118	Clay, sandy, and some gravel	11	318
Lower member:			Gravel and some clay	39	357
Sand, gray	7	125	Clay and gravel	4	361
Sand and hard clay	8	133	Sand and gravel	4	365
Gravel and sand	29	162	Sand	7	372
Sand	16	178	Clay	1	373
Sand and some gravel	4	182	Gravel and sand	15	388
Clay	9	191	Sand and some gravel	14	402
Gravel and sand	4	195	Sand, white	4	406
Sand and some gravel	5	200			
Gravel and sand	8	208			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/35-9F1. Waller-Franklin Seed Co. On Santa Maria plain. Altitude 88 feet

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	8	8
Clay, sandy	23	31
Sand	8	39
Clay, sandy	17	56
Clay	13	69
Sand	22	91
Clay	5	96
Sand	8	104
Alluvium—Continued		
Lower member—Continued		
Gravel, sandy	4	108
Clay	2	110
Gravel	9	119
Clay, yellow	19	138
Clay, sandy	14	152
Gravel	43	195
Paso Robles (?) formation:		
Clay, yellow	3	198

10/35-9L3. Campodonico Water Co. On Santa Maria plain. Altitude 90 feet

[Casing perforated 162 to 180 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	4	4
Clay and sand	4	8
Sand	32	40
Clay and streaks of sand	55	95
Lower member:		
Sand and some gravel	10	105
Sand and gravel	5	110
Sand, solid, and some gravel	6	116
Sand and gravel	6	122
Sand, solid, and some gravel	9	131
Alluvium—Continued		
Lower member—Continued		
Sand	9	140
Sand, solid	5	145
Gravel	5	150
Clay	5	155
Sand and some gravel	5	160
Clay	1	161
Gravel	19	180
Sand and small gravel	10	190
Paso Robles formation:		
Clay and sand	22	212
Clay, blue	4	216

10/35-10F1. Ernest Wineman. On Santa Maria plain. Altitude 105 feet

[Casing perforated 154 to 168, 185 to 192, and 214 to 234 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Adobe	3	3
Streaks of sand and clay	52	55
Clay, blue, streaks of sand	55	110
Lower member:		
Gravel	6	116
Clay	32	148
Gravel and sand, "rusty," not water-bearing	6	154
Gravel	14	168
Clay	1	169
Alluvium—Continued		
Lower member—Continued		
Sand and some gravel	16	185
Gravel	7	192
Paso Robles formation:		
Clay and sand	8	200
Clay, blue	14	214
Gravel	20	234
Clay	4	238
Sand	14	252
Clay, hard	11	263
Sand and clay	4	267

10/35-11J1. E. and G. LeRoy. On Santa Maria plain. Altitude 133 feet

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	3	3
Sand and streak of clay	27	30
Sand	26	56
Clay	48	104
Lower member:		
Gravel	13	117
Sand	17	134
Gravel	15	149
Alluvium—Continued		
Lower member—Continued		
Clay, blue	13	162
Gravel	8	170
Clay	8	178
Gravel	7	185
Paso Robles formation:		
Sand	27	212
Clay	3	215

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/35-12B1. E. and G. LeRoy. On Santa Maria plain. Altitude 145 feet

[Casing perforated 135 to 180 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	3	3
Clay and sand	21	24
Sand	26	50
Clay	10	60
Sand	35	95
Clay	7	102
Lower member:		
Gravel	7	109
Alluvium—Continued		
Lower member—Continued		
Clay and sand	19	128
Clay	7	135
Gravel	45	180
Sand and boulders	5	185
Paso Robles formation:		
Clay and sand	25	210
Clay	4	214

10/35-14D1. Moretti and Magoria. On Santa Maria plain. Altitude 124 feet

[Casing perforated 102 to 112, 152 to 160, 198 to 200, and 265 to 308 feet]

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil, clayey	15	15
Clay and streaks of sand	70	85
Clay, blue	2	87
Sand, blue	11	98
Clay, brown	3	101
Lower member:		
Gravel	9	110
Clay, blue	25	135
Clay, sandy, blue	11	146
Clay, blue	6	152
Gravel	8	160
Clay and sand	33	193
Clay and gravel	5	198
Gravel	2	200
Paso Robles formation:		
Clay	64	264
Clay and gravel	3	267
Sand and gravel	7	274
Clay and gravel	6	280
Clay	2	282
Gravel	3	285
Clay	1	286
Gravel	3	289
Clay	3	292
Gravel	12	304
Sand and some gravel	23	327
Clay	(?)	327+

10/35-15M2. Union Sugar Co. On Santa Maria plain. Altitude 98 feet

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil, sandy	13	13
Clay, yellow	21	34
Clay, blue	39	73
Sand, blue, and clay	6	79
Sand, blue	15	94
Clay, blue	9	103
Lower member:		
Sandstone, blue	5	108
Gravel	7	115
Clay, yellow, and gravel	30	145
Gravel	10	155
Alluvium—Continued		
Lower member—Continued		
Clay and gravel	11	166
Gravel	9	175
Clay	3	178
Gravel	14	192
Paso Robles formation:		
Clay and gravel	10	202
Clay, yellow, and sand	24	226
Clay, hard, blue	38	264
Gravel	35	299
Clay, hard, yellow	7	306

10/35-16G1. Union Sugar Co. On Santa Maria plain. Altitude 92 feet

	Thickness (feet)	Depth (feet)
Alluvium:		
Upper member:		
Soil	7	7
Clay, yellow	11	18
Clay, sandy, blue	42	60
Clay, sandy, some gravel	10	70
Sand	16	86
Clay, blue	17	103
Lower member:		
Gravel	19	122
Sand	13	135
Alluvium—Continued		
Lower member—Continued		
Clay, blue	9	144
Gravel	28	172
Clay	3	175
Gravel	32	207
Paso Robles formation:		
Clay	5	212
Sand	12	224
Clay	6	230

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/35-17D1. Union Sugar Co. On Santa Maria plain. Altitude 64 feet

[Casing perforated 100 to 128, 181 to 185, 199 to 216, and 228 to 243 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	4	4	Sand and gravel	2	184
Soil, sandy	4	8	Gravel and clay, hard	13	197
Clay, blue	14	22	Gravel, cemented	2	199
Clay, sandy, blue	64	86	Sand and gravel	17	216
Clay, sandy, yellow	11	97	Paso Robles formation:		
Lower member:			Sand, fine, yellow	4	220
Sand and gravel	31	128	Clay, sandy, yellow	8	228
Sand	4	132	Sand and some gravel	5	233
Clay, hard, blue	18	150	Clay, yellow	2	235
Sand	3	153	Sand and streaks of gravel	8	243
Clay, blue	19	172	Clay, hard, sandy	7	250
Gravel and clay, hard	10	182			

10/35-21B1. C. P. Mathison. On Santa Maria plain. Altitude 91 feet

[Casing perforated 102 to 118, 134 to 136, 145 to 175, 246 to 248, and 251 to 300 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	5	5	Clay and gravel	9	145
Clay	15	20	Gravel	30	175
Sand and clay	20	40	Paso Robles formation:		
Sand	30	70	Clay	65	240
Clay, dark	32	102	Clay and gravel	6	246
Lower member:			Gravel	2	248
Gravel	16	118	Clay	3	251
Clay, yellow	4	122	Gravel	49	300
Sand, clay, and gravel	12	134	Sand, clay, and gravel	10	310
Gravel	2	136			

10/35-22H1. J. A. Brown. On Santa Maria plain. Altitude 113 feet

[Casing perforated 143 to 168, and 176 to 186 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	2	2	Clay and gravel	5	173
Clay	5	7	Gravel, clean	13	186
Sand	5	12	Sand, yellow, and gravel	8	194
Clay	39	51	Paso Robles formation:		
Sand	13	64	Clay, sandy, hard	12	206
Pebbles and sandy clay	11	75	Clay, soft, and "ash" sand	13	219
Clay, blue	12	87	Clay	1	220
Sand	15	102	Sand	8	228
Lower member:			Clay, yellow	2	230
Sand and gravel	9	111	Clay, blue	9	239
Clay, yellow	15	126	Sand, blue	1	240
Clay, blue	15	141	Clay, blue	26	266
Clay, yellow	2	143	Clay, yellow	2	268
Gravel, sand, and clay	8	151	Sand and gravel	22	290
Clay and gravel, cemented	17	168	Gravel and some sand	6	296

10/35-24B1. Union Sugar Co. On Santa Maria plain. Altitude 144 feet

[Casing perforated 122 to 153, 169 to 175, and 178 to 288 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	8	8	Gravel	6	175
Sand	79	87	Paso Robles formation:		
Clay	15	102	Clay	2	177
Lower member:			Gravel	111	288
Gravel	51	153	Clay	2	290
Clay	16	169			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

10/36-12K1. Union Sugar Co. On Santa Maria plain. Altitude 30 feet

[Casing perforated 175 to 208 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	5	5	Clay, blue	18	130
Clay	10	15	Clay, blue, and sand	30	160
Sand, blue	35	50	Sand, yellow, and boulders	10	170
Clay	10	60	Gravel	38	208
Clay, blue, and sand	20	80	Paso Robles formation:		
Sand, yellow	30	110	Clay, blue	7	215
Lower member:					
Boulders	2	112			

11/34-29N2. John Canada. On Santa Maria plain. Altitude 156 feet

[Casing perforated 118 to 123, 204 to 243, 279 to 288, and 306 to 329 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation—Con.		
Upper member:			Sand	2	245
Soil	2	2	Clay, sandy, "light"	28	273
Sand and some gravel	90	92	Clay, sandy, red	6	279
Lower member:			Sand and gravel, "light"	9	288
Sand, blue	22	114	Clay, sandy, white	3	291
Gravel and sand, blue	9	123	Clay and gravel	11	302
Orcutt (?) formation:			Clay and sand	4	306
Clay, blue	23	146	Gravel	16	322
Clay, sandy, yellow	15	161	Clay and gravel	5	327
Paso Robles formation:			Gravel	2	329
Clay, blue	29	190	Clay, white	7	336
Clay, brown	14	204	Clay, blue	14	350
Clay and gravel	39	243	Sand, blue	14	364

11/34-30Q1. Mary Bolton. On Santa Maria plain. Altitude 148 feet

Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	8	8	Gravel	14	126
Sand, coarse	52	60	Clay, blue	27	153
Sand, fine	35	95	Gravel	14	167
Lower member:			Paso Robles (?) formation:		
Sand and gravel	17	112	Sand	13	180

11/35-19E1. Mary B. Enos. On Santa Maria plain. Altitude 34 feet

[Casing perforated 350 to 360 and 500 to 520 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Clay	28	350
Soil	10	10	Gravel	3	353
Sand and streaks of clay	75	85	Clay and gravel	7	360
Clay, blue	30	115	Sand, "light"	40	400
Orcutt (?) formation:			Sand, hard, blue	20	420
Clay and sand	65	180	Clay	25	445
Paso Robles formation:			Gravel, sand and clay	6	451
Clay, blue	20	200	Clay, hard, and some gravel	5	456
Sand and clay	35	235	Sand, hard	36	492
Clay, blue	10	245	Clay, hard	7	499
Sand	28	273	Sand and some gravel	20	519
Clay, blue	15	288	Clay	6	525
Sand and clay	34	322	Sand, fine	45	570

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

11/35-20E1. Union Sugar Co. On Santa Maria plain. Altitude 49 feet

[Casing perforated 150 to 444 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation:		
Upper member:			Sand, yellow	60	224
Soil, sandy	13	13	Clay, yellow	12	236
Sand, yellow	14	27	Sand, yellow	24	260
Sand, blue, and cobblestones	19	46	Clay, sticky, yellow	14	274
Sand, blue, and rotten wood	18	64	Clay, yellow	7	281
Sand, blue	20	84	Sand, blue, and gravel	28	309
Clay, yellow	14	98	Clay, blue	34	343
Orcutt (?) formation:			Sand, yellow, and some gravel	102	445
Sand, yellow	20	118	Clay, sticky, blue	9	454
Clay, yellow	8	126	Sand, yellow, and gravel	71	525
Sand, yellow	38	146			

11/35-21R2. B. A. Tognazzini. On Santa Maria plain. Altitude 77 feet

[Casing perforated 392 to 415 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Sand, fine streaks of clay	32	262
Soil	3	3	Clay, tough, light brown	11	273
Sand	32	35	Sand, brown	15	288
Clay and streaks of sand	45	80	Clay, brown, streaks of sand	21	309
Orcutt (?) formation:			Sand, hard	21	330
Clay, brown, hard and soft streaks of sand	40	120	Sand, hard, light brown; a little gravel	20	350
Sand, fine	6	126	Sand, hard, white	22	372
Clay, sandy, brown	19	145	Sand, hard, brown	12	384
Clay, blue	10	155	Clay, brown	6	390
Paso Robles formation:			Sand; a little gravel	10	400
Sand	5	160	Gravel and sand; a little clay	5	405
Clay, hard, and sand	7	167	Small gravel and sand	10	415
Clay, blue	8	175	Clay	5	420
Clay, brown, and streaks of sand	27	202	Clay, blue	5	425
Clay, blue	28	230			

11/35-25L1. M. C. Gracia. On Santa Maria plain. Altitude 127 feet

[Casing perforated 96 to 121, 230 to 250, 267 to 275, 295 to 300, 311 to 313, and 325 to 335 feet]

Alluvium:			Paso Robles formation—Con.		
Upper member:			Sand	2	191
Soil	4	4	Clay	2	193
Sand and some gravel	21	25	Sand	16	209
Clay	1	26	Sand and some gravel	7	216
Gravel	3	29	Clay, blue	15	231
Clay	1	30	Gravel	8	239
Sand	8	38	Clay and streaks of gravel	5	244
Clay	3	41	Clay, tough, blue	13	257
Sand and gravel	19	60	Clay, sand, and gravel	10	267
Sand	14	74	Gravel	7	274
Clay	2	76	Clay and gravel	4	278
Sand	2	78	Sand	13	291
Clay	1	79	Gravel and sand	2	293
Sand	7	86	Clay	3	296
Clay	2	88	Gravel and sand	2	298
Sand	2	90	Clay	2	300
Clay	5	95	Clay, tough	3	303
Lower member:			Clay and sand	8	311
Gravel	8	103	Gravel	2	313
Orcutt (?) formation:			Clay, soft, and sand	8	321
Clay	57	160	Clay and gravel	8	329
Paso Robles formation:			Sand and some gravel	21	350
Clay, blue	21	181	Sand, white	15	365
Clay, yellow	8	189			

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

11/35-25P1. Dave McKeen. On Santa Maria plain. Altitude 126 feet

[Casing perforated 110 to 179 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	6	6	"Hardpan"	30	164
Sand	8	14	Gravel	15	179
Clay	4	18	Paso Robles formation:		
Sand, coarse	90	108	Sand and clay	23	202
Lower member:			Clay	1	203
Gravel	26	134			

11/35-27H1. Henry Tognazzini. On Santa Maria plain. Altitude 101 feet

[Casing perforated 100 to 115, 205 to 220, and 300 to 325 feet]

Alluvium:			Paso Robles formation:		
Upper member:			"Hardpan"	10	179
Soil	8	8	Clay, soft	7	186
Loam, sandy	6	14	Clay, blue	5	191
Sand and clay	19	33	"Hardpan," yellow	17	208
Clay, blue	13	46	Gravel, coarse	4	212
"Quicksand"	17	63	Clay, yellow	10	222
Clay, yellow	21	84	Clay, blue	8	230
"Hardpan"	17	101	Clay, yellow	3	233
Lower member:			Sand, hard	17	250
Gravel, coarse	9	110	Sand and gravel	13	263
Orcutt (?) formation:			Gravel	5	268
Clay, yellow	23	133	Clay, blue	34	302
Clay, hard, brown	7	140	"Hardpan," yellow	4	306
Clay, soft, yellow	7	147	Gravel	17	323
Clay, hard, yellow	6	153	Clay, yellow	5	328
"Quicksand"	16	169			

11/35-28L1. Union Sugar Co. On Santa Maria plain. Altitude 84 feet

[Casing perforated 273 to 278 and 290 to 390 feet]

Alluvium:			Paso Robles formation:		
Upper member:			Clay, blue	16	222
Soil	12	12	Sand	4	226
Clay, yellow	46	58	Gravel	8	234
Sand and clay	40	98	Clay, yellow	31	265
Lower member:			Gravel, sandy	15	280
Sand	14	112	Clay, blue	6	286
Gravel, sandy	30	142	Gravel and coarse sand	105	391
Paso Robles (?) formation:			Clay, blue	9	400
Clay, yellow	64	206			

11/35-29D1. P. Pezzoni. On Santa Maria plain. Altitude 60 feet

Alluvium:			Orcutt (?) formation—Continued		
Upper member:			Clay, blue	6	159
Soil, sandy	19	19	Clay, yellow		
Sand, muddy, blue	4	23	Paso Robles formation:	7	
Sand, fine, blue	14	37	Clay, hard, blue	15	174
Clay, blue	5	42	Sand	18	192
Sand, yellow	44	86	Sand and some gravel	4	196
Clay, sandy, yellow	3	89	Clay, sandy, yellow	6	202
Clay, blue	9	98	Sand	1	203
Orcutt (?) formation:			Clay, sticky, yellow	4	207
Clay, yellow	41	139	Clay, sticky, blue	18	225
"Sediment", sandy, yellow	7	146	Clay, sandy, blue	5	230
			Clay, sticky, blue	9	239

TABLE 16.—*Drillers records of wells in the Santa Maria Valley area*—Continued

11/35-29R1. Union Sugar Co. On Santa Maria plain. Altitude 85 feet

[Casing perforated 144 to 154, 210 to 223, 310 to 322, and 390 to 428 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Paso Robles formation:		
Upper member:			Clay, brown	31	254
Sand	7	7	Clay, blue	38	292
Adobe	13	20	Sand and some gravel	4	296
Clay, sandy	20	40	Clay, yellow, and gravel	10	306
Sand	5	45	Sand and gravel	8	314
Clay, soft	43	88	Gravel, cemented	3	317
Lower (?) member:			Sand and gravel	5	322
Sand	34	122	Sand and some gravel	13	335
Lower member:			Clay, blue	35	370
Sand and some gravel	10	132	Gravel, cemented	23	393
Sand and gravel	22	154	Sand and gravel	3	396
Clay, blue	43	197	Gravel and boulders	32	428
Gravel and boulders	26	223	Clay and sand	6	434

11/35-33F1. Union Sugar Co. On Santa Maria plain. Altitude 84 feet

[Casing perforated 118 to 150, 154 to 170, and 174 to 208 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member—Continued		
Soil	15	15	Gravel, coarse	36	150
Clay	17	32	Clay	4	154
Sand	6	38	Gravel, cemented	17	171
Clay	4	42	Clay	2	173
Sand	16	58	Gravel, coarse	37	210
Clay	26	84	Paso Robles formation:		
Sand	16	100	Sand	18	228
Lower member:			Clay, hard, blue	6	234
Gravel, sandy	14	114			

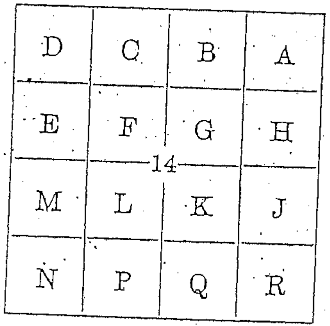
11/35-35A1. Bello Estate. On Santa Maria plain. Altitude 123 feet

[Casing perforated 125 to 189 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Alluvium:			Alluvium—Continued		
Upper member:			Lower member:		
Soil	5	5	Sand and gravel	16	121
"Hardpan"	25	30	Gravel	29	150
Sand	20	50	"Sediment"	1	151
"Sediment"	12	62	Gravel	42	103
Clay	6	68	Paso Robles formation:		
"Quicksand"	37	105	Clay	2½	195½

WELL-NUMBERING SYSTEM

The well-numbering system used by the Geological Survey in the Santa Maria Valley area shows the locations of wells according to the rectangular system for the subdivision of public land. For example, in the number 10/34-14E3, which was assigned to a well within the city limits of Santa Maria, the part of the number preceding the bar indicates the township (T. 10 N.), the part between the bar and the hyphen, the range (R. 34 W.); the digits between the hyphen and the letter indicate the section (sec. 14), and the letter indicates the 40-acre subdivision of the section shown in the accompanying diagram.



D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Within each 40-acre-tract the wells are numbered serially as indicated by the final digit of the number. Thus, well 10/34-14E3 is the third well to be listed in the SW¼NW¼ sec. 14. As all of the Santa Maria Valley area is in the northwest quadrant of the San Bernardino meridian and base line, the foregoing abbreviation of the township and range is sufficient. The west half of the area has never been public land; for this the rectangular system of subdivision has been projected.

The correlation of Geological Survey well numbers with those of other agencies has been presented in another report (La Rocque, Upson, and Worts, 1950, tables 1 and 4.)

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