Geology and Ground-Water Resources of the South-Coast Basins of Santa Barbara County, California

By J. E. UPSON

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GEOLOGY AND GROUND-WATER RESOURCES OF THE SOUTH-COAST BASINS OF SANTA BARBARA COUNTY, CALIFORNIA

By J. E. Upson

ABSTRACT

This report is the second of a series of interpretive reports on the geology and water resources of the several agricultural districts of Santa Barbara County, Calif. It has been prepared by the Geological Survey, United States Department of the Interior, in cooperation with the county. It deals with the two agricultural areas situated on the south coast of the county which are called the Carpinteria and Goleta basins after the towns in each. The report discusses the geology of the areas as it pertains to the occurrence and replenishment of ground water; it assembles the available data on runoff of streams that enter the basins, with particular reference to the streams as a source of ground-water replenishment; it shows the extent and occurrence of ground-water bodies; it summarizes the pumpage from them; estimates the long-term average annual yield of the basins; and presents data on the quality of the ground water and the possibility of sea-water contamination.

The Carpinteria and Goleta basins are in the narrow south-coast lowland of Santa Barbara County between the ocean and the Santa Ynez Mountains. They are respectively about 15 miles east and about 6 miles west of Santa Barbara, the principal town and county seat. Each comprises a central alluvial plain bordered by foothills and terrace remnants, all underlain to depths of several thousand feet by unconsolidated water-bearing deposits. The foothills and terraces, which together with the alluvial plains constitute the ground-water basins proper, are backed by the Santa Ynez Mountains which are high and rugged and are composed of consolidated rocks. Inland from the sea, the land rises to altitudes of 500 to 700 feet in the foothills, and 2,000 to 4,000 feet at the crest of the mountains. The Carpinteria basin is about 7 miles long from east to west and a maximum of 2 miles wide. Including the mountain drainage area it is 7 miles wide. The Goleta basin is about 8 miles in maximum length from east to west, and 3 miles wide; or 7 miles wide including the mountain drainage area.

In the Carpinteria and Goleta basins unconsolidated water-bearing deposits of Tertiary and Quaternary age about 6,000 feet in total thickness rest on consolidated, essentially non-water-bearing rocks of Tertiary age. The consolidated rocks include undifferentiated Eocene, Sespe, Vaqueros, Rincon, and Monterey formations, ranging in age from Eocene to upper Miocene; and the unnamed Pliocene formation. They generally do not yield water to wells,

though a few wells lately drilled in sandstone strata at places outside the basins have yielded small quantities of water. They are of importance chiefly because they underlie the runoff areas of the mountains.

The unconsolidated deposits include the Santa Barbara formation, the hitherto unnamed Casitas formation, terrace deposits, and older alluvium, all of Pleistocene age; and the younger alluvium of Recent age. The Santa Barbara formation is a body of marine clay, silt, and sand, locally very fossiliferous, and about 2,000 feet in maximum thickness. It underlies nearly all of the Goleta basin, where it is the principal aquifer, and a small part of the Carpinteria basin. It has an average permeability on the order of 100 g. p. d. per sq. ft. The Casitas formation is a body of continental deposits, red to yellow-buff in color, and consisting of compact clay, silt, some sand, and coarse, poorly sorted gravel, having a maximum thickness of as much as 4,000 feet. It is known to occur only in the Carpinteria basin where it is tapped by most irrigation wells. It is thus the principal aquifer in that basin though its average permeability is only about 35 g. p. d. per sq. ft.

The older alluvium occurs in both the Carpinteria and Goleta basins, and comprises discontinuous though fairly extensive bodies of clay, silt, sand, and gravel, about 200 feet in maximum thickness, laid down as continental terrace deposits. They are tapped by some wells, and yield water in small quantities locally, but mainly underlie a fairly large proportion of the recharge areas where they receive infiltrate of rain and transmit it to deeper water-bearing beds. The younger alluvium underlies the alluvial plains in the basins, and extends as tongues up adjoining stream canyons. It has a maximum known thickness of about 250 feet, though it may be thicker in the Carpinteria basin. It consists mostly of clay and silt, but has some lenses of sand and gravel in the lower parts beneath the alluvial plains, and in the stream canyons. It yields a little water to shallow wells but its chief significance in relation to ground water is that the fine-grained beds form impermeable confining blankets in the Carpinteria and Goleta basins.

Several streams enter each of the ground-water basins, chiefly draining the adjacent mountain areas composed of consolidated rocks. Rincon, Gobernador, Carpinteria Creeks, Arroyo Parida, and the streams in Franklin, Santa Monica, and Toro Canyons flow into and across the Carpinteria basin; and Atascadero, San Antonio, Maria Ygnacio, San Jose and Carneros Creeks and the creeks in San Pedro and Glen Anne Canyons flow into and across the Goleta basin. Rainfall on these drainage areas is largely ungaged, but the long-term average is estimated to be about 23 inches a year. Runoff has been determined by continuous gages on Carpinteria, Atascadero, and San Jose Creeks, operated since early 1941; and by miscellaneous measurements at several sites on most streams during the same period.

The total runoff of streams entering the Carpinteria basin from 1941 to 1945, estimated on the basis of measured runoff of Carpinteria Creek, ranged from less than 800 to more than 26,000 acre-feet per year, and averaged about 10,000 acre-feet per year. The corresponding runoff of streams entering the Goleta basin, computed on the basis of the records at Atascadero and San Jose Creeks, ranged from 1,100 to 16,000 acre-feet per year, and averaged about 7,000 acre-feet per year. Nearly all of this runoff passes beyond the recharge area and is wasted to the sea. On the basis of low-water measurements and estimates of seepage losses, it is estimated that the total contribution to ground water by seepage from streams in the Carpinteria basin was about 900 acre-feet per year from 1941 to 1945; and in the Goleta basin about 700 acre-feet per year during

the same period. The long-term average seepage loss probably has been about 700 and 500 acre-feet per year, respectively.

The ground-water resources of the two basins are considered seperately. The Carpinteria basin has both a shallow and a deep ground-water body, but the shallow body supplies practically no water to wells. The deep body supplies water to all the irrigation wells. It occurs in the lower part of the younger alluvium, in the older alluvium, and in the Casitas and Santa Barbara formations. It is nearly coextensive with these formations, and is several thousand feet deep, though the quality of the water at depth may be unsuitable for domestic or agricultural use. The deep body is confined by impermeable beds in the younger alluvium beneath most of the alluvial plain; and in early years wells within that area flowed. At present wells do not flow, and the confining beds now function mainly to limit the area of recharge to the ground-water body by preventing downward percolation from the land surface. The area of recharge, then, is the area between the limit of confining conditions and the boundary of consolidated rocks, about 4,500 acres.

The water of the deep body moves southward and southwestward mainly from the foothill area in the eastern and northeastern parts of the basin. Discharge is largely by pumpage but in small part by seepage into the ocean along the shore west of Carpinteria. Recharge is largely from infiltration of rain on the recharge area which is estimated to have averaged about 1,700 acre-feet per year in the five years 1941–45, and perhaps 1,000 acre-feet per year perennially. Total perennial recharge, including seepage loss from streams, is estimated to have averaged about 1,700 acre-feet per year.

Records of water-level fluctuations in observation wells show that the seasonal range of water levels is as much as 40 feet, largely the result of pumping. Water levels recover each winter, and over the period 1941–46 there has been little over-all change of the height to which the water levels recovered each year. However, water levels did decline in earlier years as much as 20 or 30 feet; a record in a pair of wells in the recharge area shows a decline of about 32 feet from 1932 to the peak in the winter of 1945.

Pumpage is determined from records of electric energy consumption and from tests of kilowatt-hours required per acre-foot of water pumped for the years 1935–44. Adding estimates for pumpage by gasoline engines, natural gas, and other means, total pumpage in the Carpinteria basin has ranged from 1,800 acre-feet in 1935 to nearly 3,700 acre-feet in 1943, and has averaged nearly 3,000 acre-feet per year. During the wet years, 1941–45, this pumpage caused no over-all decline of water levels, and hence might appear to have been within the limits of safe yield.

In regard to perennial yield, however, there is evidence that some of the water pumped was taken from storage, and thus withdrawal was greater than the natural recharge even during the wet years. It is certainly greater than long-term average recharge, and therefore is excessive. Because there is very little salvageable discharge from the basin, the perennial yield is the average perennial recharge, which is estimated to be about 1,700 acre-feet per year.

The ground water in most parts of the basin is of sufficiently good quality for ordinary uses. However, the ground water in the northwestern part of the basin is somewhat high in sodium. Also, it has been and is being contaminated by boron in sufficient concentration to be injurious to lemons. The possibility of sea-water encroachment exists along the shore west of Carpinteria and such encroachment will doubtless occur if excessive pumping is continued although there was no evidence of such contamination as of 1946.

The Goleta basin also has shallow and deep ground-water bodies, of which the deep body supplies practically all the water. The deep body occurs in the lower part of the younger alluvium, in the older alluvium, and in the Santa Barbara formation. The deep body is nearly coextensive with these formations, and is a maximum of about 2,000 feet deep, though water in the lower part may be of poor quality. As in the Carpinteria basin, the deep body is confined by impermeable beds in the younger alluvium beneath most of the alluvial plain; and in early years wells flowed at the land surface. Thus, there is an area of confined water in which there is no appreciable downward percolation of water from the land surface. The recharge area lies between the area of confined water and the consolidated rocks, and is about 6,000 acres in extent.

Most of the water of the deep body moves southwestward from the main recharge area. Movement is greatly restricted by impermeable zones along faults so that water levels along some of them are locally as much as 100 feet higher on the up-gradient side than on the down-gradient side. Such large differences of head appear to be necessary to transmit water across the fault zones. There is no natural discharge from the basin. Further, water in the western part depends on local recharge for replenishment; it cannot receive water from the main area of recharge to the northeast.

Recharge is mainly by infiltration of rain on the recharge area, which is estimated to have been about 4,400 acre-feet per year from 1941 to 1945, and about 2,600 acre-feet per year in long-term average. Total recharge, including seepage losses from streams, has been about 5,100 acre-feet per year during the period 1941–45, and has probably averaged about 3,100 acre-feet per year over the long term.

From records maintained by the Geological Survey during 1941–46, the seasonal range of water levels is 10 to 20 feet, caused largely by pumping; recoveries each winter have been to about the same level, except from 1945 to 1946 when the peak levels showed a marked decline in all wells. The first reported water levels in the Goleta basin were 40 to 50 feet above sea level in the area of confined water, and they have since declined about 50 feet. Comparison of water levels in the period 1941–46, with longer-term records available, suggests that the levels in recent years represent a temporary levelling superimposed on a general decline. The levelling is thought to be due mainly to the abundant rainfall of the winter 1940–41, with resultant decrease of pumping and delayed, hold-over recharge.

Pumpage in the Goleta basin has been estimated for the years 1935 to 1944, and ranged from 2,900 acre-feet for 1935 to a maximum of 5,700 for 1940. Pumpage in 1943 was almost as high; and the 10-year average was 4,600 acre-feet per year. The average during the period 1941–45 was about 5,100 acre-feet per year. This pumpage caused only a small over-all decline of water levels from 1941 to 1945, and during that period was probably only slightly in excess of the safe yield for that period. However, it was doubtless greater than the average expectable recharge.

There is no natural discharge from the basin and the perennial yield is therefore equal to the long-term average recharge. This is estimated to be about 3,100 acre-feet per year.

The quality of most of the ground water in the Goleta basin is satisfactory for ordinary uses; but in the western part of the basin it is reported to be rather high in salts. Opportunity for sea-water encroachment into the Goleta basin is small, but in the reported area of contamination static water levels

have been 10 to 20 feet below sea level for 10 years or more, and the contamination may be from sea water. It seems more likely, however, that the contamination is from saline connate water in the lower part of the Santa Barbara formation.

INTRODUCTION

LOCATION AND GENERAL FEATURES OF THE AREA

The south-coast basins of Santa Barbara County, Calif., are within the narrow lowland lying along the south foot of the Santa Ynez Mountains, and extending about from the Ventura County line westward for nearly 35 miles to Point Conception. This lowland is backed on the north by the Santa Ynez Mountains, a linear, rugged range which rises steeply from the coast to crestal altitudes of 2,000 to over 4,000 feet. Sharp transverse ridges separated by steep-walled narrow canyons are prominent features of the range. The coastal lowland at the base, generally less than 1 mile wide, consists at most places of elevated terraces, whose upper surfaces slope outward from the range to terminate in steep cliffs from 50 to 150 feet high almost at the water's edge. The surfaces of these terraces are at levels of about 150, 200, 350, 500, and 750 feet respectively, above present sea level, and are trenched by steep-walled canyons extending out from the mountains.

However, in the vicinity of Carpinteria and Goleta, and in the intervening area about Montecito and Santa Barbara, all but the lowest terrace lie well back from the coast and are separated from it by alluvial plains. These slope gently to sea level, or to the edge of the low terrace about 50 feet above sea level, and are 2 to 3 miles wide. The most extensive of these broader parts of the coastal lowland are the agricultural areas around Carpinteria and Goleta. They are basins in the topographic, geologic, and hydrologic senses, and hence are designated the Carpinteria and Goleta basins. The position of these two main basins, together with the intervening areas, are shown on the index map, figure 1, and in greater detail on the geologic maps, plates 1 and 2.

In the Carpinteria and Goleta basins irrigation is practiced extensively, and nearly all with ground water obtained through wells. In the Santa Barbara and Montecito areas a small amount of agriculture depends on ground water for irrigation, but the areas are largely residential and obtain water from the Santa Ynez River by diversion through the mountains in tunnels (Upson and Thomasson, 1951). In the Santa Barbara area some ground water is used by ice companies and by the Southern Pacific railroad yard. In early years ground water was used to supply the city of Santa Barbara, and outlying homes and estates, but the supply became inadequate for the expanding population, and was largely superseded by water diverted from the Santa Ynez River. In February 1948, however, the city returned to ground water for essentially all its public supply.

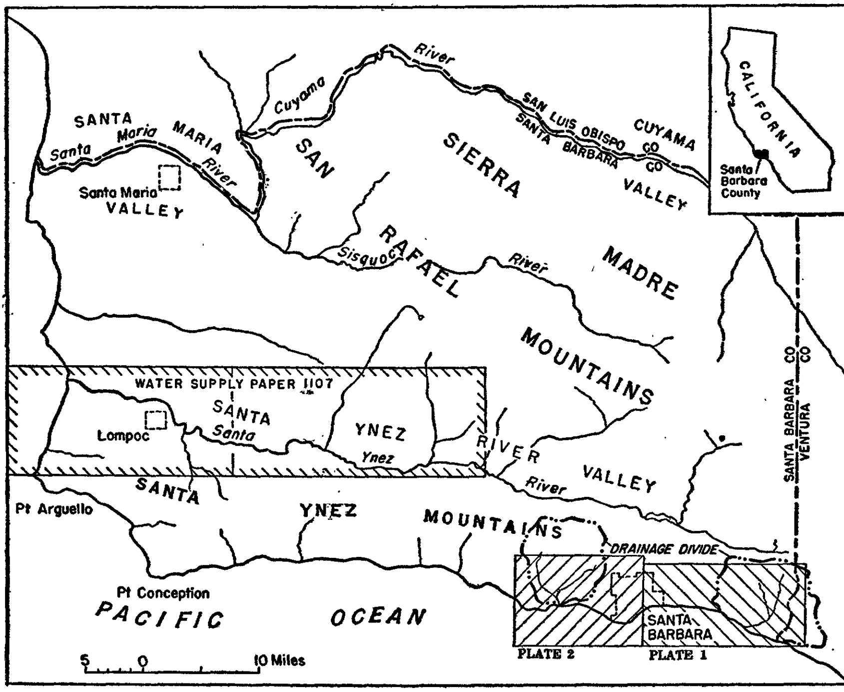


FIGURE 1.—Index map of Santa Barbara County, Calif., showing drainage areas of the south-coast basins.

Outside these areas, mainly along the coast west of the Goleta basin, there are no sizeable settlements and agriculture consists chiefly of dry farming. There is little draft on the small ground-water supplies that occur there.

PURPOSE AND SCOPE OF REPORT

This report is the second of a series of interpretive reports on the geology and water resources of Santa Barbara County. The first (Upson and Thomasson, 1951) deals with the Santa Ynez River basin north of the Santa Ynez Mountains. This report pertains to the basins along the coast south of the Santa Ynez Mountains. It presents an estimate of the natural perennial yield of the Carpinteria and Goleta ground-water basins. It describes the geology of these basins as it pertains to ground water; it summarizes the stream runoff from the mountain areas; it describes the occurrence, source, and movement of the ground water; assembles the pumpage records; and estimates the perennial average recharge to the ground-water bodies. Thus, it shows the extent to which use of ground water in the Carpinteria and Goleta basins is in excess of the amounts normally available from sources within the areas, and gives factual data which may be used as part of the basis for planning the effective utilization of the water supplies of the county.

ACKNOWLEDGMENTS

The work of which this report is a result has been carried on by the Geological Survey, United States Department of the Interior, in cooperation with the county of Santa Barbara. It was under the general direction of O. E. Meinzer, Geologist in charge of the Division of Ground Water; and under the supervision of A. M. Piper, District Geologist in charge of ground-water investigations in the Pacific Coast area.

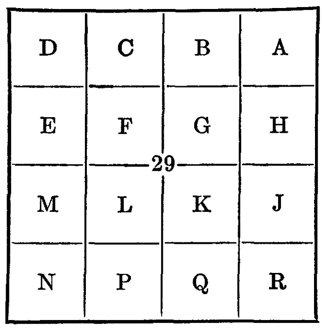
Geologic mapping was begun by C. A. Wahrhaftig in the Goleta basin, was carried forward there and in the Carpinteria basin by L. Porter, Jr., and completed by J. E. Upson. Stream-flow measurements and estimates of seepage losses were made by personnel of the Division of Surface Water, largely by H. G. Thomasson, Jr., under the direction of the Los Angeles office. Yield of wells, compilation of power records, and computations and estimates of water pumped were made by P. P. Livingston, and were somewhat extended by G. F. Gregg. Preliminary sections of the text on water-level fluctuations and on pumpage were drafted in part by Mr. Livingston. Text sections on quality of water have been revised and improved by J. F. Poland and A. A. Garrett.

Whole-hearted cooperation and support have been given by ranchers, well drillers, and installers of well pumps; and by Mr. F. W. Thomas, secretary of the Carpinteria County Water District. Also, officials and employees of the Southern California Edison Co. gave valuable assistance in the computation of power consumption.

Unpublished material on the geology was made available for study by geologists of several oil companies: Mr. Aden Hughes of the Union Oil Co. of California, Mr. E. R. Baddley of the Texas Co., and Mr. Lowell E. Redwine of the Honolulu Oil Corp. The writers acknowledge the advice and criticism of their colleagues of the Geological Survey in the preparation of this report.

WELL-NUMBERING SYSTEM AND WELL DATA

Throughout this and other reports on ground-water resources of Santa Barbara County, wells and springs are numbered according to the rectangular system of subdivision of public land. For that purpose, where the land has not actually been surveyed, appropriate subdivisions are projected as explained on plates 1 and 2. Thus, the number of a well, such as 4/25–29M1, has two parts. The part that precedes the hyphen indicates the township and range (T. 4 N., R. 25 W.), the numbers following the hyphen indicate the section (sec. 29), the letter indicates the 40-acre subdivision of the section, as shown in the accompanying diagram, and the final number is the serial number in the particular 40-acre tract. Accordingly, well 4/25–29M1 is the first well listed in the NW¼SW¼, sec. 29, T. 4 N., R. 25 W.



Factual data on wells and fluctations of water levels used in this report have been assembled elsewhere and have been published as water-supply papers of the Geological Survey (Meinzer, Wenzel, and others, 1943, pp. 141–168; 1944, pp. 176–238; 1945, pp. 143–153. Sayre and others, 1947, pp. 129–136; 1949, pp. 146–154. La Rocque, Upson, and Worts, 1950, pp. 1–118).

PHYSICAL FEATURES OF THE AREAS

TOPOGRAPHY AND DRAINAGE

Carpinteria basin.—The Carpinteria basin is the eastern of the two main south-coast basins. It consists of a low-lying alluvial plain and bordering slopes and terraces, all underlain by unconsolidated deposits that extend to depths of from several hundred to several thousand feet. The plain extends about 7 miles westward along the coast from the Ventura County line at Rincon Creek nearly to Summerland, and extends northward from the shore a maximum of about 2 miles. Its lowest point is west of Carpinteria, where a swamp, El Estero, lies about at sea level.

Along the northern border of the plain is a narrow, discontinuous belt of terrace remnants and southward-sloping dissected alluvial fans. This belt is broadest at the east end of the basin where it consists of level-topped terrace remnants, the largest of which is Shepard

Mesa whose summit is nearly 700 feet above sea level and about 600 feet above the adjoining part of the alluvial plain. North of this narrow belt are the foothills and spurs of the Santa Ynez Mountains that are underlain by consolidated rocks.

South of the alluvial plain a narrow terraced ridge slopes evenly westward, except where trenched by Rincon Creek, for an altitude of about 200 feet at that creek to sea level, a quarter of a mile east of Carpinteria. The rocks that underlie the seaward part of this ridge effectively separate the eastern part of the Carpinteria basin from the sea.

Six main streams enter the basin. Rincon Creek, the largest, crosses the east end of the basin outside the alluvial plain. The other streams—Carpinteria and Gobernador Creeks, Arroyo Parida, and the creeks in Santa Monica and Toro Canyons—debouch on the alluvial plain. These streams, whose features are discussed in another part of this report (p. 30), are usually perennial almost to the edge of the consolidated rocks, and are intermittent in their courses across the unconsolidated deposits. Numerous short canyons, such as Franklin Canyon, head in the immediately adjacent foothills and drain into the Carpinteria basin. They contain water only in wet weather.

Goleta basin.—The Goleta basin, like the Carpinteria basin, consists mainly of a central alluvial plain and bordering foothills and terraces, all underlain to depths of several hundred to several thousand feet by unconsolidated deposits. It is slightly larger than the Carpinteria basin, as it is about 8 miles long east to west and has a maximum width of about 3 miles. The alluvial plain slopes gently southward to a central slough south of Goleta, now largely artificially filled, which drains to the ocean past the so-called Mescal Island. This plain has an irregular northern margin extending into the terrace belt as long tongues along stream channels. The terrace belt is composed of unconsolidated deposits except in the western part. To the northeast long terraces slope southwestward from the mountains and lie at heights of from 50 to 300 feet above the plain. On the southeast, within the Hope Ranch, high hills and terraces rise to altitudes of more than 500 feet above sea level and separate the plain from the ocean. Along the shore they are composed of consolidated rocks. Along the entire south side of the plain a nearly continuous terrance, composed of impermeable rocks, stands 50 to 150 feet above sea level. This terrace, which is analogous in form to that on the south flank of Rincon Mountain east of Carpinteria, is trenched at the outlet of Goleta slough south of Mescal Island and at a smaller outlet about 3 miles farther west, but otherwise it forms a continuous barrier across the entire seaward side of the Goleta basin.

The consolidated rock floor of the basin gradually rises westward from beneath the unconsolidated deposits and about 1½ miles east of Ellwood merges with the coastal terrace. The extreme northwest margin of the basin is composed of high terrace remnants which are underlain by consolidated rocks and which abut sharply against the rugged foothills of the Santa Ynez Mountains.

Seven main streams drain the adjacent slopes of the Santa Ynez Mountains and cross the Goleta alluvial plain. All are comparatively short, and all are intermittent in the reaches downstream from the consolidated rocks. These streams, whose characteristics are discussed in some detail under surface-water resources (p. 30), are: Maria Ygnacio, Atascadero, San Antonio, San Jose and Carneros Creeks and the streams in San Pedro and Glen Anne Canyons.

Santa Barbara area.—At the eastern end of the Goleta basin is a lowland section of coast in which is situated the city of Santa Barbara. It occupies a small alluvial plain and a larger bordering terraced area, all about 2 miles wide, between Mission Ridge on the north and the so-called Mesa on the south. This depression is structurally continuous with the Goleta basin although separated from it on the west by high terrace remnants. On the southeast, it is open to the sea. Nearly all of this area is shown on plate 2, the geologic map of the Goleta basin.

Montecito area.—Eastward from the Santa Barbara area to the hills at Summerland is the Montecito area, so named from the village of Montecito. It consists mainly of a broad, undulating, southward sloping alluvial plain, somewhat dissected by streams. Its surface is about 2 miles wide north and south, and nearly 5 miles long in maximum east-west dimension. From the north, where it abuts sharply against the mountains at an altitude of about 500 feet, it slopes regularly southward to a low cliff at the sea shore. It is shown on the map of the Carpinteria basin, plate 1.

CLIMATE

The main climatologic features of Santa Barbara County as a whole have been described in the report on the Santa Ynez River basin (Upson and Thomasson, 1951), and are not repeated here. However, rainfall is the main source of recharge to the ground-water bodies of the south-coast basins and produces the runoff in the streams. Accordingly, there are here presented tabulations of rainfall as recorded at Santa Barbara, Carpinteria, and Goleta. The full record at Santa Barbara, covering 77 years, has been given in the report on the Santa Ynez River basin. Only the later part, which is coincident with the unfortunately much shorter terms of record at the other two stations, is given here.

TABLE 1.—*Precipitation, in inches, in the 9 water years 1937–45 at three stations along the south coast of Santa Barbara County, Calif.*

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Carpinteria (altitude about 30 feet) [1]													
1938-39	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	0.61	-----
1939-40	0	0.05	0.79	4.83	3.76	0.54	1.22	0.06	0	0	0	0	11.25
1940-41	1.25	.38	8.59	7.59	7.98	9.31	3.77	T	0	0	0	0	38.87
1941-42	.86	.56	6.44	1.13	.69	1.34	2.92	0	0	0	0	0	13.94
1942-43	.80	.40	.92	9.62	2.84	2.89	.96	.31	0	0	0	0	18.74
1943-44	.31	.03	5.30	.74	7.44	1.73	1.25	.06	0	0	0	0	16.86
1944-45	0	4.16	1.46	1.10	4.84	4.31	0	.06	0	0	0	0	15.93
Average 1940-45	.54	.93	3.92	4.17	4.59	3.35	1.68	.08	0	0	0	0	19.26
Santa Barbara (altitude 130 feet) [2]													
1936-37	1.86	0	6.93	3.09	7.99	4.79	0.03	0.11	0	0	0	T	24.80
1937-38	.16	09	4.40	1.90	8.20	10.26	1.09	T	0	0	T	0.19	26.29
1938-39	.14	.08	4.94	2.84	1.27	3.62	.17	.10	0	0	0	.26	13.42
1939-40	.09	.02	1.41	6.39	4.87	.82	1.06	.02	0	0	T	0	14.68
1940-41	.75	.43	8.92	9.68	8.21	11.71	5.50	.01	T	.03	.01	0	45.25
1941-42	.89	.44	5.00	.80	.75	1.76	3.19	T	0	0	T	.03	12.86
1942-43	1.44	.62	1.36	12.84	4.21	2.92	.92	.03	0	0	0	0	24.34
1943-44	.40	.12	5.53	1.44	7.05	1.74	1.57	.01	.06	0	0	T	17.92
1944-45	T	2.66	1.23	.60	5.87	4.87	T	T	T	0	T	.06	15.29
Average 1940-45	.60	.71	3.91	5.29	5.16	3.97	2.04	.01	.01	(3)	(3)	.02	21.72
Goleta (altitude about 70 feet) [4]													
1936-37	-----	-----	-----	2.77	9.04	4.22	0	0	0	0	0	0	-----
1937-38	0.19	0.25	4.02	4.31	6.96	5.93	1.06	.09	0	0	0	0.22	23.03
1938-39	.15	.12	5.30	3.21	1.59	3.61	.06	.11	0	0	0	.27	14.42
1939-40	.13	.05	1.46	6.27	5.66	1.01	.61	.0	0	0	0	0	15.19
1940-41	.87	.30	9.68	10.57	7.74	12.09	4.53	.25	0	.05	0	0	46.08
1941-42	1.15	.45	5.91	1.05	.88	2.00	3.44	0	0	0	.05	0	14.93
1942-43	.92	.70	1.57	11.26	3.03	2.82	.86	0	0	0	0	0	21.16
1943-44	.72	0	5.65	1.28	7.33	2.23	2.00	0	.03	.04	0	0	19.28
1944-45	.09	3.90	1.17	1.68	4.62	4.28	.10	0	.03	0	0	.06	15.93
Average 1940-45	.65	90	4.24	5.35	4.88	4.07	1.92	.04	.01	.02	.01	.01	22.10

[1] Gage at Carpinteria Union High School, records collected by county agricultural agent.
[2] Data from publications of U. S. Weather Bureau.
[3] Less than 0.01 inch.
[4] Gage on roof of lemon-packing house three-quarters of a mile northwest of Goleta; records collected by employees of Goleta Lemon Association.
T (trace) is 0.005 inch or less of rain or melted snow.

GEOLOGY

EARLIER WORK

Considerable geologic work has been done in the south coastal part of Santa Barbara County, but chiefly by geologists employed by oil companies, and the results are not generally available. Major features are shown on the California State geologic map (Jenkins, 1938) and have been described by Reed (1933). Considerable information is contained in the early report by Arnold (1907), and in the more recent summaries of the geology of local oil fields, such as the Ellwood oil field by Hill, the Goleta oil field by Vickery, and the La Goleta gas field by Swayze, and others (California Div. Mines Bull. 118, 1943, pp. 370–425). These reports deal almost solely with the consolidated rocks. Other reports dealing with unconsolidated water-bearing deposits are mentioned specifically, as also are individual acknowledgements for miscellaneous information from petroleum geologists, at appropriate places throughout the text.

STRATIGRAPHIC UNITS

AGE AND GENERAL FEATURES

Rocks and deposits exposed and penetrated by wells in the south-coast basins belong in the Tertiary and Quaternary systems, and are almost exclusively sedimentary. (See plates 1 and 2.) The rocks and deposits of the Tertiary system are continuous in the foothills and main ridge of the Santa Ynez Mountains, and discontinuous in the uplifted hills and terraces along the shore. They aggregate about 14,500 feet in maximum thickness, and are locally complexly folded and faulted. They are penetrated by only a few water wells, but by several oil-test wells. The deposits of the Quaternary system occur mainly beneath the alluvial plains and some of the bordering hills and terraces in the main ground-water basins. These deposits have a total maximum thickness of about 6,500 feet. All older formations are cut by faults which displace the Tertiary rocks, but Quaternary deposits are only slightly offset or otherwise deformed. The Quaternary deposits are penetrated by nearly all of the numerous water wells in the areas, and they yield essentially all the water used for irrigation.

Although the ground-water conditions and the occurrence of water differ somewhat in the two main coastal basins, the sequence of rocks and the geologic history are essentially the same. The following table gives the age and sequence of stratigraphic units that have been distinguished. For the most part, their definition and age are those given by Wilmarth (1938), and as summarized elsewhere under the direction of Gale (1932).

Stratigraphic units distinguished in the south-coast basins of Santa Barbara County, Calif.

	Geologic age	Unit and symbol on plates 1 and 2	Thickness (feet)	General character	Water-bearing properties
QUATERNARY	Recent.	Younger alluvium (*Qyal*).	0-250±	Unconsolidated clay, silt, and sand, with minor amounts of gravel. Underlies and forms the alluvial plains and extends as tongues into adjoining stream canyons.	Saturated with water below shallow depth, but generally yields water only moderately readily. Constitutes a confining bed throughout most of the alluvial plains.
		Unconformity			
	Pleistocene.	Terrace deposits (*Qt*), and older alluvium (*Qoal*).	0-250±	Unconsolidated clay, silt, sand, and gravel, partly alluvial and partly marine in origin. Caps terraces and underlies parts of the alluvial plains.	Terrace deposits generally above saturated zone, and mainly not tapped by wells; older alluvium yields small quantity of water to wells, mostly in the Goleta basin.
		Unconformity			
		Casitas formation (*Qc*).	0-4, 000±	Unconsolidated clay, silt, and sand, with local bodies of coarse, but poorly sorted gravel near mountains. Identified only in the Carpinteria basin, where it is continental in origin and red to buff in color.	Clay and silt predominate, so the beds yield only moderately to wells. However, it is tapped by most water wells in the Carpinteria basin and is the principal source of water.
		Santa Barbara formation (*Qsb*)	0-2, 000±	Unconsolidated clay, silt, and sand of marine origin, yellow-buff in color. Underlies most of the Goleta basin, but a small part of the Carpinteria basin.	Generally fine-grained, but sand beds are principal source of well water in Goleta basin. Tapped by few wells in the Carpinteria basin. Permeability about 70 g. p. d. per sq. ft. as determined by laboratory tests; and 100 g. p. d. per sq. ft. by well pumping tests.
TERTIARY	Pliocene.	Unnamed formation (*Tp*.)	0-1, 400	Compact mudstone and siltstone with some sand and limestone. Marine. Underlies part of the Goleta basin.	Not penetrated by water wells; probably very low permeability.
		Unconformity			
	Miocene.	Monterey shale (*Tm*).	1, 000	Consolidated marine mudstone, siliceous, and diatomaceous shale, and some limestone. Generally white to cream color.	Not penetrated by water wells in the basins. Elsewhere yields some water from fractured zones in siliceous parts.
		Rincon shale (*Tr*).	1, 700	Consolidated marine mudstone with some calcareous nodules. Fissile, and generally blue-gray in color.	Not penetrated by water wells; doubtless very low permeability.
		Vaqueros sandstone (*Tv*).	300-500	Medium to coarse sand, some clay and silt; marine. Sand generally well sorted.	Probably moderately permeable; fresh water obtained at shallow depth in one known well. Not explored as a water bearer.
	Oligocene and Eocene(?)	Sespe formation (*Ts*).	2, 600	Generally consolidated red shale and sandstone, some conglomerate at base. Continental. Sand fairly well sorted. Crops out in mountains and high foothills.	Not tapped by water wells, but has yielded large artesian flows to a few deep oil-prospect wells. Contained water, at least locally, is high in boron.
	Eocene.	Undifferentiated Eocene (*Tt*).	7, 300	Consolidated shale and sandstone in thick beds of marine origin. Composes main part of Santa Ynez Mountains.	Not tapped by water wells in the basin, but elsewhere the sand yields small artesian flows of fresh water mostly from fractures. Too deep for practicable exploitation in the basins, and water at depth may be of poor quality.

CONSOLIDATED TERTIARY ROCKS

The consolidated Tertiary rocks comprise undifferentiated Eocene deposits, the Sespe, Vaqueros, Rincon, and Monterey formations and the unnamed Pliocene formation. They are described briefly as follows:

UNDIFFERENTIATED EOCENE

Formations of Eocene age underlie a large area in the central part of the Santa Ynez Mountains. Present here are beds correlated with three units elsewhere distinguished (Kerr and Schenck, 1928, pp. 1090–1091) as the Matilija sandstone, Cozy Dell shale, and Coldwater sandstone, all of which were considered members of the Tejon formation by Kerr and Schenck. The sandstone correlated with the Matilija is moderately coarse, noncalcareous, poorly cemeted yellow to gray arkosic sandstone; the shale correlated with the Cozy Dell is noncalcareous, massive, dark olive-green to brown shale; and the sandstone correlated with the Coldwater is massive, thick-bedded, yellow to gray sandstone with intercalated clay beds. Their total thickness is about 7,300 feet. Outside the mapped area, these deposits rest without marked unconformity on shale presumed to be of Cretaceous age. The Eocene strata are overlain by the Sespe formation.

SESPE FORMATION (UPPER EOCENE? AND OLIGOCENE)

The Sespe formation underlies extensive areas on the south flank of the Santa Ynez Mountains and crops out in a few places along the north foot of "The Mesa." In the western Santa Ynez Mountains it is considered of doubtful late Eocene and Oligocene age. Elsewhere it is known to include deposits that range in age from late Eocene to early Miocene. It consists of alternating layers of red shale, red and grayish-green sandstone, and dark-red conglomerate—all of continental origin. Coarse sandstone predominates in the lower part where it alternates with red shale; alternating red shale and greenish sandstone characterize the upper part. A zone of coarse-grained conglomerate marks the base of the formation. The Sespe formation is about 2,600 feet in average thickness.

VAQUEROS SANDSTONE (LOWER MIOCENE)

The Vaqueros sandstone, of lower Miocene age, is exposed low on the south flank of the Santa Ynez Mountains. It also crops out in small bodies southwest of Santa Barbara and near the coast at Summerland. The Vaqueros is a medium to coarse, massive, calcareous marine sandstone, dirty white to yellow in color. It is quartzose, locally arkosic, and in places contains small grains of glauconite. At the base is a fossiliferous conglomerate zone. The formation varies somewhat in thickness, but averages about 350 feet. It is loose and porous where encountered in some wells and is the principal oil-bearer in the Ellwood field west of Goleta. At most places it lies too deep to be tested as a source of water in nonpetroliferous areas. The Vaqueros formation is unconformable, but without appreciable angular discordance, on the Sespe formation, and is overlain conformably by the Rincon shale.

RINCON SHALE (LOWER MIOCENE)

The Rincon shale of lower Miocene age crops out in a linear belt low on the south flank of the Santa Ynez Mountains and along the north margin of the Goleta basin, on the south coast on "The Mesa," and in hills near Summerland. It consists of massive, dark bluish-gray mudstone which develops a dark greenish-black mucky soil. It is characterized by discontinuous bands of ovoid calcareous concretions, usually limonitic, and yellowish-brown in color. The formation is about 1,700 feet thick. The Rincon shale conformably overlies the Vaqueros sandstone and is in turn conformably overlain by Monterey shale.

MONTEREY SHALE (MIDDLE AND UPPER MIOCENE)

Monterey shale crops out chiefly in the mesas and terraces along the coast in both the Carpinteria and Goleta basins where it overlies the Rincon shale and is in turn overlain with slight unconformity by the unnamed Pliocene formation and with pronounced unconformity by the Santa Barbara formation. These shales are lithologically similar to, and occupy about the same stratigraphic position as, the Monterey shale of the Santa Ynez River basin and the Santa Maria Valley (Woodring, Bramlette and Lohman, 1943). As here mapped they include the Modelo formation distinguished farther east (Woodring, 1932 and Kew, 1932, pl. 11), and also shale in the Goleta basin considered to be of Santa Margarita age and designated the Santa Margarita formation by some geologists.[1] These formations were not distinguished in the present work; hence the term Monterey shale is used.

The Monterey shale consists of thin-bedded, locally massive mudstone, diatomaceous shale, and hard siliceous shale. Some limestone occurs locally in the lower beds, as does also some volcanic material. Near Summerland the volcanic material is a coarse sandy tuff. In places these beds are highly contorted and fractured and locally are impregnated with tar. As encountered in wells and in fresh deep cuts, the shales are bluish gray, but generally they weather to a white or cream color, in places lightly stained with limonite.

[1] Baddley, E. R., personal communication, July 1946.

UNNAMED PLIOCENE FORMATION

The unnamed Pliocene deposits comprise a body of dark bluish-gray to dark olive-green, almost black, mudstone and siltstone that occurs in the Goleta basin. This body rests on the Monterey shale, and underlies the Santa Barbara formation. The contact with the Santa Barbara formation is not known to be exposed in the area, and the deposits may grade upward into that formation. They are separated here on the basis of general lithologic dissimilarity, and of the age of contained fossils. The deposits may be the equivalent of the Pico formation (Kew, 1932, p. 49 and pl. 11) recognized east of the Carpinteria basin, but the data presently at hand are considered an insufficient basis for a definite correlation.

The deposits are best exposed in the sea cliff in secs. 22 and 23, T. 4 N., R. 28 W. A section of the beds is given in the following table; the mudstone and stiltstone are illustrated in the accompanying photographs (pl. 3*A*).

Section of the unnamed Pliocene formation in beach cliff in secs. 22 and 23, T. 4 N., R. 28 W.

	Feet
Silt and fine sand, clay partings, compact, crudely stratified	50
Sand, white to gray, very fine to medium-grained, cross-bedded with strata 2 inches to 2 feet thick separated by partings of dark clay. Grades westward into a lense of fossiliferous gravel and coarse sand	33
Silt, or very fine sand, massive, mostly compact; dark bluish-gray; no contained megafossils	65
Silt, as above, with calcareous concretions as much as 1 foot thick and several feet long	6
Silt, as above, no contained megafossils	63
Conglomerate, with angular fragments of limestone	2
Silt, as above, no contained megafossils	101
Conglomerate with large angular blocks of limestone	10
	330

These beds are predominately massive mudstone and siltstone, but they contain a lenticular body of coarse sand about 300 feet above the base, and a 10-foot limestone conglomerate at the base (pl. 3, *B.*). The bulk of the formation contains only a few scattered megafossils, but a lens of beach gravel at the base of the sand body contains abundant fossils. A collection made from this lens by the writer was examined by Mr. Woodring,[2] who supplied the following faunal list and discussion thereof.

[2] Woodring, W. P., official communications, July 23, 1946 and Sept. 13, 1946.

Locality 15890. "Sea cliff about 2.5 miles southeast of Goleta."

Gastropods:

Calliostoma ligatum (Gould) ["*costatum* Martyn"].
Turritella cooperi Carpenter.
Bittium cf. *eschrichtii* (Middendorff).
Crepidula princeps Conrad.
Crepidula cf. *onyx* Sowerby.
Neverita cf. *reclusiana* (Deshayes).
Epitonium cf. *tinctum* (Carpenter).
Odostomia sp.
Mitra idae Melvill.
Neptunea cf. *tabulata* (Baird).
Calicantharus fortis (Carpenter) var. cf. *angulata* (Arnold).
Tritonalia cf. *foveolata* (Hinds).
Nucella cf. *lamellosa* (Gmelin).
Mitrella carinata (Hinds).
Mitrella carinata gausapata (Gould).
Amphissa cf. *versicolor* Dall.
Olivella biplicata (Sowerby).
Megasurcula carpinteriana (Gabb).
Elaeocyma cf. *empyrosia* (Dall).
Ophiodermella cf. *ophioderma* (Dall).
"*Drillia*" cf. *graciosana* Arnold.
"*Taranis*" cf. *inculta* (Moody).
Conus californicus Hinds.

Pelecypods:

Glycymeris sp.
Pecten cf. *hemphilli* Dall.
Chlamys cf. *hastatus* (Sowerby).
Cyclocardia cf. *ventricosa* (Gould).
Pachydesma cf. *crassatelloides* (Conrad).
Saxidomus cf. *nuttalli* Conrad.
Pseudochama cf. *exogyra* (Conrad).

Crepidula princeps, *Calicantharus fortis* var. cf. *angulata*, "*Drillia*" cf. *graciosana*, "*Taranis*" cf. *inculta*, and *Pecten* cf. *hemphilli* are not known to be living. The other forms are Recent species or are closely related to Recent species, much of the material being too incomplete for certain identification. The *Calicantharus* is more closely related to the Ventura Basin Pliocene form named the variety *angulata* than to the typical form of *fortis*, which occurs in Pleistocene formations, including the Santa Barbara formation. The incomplete left valves identified as *Pecten* cf. *hemphilli* probably represent that species, not the closely related Santa Barbara species *P. bellus*. A complete right valve, the only right valve that presumably is to be associated with the left valves just mentioned, is less inflated than *P. hemphilli* and *P. bellus*. In other characters, however, it more closely resembles *P. hemphilli*. *Crepidula princeps* occurs in formations ranging in age from Miocene to Pleistocene. The other two species mentioned as not known to be living appear to be closely related to late Pliocene forms.

The fossils from locality 15890 are considered of late Pliocene age, older than the Santa Barbara formation.

A, EXPOSURE OF MUDSTONE AND SILTSTONE OF THE UNNAMED PLIOCENE FORMATION.

B, BASAL CONGLOMERATE OF THE UNNAMED PLIOCENE FORMATION RESTING ON MONTEREY SHALE.

Somewhat similar deposits are exposed along the sea cliff southwest of Goleta, in sec. 24, T. 4 N., R. 29 W., and in the adjoining part of sec. 19, T. 4 N., R. 28 W. These deposits are composed of massive clay and mudstone in beds several feet thick alternating with equally thick beds of finely laminated clay. The color is dark blue gray to dark olive green, almost black. The beds contain only a few scattered fragments of megafossils. Along the shore the beds dip generally northward as much as 30°. Oil-prospect wells about half a mile to the north have encountered these beds, which are sufficiently compact to be logged as shale, and are known as blue shale. These deposits, on the basis of a scant fauna, are considered upper Pliocene by Aden Hughes[3] of the Union Oil Co., who tentatively correlates them with the Foxen mudstone of the Santa Maria district. The Foxen mudstone has been assigned to the middle (?) to upper Pliocene by Woodring (1943, pp. 1340–1355). As penetrated by these wells, the upper Pliocene deposits are about 1,400 feet thick.

The compact mudstone and siltstone of the unnamed Pliocene formation are essentially impermeable as exposed at the land surface. Also, the electric log of one well in sec. 24, T. 4 N., R. 29 W., shows features within the Pliocene interval that are nearly identical with those in the underlying Monterey shale. Therefore the formation is considered part of the impermeable, consolidated rocks.

The extent of the unnamed Pliocene formation to the east and north is not known as it has not been surely recognized in oil wells or in water wells, and as it is not known to be exposed. However, a few hundred feet of compact dark shale overlying reported Miocene shale penetrated by wells drilled in secs. 11 and 12, T. 4 N., R. 28 W., may be equivalent to this unit. Also, cores of material obtained at depths below 2,000 feet in a well near the central part of the alluvial plain and described as "gray and olive-gray, clayey, sandy siltstone," may also belong to this unit.

GENERAL WATER-BEARING CHARACTER OF THE CONSOLIDATED ROCKS

In general, the Tertiary rocks are consolidated and non-water-bearing in the sense that water in appreciable quantities ordinarily cannot be obtained from wells that penetrate them. However, where cut by faults and fractures, the rocks do yield water. For example, the Mission Tunnel of the city of Santa Barbara, driven in undifferentiated Eocene deposits has received seepage of water from faults and fractures at a rate of 1,000,000 to 2,000,000 gallons a day. Also, a well recently completed on the Hollister Ranch in Winchester Canyon west of Goleta obtains water in fractures in the Vaqueros

[3] Hughes, Aden, personal communication.

sandstone and has been pumped at a rate of 125 gallons a minute. Thus, at least at some places, water for small demands can be obtained from the standstones. A large yield, such as 500 or 1,000 gallons a minute, probably cannot be obtained from a well in any of the older rocks unless the well happened to encounter an especially open fracture or system of fractures. The shales probably will not yield more than a few gallons a minute to any well.

QUATERNARY DEPOSITS

The Pleistocene and Recent deposits comprise the Santa Barbara formation, the Casitas formation, several bodies of alluvial deposits, and marine and fluviatile terrace deposits including some wind-blown sand. These formations and deposits contain the principal water-bearing zones in the southern part of Santa Barbara County.

SANTA BARBARA FORMATION (PLEISTOCENE)

Definition and general features.—The term "Santa Barbara" was first used by Smith (1912, p. 169), and later by Gale (Grant and Gale, 1931, p. 35) who applied it in a zonal sense to exposures on Packard's Hill, Santa Barbara. The name "Santa Barbara beds" is commonly used among petroleum geologists for corresponding and presumably equivalent deposits in the Carpinteria and Goleta areas. Woodring (Woodring, Stewart, and Richards, 1940, pp. 110, 111) specifically applied the name "Santa Barbara" to "the marine formation exposed in the southwestern part of Santa Barbara", and also to deposits that contain similar fossils at Rincon Point in the southeastern part of the Carpinteria basin.

The Santa Barbara formation of this report comprises marine sand, silt, and clay, and has a total maximum thickness of about 2,000 feet; it underlies the alluvium and terrace deposits and rests unconformably upon the older rocks that range from Monterey shale at least down through the Sespe formation. In the Carpinteria basin it is believed to grade upward into continental beds which are here called the Casitas formation. It may be conformable upon or transitional with the unnamed Pliocene formation. It includes the deposits in the type region at Santa Barbara, and at Rincon Point, and also deposits beneath the Carpinteria and Goleta alluvial plain that are penetrated by wells. It occurs in the hills in the northeastern and southeastern parts of the Goleta basin, where its maximum thickness is about 1,000 feet, and east of Rincon Creek in Ventura County. In Ventura County it probably includes deposits called San Pedro by Bailey (1943, p. 1561).

In the prominent upland adjacent to Santa Barbara on the south known as The Mesa, which embraces the type locality, in the hills northeast and southeast of the Goleta alluvial plain, and also in the extreme eastern part of the Carpinteria basin, the Santa Barbara formation consists predominantly of moderately coarse to fine sand and silt occurring in uniform massive beds. The sand is generally medium-grained and is largely rounded quartz grains. Even the best-sorted sands contain some fine sand, silt, and clay. Silt occurs in fairly extensive beds, and clay, in exposures, is in thin discontinuous beds. The beds of sand and silt range in thickness from a few tens of feet to over 100 feet. Locally they contain scattered rounded pebbles and lenses of pebbles, but few persistent gravel zones.

A few fossil shells occur scattered throughout the formation, and locally in well-defined lenses. Some of these are thoroughly cemented by redeposited calcium carbonate and form resistant marl beds. One of these beds is a zone about 50 feet thick and is traceable nearly continuously throughout the hills in south and southwest Santa Barbara. It has a discontinuous gravelly zone near the bottom. Farther west the marl and gravel beds are discontinuous. The bulk of the formation as exposed is not fossiliferous, possibly because shells have been dissolved out by circulating ground water. The marine fossil shells proclaim the marine origin of the formation. However, certain thin red clay and sandy clay beds that crop out in the south side of the upper part of the hills in sec. 11, T. 4 N., R. 28 W., and which are interbedded with fossiliferous sand, may be remnants of a continental member or formation such as the Casitas formation of the Carpinteria basin.

Representative sections.—The accompanying sections show the characteristic features of the Santa Barbara formation in the type area.

Section of Santa Barbara formation exposed along West Valerio St., in Santa Barbara

	Feet
Sand, brown, calcareous	12
Silt, brown	50
Marl, silty, bryozoal; conglomerate lenses at base	40
Sand, white to yellow, unconsolidated, medium-grained, well-sorted	100
Sand, as above, but with shale or compact clay partings	40
Silt, calcareous, fossiliferous	10
	252

Section of Santa Barbara formation exposed along West Victoria St., in Santa Barbara

	Feet
Sand, coarse, brown, slightly cemented	60
Silt, brown	60
Silt, yellow and white, alternating with yellow to white sand containing iron-stained calcareous concretions and yellow to orange shale partings	60
Marl, silty, bryozoal	45
Silt, brown	15
Sand, white, medium-grained, well-sorted	10
Silt, brown, conglomerate lenses on local unconformity at base	20
Sand, yellow and white, fine-grained, cross-bedded	55
Silt, yellow, tough	40
Silt, with calcareous concretions	10
Silt, yellow, tough, fossiliferous near top	50
	425

As encountered in several water wells beneath the Goleta alluvial plain, the deposits contain a high proportion of silt and clay, evidently in fairly thick lenses.

There are no thick sections exposed within the Goleta basin, but for the extensive outcrop near the eastern end of the Carpinteria basin, a representative section is given in the following table.

Section of Santa Barbara formation exposed along former U. S. Highway 101 on west side of Rincon Creek in the NW¼SW¼ sec. 35, T. 4 N., R. 25 W.

	Feet
Clay, sandy, limy, very fossiliferous, yellow	49
Clay, bluish-brown	17
Clay, brown	2
Sand, brown	19
Sand, red, interbedded with orange and blue clay	11
Clay, fossiliferous, blue	11
Sand, very fossiliferous, brown	28
Sand, brown	19
Clay, blue; in thin beds, alternating with brown sandy clay	10
Sandstone, limy, very fossiliferous, brown; some shale inclusions 12 inches in maximum diameter	22
Sandstone, white	2
Clay, sandy, fossiliferous, brown; with rocks ¼-inch to 18 inches in diameter	5
Sandstone, fossiliferous, brown	3
Sand, fine, white with orange stains	5
Sandstone, hard, brown	18
Clay, sandy, brown	29
Concealed	23
Sand, brown; some clay; fossiliferous at base	143
Sand, fossiliferous, light brown	4
Clay, sandy, fossiliferous, brown	79
Concealed	26
Sand, fossiliferous, fine, hard, brown	2
Concealed	34
Clay, brown	35
	596

On the north side of the Goleta basin in the complexly faulted area in sec. 4, T. 4 N., R. 28 W., certain poorly exposed beds of reddish-colored clay, sand, and gravel are mapped with the Santa Barbara formation as remnants of a marginal continental facies, but may represent the Casitas formation of the Carpinteria area, or even the overlying older alluvium.

Age.—From fossils early collected in the type area, the Santa Barbara formation was held to be upper Pliocene, possibly in part lower Pleistocene (Arnold, 1907, p. 31). Bailey (1943, p. 1562) has suggested that lowermost beds in the Santa Barbara, as exposed in the Ventura region and which are characterized by a *Pecten bellus* fauna, may be upper Pliocene, and upper beds lower Pleistocene. Also, Grant (Grant and Hertlein, 1941, p. 202) considered that the so-called *Pecten bellus* beds of the Santa Barbara formation are uppermost Pliocene. Woodring (Woodring, Stewart and Richards, 1940, p. 111) placed the Santa Barbara formation in the lower Pleistocene, and that assignment is followed in this report.

CASITAS FORMATION (PLEISTOCENE)

Definition and general features.—The Casitas formation, here named, is a body of considerably deformed red continental deposits in the Carpinteria area which lies above the Santa Barbara formation and beneath overlying older alluvium, terrace deposits, and younger alluvium. It is well exposed along Rincon Creek and in the area of the junction of Rincon Creek with Casitas Creek, from which the formation is named. The deposits are nonfossiliferous and entirely continental in origin. If the underlying Santa Barbara formation is the equivalent of the Santa Barbara formation of Bailey (1943, pp. 1557–1560) in Hall Canyon near Ventura, then the Casitas formation is probably the equivalent of at least the upper part of Bailey's San Pedro formation in the Hall Canyon area, which the Casitas formation resembles lithologically. Although the outcrop area of the Casitas formation is shown in part on a general map compiled by Kew (1932, pl. 11), it is not identified on the map and apparently has not been described heretofore. Also, it is geographically isolated from the Ventura area. Accordingly, the writer considers the introduction of the new name justified.

The Casitas formation consists of clay, silt, sand, and gravel. In the lower part clay and silt in thin, fairly regular beds, predominate; but in the upper part, as exposed to the north and northeast, coarser-grained poorly sorted silty sand and gravel in lenticular ill-defined strata predominate. The sand grains, pebbles, and boulders are chiefly of Eocene sandstone, but in part of quartzite, jasper, and other rocks probably derived from conglomerates in the Sespe formation. The formation is predominantly red in color, probably because the contained silt and clay is derived in large part from the Sespe formation.

Representative sections.—The following sections indicate the characteristics of the Casitas formation.

Section of coarse-grained beds of the Casitas formation exposed along State Highway 150 on west side of Rincon Creek, in the NE¼ sec. 35, T. 4 N., R. 25 W.

	Feet
Clay, sandy, gray	1
Sand, hard, yellow	1
Sand, hard, gray	1
Cobbles and sand, interbedded and mixed	10
Sand, coarse, with pebbles, red	1
Cobbles	3
Sand, coarse, red	1
Cobbles and boulders in sand	8
Sandstone, coarse, red	2
Sand, medium-grained, with scattered cobbles, brown	10
Concealed	196
Clay, brown	13
Sand, fine-grained, brown	5
Concealed	25
Sand, fine-grained, brown	8
Cobbles	1
Sand, fine-grained, brown	6
Cobbles in brown sand	2
Clay, sandy, brown	3
Sand, medium-grained, brown	7
Clay, gray and brown	21
Sand, alternating fine and coarse strata, brown	16
Cobbles, sandy, hard	5
Sand, coarse, with pebble stringers, brown	2
Cobbles (average diameter 2 in.)	3
Sand, fine-grained, massive, brown	13
Sand, coarse with subangular to rounded pebbles, cobbles, and boulders ¼ inch to 2 feet in diameter	17
Clay, sandy with pebbles, cobbles, and boulders as above, brown	20
Total thickness of section	401

Section of fine-grained beds in lower part of Casitas formation exposed along Rincon Creek road in the SW¼NW¼ sec. 35, T. 4 N., R. 25 W.

	Feet
Sand, clayey, brown	10
Clay, red	2
Sand, clayey, brown	20
Sand, medium-grained, yellow	26
Sand with stringers of small pebbles, light gray	23
Sandstone, coarse, light brown	10
Clay, hard, with gypsum, light gray	7

Section of fine-grained beds in lower part of Casitai formation exposed along Rincon Creek road in the SW¼NW¼ sec. 35, T. 4 N., R. 25 W.—Continued

	Feet
Sand, coarse, brown	10
Clay, brown	1
Sand, hard, brown	2
Clay, gray	16
Clay, brown	6
Sand, clayey, hard, gray	3
Sand, brown	4
Clay, sandy, gray	4
Sand, hard, brown	1
Sandy, hard, gray	4
Clay, tough, brown	1
Sand, brown	1
Clay, brown	1
Sand, brown	5
Clay, brown	3
Sand, brown	1
Clay, brown	12
Clay, sandy, and sand, brown	7
Clay, brown	8
Total thickness of section	188

The formation is extensively exposed in the valley of Rincon Creek and also of Carpinteria and Gobernador Creeks. It lies beneath the Carpinteria alluvial plain and is tapped by most of the water wells in the eastern part of the plain. Continental deposits exposed along the shore at Summerland probably also belong to the Casitas formation. It is not known to occur elsewhere along the south coast, but the few continental beds in the Goleta area that are mapped with the Santa Barbara formation may belong to the Casitas formation. As seen in road cuts along the west side of the valley of Rincon Creek, the Casitas formation seems to be conformable upon the Santa Barbara formation. East of Rincon Creek, however, it evidently overlaps and cuts out the Santa Barbara formation, and rests on the Rincon shale and older formations. (See pl. 1.) Thus, it is unconformable on older formations at least at the margins of the Santa Barbara basin. Beneath Shepard Mesa the Casitas formation is about 1,000 feet thick, and may be more than 3,000 feet thick beneath the alluvial plain farther south. (See pl. 1.)

Age.—No fossils have been found in the Casitas formation. However, it is apparently unconformable on the Santa Barbara formation only locally and is deformed to about the same degree as that formation. Accordingly, it is here considered probably lower Pleistocene in age, though it may be middle Pleistocene.

TERRACE DEPOSITS (PLEISTOCENE)

The terrace deposits are thin veneers mainly of shore deposits that cap elevated marine terraces. At most places they consist of a basal layer of cobbles and boulders 1 to 5 feet thick containing shell fragments and resting unconformably on the worn surfaces of the older consolidated rocks, and an overlying body of beach or eolian sand with some alluvial clay and silt. The upper bodies range from about 30 feet to 50 or 60 feet in thickness. The most extensive of these bodies occur on the lowest marine terrace 50 to 150 feet above sea level, but small remnants and traces of such deposits also occur on higher benches. At most places, the deposits are too thin or inextensive to contain ground water, though at a few places they supply small domestic wells.

The age of these deposits varies. Those on the higher terrace remnants actually are older than the older alluvium, but the most extensive bodies are younger than the older alluvium. They are all older than the younger alluvium. In a cut along the Southern Pacific tracks about 11 miles west of Goleta, in alluvial deposits on a marine terrace, railroad workmen discovered a well-preserved lower jaw of a mammoth. This fossil has been identified by Phil C. Orr, Curator of Vertebrate Paleontology at the Santa Barbara Museum of Natural History, as *Archidiscodon imperator*, of Pleistocene age. Thus, even the latest terrace is Pleistocene in age.

OLDER ALLUVIUM (PLEISTOCENE)

The older alluvium comprises several separate extensive bodies of alluvial beds that were deposited by streams. They attain thicknesses of as much as 250 feet and are distinct from the younger alluvium of the alluvial plains. These bodies of older alluvium occur in the northern part of the Carpinteria basin, in the Montecito area, in the Santa Barbara area, and between Santa Barbara and the Goleta alluvial plain. The deposits rest unconformably on the Casitas formation, Santa Barbara formation, and older rocks, and are overlain by the younger alluvium.

The older alluvium consists of clay, silt, sand, and gravel in lenticular beds, generally red or yellow in color. Silt and silty sand beds predominate, but some are of clay and some are of clayey and silty gravel. They resemble much of the Casitas formation in the Carpinteria area, but in surface exposures they are distinguished by gentler dips. They are virtually indistinguishable in well logs.

The older alluvium has been warped locally by crustal movements, and in both the Carpinteria and Goleta basins it apparently was tilted slightly downward to the south prior to deposition of the younger alluvium. In the Goleta basin the older alluvium probably was eroded everywhere before the younger alluvium was deposited, but in the western part of the Carpinteria basin downwarping of the basin and deposition of the older and younger alluvium may have been a continuous process. In that area there seems to be no distinction in well logs between the younger and older alluvium.

As the older alluvium underlies the younger alluvium it is considered upper Pleistocene in age. In the Goleta area, in sec. 7., T. 4 N., R. 27 W., a fragment of a Pleistocene mastodon jaw was removed from these deposits by Phil C. Orr of the Santa Barbara Museum of Natural History, and identified by him as *Mastodon americanum* of Pleistocene age.

YOUNGER ALLUVIUM (RECENT)

The younger alluvium underlies and forms the main agricultural plains in the Carpinteria and Goleta basins, and the lowland landward from the beach in the Santa Barbara area. It extends as narrow tongues up the valleys of streams entering the lowlands. Except for narrow threads along the streams, it is absent from the Montecito district. A narrow body lies along Rincon Creek in the east end of the Carpinteria basin. The alluvium was deposited by streams initially graded to a lower stand of the sea, at least 200 and possibly 300 feet below present level, and accumulated as the sea rose about to its present position. In the Goleta basin its thickness ranges from a feather edge to about 225 feet. In the Carpinteria basin contemporaneous subsidence probably made the formation somewhat thicker beneath the western part of the plain.

The younger alluvium rests with marked angular unconformity on the Casitas formation and all older formations. It laps unconformably upon the older alluvium, but locally, as beneath the Carpinteria alluvial plain, may be transitional with it.

The younger alluvium consists mainly of fine-grained clay and silt and some sand, with local bodies of gravel at the base. Old residents in the Goleta basin recall sea water as much as 10 feet deep near the middle of the basin now filled with alluvium. Thus, the uppermost 10 to 20 feet of alluvium has been deposited within historic time. It is believed to have been deposited contemporaneously with the alluvium in the Lompoc area of the Santa Ynez River valley (Upson and Thomasson), and is considered of Recent age. The younger alluvium contains some water-yielding beds but is only a minor producer of ground water in the south-coast basins.

GEOLOGIC STRUCTURE

The geologic structures of the south-coastal part of Santa Barbara County consist mainly of the anticlinal arch of the Santa Ynez Mountains together with several minor folds, and a number of large faults with associated minor faults. The faults are considered to be younger than the folds, and have a more profound effect on the ground water. They are shown on the geologic maps and geologic cross sections, plates 1 and 2. In all areas these faults to a large extent determine the distribution of the water-bearing deposits; in the Goleta basin those that cut the water-bearing Santa Barbara formation locally inhibit the movement of ground water.

Many of the faults are poorly exposed, and much of the knowledge concerning them is derived from data on oil wells in the district. Much remains to be learned about them; and some information can be discovered only by additional drilling. Most of the faults in the Goleta basin were described by Mason Hill (1932) who made careful studies of the amount and direction of their displacement. Where named, the terms used are those applied by Hill. For the most part these faults were identified in the present investigation; and some have been extended beneath the alluvium on the basis of water-level discontinuities and other hydrologic data. (See pp. 27 and 95.)

Most of the faults occur within 3 miles of the shore. The main faults trend westward or somewhat north of west at a slight angle with the shore. Hill (1932, pp. 542–543) concluded that the horizontal component of displacement on the faults in the Goleta area is greater than the vertical component. Possibly the same is true of those in the Carpinteria area. Along most of the faults, however, the vertical component of displacement is large, with the south side being upthrown. The faults apparently slightly displace the terrace deposits and older alluvium at least in the Carpinteria basin, and displace the Santa Barbara and Casitas formations by several thousand feet. Therefore, the major movements occurred in the middle or late Pleistocene, though movement on some of them probably began in the early Pleistocene, or in the Pliocene. Recent earthquakes suggest that movements are still occurring in the area.

In regard to their effect on the distribution of water-bearing deposits, the principal faults are those beneath and south of Carpinteria (pl. 1), the Mesa fault in the Santa Barbara district, and the More Ranch fault in the Goleta area. Along a part of the extent of each of these faults, consolidated rocks are raised above sea level. Where this condition exists, the consolidated rocks effectively seal the water-bearing deposits from sea water.

The faults beneath Carpinteria extend into the Carpinteria basin from east of Rincon Creek. Vertical displacement on the southern of the two faults is at least 3,000 feet, as a well drilled in the extreme southern corner of Carpinteria is reported to have passed from shale into unconsolidated fossiliferous sand and silt at a little more than that depth. Also, a little to the northwest, the Western Oil Royalies Limited well 1 (4/25–29M1,[4] table 16) penetrated unconsolidated material to a depth of 2,023 feet without encountering consolidated rocks.

Similarly in the Goleta basin, along the More Ranch fault, the Santa Barbara formation is down-dropped on the north to depths of 2,000 feet or more, whereas Monterey shale lies above sea level on the south side of the fault. This fault apparently continues eastward and is thought to end against the Mesa fault of Willis (1925), which elevates consolidated rocks southwest of the city of Santa Barbara.

Faults that in themselves inhibit the movement of ground water also occur along the north side of the Goleta basin, where they cut the water-bearing Santa Barbara formation. Perhaps by cementation or by offset of permeable strata, or both, these faults have created zones of low permeability which greatly retard the movement of ground water. These faults include extensions of the Carneros and Glen Anne faults of Hill, as well as the Goleta fault and the Modoc fault named here. The geologic cross section, plate 2, shows the approximate displacements along these faults and their relation to the Santa Barbara formation. The evidence for extending the faults named by Hill and for mapping the Goleta and Modoc faults consists of large differences in water level in wells on opposite sides of the faults, and of lack of transmission of pumping effect across the inferred faults.

For example, it is reported that when the pump is operated in well 4/28–4R4 on the north side of the Goleta fault the water levels in other wells on the north side decline, but the water level in well 4/28–9A3 on the south side does not. All these wells penetrate the Santa Barbara formation. Water-stage recorders were operated for several months during 1945 in wells 4/28–12L4 and 4/28–12P1 on the north and south sides, respectively, of the Modoc fault. When well 4/28–12L3 (north of well 4/28–12L4) was pumped the water level declined in nearby well 4/28–12L4 on the same side of the fault, but no effect was observed on the water level in well 4/28–12P1. Similarly, when well 4/28–12P2 was pumped the water level declined in 4/28–12P1 on the same side of the fault, but no effect was observed on the water level in well 4/28–12L4. Thus, a highly impermeable

[4] For description of well-numbering system, see page 7.

barrier is inferred to exist between the two wells, each of which penetrates the Santa Barbara formation. It is inferred that the impermeable barrier is a fault zone and the Modoc fault is postulated. The position of the fault elsewhere is based in part on alinement parallel with the water-level contours (pl. 9) and in part on a report by Willis Hughes, formerly a water-well driller in the area, as to material penetrated in two abandoned wells in the SE¼SW¼ sec. 2, T. 4 N., R. 28 W. One of these is said to have encountered consolidated rocks at a depth of 100 to 150 feet; the other, 20 feet farther west, is said to have penetrated over 400 feet of material so unconsolidated that drilling was accomplished with a small water jet. The fault is drawn as shown on plates 2 and 9, with an inferred downward displacement of at least 250 feet on the south side. Water levels on the north side of the Modoc fault at the east end are about 100 feet higher than on the south side, and similar differences in water level occur on opposite sides of the other faults. These differences are discussed at greater length on page 95.

GEOLOGIC HISTORY

Following the long period of marine and continental deposition from Eocene through Miocene time, during which the undifferentiated Eocene deposits, and the Sespe, Vaqueros, Rincon, and Monterey formations were laid down, the rocks began to be arched upward to make the large anticlinal fold of the Santa Ynez Mountains. Thus began the complex crustal deformation that later resulted in the localization of the ground-water basins along faults. Possibly this arching was accompanied by early displacements on the faults, but the principal displacements came later.

As a result of the folding the sea retreated from the area, and during the early Pliocene erosion ensued, exposing rocks at least as old as Eocene. With return of the sea later in the Pliocene, mud and silt accumulated to a thickness of at least 1,400 feet—the unnamed Pliocene formation. Possibly deposition was continuous into the early Pleistocene with only a gradual increase in coarseness of the material laid down. At first, clay and silt were laid down, perhaps only in protected places, but later sand and sandy silt predominated. The coarse-grained material was composed largely of debris worn from the Oligocene and Eocene rocks. The resulting deposits, the Santa Barbara formation, accumulated to a thickness of about 2,000 feet. Early movements on the coastal faults doubtless occurred during the deposition, and may have in part provided subsiding basins for the thick local accumulations.

Near the close of this marine deposition, perhaps in the middle

Pleistocene, further general uplift occurred. In the early stages of the uplift the coast began to be elevated above the sea, and streams flowing from the north and east laid down continental deposits, which became the Casitas formation. Remnants of this formation exist mostly in the northeastern part of the Carpinteria basin and westward along the shore to a little beyond Summerland. The beds may once have extended farther west, but their presence is not surely known.

This period of continental deposition was ended by major movements on the faults, which displaced the Casitas and Santa Barbara formations by several thousand feet. The older formations were once more folded and faulted, and at places overturned. These movements, by uplifting the consolidated rocks, determined the approximate extent, shape, and depth of the ground-water basins.

Subsequent events are rather obscure, as they involve the complicated interplay of general crustal movements, independent fluctuations of sea level, and some renewed movement along the faults. At some time or times during these events the continental deposits that became the older alluvium were laid down. The coastal area was again submerged by the sea in late Pleistocene time as indicated by remnants of benches and marine shore lines at higher levels. Benches, accordant summits, and bodies of terrace deposits occur at several levels from about 75 feet to 1,000 feet or more above present sea level. Some of the levels may result from local deformation; others doubtless represent halts in the retreat of the sea from higher levels. At each of the levels deposits were formed which usually consist of a veneer of beach gravel and sand at the base, and fluviatile sand and gravel above. At places the basal marine deposits are absent as a result of nondeposition or subsequent removal, and from the higher levels nearly all traces of terrace deposits have been removed. Small remnants of the thin deposits on benches and summits are in part marine and are called terrace deposits.

In the late Pleistocene, further movements on the faults tilted the older alluvium somewhat in the Carpinteria and Goleta basins so that the deposits now slope as much as 8°, and their seaward parts are buried by younger deposits. Following the successive lowering of sea level and deposition of the terrace deposits, the sea fell to a level at least 200 and possibly 300 feet below its present level, probably in the late Pleistocene and inferentially at the time of the maximum advance of glaciers of the Wisconsin stage elsewhere on the continent. In the Goleta basin streams excavated valleys graded to the lowered sea level and cut a single narrow gap through the consolidated rock barrier south of Mescal Island. Another smaller gap was cut about

3 miles farther west, perhaps by a stream flowing south from Glen Anne Canyon. In the Carpinteria basin, because of probable continuous access of the sea, and intermittent subsidence of the basin along the main coastal faults, conditions of deposition evidently prevailed throughout late Pleistocene time.

After the valleys had been excavated, the sea readvanced, probably in Recent time, and the valleys were backfilled with alluvial flood plain and swamp deposits, predominantly mud and silt. Locally linear bodies of sand and of gravel were laid down in the stream channels. This material is the younger alluvium. In the Goleta basin it is distinct from the older alluvium, but beneath the Carpinteria alluvial plain it is evidently continuous with the older alluvium. Conditions of deposition in the coastal basins have continued virtually up to the present time.

SURFACE-WATER RESOURCES

By H. G. Thomasson, Jr.

INTRODUCTION

GENERAL FEATURES OF THE DRAINAGE AREAS

The south-coast basins of Santa Barbara County constitute the lowest parts of two main drainage areas. The eastern of the two includes the drainage areas of Rincon, Gobernador, and Carpinteria creeks, and Arroyo Parida, Franklin, Santa Monica, and Toro Canyons, which flow into or across the Carpinteria basin of this report. The western includes the drainage areas of Atascadero, San Antonio, Maria Ygnacio, San Jose, and Carneros Creeks, and Glen Anne and San Pedro Canyons which flow into or across the Goleta basin (p. 9). Between these two drainage areas are several streams which drain the Santa Barbara-Montecito area, and whose runoff is not directly pertinent to this report. The over-all length of these drainage areas from east to west is about 25 miles, and the width ranges from 3.5 to 7 miles. Within this narrow area the land rises from sea level to 3,000 to 4,000 feet at jagged crest of the Santa Ynez Mountains.

The two stream drainage areas, which respectively include the Carpinteria and Goleta basins, each comprise three parts: a mountainous headwater area, the principal area of surface-water runoff; the marginal part of the ground-water basin proper, underlain to considerable depth by unconsolidated water-bearing deposits that can absorb stream runoff; and the central lowermost part of the ground-water basin, also underlain by unconsolidated deposits but having impermeable beds near the land surface.

Bordering each ground-water basin, the rugged headwater area extends from the top of the mountains to the upper edge of the unconsolidated deposits, and is underlain by consolidated rocks at depths commonly less than 3 feet. The rocks are described in the foregoing part of this report (see pp. 12–29); the area is here termed the area of consolidated rocks. In the Carpinteria drainage area it is entirely covered with brush, but in the Goleta drainage area the brush is replaced by grass at the lower altitudes.

The marginal parts of each ground-water basin adjacent to the areas of consolidated rocks extend along the base of the mountains and are underlain by unconsolidated deposits ranging in thickness from a few feet to as much as 1,000 feet. These areas are partly brush-covered, partly grass-covered, and partly under cultivation. The underlying deposits have been described briefly in the section on geology and are more fully described in subsequent pages in relation to the occurrence of ground water. (See pp. 54–57.) The deposits receive water partly by direct infiltration of rain and partly by seepage from the streams. Thus, though there is some runoff from these areas in times of heavy rains, they are the only areas in which appreciable recharge to the ground-water bodies occurs. Therefore, they are designated as recharge areas.

Finally, the central parts of each ground-water basin, though underlain by unconsolidated deposits to depths of as much as 2,000 feet, have impermeable beds near the land surface. As discussed in later paragraphs (pp. 54 and 85), these beds create confining conditions which prevent the downward movement of water to underlying ground-water bodies. They are termed the areas of confined water.

Thus, in summation, the areas of consolidated rocks afford nearly all the runoff; in the areas of recharge, part of this runoff is absorbed and transmitted to the ground-water bodies; and in the areas of confined water, runoff is not absorbed. but wastes to the sea. The size and relationships of each of these areas in the respective ground-water basins are shown on plates 4 and 5; characteristics of runoff and the amount of recharge from the streams to ground water in each basin are discussed in detail in subsequent paragraphs.

PRECIPITATION

The source of all water supplies in the south-coast basins of Santa Barbara County, exclusive of that imported by man, is rainfall in the area. The rainfall characteristics of the area are therefore prime factors in the study of native water resources. Monthly records of precipitation at three stationsare presented in table 1, and complete records of rainfall at the main stations in the County have been given in the report on the Santa Ynez River basin. (Upson and Thomasson, 1951). Precipitation within the area varies considerably from year to year and within each year, and also varies greatly with altitude.

Seasonal and yearly variation.—At Santa Barbara, about 85 percent of the yearly rain falls between December 1 and April 30, and only about 2 percent falls in June, July, and August. With respect to yearly variation at Santa Barbara, where rainfall has been measured since 1868, the 77-year average is 18.40 inches but the least yearly amount of record was 4.49 inches in 1876-77, and the greatest was 45.25 inches in 1940–41. In other words, the range has been between 24 and 246 percent of the average. Between these extremes the yearly rainfall has fluctuated in rude "cycles" with a period of about 30 years each.

Variation of precipitation with altitude.—At lower altitudes precipitation is entirely in the form of rain. Light snow occasionally falls along the crest of the mountains, but it usually disappears in one or two days and it is never an important factor in stream runoff. In any single year the amount of precipitation at the seashore differs considerably from that at the top of the Santa Ynez Mountains. As pointed out in the report on the Santa Ynez basin, the variation in rainfall is due to the presence of the 3,000-foot to 4,000-foot Santa Ynez Moutains and their influence on storms traversing this part of the Pacific Coast. At numerous places along the south coast rainfall has been measured at the lower altitudes, but there are few factual data available for the higher altitudes. The longest record is at Santa Barbara at a station 130 feet above sea level, and the next longest record is at San Marcos Pass, 9 miles northwest of Santa Barbara, at an altitude of 2,225 feet. The latter is the only record of any length at a high altitude in the south-coast area.

From studies made of the storm of February 27 to March 4, 1938 (Troxell, 1942, pp. 48–49) it was found that a fairly straight-line relation existed between precipitation and altitude. For that particular storm, the increase in amount of precipitation on the front side of the mountain ranges of southern California was about 3 inches for each 1,000 feet increase in altitude. In regard to long-term rainfall on the south slope of the Santa Ynez Mountains, the 16-year average for the period 1928–29 to 1943–44 is 19.10 inches at Santa Barbara and 32.37 inches at San Marcos Pass. Thus, for the 16-year period the average rainfall at San Marcos Pass is 170 percent of the rainfall at Santa Barbara. As discussed in the Santa Ynez basin report (Upson and Thomasson, 1951), estimates of rainfall and runoff in that river basin during the 16-year period 1928–29 to 1943–44 agreed closely with 50-year and 75-year estimates by other agencies.

Because the rainfall station on San Marcos Pass is about 1,700 feet lower in altitude than the average mountain crest back of the Carpinteria basin and about 800 feet lower in altitude than the average crest back of the Goleta basin, it is conservative to consider 175 to 200 percent as the ratio of average yearly rainfall at the crest above the Carpinteria and Goleta basins to the corresponding rainfall at Santa Barbara. That is, the average yearly rainfall at the top of the mountains may be as much as 35 inches. Further, on the basis of altitude-rainfall relations and study of topography, 125 percent is selected as the approximate ratio between the average yearly rainfall on the entire runoff areas above the Carpinteria and Goleta basins and that at Santa Barbara. This ratio yields 23.0 inches a year as the 77-year average rainfall on the areas of consolidated rocks, or 23.9 inches a year for the 16-year period 1928–29 to 1943–44.

Long-term average rainfall on the recharge areas of the basins is considered to be only slightly greater than that at Santa Barbara because those areas are at relatively low altitudes—all below about 1,000 feet at the maximum.

Long-term average rainfall on the areas of confined water is believed to be closely represented by the rainfall record at Santa Barbara. A short rainfall record at Carpinteria Union High School (table 1) varies somewhat from the Santa Barbara record from year to year but the average precipitation at that station for the past 6 years has been only 11 percent less than that at Santa Barbara for the corresponding period. Likewise a record at the Goleta Lemon Association packing house at Goleta (table 1) for the past 8 years shows precipitation only 2 percent more than that at Santa Barbara during the same period. Measured rainfall at Goleta has been somewhat more consistent with that at Santa Barbara than has rainfall at Carpinteria. However, it too shows the usual spread in individual observations which seems to be present in all records of precipitation.

GAGING-STATION RECORDS OF RUNOFF

The Carpinteria and Goleta basin drainage areas range from steep rocky brush-covered mountain slopes to intensively cultivated alluvial coastal flats. Runoff varies widely within the areas and from year to year. Flash floods concurrent with rainstorms and progressive depletion through the dry season of summer and autumn are characteristic. The streams are all short and have small individual drainage areas. Although many of them have small flows at the lower edge of the consolidated rocks throughout most years, none of them is perennial across the valley floors or coastal flats. The capacities of

TABLE 2.—*Measured runoff, in acre-feet, of three streams along the south coast of Santa Barbara County, Calif., in the water years 1941–45*

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

Water year	October	November	December	January	February	March	April	May	June	July	August	September	Total
Carpinteria Creek near Carpinteria (13.8 square miles)													
1940–41				689	1,840	3,570	2,930	543	194	137	31	26	[1] 9,960
1941–42	10	5.0	103	39	15	34	97	13	0	0	0	0	316
1942–43	.06	.02	.4	3,990	685	1,410	220	35	1.8	0	0	0	6,340
1943–44	.04	0	23	3.0	850	762	34	7.5	.1	1.3	.2	0	1,680
1944–45	.2	119	3.8	0	654	197	29	0	0	0	0	0	1,000
Atascadero Creek near Goleta (18.3 square miles)													
1941–42	0	0	96	14	2.4	26	82	0	0	0	0	0	200
1942–43	0	0	0	3,040	744	1,040	53	.9	0	0	0	0	4,880
1943–44	0	0	49	7.1	1,570	627	15	10	1.4	.3	.4	.4	2,280
1944–45	0	73	0	.6	1,020	178	11	.8	7	.08	0	0	1,290
San Jose Creek near Goleta (5.5 square miles)													
1940–41				1,160	1,870	2,250	1,480	165	82	51	35	29	[1] 7,120
1941–42	23	27	228	84	29	43	247	48	14	8.9	3.6	9.7	765
1942–43	12	19	23	1,810	361	556	97	45	15	15	5.9	6.9	2,970
1943–44	13	12	61	25	520	319	46	41	16	7.3	5.5	4.9	1,070
1944–45	11	222	29	31	408	110	41	25	5.0	6.2	.4	.9	890

[1] Period January 1 to September 30, 1941.

present diversion facilities exceed the summer and autumn flows of all the streams at the lower boundary of the consolidated rocks.

Gaging stations equipped with continuous water-stage recorders have been operated since 1941 on Carpinteria Creek in the Carpinteria basin and on San Jose Creek and Atascadero Creek in the Goleta basin. Table 2 shows monthly and yearly measured runoff, in acre-feet, from the drainage areas above the gaging stations. From June 24, 1916, to August 23, 1923, a fragmentary record had been obtained on Gobernador Creek, 1,000 feet below the confluence of Eldorado and Steer Creeks and within the area of consolidated rocks adjacent to the Carpinteria basin, but as this record is not complete it is not included in the tabulation. In addition to the continuous records, numerous miscellaneous measurements and estimates of discharge have been made since 1943 on all streams in connection with seepage-loss studies in the present investigation. (See pls. 4 and 5.)

The records of daily flow at the continuous gaging stations and the discharge measurements made at miscellaneous sites along the streams are not included in this report. They may be found in the regular series of water-supply papers entitled Surface Water supply of the United States, part 11, Pacific slope basins in California, which are published annually by the Geological Survey.

SURFACE-WATER RESOURCES OF THE CARPINTERIA BASIN

GENERAL FEATURES

From Rincon Creek on the east to Toro Canyon on the west, the entire drainage area tributary to the Carpinteria basin is a wedge-shaped area roughly 9 miles long from east to west, 7 miles wide at the east end but tapering to less than 4 miles wide at the west end. Plate 4 shows the drainage area, the hydrologic subdivisions previously discussed (p. 30), and the location of stream-gaging sites and the Carpinteria rain gage. The area includes approximately 49 square miles as follows: brush-covered mountain slopes comprising the area of consolidated rocks, about 37 square miles; the recharge area, about 7 square miles; and the area of confined water, about 5 square miles.

The area is drained by six roughly parallel stream systems, which extend from the crest of the Santa Ynez Mountains to the ocean, and also by one small stream in Franklin Canyon, which heads in the foothills and crosses the coastal plain. The areas above the lower boundary of the consolidated rocks drained by each of the six streams are given in the following table.

Drainage areas upstream from the lower boundary of consolidated rocks for streams tributary to the Carpinteria basin

Name of stream	Area included	Drainage area (square miles)
Rincon Creek	Above upper bridge on Highway 150 (includes Casitas Creek).	12.9
Gobernador Creek	Above consolidated rock boundary	7.3
Carpinteria Creek	do	4.6
Santa Monica Canyon	do	3.5
Arroyo Parida	Above State Highway 150	3.7
Toro Canyon	do	1.4
Total measured area		33.4
Drainage area above consolidated rock boundary not included in above areas (estimated)		3.6
Total area of consolidated rocks		37

Downstream from the area of consolidated rocks each stream crosses the recharge area, which is about ½ to 1½ miles in width, and all but Rincon Creek and Toro Canyon cross the area of confined water. (See pl. 6.) Rincon Creek crosses the east end of the recharge area, and flows into the ocean through a notch in the consolidated rock barrier that separates the east end of the Carpinteria basin from the ocean. The creek in Toro Canyon flows to the ocean west of the area of confined water. With respect to the total quantity of water available for direct use, and also the seepage to the ground-water bodies within the recharge area, the amount and duration of runoff at the lower boundary of the area of consolidated rock is critical.

Stream-flow records in the area are meager. The fragmentary record from June 1916 to August 1923 on Gobernador Creek, above the consolidated rock boundary and above any diversion, consisted of occasional gage readings with corresponding mean daily discharges on those days. The record for Carpinteria Creek near Carpinteria (at Highway 150 and about 400 feet downstream from the mouth of Gobernador Creek) is continuous since January 1941, but it is short and covers a period of predominantly wet years so that long-term estimates of runoff cannot be made from it. Nevertheless, it is the only record available on which estimates of runoff from the entire area of consolidated rocks can be made.

RUNOFF FROM AREA OF CONSOLIDATED ROCKS

MEASURED RUNOFF FROM CARPINTERIA CREEK DRAINAGE BASIN

The total drainage area above the Carpinteria Creek gaging station is 13.8 square miles. About 12 square miles of this is within the area of consolidated rocks and the remainder is largely in the recharge area. Included in the area of recharge is a closed basin area of 0.74 square mile, which drains into a small intermittent lake three quarters of a mile southeast of the gaging station; storm waters from this lake are pumped into the stream channel above the station. Low-water discharges at this station are materially affected by seepage losses and diversions above the station. Such losses, however, are very small compared with high-water flows. Owing to the flashy character of the stream, most of the total seasonal runoff occurs within short periods of high flow. The gaging-station records therefore do not accurately show the low-water characteristics of the basin, but they are fairly representative of total seasonal runoff from year to year. Table 3 contains quantities of yearly runoff in acre-feet, acre-feet per square mile, and inches of depth, measured at the Carpinteria Creek gaging station at Highway 150. The figures shown are less than true runoff by the amounts of seepage loss plus diversions above the gage.

TABLE 3.—*Measured runoff of Carpinteria Creek at gaging station at Highway 150, in the 5 water-years 1941–45*

Water-year	Runoff		
	Acre-feet	Acre-feet per square mile	Inches of depth
1940–41	[1] 9, 960	722	13. 54
1941–42	316	23	. 43
1942–43	6, 340	459	8. 61
1943–44	1, 680	122	2. 29
1944–45	1, 000	72	1. 35

[1] The 9-month period January 1 to September 30, 1941.

SUMMARY OF RAINFALL-RUNOFF OBSERVATIONS, BY YEARS

Year 1940–41.—As shown in table 3, surface flow past the Carpinteria Creek gaging station for the 9-month period January 1 to September 30, 1941, was 9,960 acre-feet, which was 722 acre-feet per square mile, or a depth of 13.54 inches over the drainage basin. During this 9-month period, 35.15 inches of rain was recorded at Santa Barbara, 35.23 inches at Goleta, and 28.65 inches at Carpinteria. During the first 3 months of that water year, between October 1 and December 31, 1940, rainfall at the same three sites was as follows: 10.10 inches at Santa Barbara, 10.85 inches at Goleta, and 10.22 inches at Carpinteria. Thus, total rainfall during the water-year 1940–41 was 45.25 inches at Santa Barbara, 46.08 inches at Goleta, and 38.87 inches at Carpinteria. No records of runoff at the Carpinteria Creek gage prior to January 1, 1941, are available. However, because most of the 10 inches of rain prior to that date fell during the latter half of December, it is assumed that there was some runoff. Total yearly flow past the gage was therefore slightly in excess of 10,000 acre-feet, or about 14 inches of depth over the drainage basin above the gage.

The ratio between average rainfall on the area of consolidated rocks and average rainfall at the coast has been inferred to be 125 percent (see p. 33); this would suggest that 50 to 55 inches of rain fell on the area above the gage during the year. Subtracting the 14 inches of measured stream runoff leaves 35 to 40 inches of water that did not reach the gage. This quantity is accounted for as seepage loss and diversion from the stream channel, evapotranspiration losses from the drainage area, and water retained in the drainage area.

Based on subsequent measurements of stream flow made simultaneously at the places where the two tributary streams leave the consolidated rock and at the gage, it is estimated that possibly as much as 1,000 acre-feet, or a depth of more than an inch over the drainage basin, may be accounted for as seepage loss and diversion from the stream channel during the year. The unaccounted-for balance of water is then 34 to 39 inches.

A large part of this balance may have been consumed by vegetation. Studies in the Santa Ana River valley (Blaney, 1930, p. 54) in the 3 years ending June 30, 1928–30,

> indicate that at least 19 inches of seasonal rainfall is necessary before any material amount of water will penetrate below the root zone of the brush on the valley floor. A seasonal rainfall of less than 19 inches is usually consumed by the brush cover before any portion of it reaches the ground water.

The studies furnished evidence that evapotranspiration losses might exceed 19 inches considerably if additional water were available. For example, table 27 of Blaney's report shows that of 32 inches of natural and artificial rain supplied to one test plot during 1927–28, 27 inches was lost by evaporation and transpiration and only 5 inches penetrated below the root zone. Other writers (Sopp, C. W., in Sonderegger, 1930, p. 1276; Rowe, W. P., in Sonderegger, 1930, p. 1278) suggest that 30 to 36 inches may be lost by evaporation and transpiration, if available. Experimental data supporting any maximum rate of loss are not known to be available at this time.

Several factors complicate the application to the Carpinteria area of the results of studies made elsewhere, such as those for the Santa Ana Valley. For one thing, the climate in the Santa Ana Valley is warmer and drier than the local climate. Furthermore, those experimental data were obtained from brush plots on debris cones where the unconsolidated deposits are much deeper than the penetration of the brush roots. Root activity was observed 16 feet below the land surface in a shaft and in soil samples.

In contrast, in the area of consolidated rocks bordering the Carpinteria basin the soil is very thin. The underlying rocks are similar to those classified as the "sandstone-shale group" in a flood survey report on the Santa Ynez River basin by the United States Forest Service.[5] According to that report the soil on this rock group in the Santa Ynez River basin is from 6 inches to 2 or 3 feet deep. Furthermore, the water-storage capacity of this soil mantle at field saturation is 1 to 5 inches, which in itself is small but the water-storage capacity of the underlying rocks is given as 15 inches on the average, and more than 36 inches for some of the sandstone bodies.[6]

Because similar rocks underlie most of the consolidated rock area adjacent to the Carpinteria basin the water-storage capacities, expressed as inches of depth, are probably about the same. Accordingly, after runoff, seepage loss, and diversions have been deducted from total rainfall for 1940–41, the 34 to 39 inches of precipitation that remain may easily be accounted for as evaporation, transpiration, and water in storage at the end of the year. Undoubtedly evaporation and transpiration consumed the greater part of it, but some water was still in storage at the end of the year, as indicated by flow at the Carpinteria Creek gage as late as November 17, where flow normally ceases early each summer.

A small part of the rainfall probably penetrated deep into the fractures in the unweathered rock and was lost to vegetation and stream flow. There is no basis on which to estimate the quantity of water penetrating beyond the reach of vegetation. Such contribution does take place, however, because considerable water was encountered in joints and fractures throughout the 20,000 foot length of Mission Tunnel through the Santa Ynez Mountains, when it was drilled about 30 years ago by the city of Santa Barbara. Total seepage into the tunnel, about 1,000 feet above sea level, was 5 to 6 second-feet at first, but it has declined to 1 to 1½ second-feet at the present time.

Year 1941–42.—The water stored at the end of a wet year such as 1940–41 might be expected to produce a disproportionately high runoff during succeeding years. Such, however, is not the case in the Carpinteria Creek drainage basin. The 1941–42 water year was below average in rainfall, with 12.86 inches at Santa Barbara, 14.93 at Goleta, and 13.94 at Carpinteria, and the estimated average on the Carpinteria Creek drainage basin was about 16 inches. Rainfall was rather uniformly distributed throughout the season and the total was well within the suggested requirements of the native vegetation. Absence of any great amount of runoff from ground

[5] United States Forest Service, Runoff and water-flow retardation and soil-erosion prevention for flood-control purposes in the Santa Ynez River basin, Calif.: pp. 8 and 12 and table 5, typed Survey Report in the files of the U. S. Dept. Agr. Forest Service, 1942.

[6] Op. cit., tables 6 and 7, and Appendix 8, p. 5.

water held over in storage from the preceding year is suggested by the fact that the total measured runoff past the gaging station that year was only 316 acre-feet, 23 acre-feet per square mile, or 0.43 inch in depth over the basin. Seepage loss and diversions from the channel augment this figure slightly, but by less than 1 inch of depth. Therefore the hold-over storage in the soil and in rock fractures from 1940–41, plus about 14 or 15 inches of the rainfall during 1941–42, probably was consumed in 1941–42.

Year 1942–43.—The relatively high runoff from the Carpinteria Creek drainage basin in the water year 1942–43 (table 3) was due primarily to the fact that nearly half of the rain fell in a 3-day storm. Total yearly rainfall (table 1) at Santa Barbara was 24.34 inches, or about 132 percent of the long-term average; at Goleta it was 21.16 inches, and at Carpinteria 18.74 inches. Estimated average rainfall on the drainage basin during the year was about 25 to 30 inches. The storm of January 21–23 produced 10.91 inches of rain at Santa Barbara, and almost two-thirds of the total year's runoff in Carpinteria Creek. Total flow past the gaging station for the year was 6,340 acre-feet, which represented 459 acre-feet per square mile, or a depth of 8.61 inches over the drainage basin. Addition of losses by evaporation and transpiration and by seepage and diversion from the channel leaves little water to be accounted for as deep penetration. Thus, in this year of excessive rainfall, little water was stored in the mountain area because of the uneven distribution of rainfall throughout the year. A large part of the water was wasted to the ocean. The same amount of yearly rainfall, if in the form of well-distributed gentle rains, might have resulted in considerably less runoff, with resulting storage in the mountains.

Year 1943–44.—The water year 1943–44 had very nearly average rainfall. Rainfall at Santa Barbara was 17.92 inches, compared with the 77-year average of 18.40 inches. Average rainfall above the Carpinteria Creek gaging station was probably between 21 and 24 inches. Total measured flow past the gaging station was only 1,680 acre-feet, 122 acre-feet per square mile, or 2.29 inches of depth. During the month of December 1943, measured rainfall at Santa Barbara was 5.53 inches, but because the soil of the drainage basin was dry and because this total was the result of four separate storms, each of small magnitude, only 23 acre-feet reached the gaging station. On the other hand, the 5-day storm of February 19–23, 1944, in which 4.71 inches of rain was recorded at Santa Barbara and which fell on relatively wet soil, produced a runoff of over 850 acre-feet or more than half of the total for the year.

Year 1944–45.—During the water year 1944–45, rainfall at Santa

Barbara was 15.29 inches or about 83 percent of the long-term average. Total measured flow past the Carpinteria gage was 1,000 acre-feet, 72 acre-feet per square mile, or 1.35 inches of depth. Rainfall in the amount of 10.74 inches, or more than two-thirds of the yearly total, and runoff amounting to 85 percent of the yearly total occurred during February and March.

MEASURED RUNOFF FROM GOBERNADOR CREEK DRAINAGE BASIN

The fragmentary record of discharge in Gobernador Creek between 1916 and 1923 contributes little information regarding runoff from the area of consolidated rocks during periods of high flow. It does, however, demonstrate the low-flow characteristics of the stream during those years. The following table contains values of yearly rainfall at Santa Barbara, suggested values of rainfall on the area of consolidated rocks above the measurement site, and average low-water flow at the station during the corresponding water years. It is evident from this table that although some low-water flow is present during normal and wet years, water in quantities sufficient for irrigation is not available during years of low rainfall. Some water, however, could be obtained from the stream channel during winter months for artificially recharging the ground-water bodies downstream.

Average late summer discharge in Gobernador Creek from the area of consolidated rocks, 1916–23

Water-year	Yearly rainfall, in inches		Late summer flow (second-feet)
	At Santa Barbara	On area of consolidated rocks [1]	
1915–16	27. 84	34. 80	1. 0
1916–17	20. 63	25. 79	1. 3
1917–18	24. 56	30. 70	1. 1
1918–19	12. 34	15. 42	. 6
1919–20	13. 84	17. 30	0-0. 1
1920–21	14. 55	18. 19	. 1
1921–22	18. 98	23. 72	1. 0
1922–23	17. 40	21. 75	. 8
8-year average	18. 77	23. 46	0. 7
77-year average	18. 40		

[1] Rainfall at Santa Barbara times 125 percent.

TOTAL RUNOFF FROM THE AREA OF CONSOLIDATED ROCKS

The preceding study of gaging-station records has dealt with only about one-third of the total area underlain by consolidated rocks. The balance of that area is more or less similar to that third with re-

TABLE 4.—*Estimated yearly runoff,*[1] *in acre-feet, at lower boundary of consolidated rock area tributary to the Carpinteria basin*

Stream	Drainage area (square miles)	1940-41 [2]	1941-42	1942-43	1943-44	1944-45	5-year average	Percent of total
Rincon Creek	12.9	9,300	300	5,900	1,600	930	3,600	36
Gobernador Creek	7.3	5,300	170	3,400	890	530	2,100	21
Carpinteria Creek	4.6	3,300	110	2,100	560	330	1,300	13
Santa Monica Canyon	3.5	2,500	80	1,600	430	250	970	9
Arroyo Parida	3.7	2,700	80	1,700	450	270	1,000	10
Toro Canyon	1.4	1,000	30	640	170	100	390	4
Local drainage area [3]	3.6	2,100	0	1,400	270	90	770	7
Total	37.0	26,200	770	16,700	4,400	2,500	10,100	100

[1] Estimated on basis of drainage areas from table 10 and yearly measured runoff, in acre-feet per square mile, of Carpinteria Creek at gaging station at Highway 150 during the respective years, from table 11.

[2] The 9-month period January 1 to September 30, 1941.

[3] Runoff adjusted for decrease in rainfall on the lower altitudes of this part of the area.

spect to geology, altitude, slope, exposure, and vegetative cover. Runoff from each stream-drainage basin above the lower boundary of consolidated rocks has been estimated for the years ending September 30, 1941–45, on the basis of unit runoff from the area upstream from the Carpinteria Creek gage. These estimates are given in table 4.

Runoff presented in table 4 is subject to considerable error in the individual quantities. Also, because the period involved is predominantly wet, the 5-year average quantities should not be regarded as long-term average supplies. The table shows principally the relative quantities delivered by the respective streams. That is, about one-third of the total is from Rincon Creek, one-third from the Gobernador-Carpinteria Creek system, and the remaining third from the several smaller streams west of Carpinteria Creek. Yearly total runoff has ranged from less than 1,000 acre-feet to as much as 26,000 acre-feet. As is indicated beyond, however, the total runoff is ordinarily many times greater than the amount of water that seeps from the streams to the ground-water bodies.

DIVERSIONS FROM STREAMS

The streams in the Carpinteria area are equipped for diversion of low flows for irrigation during the summer. All such diversions are made within the area of consolidated rocks. In addition, some water has been diverted from Gobernador Creek during the winter and spring for use in artificial recharge of ground water through wells. Such recharge is limited to times when the stream is flowing clear water, as no filtering facilities are in use.

No records of quantities of water diverted are available. The average yearly total is estimated to be approximately 100 acre-feet. The total diverted in any year is dependent upon the quantity available in that year because the capacity of diversion facilities exceeds the low-water flow in normal years. The amount of water available for surface diversion varies from year to year with variations in rainfall. Because in dry years the low flow in streams is very small, this source of water is not dependable and it must be augmented by wells to supply the irrigation demands.

SEEPAGE LOSSES FROM STREAM CHANNELS IN THE AREA OF GROUND-WATER RECHARGE

Some water is lost as seepage from the stream channels within the area of recharge in the Carpinteria basin (pl. 4). In large part this seepage moves into the main ground-water body, as is discussed elsewhere. (See pp. 61 and 64.) In order to determine the amount of this seepage loss or recharge to ground water, numerous measurements and estimates of stream flow have been made since 1943 at places near the lower boundary of consolidated rocks and near the boundary of the area of confined water. Rates of loss determined from these measurements do not include surface diversions from the channels; they represent only the rates of influent seepage. Greatest loss was noted along the Carpinteria-Gobernador Creek channel. Small losses were observed along Rincon Creek, the creek in Santa Monica Canyon, and Arroyo Parida, and quite small losses were noted along Toro Canyon and the small unnamed creek adajacent to it on the north. No observations of loss are available for the stream from Franklin Canyon because it is not definitely channelized at the downstream limit of consolidated rock and it is dry at the upper boundary of the area of confined water except during and immediately following heavy rains.

All measurements and estimates of stream flow are confined to times during which flow was low. No data are available regarding losses during times of high flow. The losses are so small that they cannot be determined accurately by current-meter measurements made during floods in the steep boulder-strewn channels. Ordinarily, losses are greater during times of high flows because of greater wetted areas available for seepage. However, because these streams are confined to narrow well-defined channels and because the periods of high flows normally are very short, the excess quantity of water lost during such periods is not believed to increase materially the total yearly loss. The following lists approximate rates of loss in second-feet and average yearly total loss in acre-feet from the various streams during the 5 years ending September 30, 1941–45.

Estimated average seepage losses from the five principal stream channels in the Carpinteria basin, in the 5 water-years 1941–45

Stream	Loss	
	Second-feet	Acre-feet per year [1]
Rincon Creek	0. 4	65
Carpinteria Creek (including Gobernador Creek)	3. 5	560
Santa Monica Canyon	. 3	50
Arroyo Parida	. 2	30
Toro Canyon	. 2	30
Total	4. 6	735

[1] Based on average of 80 days of flow per year.

The estimates of yearly quantities were based on observed rates of loss from the streams and the average length of time during which the streams flowed each year. These estimates make no allowance for higher rates of seepage during periods of high flow. During the 5 years of record, the time during which sufficient flow to satisfy the observed rates of loss left the area of consolidated rocks averaged 80 days per year. The length of time, of course, varied widely from year to year and consequently the yearly seepage loss also varied. For example, in 1940–41 streams flowed for over 200 days at sufficient rates to reach the area of confined water and as much as 2,000 acre-feet of water may have been lost from the several channels, but in 1941–42 the period probably was less than 30 days and total seepage loss was less than 300 acre-feet. Also, during a series of dry years such as 1928–31 the time each year during which the streams flow may have been so short as to produce negligible recharge to ground water. The average yearly total from 1940–41 through 1944–45, about 750 acre-feet, represents average yearly recharge to ground water by seepage loss from the five stream channels during the years of record.

In addition to the seepage losses from the five principal streams (see preceding table), some additional losses occur along many small ditches crossing the recharge area. These ditches drain some 3.6 square miles in the foothill areas of consolidated rocks adjacent to the recharge area, which are not included in the drainage basins of the five principal streams. Estimated runoff from this adjacent area in the last five years has ranged from a negligible amount to 2,100 acre-feet per year. Average for the 5 years is 770 acre-feet per year.

The part of this runoff that reaches the ground-water bodies is not known, but it is arbitrarily assumed to be about 25 percent. Under this assumption the yearly recharge from this source has ranged from nothing to about 500 acre-feet; the yearly average from 1941 to 1945 is assumed to have been about 190 acre-feet.

Thus, in the 5-year period the average yearly seepage loss in the area of recharge has been approximately 900 acre-feet. The range in seepage loss during those 5 years has been from about 300 acre-feet to as much as 2,500 acre-feet per year.

During this 5-year period, however, rainfall at Santa Barbara was 126 percent of the long-term average. Because runoff and, hence, seepage losses do not vary directly with amount of yearly rainfall, but diminish more rapidly than rainfall, it is believed that the long-term average yearly seepage loss is about 700 acre-feet.

SURFACE-WATER RESOURCES OF THE GOLETA BASIN

RUNOFF FROM AREA OF CONSOLIDATED ROCKS

From Atascadero Creek on the east to Glen Anne Canyon on the west, the drainage area tributary to the Goleta basin is a rectangular area about 8 miles long from east to west by about 6.5 miles wide. (See pl. 5.) It includes about 47 square miles distributed among the hydrologic subdivisions as follows: brush-covered mountain slopes comprising the area of consolidated rocks, about 30 square miles; the recharge area, about 9 square miles; and the area of confined water, about 8 square miles.

The area is drained by numerous small streams, which converge across the valley floor and discharge to the ocean through the single outlet near Mescal Island. Although some of the streams flow throughout most years above the downstream boundary of the consolidated rocks, none is perennial across the valley floor. The following table shows the area of consolidated rocks drained by the various streams and also the area of consolidated rocks immediately adjacent to the valley but not tributary to those streams. (See pl. 5.)

Drainage area upstream from the lower boundary of consolidated rocks for streams tributary to the Goleta basin

Name of stream	Drainage area (square miles)
Atascadero Creek	1. 5
San Antonio Creek	4. 3
Maria Ygnacio Creek	5. 6
San Jose Creek	5. 5
San Pedro Canyon	2. 8
Carneros Creek	3. 3
Glen Anne Canyon	4. 2
Total measured area	27. 2
Local drainage area above consolidated rock boundary not included in above areas (estimated)	2. 8
Total area of consolidated rock	30. 0

A small part of the water leaving the area of consolidated rocks as stream flow seeps from the channels of streams in the eastern part of the basin and reaches the ground-water body beneath the valley floor. No appreciable loss has been observed from streams west of San Jose Creek.

Water that reaches the area of confined water as stream flow is not in hydraulic continuity with the main ground-water body of the basin (p. 90) and practically all of it wastes to the ocean. Some small interchange of water between the shallow ground-water body and the streams appears to take place, as indicated by trickles and pools in

Atascadero Creek at the gaging station each spring for some time after the stream is dry upstream from the station. However, the irrigation wells do not receive their water from this shallow water body and such minor interchange is not considered important in the study of the water resources of the basin.

MEASURED RUNOFF FROM ATASCADERO CREEK AND SAN JOSE CREEK DRAINAGE BASINS

Two continuous gaging stations, equipped with water-stage recorders, have been operated in the Goleta basin; one on Atascadero Creek since October 1941, and the other on San Jose Creek since January 1941. (See table 2.) Also, numerous miscellaneous measurements of stream flow have been made on all of the streams in connection with seepage-loss studies. Table 5 presents yearly measured runoff, in acre-feet, acre-feet per square mile, and inches of depth, at the two gaging stations for the periods of record.

TABLE 5.—*Measured runoff of Atascadero and San Jose Creeks*

Water-year	Runoff		
	Acre-feet	Acre-feet per square mile	Depth (inches)
Atascadero Creek near Goleta (drainage area 18.3 square miles)			
1940–41 [1]	[2] 5, 860	320	6. 0
1941–42	220	12	. 22
1942–43	4, 880	267	5. 01
1943–44	2, 280	124	2. 32
1944–45	1, 290	70	1. 31
San Jose Creek near Goleta (drainage area 5.5 square miles)			
1940–41 [1]	7, 120	1, 295	24. 28
1941–42	765	139	2. 61
1942–43	2, 970	540	10. 12
1943–44	1, 070	194	3. 64
1944–45	890	162	3. 04
Combined runoff of Atascadero and San Jose Creeks (drainage area 23.8 square miles)			
1940–41 [1]	13, 000	545	10. 2
1941–42	985	41	. 77
1942–43	7, 850	330	6. 19
1943–44	3, 350	141	2. 64
1944–45	2, 180	92	1. 72

[1] The 9-month period January 1 to September 30, 1941.
[2] Estimated on basis of runoff relations with San Jose Creek and Carpinteria Creek.

The drainage basin characteristics of the two streams equipped with continuous gaging stations differ considerably. The Atascadero Creek gage, 300 feet downstream from the mouth of Maria Ygnacio

Creek (pl. 5), is in the area of confined water near the ocean side of the valley floor, and is downstream from the recharge area. The total area tributary to the station is 18.3 square miles; about 7 or 8 square miles of this is within the area of confined water and the recharge area of the ground-water basin, is at low altitude, and receives relatively light precipitation. The remaining 11 square miles is within the area of consolidated rocks and extends to the crest of the Santa Ynez Mountains. Within the latter area the average yearly rainfall increases progressively with altitude from about 20 inches at the lowest altitude to 30 or 35 inches at the highest. The gage on San Jose Creek, on the other hand, is at the upper limit of the recharge area and essentially all of the drainage area above the gage is in the area of consolidated rocks. The drainage area, 5.5 square miles, is in the form of a right angle the upper leg of which extends for over 4 miles east and west along the crest of the mountains. Almost half of the total drainage basin lies at the higher altitudes. Here the average rainfall is considerably greater than on a corresponding portion of the Atascadero Creek drainage basin.

These features combine to make the runoff characteristics of the two immediately adjacent drainage areas quite different. Study of the relation between the two is further complicated by numerous small diversions from the streams in the mountain area. (See p. 50.) Low-water gaging station records therefore do not represent the total quantities of water available from the mountain area during the summer and autumn of each year.

Study of the records for the two gaging stations near Goleta (table 5) leads to the conclusion that unit runoff from the Atascadero Creek drainage basin is considerably below that from the San Jose Creek drainage basin. For years having average or less than average rainfall, the difference is from 1 to 2 inches of depth. However, for wetter years the difference increases rapidly with increase in precipitation. For example, in the water year 1942–43 runoff past the San Jose Creek gage was 10.12 inches of depth and that past the Atascadero Creek gage was only 5.01 inches, or 5.11 inches greater at the San Jose Creek gage. Curves of yearly runoff relations among the three south-coast gaging stations suggest that during the extremely wet water year 1940–41, in which rainfall was 45.25 inches at Santa Barbara and 68.59 inches at San Marcos Pass, runoff past the Atascadero Creek gage may have been hardly more than 6 inches in depth over the drainage area. During the 9-month period January 1 to September 30, 1941, however, the depth of runoff measured at the San Jose Creek Gage was 24.28 inches so that total yearly runoff was in excess of 25 inches, or about 19 inches greater than the amount estimated to have passed the Atascadero Creek gage that year. The relatively low runoff from the area above the Atascadero Creek gage appears to have been because about 38 percent of the drainage area is composed of low terraces and valley floor, two-thirds of which is in the recharge area, and the rain fell in a long continuing series of light storms with optimum opportunity for infiltration. The 5.01 inches of runoff past the Atascadero Creek gage in 1942–43 seems excessive when compared with that in 1940–41. However, 10.91 inches of the 24.34 inches of total rainfall at Santa Barbara in 1942–43 occurred during a single 3-day storm so that a large surface runoff occurred in that year.

TOTAL RUNOFF FROM THE AREA OF CONSOLIDATED ROCKS

Because a considerable part of the drainage area above the Atascadero Creek gage is largely noncontributive, the elimination of that portion from studies of unit runoff might yield some further results of value. However, with the scant data available, such treatment seems hardly justified.

In order to arrive at estimates of the total quantities of water available from the mountain areas, the yearly quantities of runoff, in acre-feet, at the two gaging stations have been combined and reduced to quantities of average unit runoff from the combined area drained by the two streams. (See table 5.) Values of average unit runoff have then been applied to the drainage areas of the principal streams within the area of consolidated rocks adjacent to the Goleta basin (p. 46), to obtain estimated yearly runoff from those areas during the period of gaging-station records. Table 6 presents total yearly quantities of water thus obtained.

TABLE 6.—*Measured and estimated[1] runoff, in acre-feet, at lower boundary of area of consolidated rocks tributary to the Goleta basin*

Stream	Drainage area (sq. mi.)	1940–41 [2]	1941–42	1942–43	1943–44	1944–45	5-year average	Percent of total
Atascadero Creek	1.5	820	60	500	210	140	350	5
San Antonio Creek	4.3	2,300	180	1,400	610	390	980	15
Maria Ygnacio Creek	5.6	3,100	230	1,900	790	510	1,300	19
San Jose Creek (gaged)	5.5	3,000	230	1,800	780	510	1,300	19
San Pedro Canyon	2.8	1,500	110	920	390	260	640	9
Carneros Creek	3.3	1,800	140	1,100	470	300	760	11
Glen Anne Canyon	4.2	2,300	170	1,400	590	390	970	15
Local drainage area [3]	2.8	1,200	0	800	280	140	480	7
Total	30.0	16,000	1,100	9,000	4,100	2,600	6,800	100

[1] Estimated on basis of drainage areas from table p. 46 and yearly measured runoff, in acre-feet per square mile, of combined Atascadero and San Jose Creeks at gaging stations during the respective years from table 5.
[2] The 9-month period January 1 to September 30, 1941.
[3] Runoff adjusted for decrease in rainfall on the lower altitudes of this part of consolidated rock area.

Estimates of runoff contained in table 6 furnish some information regarding yearly quantities of surface water available from the various streams. Thus, the table suggests that total yearly runoff from the area of consolidated rocks has ranged in recent years from about 1,100 acre-feet to as much as 16,000 acre-feet. Because the records cover a very short period of predominantly wet years, the estimates do not represent long-term average quantities. They do, however, show the relative quantities available from the different stream drainage basins. These quantities are much larger than estimated and observed seepage losses to ground water discussed in a subsequent section of this report.

DIVERSION FROM STREAMS

Surface diversions of low flows from the stream channels are numerous, particularly in the montain area where flow is present throughout most years. Water thus diverted has been used for domestic purposes for many years. However, in recent years several small off-channel reservoirs have been constructed to store water during winter and spring for irrigation. A notable instance of this type of reservoir is to be found on San Jose Creek, for which the water right is reported to be 150 acre-feet per year. This water right terminates May 1 of each year, is therefore confined to the rainy season, and is intended to conserve flood waters which otherwise would be wasted to the ocean.

Total quantity of water diverted from the streams each year, like the total quantity lost by seepage from the streams, depends to some extent on the length of time in which the streams flow. Some installations pump water from the stream channels to augment irrigation supplies from wells and these generally are operated as long as water is available. The average total diversions of water from all streams is estimated to be about 250 acre-feet a year.

Surface diversions of stream flow for irrigation cannot be depended upon as a safe perennial source of supply, even with the use of small reservoirs, because in a series of dry years the quantity of water available would be sufficient only for very small-scale irrigation. It does, however, augment ground water as a source during wet periods, thereby reducing the continual drain on the ground-water body. However, no attempt has been made in the Goleta basin to utilize water diverted from streams for artificial recharge of ground water through wells.

SEEPAGE LOSSES FROM STREAM CHANNELS IN THE AREA OF GROUND-WATER RECHARGE

A part of the recharge to ground water in the Goleta basin is by seepage loss from stream channels. The largest loss has been observed in the stream system which converges a short distance upstream from the Atascadero Creek gaging station, a small loss has been observed from San Jose Creek, but very little loss has been noted along the streams west of San Jose Creek.

Numerous miscellaneous measurements and estimates of low flow have been made on all streams at places above and below the recharge area. (See pl. 5.) The very small rates of loss from the stream channels cannot be evaluated by high-water measurements because of the flashy character of the streams and because of difficult measuring conditions. Rates of loss during floods are necessarily greater than during low water, but in this basin, as in the Carpinteria basin, the streams are all confined to narrow well-defined channels, and the total quantity of water lost during the extremely flashy rises is not believed to be great.

The small streams constituting the drainage system of Atascadero Creek above the mouth of Maria Ygnacio Creek are dry except during heavy rainfall. Only 1.5 square miles of consolidated rock area are contained within the drainage basin; the remainder is in the recharge area and the area of confined water. Atascadero Creek immediately upstream from its confluence with Maria Ygnacio Creek flows in a narrow channel which is choked with vegetation. Discharge of less than 0.1 second-foot has been observed here simultaneously with measured discharge as great as 50 second-feet at the gage 300 feet below Maria Ygnacio Creek. Runoff from the Atascadero Creek drainage area above Maria Ygnacio Creek is therefore very low and essentially all the rain is retained. Therefore, no estimate is made of seepage losses; and recharge to ground water in this area is covered in a subsequent part of this report.

San Antonio Creek flows across the recharge area for about 1.5 miles and Maria Ygnacio Creek flows across it for about 1 mile. The two streams converge at the Southern Pacific railroad in the area of confined water, and from there a single channel continues south to Atascadero Creek. Seepage loss from this channel system during low water has been observed as about 2 second-feet. No loss has ever been observed downstream from the railroad. On the other hand, a slight gain has been noted occasionally near the Atascadero Creek gage and appears to be drainage of the shallow ground water in that vicinity. In order to include increased loss during times of high flow, a loss of 3 second-feet from the channels is estimated as the average rate each year during the time the streams flow beyond the area of consolidated rocks.

San Jose Creek flows across the recharge area for about three-quarters of a mile. In addition a small section of unconsolidated deposits at the gage may transmit a small quantity of underflow. As in Maria Ygnacio Creek, some gain in flow is noted in the lower reaches of this stream. Simultaneous measurements made at the San Jose Creek gaging station and a mile upstream, where underflow section is negligible, indicate no loss from the channel above the gage. Underflow at the gage is then derived from lateral drainage within the 1-mile reach. Combined underflow and seepage loss for this stream is estimated as 0.5 second-foot, effective for only a portion of each year.

The streams west of San Jose Creek flow across the recharge area for short distances. Field observations showed no loss from these streams during low flows. However, there is some possibility of underflow through unconsolidated deposits in the stream canyons where they leave the consolidated rocks. Contribution to ground water from streams west of San Jose Creek is estimated not to exceed 0.5 second-foot.

Average yearly recharge from streams to ground water in the Goleta basin has been estimated on the basis of the observed losses from stream channels, estimated underflow through unconsolidated deposits at the mouths of stream canyons, and the estimated duration of flow per year. Evaluation of the first two factors has been discussed. The length of time in which water is available outside the area of consolidated rocks varies widely from year to year and consequently the yearly quantity of water transmitted to the ground-water body also varies. It is assumed that the estimate of 80 days each year, on the average used for the Carpinteria basin (p. 45) as the length of time during which the average rate of loss takes place, is applicable to the Goleta basin. Estimates of yearly recharge to ground water from streams computed on this basis are contained in the following table. As for the Carpinteria basin, these quantities are exclusive of surface diversions from streams.

Estimated recharge to ground water from streams in the Goleta basin

Stream	Recharge to ground water	
	Second-feet	Acre-feet per year [1]
San Antonio-Maria Ygnacio Creeks	3	480
San Jose Creek	.5	80
Streams west of San Jose Creek	.5	80
Total	4.0	640

[1] Based on average of 80 days of flow per year.

Here, as in the Carpinteria basin, a part of the consolidated rock area above the recharge area is not within the stream drainage basins whose extent is shown in the table on page 46. This unaccounted-for area, designated as "local drainage area" in that table, lies largely west of San Jose Creek and probably supplies very little recharge to ground water. However, a small part of the unaccounted-for area is between San Jose Creek and Maria Ygnacio Creek, and part of the runoff from this area can percolate to ground water. The ratio between percolation and runoff, assumed to be 25 percent for the Carpinteria basin (p. 45), is probably excessive for the Goleta basin. It is believed that ample allowance is made for this "local" area by rounding upward the average seepage loss from stream channels (table 18) from 640 acre-feet per year to 700 acre-feet per year, to derive the average total recharge to ground water during the 5-year period from supplies originating in the mountain area of consolidated rocks. The long-term yearly average is less than 700 acre-feet because the average rainfall at Santa Barbara during the 5 years 1941–45 was 126 percent of the long-term average at that place. In view of that variation in rainfall, the long-term average yearly recharge from streams is probably about 500 acre-feet.

GROUND-WATER RESOURCES

GROUND-WATER IN THE CARPINTERIA BASIN

The Carpinteria basin comprises that part of the vicinity of Carpinteria which is underlain to appreciable depth by the unconsolidated deposits discussed in the earlier paragraphs on the geology. These deposits are the younger alluvium, terrace deposits, older alluvium, Casitas formation, and the Santa Barbara formation. Their distribution and thickness are shown on the geologic map and in the cross sections (pl. 1). As thus defined, the basin includes the alluvial plain about the town of Carpinteria and certain adjoining foothills and terraces. In shape it is crudely a narrow triangle with its base in Ventura County and its apex at the shore, a short distance east of Summerland. On the north the basin lies against the Sespe and Tejon formations that compose the main foothills of the Santa Ynez Mountains, and comprise most of the area of consolidated rocks, or the area of runoff discussed in the foregoing section of this report. On the south it abuts in part against the uplifted Monterey shale along the shore, but west of Carpinteria it is bordered by the ocean.

OCCURRENCE OF GROUND WATER

PROPERTIES OF THE WATER-BEARING FORMATIONS

The formations that contain the ground water differ in thickness and extent, and also in detailed lithologic characteristics. Hence some yield and transmit water comparatively readily, and others largely prevent the movement of water. The lithologic features of the formations are shown by logs of representative wells. (See pl. 6 and table 16. These features, insofar as they pertain to the occurrence and movement of ground water, are summarized as follows.

Younger alluvium.—As shown on plate 1, many wells penetrate the younger alluvium, but most of them are not perforated in it, deriving water from the underlying formation. However, in a small area along Carpinteria Creek, extending for about a mile below its junction with Gobernador Creek, several wells obtain water entirely from the younger alluvium (pl. 6). Here the younger alluvium is comparatively coarse-grained, and a few wells have fairly large yields. For example, well 4/25–28J1, which is generally considered to be the most productive well in the valley, pumps at a rate of about 500 gallons a minute and derives water from gravel and sand in the younger alluvium.

In other parts of the valley the younger alluvium consists mainly of clay and silt with only a little sand and gravel. Some wells encounter gravel or gravel and sand in the lower part, such as water-yielding sand beneath the town of Carpinteria reported by early settlers to lie between 80 and 200 feet below the land surface, but the uppermost 100 to 250 feet in most of the area (see logs of wells 4/25–29D2, 4/25–29B1, 4/25–28F3) consists of masses of brown or blue clay as much as 50 feet thick, with only thin intercalated strata of sand and of gravel. Because this material is generally too fine-grained to transmit water readily, it prevents the downward percolation of water from the land surface, and it also confines water in underlying deposits under artesian pressure. The extent of the area of confinement is more fully discussed in subsequent paragraphs (p. 58).

Older alluvium.—Deposits of the older alluvium occur at the mouths of Santa Monica Canyon and Arroyo Parida, and in the lower part of Toro Canyon. They wedge out to the north against the consolidated rocks of the mountains, and to the south pass beneath the younger alluvium. Remnants also occur on Shepard Mesa and adjacent terraces, but are mainly above the zone of saturation by ground water.

As exposed these deposits are composed of poorly sorted clay, sand, and gravel, generally yellow to reddish-buff in color and occurring in inextensive lenses. Few lenses consist purely of clay, sand, or gravel. Those of sand and clay contain some pebbles and cobbles, and those of gravel generally contain some clay and sand. In the deposits near the mountains the gravel is very coarse and contains rounded boulders as much as 6 feet in diameter. Records of wells that begin on the outcrop of the older alluvium, such as well 4/25–19G1 (table 16), show that the formation is essentially the same to some depth. However, farther south, beneath the lower end of Toro Canyon and beneath the alluvium south of Santa Monica Canyon, the deposits are finer-grained and in well logs are indistinguishable from the younger alluvium. (See logs of wells 4/26–23H3, 4/26–24F4, 4/25–29D2, and 4/25–19Q3.) The older alluvium is also lithologically similar to the Casitas formation.

The older alluvium in general yields water only moderately readily. Its chief water-yielding materials are the discontinuous lenses of gravel and sand, which occur at all depths and do not constitute any widespread zones. They are more numerous and of coarser grain in the central and headward parts of the alluvial fans, and wells drilled there obtain yields of a few hundred gallons a minute.

Casitas formation.—The Casitas formation composes nearly all of the hilly and terraced area bordering the eastern part of the Carpinteria alluvial plain. It composes the foothills and terraces along Carpinteria, Gobernador, and Rincon Creeks, and also the northern part of the west-sloping terraces south of the plain and east of Carpinteria. It extends beneath the eastern part of the plain and lies at progressively greater depths to the south and west. It crops out at the land surface at well 4/25–35C3, the depth to its top is about 100 feet at well 4/25–27R2 and below 250 feet at well 4/25–28F3. Beneath the western part of the plain the formation is barely distinguishable from the overlying older alluvium, but its top is believed to occur at depths ranging from 150 to more than 300 feet, and it is probably penetrated by the deeper wells there.

The Casitas formation is not highly productive of water, but numerous wells obtain moderate yields. It consists of poorly sorted lenticular, nonfossiliferous strata of clay, silt, sand, and gravel, dark red to reddish orange in color. These strata are relatively coarse-grained to the north near the consolidated rocks, in that they contain lenses of poorly assorted gravel. They supply water to a number of wells drilled north of Shepard Mesa, east of Rincon Creek, and along Gobernador Creek. (See logs of wells 4/25–26J1, 4/25–27G2, and 4/25–35A2, table 16.)

Farther south, wells penetrate the lower part of the formation, which is finer-grained and contains thin-bedded clay and silt with some massive sand strata, but little gravel.

The clay and fine sandy clay beds of the Casitas formation are so fine-grained and massive that they are essentially impermeable, but the sand and gravel beds are sufficiently permeable to transmit water fairly freely. These permeable beds, however, are so lenticular and discontinuous that they do not constitute extensive aquifers. Thus, the Casitas formation can be considered as a single water-bearing zone of rather poor productivity. The wells that derive water from the formation in the eastern part of the area range in depth from 177 to 543 feet, depending in part on their altitude, and penetrate minimum thicknesses of saturated material ranging from 100 to as much as 345 feet. Saturated thicknesses of this magnitude appear to be necessary to obtain sufficient water for irrigation.

Along the foothills in sec. 21, T. 4 N., R. 25 W., is an area underlain by predominantly fine-grained deposits in which even such thicknesses do not yield adequate water. There wells and test holes are reported to have been abandoned because of small yield. For example, well 4/25–21R1 (see log in table 16) is 468 feet deep, and it failed to obtain an appreciable quantity of water from more than 300 feet of saturated deposits.

A pumping test was made on well 4/25–27R2 to obtain an approximate value for the transmissibility, or rate of water transmission, of the Casitas formation. The well is 421 feet deep and penetrates 319 feet of the Casitas formation, in which the casing is perforated. (See table 16.) The pump was run at a discharge rate of about 200 gallons per minute for 8 hours and 31 minutes; then it was shut down and the recovery of the water level was measured for 15 hours and 9 minutes. Using the recovery method described by Theis (1935, p. 522. Wenzel, 1942, p. 95–97), the value for transmissibility was calculated to be about 1,410 gallons per day per foot. The driller's record (table 16) shows that the well casing is perforated for a total length of 71 feet within an interval of 125 feet, from 295 to 420 feet.

The log indicates that the water-yielding materials tapped in this well are overlain by 128 feet of hard brown clay. Hence it is wholly reasonable to conclude that the transmissibility obtained is a measure of the capacity of this 125-foot thickness to yield water. Dividing the transmissibility of 1,410 by 125 feet of thickness gives an average permeability of about 11 g. p. d. per sq. ft. The thickness of only those sand and gravel beds which are opposite perforations is 41 feet; if the fine-grained layers are assumed to transmit no water, the apparent permeability for these sand and gravel layers is about 34 g. p. d. per sq. ft.

Santa Barbara formation.—Comparatively few wells penetrate the Santa Barbara formation in the Carpinteria area. It mainly underlies the steeply sloping area east of Rincon Creek, but it occurs also in a narrow band west of Rincon Creek and north of United States Highway 101, where it is covered by terrace deposits. Its characteristics are indicated by the stratigraphic section (p. 20) and by logs of wells 4/25–29E1, 4/25–29M1, and 4/25–35E2 (table 16). These show that the formation contains numerous rather think, and probably extensive, bodies of fine sand and silt. Such beds may transmit and yield water with moderate facility not only along the bedding parallel with the strike of the strata, but also across the bedding. However, the Santa Barbara formation is virtually untapped by water wells, and information on its water-yielding character is lacking.

GROUND-WATER BODIES

Ground water in the Carpinteria basin comprises two bodies largely hydraulically separate: a shallow body which occurs principally in the upper part of the younger alluvium and is restricted to the alluvial plain; and a deep, or main body, which occurs in the lower part of the younger alluvium, in the Casitas formation, and in the Santa Barbara formation. This body extends beneath the bordering foothills and terraces where composed of unconsolidated deposits. Along the north margin of the alluvial plain the two water bodies are interconnected.

Shallow water body.—The shallow water is chiefly unconfined. Its static level is a few feet below the land surface, and it supplies water to only a few shallow domestic wells.

Deep water body.—The main, or deep body, is considered a single body hydraulically continuous throughout by means of interconnecting lenses of relatively permeable material in the several containing formations. However, as is discussed in subsequent paragraphs, there apparently is not equal freedom of movement throughout all parts of the body.

The static level of the deep body varies from a few feet below the land surface near the ocean to as much as 250 feet in the area north of Shepard Mesa. In the winter of 1941, well 4/25–29D1 had a small flow. In early years, according to reports of old residents, several wells within the town of Carpinteria flowed strongly at the land surface. Thus, the deep water body is known to be confined at least locally, and it is inferred to be partially confined nearly everywhere.

It is important to know the full areal extent of the confining beds of the younger alluvium because within that area water cannot percolate downward from the land surface. Fortunately, the area of flowing wells can be fairly well determined by reports of old residents still living in the area. For example, it is reported that the water from a well 200 feet deep in the town of Carpinteria flowed into an elevated tank and had a pressure at ground level of about 20 pounds per square inch. This is sufficient to raise the water about 46 feet. The altitude of Carpinteria is about 23 feet so that the original artesian head probably was about 70 feet above sea level in that vicinity. A well is said to have been drilled in 1898 on the east side of Casitas Pass Road in the general vicinity of well 4/25–28L3, and the water from the well rose to the top of a two-story house. The altitude at that place is probably a little under 50 feet and therefore the artesian water rose about 70 feet above sea level. Well 4/25–28F3 had a natural flow until about 1915. The water in that well rose 6 or 7 feet above the ground and considerably more than 70 feet above sea level when it was first drilled. Well 4/25–28K1 is said to have had a flow when first drilled. The water in a well near the road intersection in the southeast corner of sec. 20, T. 4 N., R. 25 W., was reported to have risen 14 feet above the ground. The water also rose 14 feet above the ground surface in well 4/25–19K2. Another well in the vicinity of the intersection of Cravens Lane and Highway 101 is said to have had a flow in 1899. No information was found to indicate that any artesian wells were drilled west of Cravens Lane although geologic conditions seem to be favorable to confinement of water in that area.

Thus, flowing wells could have been drilled initially in a large part of the Carpinteria area. That confining conditions exist beneath a still broader area is indicated by the behavior of water levels in wells when pumped. As shown on plate 7, the confining conditions caused by relatively impermeable beds of younger alluvium exist beneath nearly all of the alluvial plain. This area is called the area of confined water.

Outside this area, water is both confined and unconfined. As has been pointed out, the older alluvium and the Casitas formation contain both permeable and impermeable strata, which lie at an angle to the horizontal. Under these conditions, water in the permeable strata near the land surface is unconfined, whereas water at greater depth lies below impermeable strata and is confined. The artesian head is supplied by the mass of water in the intake, or recharge area. Such artesian conditions exist in the older alluvium and Casitas formation a considerable distance outside the limits of the younger alluvium. They exist in the older alluvial fans of such streams as Toro Canyon. To the northeast beneath the hills composed of the Casitas formation the deeper water is doubtless confined, though water encountered at levels above the creek beds may be unconfined. Similarly in the NW¼ sec. 35 and N½ sec. 34, T. 4 N., R. 25 W., where the strata of the Santa Barbara formation have a northerly dip, water at shallow depths in the upper parts of permeable zones is probably unconfined, but deeper water in beds overlain by impermeable strata is confined. Thus, in the area outside the limits of the younger alluvium, ground water may be recharged by percolation from the outcrop of the water-bearing strata. Therefore this area is considered part of the recharge area although the water at depth in the aquifers is under some artesian pressure.

Thus, the deep water body occurs throughout the basin and is coextensive with the unconsolidated deposits. It is confined beneath nearly all of the alluvial plain and somewhat confined in the recharge areas to the northeast, east, and southeast. On the south side, from Carpinteria east, it is completely separated from the ocean, but from Carpinteria west, it is in contact with sea water along the shore.

The containing formations extend to depths as much as 3,000 feet below sea level, but the water in the lower part may be of a quality unsuited to agricultural or other use. One of the several oil-test wells that penetrated over 2,000 feet of unconsolidated deposits is said to have encountered fresh water in the bottom deposits, but water wells have penetrated only about 400 feet of the deposits. Water at depths of as much as 2,000 feet is probably of poor chemical quality, as water flowing from a 2,300-foot oil prospect well is reported to have had 6,000 parts per million of total solids. Thus, the depth of usable fresh water is somewhat less than the thickness of the unconsolidated deposits.

The quality of the ground water with especial reference to possible contamination by sea water and by water of high boron content is more fully discussed in a subsequent part of this report.

SOURCE AND MOVEMENT OF WATER

Data on the source and movement of the shallow water are not available because of the scarcity of shallow wells. Presumably the shallow water is derived chiefly from infiltration of rain and irrigation water and moves slowly southward. It is discharged in part into the sea, and part is lost by evaporation and transpiration from the slough southwest of Carpinteria.

Considerable data are available as to the source and movement of water in the deep body. Plate 7 shows water-level contours for the deep water body based on depth-to-water measurements made March 19 and 20, 1945, in all accessible wells in the area. The altitudes of the wells had been determined by altimeter or spirit level, so that the altitude of the water surface in each well was readily ascertained. The altitudes were plotted on the map and from them the contours, or lines of equal altitude, were drawn. The levels in all wells were used, except those for a few extremely shallow wells in which the water level stood higher than the levels in surrounding deeper wells. In the area of confined water the contours represent the piezometric, or pressure surface; in the recharge area they represent the water table.

In sec. 26, T. 4 N., R. 25 W., the control for contours is scanty, and the altitudes of wells in the northern part of the section are based solely on altimeter readings. The rather sharp curvature of the 200-foot contour may be caused by partial hydraulic discontinuity of deep water on opposite sides of the fault there, but the data are not considered adequate to establish such discontinuity. Similarly, the abrupt curvature of contours in sec. 35, T. 4 N., R. 25 W., and the steep northward gradient in sec. 34, T. 4 N., R. 25 W., are believed to be caused, at least in part, by low permeability in the zone of the fault that cuts the water-bearing Casitas formation.

Water tends to move from points of high head toward points of low head, or from one contour to the next lower contour. Thus, the contours show the direction of movement of the water in the deep water body, and hence the general areas from which the water originates, or areas of recharge. Accordingly, the map shows that the ground water in the Carpinteria basin originates chiefly east and northeast of the alluvial plain in the hilly area underlain by the Casitas formation. In the western part of the basin, water originates to the north in the areas of older alluvium, and in the extreme southeastern part, it originates in the terraced upland south of the alluvial plain. In the valleys of the dry creeks east of Rincon Creek there are no wells, and hence no measurements of water level. Contours are based on measurements in wells close to the creek. They suggest movement of water from the east; therefore the area east of Rincon Creek underlain by the Casitas and Santa Barbara formations is included in the areas of recharge to the basin.

Although the water level in wells near Rincon Creek is about at the level of the bed of the creek, it is thought that the ground water moves underneath across the direction of the stream course and is mainly not intercepted and drained. In the first place, the contours show no movement of water toward the creek from the west; and in the second place, the creek is usually dry in summer from near its junction with Casitas Creek downstream to the vicinity of well 4/25–35M1, below which it flows perennially.

The ground water east of Carpinteria Creek moves into a closed depression whence it is discharged by pumping wells. The water west of Carpinteria Creek moves westward and southward and toward the sea. In early years of high water levels, considerable water doubtless was discharged into the sea below sea level, but under present conditions probably a relatively small quantity of water is discharged in this way. Thus, there is little natural discharge of the deep water body from the Carpinteria basin.

NATURAL RECHARGE TO THE DEEP WATER BODY

The source of the water in the deep water body, or its recharge, is by infiltration of rain and seepage from the creeks that enter the basin. However, the area of confined water (see p. 58 and pl. 7) covers a large part of the Carpinteria alluvial plain, and within its limits water cannot percolate to the deep water body. Rain, irrigation water, and water from streams that flow across the area of confined water percolates some distance below the land surface into the shallow water body and is restrained from farther downward movement by impervious beds. Essentially all this water is discharged directly from the shallow body (p. 54) and does not reach the deep body. However, a very small part of the water thus percolating runs into wells that are perforated near the surface, and thus reaches the deep water body.

Therefore, natural recharge to the deep body must take place between the area of confined water and the boundary of the consolidated rocks. This area is called the recharge area. Its limits are shown on plate 7 and also on plate 4. The extent of the recharge area is about 7 square miles, or 4,480 acres.

INFILTRATION OF RAIN

Some of the rain that falls on the hills and slopes in the recharge area percolates downward below the plant roots and ultimately reaches the water table within the unconfined part of the deep water body. Thence it percolates down the hydraulic gradient, or in about the same direction as the dip of the water-bearing beds. When it passes beneath the confining beds it cannot naturally return to the surface and therefore is confined and is called artesian water.

Because the water table is 100 to 200 feet below the land surface in most of the recharge area, percolation to the water table of any one season's rain infiltrate probably is delayed several months and perhaps as much as a year. Piper (1933, pp. 139–140, 145) has shown that in the Mokelumne area the effect of rain infiltration from a single storm usually could not be detected where the water table was more than 30 feet deep. Successive increments of recharge moving downward to the water table were damped and largely merged before reaching it; and the recharge to the water body took place throughout much of the year. Corresponding conditions doubtless prevail in the Carpinteria basin. Further, the successive yearly increments of rain infiltration, at least in years of ordinary rainfall, probably merge to such an extent that the rate of accretion of water on the water table is nearly constant from year to year; yearly or seasonal rises of the water table as a result of infiltration of rain alone are probably about 2 to 3 feet.

As to the amount of infiltration of rain, it is extremely difficult to estimate the proportion of the rainfall that seeps into the water-bearing beds. The surface slopes are steep and irregular, the permeability of the soil on the outcrop areas varies widely from place to place, and the type of vegetation also varies widely throughout the area.

However, an approximation can be made by use of values derived by Blaney (1933) in a study of the deep penetration of rain below plant roots in agricultural areas in Ventura County, Calif. Table B of the report cited lists computed "deep penetration," the amount that is able to reach a deep water table, for observed annual rainfall on land classified according to types of crops and natural vegetation. By field examinations and inspection of aerial photographs it is estimated that about 2,000 acres of the recharge area in the Carpinteria basin is land devoted to citrus crops and the remaining 2,480 acres largely to grass and weeds. Points for Blaney's values of deep penetration and corresponding seasonal rainfall on land of these two types are plotted on rectangular coordinates on figure 2. Curves are drawn through the points so plotted. The points as plotted for citrus land seem to define two curves. Those defining Curve *B* were mostly for the season 1929–30, when conditions may have been especially favorable to deep penetration of low rainfall. Curve *A* is based on a greater number of points and shows a lower proportion of deep penetration. It is here favored as being the more conservative.

Curve *C* is based on relatively few points and is not well defined, but it gives an approxiation for deep penetration below grass and weeds.

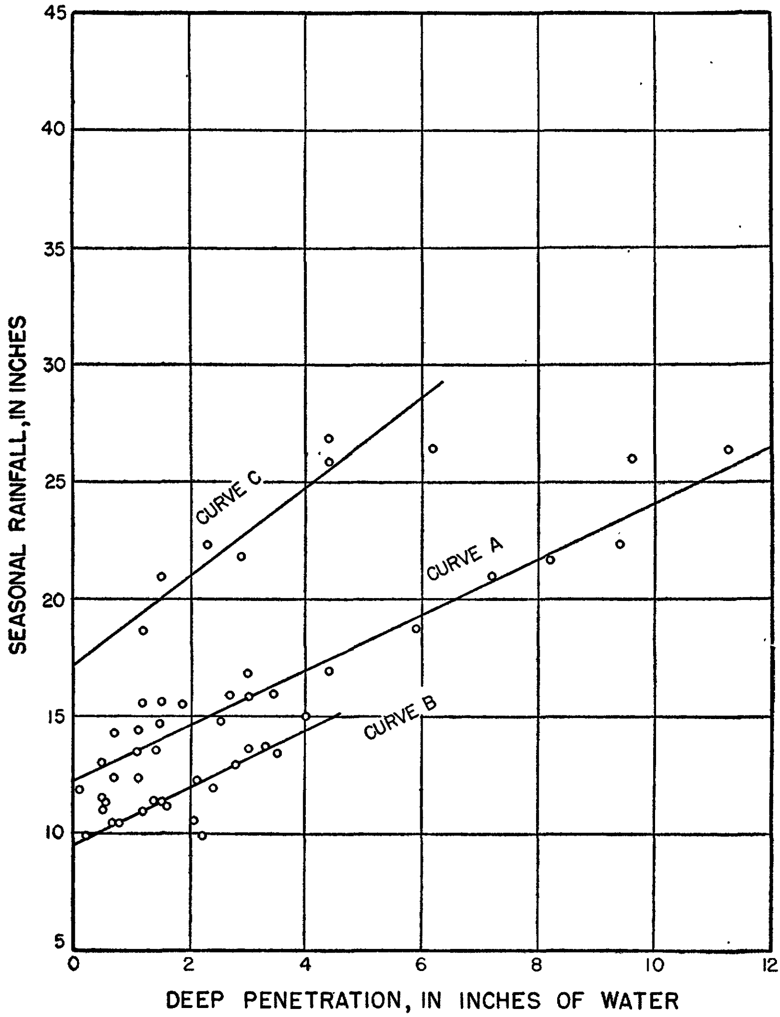


FIGURE 2.—Graphs showing deep penetration in comparison with seasonal rainfall on land in citrus crops (curves *A* and *B*) and on land in grass and weeds (curve *C*).

For purposes of analysis it is assumed that conditions in the Carpinteria basin are generally comparable to those in the Ventura County areas. Values for the seasonal rainfall at Carpinteria during the years 1939 to 1945 are applied to the curves of figure 2 to derive approximate amounts of deep penetration of rainfall. The data are summarized in the accompanying table.

Estimated recharge by infiltration of rain in the Carpinteria basin

Year	Yearly rainfall[1] at Carpinteria (inches)	Deep penetration of rain				Total recharge (acre-feet)
		Citrus crop land		Land in grass and weeds		
		(Inches)	(Acre-feet)	(Inches)	(Acre-feet)	
1939–40	11.25	0	0	0	0	0
1940–41	38.87	22	3,667	11.2	2,315	5,980
1941–42	13.94	1.5	250	0	0	250
1942–43	18.74	5.4	900	0.8	165	1,065
1943–44	16.86	3.9	650	0	0	650
1944–45	15.93	3.1	516	0	0	516
Average 1941–45						1,690
1868–1945[2]	18.40	5.2	867	0.7	145	1,000

[1] From table 1.
[2] Long-term rainfall at Santa Barbara.

The values given for recharge from rain are not considered very accurate, but they do give the relative recharge in different years and may approximate the actual recharge. The figure for the year 1940–41 may be too high, as the curve is extended on a straight line to the high rainfall of that year without control. Actual deep penetration may have been somewhat less. On the other hand, the long-term average rainfall used for calculations is that at Santa Barbara. Concievably rainfall may have been somewhat greater on the higher ground of the Carpinteria recharge area.

SEEPAGE FROM STREAMS

In recharge by seepage from streams, water can seep to the deep water body only within the recharge area. There the streams flow on alluvium which receives the water and transmits it to the truncated and upturned edges of the underlying water-bearing deposits containing the deep water body.

Estimates of the amount of recharge from this source are based on records of stream flow kept on Carpinteria Creek at the point where the foothill road crosses the stream, and on measurement of seepage loss directly from this creek and other small creeks that flow out of the foothill area. These are discussed in pages 43 to 45 of this report. It is concluded that the average seepage loss from creeks that enter the Carpinteria basin during the relatively wet period from 1941 to 1945 was about 900 acre-feet a year, but that the long-term average is about 700 acre-feet a year. Essentially all of this amount is considered to pass to the deep water body.

Thus, natural recharge to the deep water body has occurred by infiltration of rain plus seepage loss from streams in a long-term average amount estimated to be approximately 1,700 acre-feet a year. During the period 1941–45, the recharge may have been as much as 2,600 acre-feet a year.

FLUCTUATIONS OF WATER LEVELS

Short-term fluctuations.—During 1941 the Geological Survey began to make periodic measurements of the water level in wells; records of about 20 wells have been continued to date. Measurements made during 1941 and subsequent years have been published in Water-Supply Papers and released locally in typewritten reports. (See p. 8.) Water-stage recorders have been operated in three wells in the area. For well 4/25–27P3 water-level charts are available from April 29 to August 23, 1943; for well 4/25–27Q2, from January 30, 1941, to April 20, 1943; and for well 4/25–29R1, from April 20 to December 30, 1943.

Figure 3 shows fluctations of water level in each of four observation wells in the Carpinteria basin in the years 1941–46. These graphs show the usual seasonal decline that accompanies summer pumping, and the corresponding winter recovery. The hydrographs of figure 3, measurements in other wells, and the recorder graphs, all show that the fluctuations of the water level in wells during the pumping season from June to October, inclusive, are very rapid. The effect of pumping a well is reflected promptly in a nearby well by a lowering of the water level that usually amounts to several feet. At the start of the pumping season the water levels in all wells drop rapidly, even though not all may be pumped. The amount of lowering in an idle well depends, of course, upon how close the well is to a pumped well or to an area of heavy pumpage, but the lowering of the water level is generally as much as 20 feet, and in heavily pumped areas as much as 40 feet.

The graphs of figure 3 show that water levels have been lowest at the end of the pumping season in the autumn, after which they have risen until May or June. The rise usually has been about half as rapid as the previous lowering of the water level. The pumping, which has usually begun in June, ordinarily has sharply cut off the rise but in some cases the rise at the end of the cycle is slow, indicating that the water level probably would not have risen much higher if pumping had not been started.

Taking the period 1941 to 1946 as a whole, the water levels in wells far from the pumped area, such as well 4/25–21R1, show a progressive rise whereas in other wells in the pumped area, such as well 4/25–29D1, the water levels showed a progressive lowering. The water level in

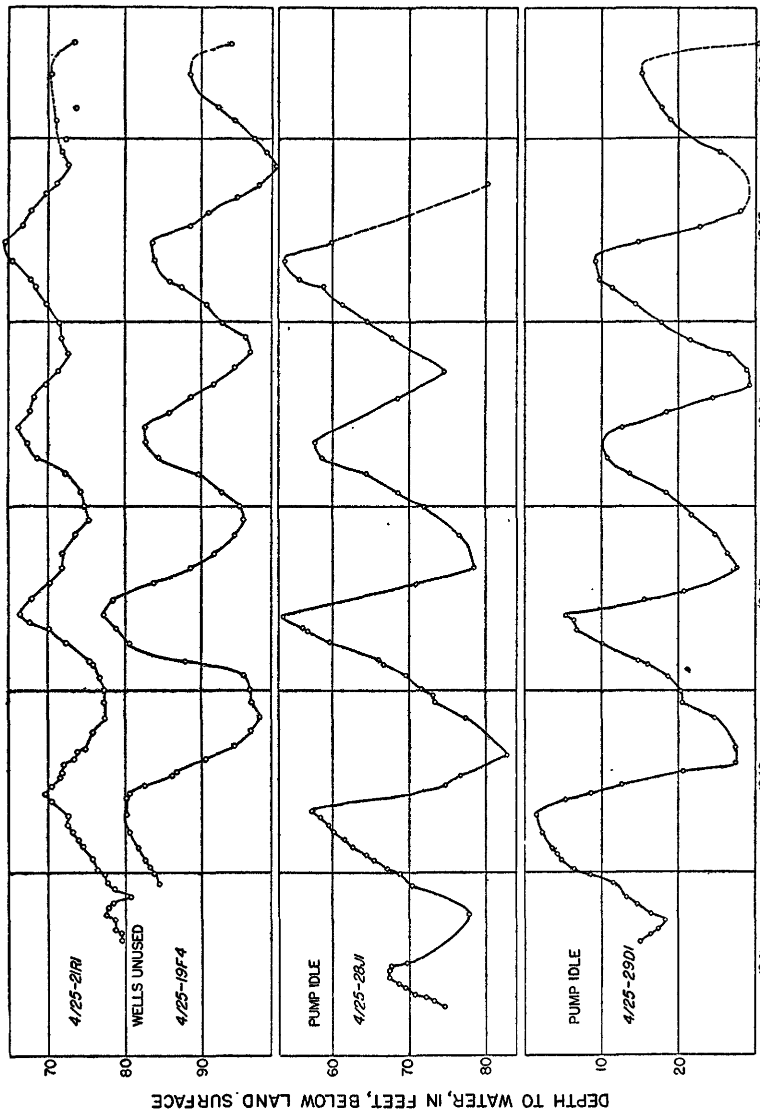


FIGURE 3.—Fluctuations of water level in wells in the Carpinteria basin, 1941–46.

well 4/25–28J1, in the pumped area but close to recharge from Carpinteria Creek, remained about constant. The level in well 4/25–19F4, unused and not in a heavily pumped area, also showed a small net decline over the period of record. Thus, whereas there is no large progressive change over this period, and whereas the direction of change (up or down) has not been the same in all parts of the area, the records do show a small deficiency of recharge as against withdrawals. In view of the fact that 4 of the 6 years of record here depicted were marked by an average excess of rainfall, it is believed that the water levels would have shown a larger average net decline had rainfall been average or below-average.

Long-term fluctuations.—Original water levels in the Carpinteria basin were considerably higher than at present. The former occurrence and distribution of flowing wells has been discussed (p. 58). It should be recalled here that in about 1900, when the first wells were drilled, original pressures corresponded to static heads of as much as 70 feet above sea level in the area of confined water. At that time artesian heads and water levels doubtless were even higher near the bordering hills, or recharge areas, but data on altitudes of water level in those areas as early as 1900 are lacking. However, there doubtless has been considerable decline of water levels since 1900 in all parts of the basin.

Quinton [7] and others measured the water levels in some wells during 1938 and a few observations made by well owners before 1938 are on record. The best record known to be available is that for wells 4/25–26A1 and 2. These two wells are north of Shepard Mesa in the main area of recharge and are about 40 feet apart. They are over 300 feet deep and tap the same water body. Well 4/25–26A2 was drilled in 1932, and water-level measurements in it are available for 1932, 1938, and 1939. Well 4/25–26A1 was drilled in 1940, and thereafter water-level measurements were made in this new well only. Figure 4 shows a single graph of water-level fluctuations based on measurements in the two wells. The measurements were made by J. F. Dewar, Secretary of the Moses Mesa Water Association, and kindly supplied by him to the Geological Survey.

The graph shows the seasonal fluctuation in years when measurements were frequent, and it also shows a net decline since 1932 of about 33 feet to the approximate peak of recovery in 1945. The decline since 1935, the first year for which pumpage is estimated in this report, is roughly 27 feet.

[7] Quinton, Code, and Hill-Leeds and Barnard, Consulting Engineers, Utilization of water resources in southern portion of Santa Barbara County, California; Mimeographed report, 85 pp., 1939.

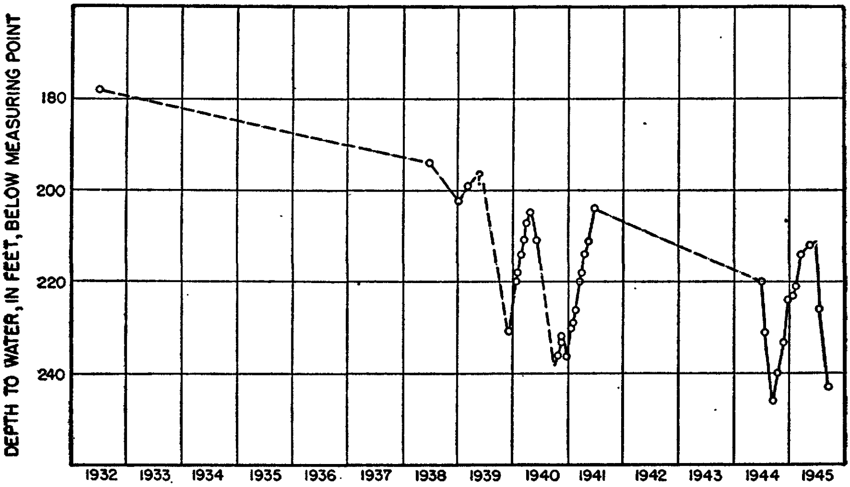


FIGURE 4.—Fluctuations of water level in wells 4/25–26A1 and 2, 1932–45.

PUMPAGE FROM WELLS

The first wells constructed in the Carpinteria area were hand dug and for the most part served domestic and stock needs. Prior to 1900 small hand-operated well drilling equipment was used to put down wells about 2 inches in diameter. Wells having a natural flow of a few gallons a minute were obtained at a depth of about 100 feet in the vicinity of the town of Carpinteria. Flowing wells became very popular and further drilling with power-driven equipment penetrated other artesian water-bearing beds as much as 200 feet below the surface. As the demand for irrigation water increased, the drilling of new and deeper wells continued. With this added withdrawal, wells ceased to flow and water levels dropped below the land surface. Little interest was shown regarding the ultimate effect upon the water levels by the increased pumpage from wells until 1938, when Quinton and others were requested to prepare a report on the water resources of Santa Barbara County. They included in their report an estimate of the water requirements of the Carpinteria basin and an estimate of the safe yield of the water-bearing beds underlying the basin. They [8] estimated that about 2,600 acre-feet was pumped from wells in 1938 and that the safe yield of the water-bearing beds was about 1,600 acre-feet a year.

During the present investigation by the Geological Survey an attempt has been made to estimate the amount of water pumped from wells for the years 1935 through 1945. Wells and pumps were visited in the field and the meter numbers were recorded for those meters

[8] Quinton, and others, op. cit., pp. 36–37.

registering power used to pump water from wells. These meter numbers were then used to identify accounts in the files of the Southern California Edison Co. The total kilowatt-hours used each year to pump water was then obtained by adding the kilowatt-hours of the individual accounts. Deductions were made for those accounts that had booster pumps or other consumptions connected through the same meter with the motors on the well pumps. The accounts of the Southern California Edison Co. are based on the year between May of one calendar year and April of the next year. The total as of April is essentially the electric power used for the preceding irrigation season, because ordinarily very little power is used during the winter months. During wet years practically no power is used to pump water from wells during the winter months December through April. In the following discussion and tables, the total pumpage of any "pumpage-year," such as May 1, 1935, to April 30, 1936, is listed under the earlier of the two calendar years because most of the total pumpage takes place in the irrigation season of that year.

In order to estimate the total amount of water pumped each year from the electric power consumed, it is necessary to obtain a reasonably accurate figure for the amount of power required to pump a given amount of water—usually taken as an acre-foot. The power required varies widely in different parts of the Carpinteria basin because pumping conditions vary. Chief of these is the pumping lift. Static water level varies from a few feet below the surface in the alluvial plain near the ocean to as much as 240 feet in the foothills northeast of the plain, and pumping lifts have a comparable range. Accordingly, the basin was divided into five subareas within each of which pumping conditions are considered fairly uniform; and a value for power consumption per acre-foot of water pumped was obtained for each subarea by discharge and efficiency tests on from two to four representative wells in each area. The yearly power consumption in kilowatt-hours was then totaled for each subarea and divided by the appropriate number of kilowatt-hours per acre-foot to obtain the yearly pumpage in each subarea. The sum of these figures is the total amount of water pumped per year by electrically driven pumps in the Carpinteria basin.

Subarea 1 lies in the western part of the basin between Toro Canyon on the west, Arroyo Parida on the east, State Highway 150 on the north, and the ocean on the south. The altitude of this area is everywhere less than 50 feet above sea level. Discharge tests made on two wells give an adjusted value of 375 kilowatt-hours per acre-foot.

Subarea 2 extends east of subarea 1 to the stream from Santa Monica Canyon, and north from the ocean to the edge of the alluvial plain or to a line about 500 feet south of State Highway 150. Discharge tests made on three wells give an average value of about 400 kilowatt-hours per acre-foot of water.

Subarea 3 embraces the central part of the alluvial plain between the stream from Santa Monica Canyon and Carpinteria Creek, and extending half a mile east of Carpinteria Creek along United States Highway 101. Tests on three wells give an adjusted value of 300 kilowatt-hours per acre-foot of water pumped.

Subarea 4 includes the remainder of the alluvial plain south of State Highway 150. In general the depths to water are considerably greater than in subarea 3. The average of results of four tests is 550 kilowatt-hours per acre-foot.

Subarea 5 includes the rest of the basin, chiefly the dissected foothill area northeast of the alluvial plain. Here the lifts are high, and the results of three tests give an adjusted value of 575 kilowatt-hours per acre-foot.

The following table gives the estimated annual pumpage by years for each of the subareas, and the total amount pumped for the whole basin, computed according to the foregoing methods.

TABLE 7.—*Estimated irrigation water, in acre-feet, pumped by electric energy in the Carpinteria basin during the years 1935–44*

Year	Subarea					Total (rounded off)
	1	2	3	4	5	
1935	78. 7	168. 5	575. 9	187. 7	289. 8	1, 300
1936	152. 0	228. 5	883. 4	340. 0	391. 2	2, 000
1937	131. 2	209. 5	783. 8	360. 4	446. 5	1, 900
1938	140. 8	193. 8	706. 7	346. 2	400. 7	1, 800
1939	185. 5	272. 1	1, 026. 0	588. 4	567. 3	2, 600
1940	123. 7	249. 2	884. 6	499. 0	615. 6	2, 600
1941	105. 8	172. 2	588. 9	350. 6	514. 9	1, 700
1942	123. 9	205. 0	651. 2	481. 8	773. 8	2, 200
1943	185. 3	232. 3	858. 9	566. 7	923. 6	2, 800
1944	158. 6	206. 6	752. 1	486. 1	824. 5	2, 400

In addition to water pumped by electric energy there are eight well pumps that are driven by engines using natural gas. It was found by testing several pumping plants that it requires on the average about 10,000 cubic feet of natural gas to deliver one acre-foot of water. The following table indicates the amount of gas used and the corresponding amount of water pumped each year.

Finally, some water pumped for the town of Carpinteria is not accounted for in the foregoing computations. The amount is estimated on the basis of energy consumption as related to pumpage during 1944. The total water pumped from wells in the Carpinteria basin, in acre-feet, is determined by adding the amount pumped by electric energy from irrigation wells, the amount pumped by natural gas, and the amount pumped for the town of Carpinteria. The totals are shown in the following table.

TABLE 8.—*Estimated irrigation water, in acre-feet, pumped by engines using natural gas in the Carpinteria basin 1935–44*

Year	Natural gas (cubic feet)	Water pumped (acre-feet)	Year	Natural gas (cubic feet)	Water pumped (acre-feet)
1935	3, 031, 000	300	1940	4, 556, 000	460
1936	4, 337, 000	430	1941	2, 932, 000	290
1937	3, 231, 000	320	1942	4, 156, 000	420
1938	3, 437, 000	350	1943	3, 914, 000	390
1939	5, 105, 000	510	1944	3, 618, 000	360

TABLE 9.—*Estimated total water, in acre-feet, pumped from wells in the Carpinteria basin 1935–44*

Year	Pumped by electric energy	Pumped by natural gas	Pumped for town of Carpinteria	Total
1935	1, 300	300	210	1, 810
1936	2, 000	430	320	2, 750
1937	1, 900	320	220	2, 440
1938	1, 800	350	300	2, 450
1939	2, 600	510	360	3, 470
1940	2, 600	460	280	3, 340
1941	1, 700	290	400	2, 390
1942	2, 200	420	500	3, 120
1943	2, 800	390	500	3, 690
1944	2, 400	360	500	3, 260
Average 1940–44				3, 160
10-year average				2, 870

There are many sources of error in this method of arriving at the total amount of water pumped from wells each year, but it is believed to give results that are approximately correct. The yearly figures are approximately correct, and they at least indicate the trend from year to year. In the Carpinteria basin most of the irrigation is within the area of confined water, and it is believed that the amount of return seepage of irrigation water to the main water body is negligible.

The total amount of water pumped during the year is governed to some extent by the distribution of the rainfall. No rain falls during the summer months, but the summer irrigation season may be shortened considerably if a heavy rain occurs as late as June or as early as November. During some years a little pumping is necessary in the months of January or February if a rain that occurs early in the fall is followed by a dry period. Generally, pumpage has been low in years of high rainfall, and high in years of low rainfall. Pumpage increased steadily from 1935 to 1939 and for 1939 was nearly twice as much as for 1935. Less water was pumped in 1940 than in 1939. In 1941, which followed the year of maximum recorded rainfall, the pumpage dropped down to what it had been in 1938. The pumpage in 1942 was somewhat greater and in 1943 was the greatest of the period of record.

RELATION OF PUMPAGE TO FLUCTUATIONS OF WATER LEVELS

It has been shown that the ground water in the area of withdrawal (chiefly the alluvial plain) in the Carpinteria basin is confined. Therefore, water must reach the area of withdrawal by lateral transmission through the deposits from the area of recharge. It has been indicated (p. 62) that seasonal rises of water level in the recharge area owing to infiltration of rain probably are very small. They probably are so small that they do not appreciably change the hydraulic gradient between the area of recharge and the area of withdrawal. Furthermore, most of the recharge area is fairly remote from the area of withdrawal and the intervening material has a low transmissibility. Accordingly, the seasonal declines of water level caused by pumping probably do not extend appreciably into the recharge area. Therefore, the hydraulic gradient has probably been nearly constant and the rate of transmission of water to areas of withdrawal is considered nearly constant. Thus, the water levels in wells reflect principally the changes in quantity of pumpage.

The chief effect of rainfall is to cause irrigation to cease, and thus rainfall does affect water levels indirectly. For example, in a wet year the necessity for irrigating is less, and the amount of water pumped from wells during the following summer is less. Conversely in a dry year, pumping begins early in the spring and the total quantity is greater. In the succeeding winters, water levels generally recover to higher levels after summers of small pumpage, and to lower levels after summers of large pumpage. Thus, the peak of water-level recovery each spring has a direct relation to the total pumpage of the preceding year. Of course, the height to which water levels will recover each spring depends partly on how early pumpage begins. But ordinarily the peak of recovery in a spring of early pumpage is nearly what it would have been had pumpage begun a little later. Figure 5 gives a comparison between spring water-level peaks in wells 4/25–27Q2 and 4/25–29D1 on one hand, and the pumpage during

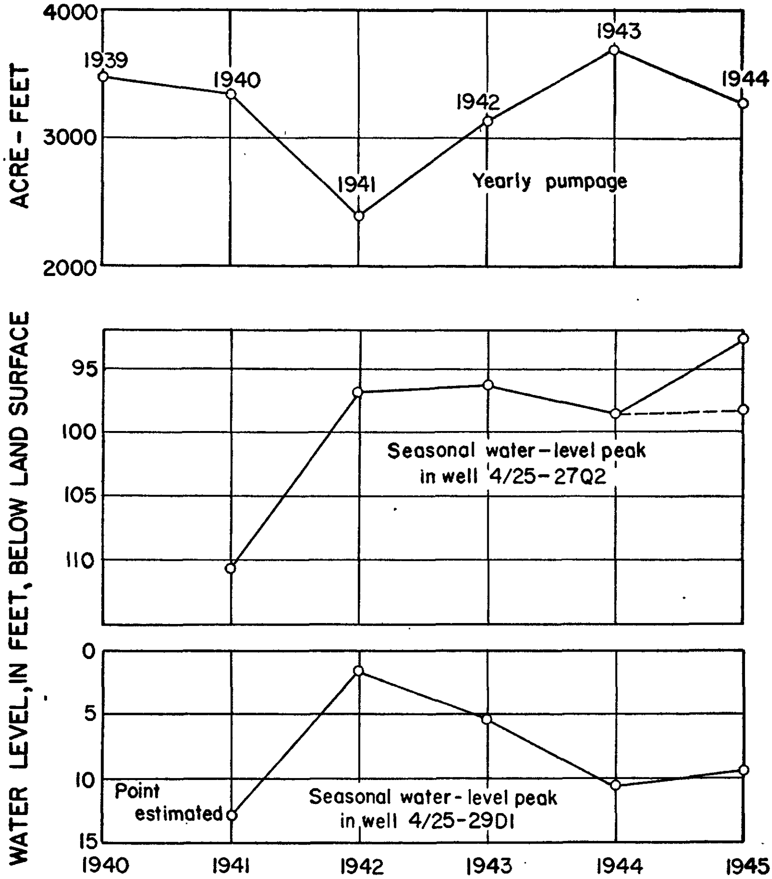


FIGURE 5.—Relation between total yearly pumpage and seasonal water-level peaks in two wells in the Carpinteria basin.

the preceding irrigation season on the other. The two wells are within the area of withdrawal. As explained on p. —, pumpage is totalled for the year as of April, but represents mainly the pumpage in the preceding irrigation season. In 1940 pumpage was fairly large, and the water-level peak in the spring of 1941 was low even though rainfall during that winter was the highest of record. In 1941 pumpage was small and the water level peak in the spring of 1942 was almost if not quite the highest in the 5 years 1941–45. In 1942 the pumpage was nearly as high as in 1940, and the 1943 water-level peak was somewhat less than in 1942 in well 4/25–29D1, but slightly higher in well 4/25–27Q2. In 1943 the pumpage was the highest of record, and 1944 water-level peaks were considerably lower than in 1943. The pumpage in 1944 was somewhat less than in 1943, and the

1945 water-level peak in well 4/25–29D1 was a little higher than in 1944.

In well 4/25–27Q2 the measured peak was quite high, but it may have been affected by artificial recharge. A more likely level is shown on the curve. The fact that the peaks in well 4/25–29D1 show a net decline from 1942, and those of most other wells also show a decline or else barely remain constant (see fig. 3), suggests that the pumpage in the 5 years 1941–45 has been somewhat in excess of the rate of transmission of water to points of withdrawal. The fact that water-level peaks in well 4/25–27Q2 remained at about the same level whereas those in 4/25–29D1 declined somewhat in 1942 and 1943, years when pumpage rose from 2,400 to 3,200 acre-feet, suggests that pumpage of more than about 3,200 acre-feet is in excess of the normal rate of transmission to the points of withdrawal.

This relationship may be expressed in a somewhat different way that gives more specific results. Assuming the rate of transmission to the area of withdrawal to be essentially constant, the pumpage can be compared directly with average net change of water level over the area of withdrawal. The basic principal has been expressed by Harold Conkling (1945, pp. 55, 56) and is here considered applicable to the small Carpinteria basin because of the confining conditions that exist throughout the greater part of the area of withdrawal.. A few wells have been drilled in the recharge area, during the period 1935–44, but most of the wells are in the area of confined water within the alluvial plain. Even in the recharge area the water is to some extent confined, as explained on p. 59. If the pumpage in any one year is greater than the transmission rate, the average water-level peak from the preceding year will decline. If the pumpage is less, the average water-level peak will rise. If the pumpage and net water-level change for several years be graphed, with pumpage as one coordinate and water-level change as the other coordinate, the points should fall on a straight line, and the pumpage coordinate at the point of no water-level change on the line should equal the transmission rate.

Figure 6 shows the graph obtained by that method for the years 1941 to 1945. On the plate the date shown at each plotted point is that of the irrigation season in which the bulk of the pumpage took place. The corresponding water-level change is that between the two peaks: one before and one after the pumping season indicated. The pumpage figures were obtained by the method outlined previously. The net water-level change from year to year between 1941 and 1945 was obtained by plotting on a map the yearly net change at each well measured within the area of confined water—the main area of withdrawal—and apportioning the change over the entire area by averaging the changes within each quarter section where more than one value exists, and interpolating or extending in other quarter sections where no values exist. Thus, the net change is roughly averaged according to area, and a concentration of values in any one small area is not overweighted. In this way the four points on the graph corresponding to the years 1941, 1942, 1943, and 1944 were obtained. The fifth point is an average for the 3-year period 1938–40.

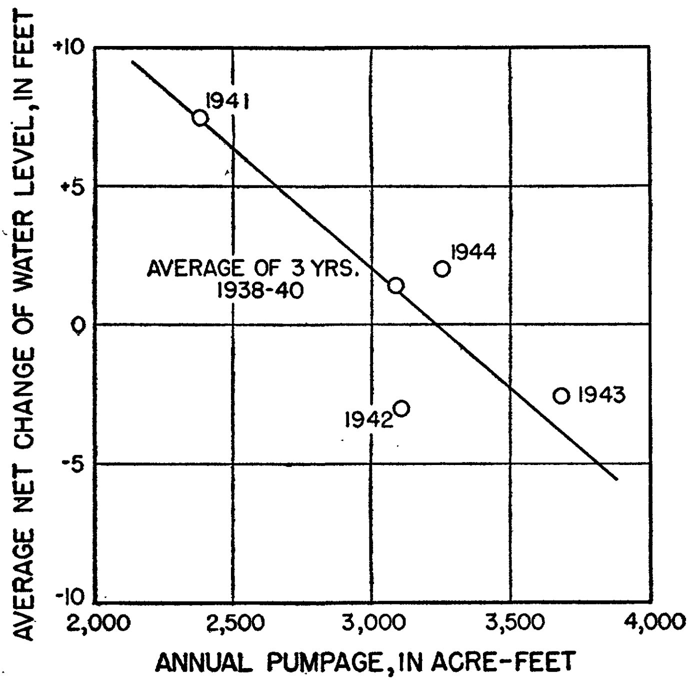


FIGURE 6.—Graph showing relation of pumpage to annual net change of water-level peaks in the Carpinteria basin.

A number of water-level measurements made by Quinton and others [9] were made available by the County. As most of these were made in other wells than those measured by the Survey in 1941, a different means of obtaining the average net change was used. The measurements by Quinton and others, which were all made in April and May 1938, and thus near the probable spring peak, were plotted on a map; and contours of altitude of the water surface as of that date were drawn. The map is reasonably accurate, considering that actual conditions at the time of measurement were not known. Then the altitudes of water surface determined by the Geological Survey in the spring of 1941 were plotted on the same map, and the net change

[9] Quinton, and others, op. cit.

interpolated or, in a few cases, observed. The net changes were extended into areas where no measurements exist, and prorated according to quarter sections as before. The total net change was divided by 3 to obtain the average per year. The total pumpage was also averaged and the point plotted on the graph.

The points are somewhat scattered, but they roughly define a straight line which passes through the line of zero water-level change opposite an annual pumpage of between 3,200 and 3,300 acre-feet. This pumpage, then, is considered to be approximately the annual quantity of water being transmitted to the area of withdrawal during the period 1938 to 1944.

PERENNIAL YIELD OF THE CARPINTERIA BASIN

The perennial yield of the Carpinteria basin is the average quantity of fresh ground water that is available for withdrawal every year. Here this quantity is essentially the long-term average recharge, inasmuch as there is apparently very little salvagable discharge. In wet years relatively more water may be available; in dry years relatively less water is available. In dry years the recharge may be exceeded somewhat by pumpage, provided the excess is restored during wet years. In some areas current recharge may be exceeded beneficially by allowing excess water to be taken from storage, thereby creating additional storage space that may allow an increase in natural recharge. However, in the Carpinteria basin, this is believed not to be the case. Additional lowering of water levels probably will not afford much additional recharge and, conversely, may allow damaging encroachment of sea water.

The recharge is very difficult to determine, but is here estimated to have averaged about 1,700 acre-feet a year from rain (table on p. 64) and about 900 acre-feet a year from streams (table on p. 44 and p. 45) during the period 1941–45, making an average total of 2,600 acre-feet a year. The pumpage during the same period averaged about 3,200 acre-feet a year (table 9), or an excess of about 700 acre-feet. Yet, as discussed on p. 65, the water levels in the pumped area showed only a small over-all decline, and the pumpage apparently was within the natural rate of transmission of water to the pumped area.

However, the amount transmitted is not necessarily the total recharge. The amount transmitted is supplied by seepage from streams and infiltration of rain; it also may be supplied in part from storage by unwatering the water-bearing deposits in the outcrop areas. The natural recharge in 1941–45, as indicated, accounts for only 2,600 of the estimated 3,200 acre-feet being transmitted. The remainder is probably largely derived from storage, as discussed in the ensuing paragraph.

In few wells in the recharge areas are there any records of net change of water level over any period of time. Well 4/25–19F4 (fig. 3) reached a peak in 1943 and thereafter declined an average of about 3.5 feet a year. Well 4/25–28J1 shows little change, but is close to recharge from Carpinteria Creek and largely reflects changes in a very small area. The best record is in the pair of wells, 4/25–26A1 and 2 (fig. 4), situated high in the recharge area. This record shows a net decline from 1932 to 1945 of 33 feet, or about 2.5 feet per year. From 1940 to 1945, a period of relatively high rainfall, the net decline was roughly 7 feet, or slightly less than 2 feet per year. No information is at hand on the specific yield of the deposits. They contain considerable clay and probably have somewhat less specific yield than the less-compacted younger alluvium in the Lompoc plain of the Santa Ynez River basin, estimated to have a specific yield of 14 percent (Upson and Thomasson, 1951). Accordingly, a specific yield of 10 percent for the water-bearing formations of the Carpinteria basin is thought to be reasonable. If the decline of water level in well 4/25–26A1 from 1940 to 1945, nearly 2 feet per year, is representative of the whole area of recharge, and if the value of 10 percent for average specific yield is correct, the amount of water taken from storage and transmitted to the pumped area in any one year has been about 900 acre-feet. This amount is more than required but is considered to balance the deficiency from seepage loss and rainfall infiltration in view of the rather wide limits of accuracy of the computation.

Thus, the amount of water currently being transmitted is evidently greater than the natural recharge. Existing hydraulic gradients in the Carpinteria basin are so steep that a continued decline of 2 feet per year in the recharge areas will not greatly affect the amount of water transmitted for some years to come, but it will do so eventually. In anticipated years of low rainfall, the decline may be somewhat more rapid when the annual increment from rain infiltration is low. Therefore, the average draft of about 3,200 acre-feet a year in the years 1941–45 could be sustained for some years, but not indefinitely.

Thus, the safe yield of the Carpinteria basin is considered to be the long-term average recharge. If this recharge equals the average infiltration of rain of 1,000 acre-feet a year (table on p. 64) and average seepage from streams of 700 acre-feet a year, the total is 1,700 acre-feet a year.

QUALITY OF WATER

The Geological Survey collected 50 samples of water from wells, springs, and streams to study the quality of ground water in the Carpinteria basin. Partial analyses (comprising determinations of chloride, soap hardness, and specific electrical conductance) were made of 30 of these; complete analyses of 4 were made by the Geological Survey; and complete analyses, except for determination of iron and silica were made of 16 by the Rubidoux Laboratory of the United States Department of Agriculture. In addition, several chemical analyses were assembled from other sources. The analyses are given in the following tables.

These analyses show that for most wells tapping the deep water body in the Carpinteria basin, those in the central and eastern parts yield water in which the chloride content ranges from 19 to 63 p. p. m. and the hardness ranges from 250 to 415 p. p. m. One well in the pumped area, 4/25–27R2, yields water having 114 p. p. m. of chloride, and another well, 4/25–34L1, which probably penetrates the consolidated rocks, yields water having 182 p. p. m. of chloride. In the western part of the basin, chiefly in sec. 19, T. 4 N., R. 25 W., and sec. 24, T. 4 N., R. 26 W., water from wells is definitely poorer in quality than in the central and eastern parts. Here the chloride content of water from most wells is over 100 p. p. m. and as high as 314 p. p. m. The hardness of water from most wells is between 300 and 500 p. p. m. and as high as 793 p. p. m. in one well—4/25–19K1. The increase in chloride content may be related to boron concentration, but the increase in hardness apparently is not.

For domestic use, waters in the central and eastern parts of the basin are rather low in mineral content and only moderately hard; a few waters in the western part are so hard as to be undesirable for domestic use. For agricultural use, those waters in the central and eastern parts of the basin have a sufficiently low sodium percentage to be suitable for use in irrigation. Of the more saline waters in the western part, only two wells, 4/25–19F5 and 4/25–19M3, are sufficiently high in sodium percentage that some danger of soil impairment might follow their use for irrigation. These waters, however, contain boron also. Their suitability for irrigation is discussed on subsequent pages.

The deep water body is in contact with sea water along the coast west of Carpinteria. Thus, there is opportunity for encroachment of such water provided the hydraulic gradient is favorable. However, existing data do not show any sea-water contamination of the zones from which water is pumped. In wells 4/25–30C1 and 4/25–30D1, reported to be 124 and 210 feet deep, respectively, which are within a quarter of a mile of ocean, the concentration of chloride is 21 and 23 p. p. m. respectively. This is a low concentration even for fresh ground water. In well 4/26–23G1 farther west and also near the ocean, the chloride concentration is 124 p. p. m., but this is less than the concentration of 148 parts at well 4/26–24B1, which is much farther inland. It, therefore, probably does not show sea-water encroachment.

TABLE 10.—*Partial chemical analyses of waters from wells in the Carpinteria basin*

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

Well	Date of collection	Chloride (Cl), parts per million	Soap hardness, as $CaCO_3$, parts per million	Specific conductance ($K \times 10^5$ @ 25° C.)
4/25–19F1	Dec. 1941	38	300	73.1
19F1	Jan. 1942	314	475	158
19G1	Apr. 21, 1942	36	250	72.6
19G3	Dec. 1941	68	315	84.3
19L1	do	283	475	122
19Q4	do	30	340	79.0
20K1	do	27	295	81.4
20M3	Oct. 24, 1941	20	275	72.5
21N1	do	36	300	82.7
21N1	Apr. 21, 1942	32	325	84.4
21N2	Oct. 24, 1941	30	300	82.2
26C3	Jan. 1942	19	300	73.1
27B1	do	30	300	85.2
27F1	Oct. 24, 1941	24	325	79.8
27G1	do	35	275	71.1
27P2	Apr. 21, 1942	41	300	80.4
27Q1	Oct. 23, 1941	42	340	98.8
27Q5	Oct. 24, 1941	35	275	81.4
27R2	do	114	275	92.7
28F3	Jan. 1942	27	315	78.5
28J1	Oct. 23, 1941	37	340	84.9
28L1	do	49	340	86.0
30C1	Dec. 1941	21	300	74.0
30D1	do	23	250	76.9
34L1	Nov. 1941	182	525	388
35A1	do	62	415	108
35A2	do	63	400	101
4/26–23A3	Dec. 1941	115	250	125
23G1	do	124	265	84.4
24B1	do	148	325	118

However, if pumpage should reduce the fresh-water head to or below sea level, landward migration of sea water would develop. In fact, a wedge of sea water may now lie at fairly shallow depth in the seaward part of the unconsolidated deposits. The contour map (pl. 7) shows only a slight hydraulic gradient toward the sea. On March 30, 1945 the altitude of the water surface at well 4/25–30D1 was 5.3 feet. According to the Ghyben-Herzberg principle (Brown, 1925), this head of fresh water is adequate to hold sea water at a depth of about 210 feet at the well. Farther inland the sea-water contact lies deeper, and may be about 400 feet below sea level in the area shown beneath the 10-foot contour line of plate 7. However, this is a considerable distance inland, and the deposits are not very permeable. Furthermore, no salty water is reported from wells within the 10-foot contour. Therefore, current conditions of low

TABLE 11.—*Selected chemical analyses of well, stream, and spring waters of the Carpinteria basin*

Number	Location symbol [1]	Source	Date of collection	Temperature (°F.)	Parts per million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
1	4/25-19F5	G. L. Morriss (formerly M. F. Lewis, "old well"). Drilled irrigation well 161 feet deep. Sample taken by U. S. Geol. Survey (No. AP-15); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17972).	Aug. 11, 1944	64	[2] 777	------	------	79	31	[2] 169		tr.	281	116	237	2.68	------	1.9	325
2	4/25-19G1	S. M. Brown. Drilled irrigation well 270 feet deep. Sample taken by U. S. Geol. Survey; analysis by G. J. Petretic, U. S Geol. Survey (No. 27410).	Apr. 21, 1942	------	473	31	3.2	76	22	52	2.1	0	280	113	34	------	1.4	.1	280
3	4/25-19G3	Stewart Meigs. Drilled irrigation well 300 feet deep. Sample taken by U. S. Bureau of Reclamation; analysis by National Bureau of Standards.	Dec. 10, 1942	------	570	------	------	94	26	49	2.8	0	290	110	72	.1	------	.9	342
4	4/25-19K1	D. R. Stone. Drilled irrigation well 143 feet deep. Sample taken by U. S. Geol. Survey (No. AP-11); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17968)	Aug. 11, 1944	66	[2] 614	------	------	120	37	[2] 55		tr.	288	84	163	.13	------	11.2	793
5	4/25-19L1	Neal Ballard. Drilled irrigation well more than 200 feet deep. Sample taken by U. S. Geol. Survey (No. AP-12); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17969).	do	66	[2] 626	------	------	121	38	[2] 54		0	287	105	153	.20	------	11	458
6	4/25-19M3	T. C. Abbott. Drilled domestic well. Sample taken by U. S. Geol. Survey (No. AP-10); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17967).	do	67	[2] 795	------	------	98	29	[2] 161		6.0	320	127	210	1.72	------	1.9	364

7	4/25-21N1	C. B. Franklin. Drilled irrigation well, 501 feet deep. Sample taken by U. S. Geol. Survey; analysis by G. J. Petretic, U. S. Geol. Survey (No. 27412).	Apr. 21, 1942	65	529	24	6.2	75	37	62	1.8	0	388	113	30	------	.5	.2	339
8	4/25-27P2	C. B. Franklin. Drilled irrigation well, 480 feet deep. Sample taken by U. S. Geol. Survey; after 20 minutes pumping; analysis by G. J. Petretic, U. S. Geol. Survey (No. 27411).	do	66	500	24	6.9	79	26	63	2.2	0	338	106	41	------	.4	.5	304
9	4/25-27P4	G. R. Bliss. Drilled irrigation well more than 200 feet deep. Sample taken by U. S. Bureau of Reclamation; analysis by National Bureau of Standards.	Dec. 10, 1942	------	630	------	------	92	30	68	3.5	0	370	98	53	0.05	------	13	353
10	4/25-28J1	W. C. and C. A. Catlin. Drilled irrigation well, 170 feet deep. Sample taken by U. S. Geol. Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geol. Survey (No. 26559).	Oct. 23, 1941	64	547	15	.02	108	31	34	2.6	0	346	121	35	------	.1	14.	397
11	4/26-24G1	Stanley Shepard (formerly Mark Lang?). Drilled irrigation well more than 200 feet deep. Sample taken by U. S. Geol. Survey (No. AP-16); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17973).	Aug. 11, 1944	------	[2] 736	------	------	89	34	[2] 138		0	320	109	203	1.12	------	1.9	362
12	4/26-24H1	Ben Fish. Drilled domestic and irrigation well 120 feet deep. Sample taken by U. S. Geol. Survey (No. AP-9); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17966).	do	63	[2] 726	------	------	95	32	[2] 128		6.0	293	140	170	1.24	------	6.8	369
13	4/25-19C	Arroyo Parida, at point about 2 miles northwest of Carpinteria and below edge of consolidated rock at mountain front. Discharge about 75 gpm., estimated. Sample taken by U. S. Geol. Survey (No. AP-1); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17657).	Dec. 3, 1943	51	[2] 1,235	------	------	75	20	[2] 384		18	422	48	473	5.79	------	tr.	270
14	4/25-19C	Arroyo Parida, same locality. Discharge about 15 gpm. Sample taken by U. S. Geol. Survey (No. AP-13); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17970).	Aug. 11, 1944	68	[2] 979	------	------	56	21	[2] 294		tr.	337	87	348	4.25	------	tr.	226
15	4/25-18Q3	Spring, issuing from consolidated rock in canyon of Arroyo Parida about 2 miles northwest of Carpinteria and about ¼ mile above site of samples from creek. Sample taken by U. S. Geol. Survey (No. AP-4); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17660).	Dec. 3, 1943	66	------	------	------	------	------	[2] 467		27	527	20	471	7.07	------	tr.	------

See footnotes at end of table.

TABLE 11.—*Selected chemical analyses of well, stream, and spring waters of the Carpinteria basin*—Continued

Number	Location symbol [1]	Source	Date of collection	Temperature (°F.)	Parts per million: Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
16	4/25-18Q	Spring, same locality, resampled by U. S. Geol. Survey (No. AP-14); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17971).	Aug. 11, 1944	66	[2]1,292	------	------	35	12	[2]470		20	503	22	475	6.94	------	tr.	137
17	4/25-18K	Arroyo Parida, at point about 2 miles northwest of Carpinteria and ¼ mile above spring at 4/28-18Q. Sample taken by U. S. Geol. Survey (No. AP-5); analysis by U. S. Dept. Agriculture, Rubidoux Laboratory (No. 17661).	Dec. 3, 1943	------	[2]717	------	------	77	26	[2]162		12	398	109	131	1.24	------	tr.	299
18	4/25-27G	Carpinteria Creek at crossing of State Highway 150. Discharge 73 cfs. Sample taken by U. S. Bureau of Reclamation (No. 20); analysis by National Bureau of Standards, San Francisco Laboratory (No. 61274).	Mar. 4, 1943	------	200	------	------	31	9.7	12	0.3	0	110	41	6.4	------	------	1.3	117
19	4/25-27G	Same; discharge 5 cfs. Sample taken by U. S. Bureau of Reclamation (No. 33); analysis by National Bureau of Standards, San Francisco Laboratory (No. 61725).	Apr. 8, 1943	------	410	------	------	68	23	29	.8	10	210	110	15	.07	------	0	264
20	4/25-25N	Rincon Creek at crossing of State Highway 150. Discharge estimated 250 cfs. Sample taken by U. S. Bureau of Reclamation (No. 21); analysis by National Bureau of Standards, San Francisco Laboratory (No. 61275).	Mar. 4, 1943	------	200	------	------	26	10	14	.7	0	110	26	7.4	------	------	1.5	106

[1] Symbol is well or spring number as described in text; or a location symbol only where applied to a stream locality.
[2] Calculated.

fresh-water head have probably not obtained sufficiently long to cause sea water to encroach very far, and evidently not at all within the 200-foot depth generally penetrated by the wells. However, excessive pumpage would cause a progressive lowering of fresh-water head, and doubtless a resulting invasion of the water-bearing beds by sea water.

Of somewhat more immediate concern in the Carpinteria basin is the presence of boron, in concentrations injurious to lemons and oranges, in the ground water of part of the area. The presence of boron in the Carpinteria basin was noted, from its effect on orchards in 1926 or 1927, by officials of the Department of Agriculture, Bureau of Plant Industry, and reported in 1931 (Scofield and Wilcox, 1931, pp. 40–43). The contamination appeared to be restricted to a small area along Arroyo Parida and the source seemed to be a so-called spring, actually an unsealed oil test well, which had been flowing highly borated water for several years. This water was percolating into the Arroyo Parida and thence into the ground water tapped by a number of the wells.

Although an attempt was made to plug the oil test well with cement in 1938, there seemed to be no diminution of the boron injury to plants in ensuing years except in orchards that were no longer irrigated from the contaminated wells. In 1943 the Geological Survey collected eight samples of water from Arroyo Parida, both above and below the site of the oil test well. These samples were analyzed by the Rubidoux Laboratory of the United States Department of Agriculture, Bureau of Plant Industry; the results of three of them are given in table 11. (See analyses 13, 15, and 17.) Number 13 was taken downstream from the site of the oil test well; numbers 15 and 17 were taken upstream. These analyses show that, regardless of whether or not the oil test well was successfully plugged, there are natural sources of highly borated water along Arroyo Parida which would be sufficient to contaminate ground water being recharged from that stream.

This contamination doubtless has been going on for many years, and seems to be progressing slowly. Numerous samples of water from wells in the contaminated area were taken during 1930 by local land owners and by the County Farm Advisor, and were analyzed by the United States Department of Agriculture, Bureau of Plant Industry. The concentrations of boron when plotted on a map show that most wells between Arroyo Parida and a diagonal line drawn just north of well 4/28–19G1 and south of well 4/28–19M1 had a concentration of boron of more than 1 part per million. (See pl. 1.) Well 4/26–24J1 was not sampled. Wells outside this area had concentrations of boron of less than 0.6 p. p. m.; and all wells south and east of the area had concentrations of less than 0.11 p. p. m. Subsequently a series of samples was taken in well 4/25–19F5; and in 1944 the Geological Survey collected samples of water from five of the wells on which earlier tests had been made. (See analyses 1, 4, 5, 6, and 11, table 11.) Comparison of the results of analyses of these samples and those taken in 1930 and also the series of analyses for well 4/25–19F5 suggests a progressive increase in boron concentration, and probably also slight extension of the area of contamination. These results are summarized in the following table.

Progress of boron contamination in ground water near Arroyo Parida, Carpinteria basin

Well	Date	Boron (ppm)	Date	Boron (ppm)
4/25–19F5	1930	1.89		
Do	Apr. 30, 1939	2.57		
Do	Oct. 20, 1939	2.64		
Do	July 17, 1940	2.68	Aug. 11, 1944	2.68
4/25–19K1	1930	.10	do	.13
4/25–19L1	do	.06	do	.20
4/25–19M3	do	1.58	do	1.72
4/26–24H1	do	1.10	do	1.24

The boron contamination appears to have moved down the normal hydraulic gradient from Arroyo Parida and under natural conditions can be expected to continue. Pumpage of ground water will only accelerate inflow of contaminated water. There seem to be no obvious and practicable means of stopping the contamination, though it might be feasible to pipe off the contaminated water during the periods of low water, and allow only the much larger and more dilute winter flow to recharge the ground-water body.

GROUND-WATER IN THE GOLETA BASIN

The Goleta basin, like the Carpinteria basin, lies along the south coast of the county and comprises the alluvial plain about Goleta and adjoining foothills and terraces. Included with this area is that area about Santa Barbara, with which it is contiguous on the east and in which the geologic and hydrologic features are basically the same.

The water-bearing deposits of the Goleta basin are the younger alluvium, the older alluvium, and the Santa Barbara formation. The distribution of these formations is shown on the geologic map, plate 2. As in the Carpinteria basin, they form a large wedge with the thin edge lapping against the consolidated rocks on the north, and the opposite side abutting against consolidated rocks brought up along faults on the south. The deposits are generally finer-grained but more uniform, and hence probably more permeable, than those of the

Carpinteria basin. However, the permeable deposits are about 2,000 feet in maximum thickness, as compared to 5,000 feet in the Carpinteria basin. Finally, the Goleta basin differs from the Carpinteria basin in that the coastal barrier, composed of the Monterey shale and unnamed Pliocene formation, lies along the entire shore and almost completely separates the water-bearing deposits from the ocean.

OCCURRENCE OF GROUND WATER

PROPERTIES OF THE WATER-BEARING FORMATIONS

Younger alluvium.—The younger alluvium, as shown on plate 2, is penetrated by numerous wells drilled on the Goleta alluvial plain, most of which, however, penetrate the entire formation and derive water from the underlying Santa Barbara formation. Logs of many of the wells (pl. 8 and table 17) show that the materials composing the younger alluvium are chiefly clay and silt with intercalated lenses of sandy clay, sand, and gravel. Fine-grained materials predominate beneath the central part of the plain where the clay, sandy clay, and silt accumulated in swamps, sloughs, and stream flood plains. Beneath the marginal parts of the plain the deposits are generally somewhat coarser. In the alluvial tongues in the canyons of streams that enter the plain, the deposits contain a fairly large proportion of sand and of gravel. These alluvial tongues extend a short distance across the plain and are penetrated by a few wells such as 4/28–9E1, 4/28–10G2, and 4/28–10N2. (See table 17 and pl. 8.) Linear bodies of gravel, which may extend across the entire plain, occur at the base of the younger alluvium, and evidently lie in channels cut by streams flowing across the underlying Santa Barbara formation prior to and during the early stage of deposition of the alluvium.

The clay and silt that compose most of the younger alluvium occur in nearly continuous or closely overlapping lenses, and yield water only very slowly. For example, the few shallow wells known, such as wells 4/28–8K3 and 4/28–16B2, obtain only enough water for small domestic supplies. Some wells, such as 4/28–3E2 and 4/28–3E6, that penetrate the coarser deposits in the stream canyons yield enough water for a small amount of irrigation as well as for domestic use. In the canyons, however, the deposits are too thin to contain a large volume of water and even there most wells have been drilled deeper so as to derive water from the underlying deposits. The coarser deposits, however, are capable of absorbing water from the streams and transmitting it to the underlying water-bearing formations.

The predominantly fine-grained deposits of most of the younger alluvium not only cause the formation to yield only small quantities of water to wells but also form a restraining layer that largely prevents upward or downward percolation of water. These impermeable deposits permit practically no downward percolation of water from the land surface; and conversely, they confine under artesian pressure the water in the underlying deposits. The area of confined water occupies nearly all the alluvial plain but does not include all of the marginal parts. Well logs show that, opposite and a short distance out from the mouths of the main stream valleys entering the plain, the deposits contain strata of permeable material that locally may transmit water quite readily. The limit of the area of confined water is discussed from hydrologic evidence on the following pages (pp. 92–93) and is shown on plate 9.

Older alluvium.—Plate 2 shows the extent of the older alluvium and shows also that these deposits are penetrated by wells chiefly in secs. 6 and 7, T. 7 N., R. 27 W. Only a few wells enter the deposits within the city of Santa Barbara, in the eastern part of the Goleta alluvial plain, and elsewhere. The deposits have a maximum thickness of about 250 feet in the foothills east of the Goleta alluvial plain but may be as much as 400 feet thick beneath the northwestern part of Santa Barbara. The unfossiliferous deposits, predominantly of sand beneath the western part of the alluvial plain, may represent the older alluvium. (See pl. 8.)

Lithologically, the older alluvium consists chiefly of red and yellow clay and sandy clay interbedded with lenticular strata of sand and gravel 5 to 15 feet thick. (See well logs in table 17.) The deposits are poorly sorted; the predominating compact clay and sandy clay beds contain scattered cobbles and boulders. However, some moderately well-sorted sand and gravel occur in isolated lenses. These coarse-grained materials are incoherent and contain little fine material, but they are thin and discontinuous and are rather completely enclosed by the beds of compact clay and silt. Therefore, the lenses of gravel and sand yield only small to moderate quantities of water, and the older alluvium in general is a poor water-yielder. Wells drilled into it produce enough water for the needs of several families, or for the irrigation of a few acres. The yield of six wells owned by the city of Santa Barbara, which derive water chiefly from the older alluvium, has not been sufficient to supply the full city demand in recent years, and the wells have not been used except in emergencies.

Santa Barbara formation.—The Santa Barbara formation underlies the younger alluvium beneath the Goleta alluvial plain and crops out in bordering foothills and terraces. It lies beneath the older alluvium in Santa Barbara and adjoining areas to the west. It attains a maximum thickness of about 2,000 feet beneath the southern part of the Goleta alluvial plain and may be of comparable thickness beneath Santa Barbara. It is the main source of ground water, supplying nearly all the water to the irrigation wells of the Goleta basin.

The Santa Barbara formation is missing in a small area in the northwestern part of sec. 7, T. 4 N., R. 28 W., but it underlies the rest of the alluvial plain. The formation is thickest beneath sec. 16, T. 4 N., R. 28 W. It pinches out at the west end of the basin between the consolidated rocks and overlying terrace deposits and alluvium; on the north it feathers out against the consolidated rocks north of the faults near the edge of the basin.

Lithologically, the Santa Barbara formation is composed chiefly of sand, silt, and clay, with small amounts of marl and of gravel. The lower part of the formation consists mainly of clay and silt with minor amounts of sand, whereas the upper part contains a little more and somewhat coarser sand. The coarser beds crop out in the hills and are encountered in wells in the northern and northeastern parts of the alluvial plain. Wells north of the Goleta fault in secs. 3 and 4, T. 4 N., R. 28 W. (pl. 2), such as 4/28–3M7 and 4/28–4R4 (table 17), encounter considerable sand. On the other hand, the finer-grained parts of the Santa Barbara formation have been uplifted on the south side of the Goleta fault and wells there encounter a greater proportion of clay and silt. (See logs of wells 4/28–8A1, 4/28–9A2, and 4/28–9C3, in table 17.) Well 4/28–3N2, drilled recently, penetrated 150 to 200 feet of predominantly fine silt and clay and is reported to have a very small yield. Farther south, wells such as 4/28–9H1 and 4/28–10F1 (pl. 8 and table 17), beneath the main part of the alluvial plain, apparently encounter relatively more sand in the upper part of the Santa Barbara formation.

In the Santa Barbara formation single strata are not traceable for any distance and no extensive zones are distinguishable throughout the formation. Therefore, it is lenticular, but some lenses are quite thick. For example, some wells, as 4/28–8C1, penetrate single clay zones over 100 feet thick. Others, such as 4/28–9H1, penetrate alternating layers of sand and clay, each only a few feet thick. Essentially only the sand strata yield water; the clay, as reported by drillers, is so fine-grained that, even where loose, it transmits water only slowly, and, where compact, transmits virtually no water. However, the sand strata are more or less inter-connecting; so water is enabled to percolate, albeit by devious paths, more or less freely throughout the formation, provided the local hydraulic gradients are favorable. The beds of clay act as confining beds locally thus aiding in holding water under artesian pressure.

Because the sand is medium-grained to fine-grained, and because there is virtually no gravel, the Santa Barbara formation at most places does not yield water copiously to wells. Wells capable of yielding as much as 500 to 600 gallons of water per minute may be developed by penetrating 300 to 400 feet of the formation and perforating the casings throughout their entire length. Most wells yield less than 500 gallons per minute.

The permeability of the Santa Barbara formation has been determined directly by pumping tests on two wells: 4/28–4R4 and 10G4. In both tests the "recovery" method described by Theis (1935, p. 522; Wenzel, 1942, pp. 95–96) was used, and in one test another method also was used.

Well 4/28–4R4 was pumped for about 11¼ hours at a rate of 408 gallons per minute. Beginning when the pump was shut down, measurements of recovery of water level were made for about 25½ hours, and the exact time recorded. The water-level measurements were plotted against the log of the quantity (time since pumping began divided by time since pumping stopped). The plotted points defined a straight line whose slope is the quantity between parentheses in the equation (Wenzel, 1942, p. 95)

$$T=264q\left(\frac{\log_{10}t/t'}{s}\right)$$

In this equation T is the transmissibility in gallons per day per mile width of formation under 1 foot per mile hydraulic gradient for the full thickness of aquifer affected by the well; q is the discharge of the well in gallons per minute; t is time since pumping began, and t' is time since pumping stopped; and s is the water level in the well. As originally used, s is residual drawdown, or the departure of the recovering water level from the static level, or level toward which it is recovering. In practice it is difficult or impossible to determine the static level, or level of zero residual drawdown, and in the determination of transmissibility by the "recovery" method only the slope of the line, not its zero point, is used. Accordingly, any means of showing relative elevation of the recovering water surface with time is satisfactory, and depths to water are used here as values for s. The value of transmissibility thus obtained for this pumping test is about 25,500 g. p. d. per ft. In other words, the formation is capable of transmitting 25,500 gallons of water per day through a mile width of formation with thickness equal to that tapped by the wells, or 393 feet, under a hydraulic gradient of 1 foot per mile. The coefficient of permeability is determined by dividing transmissibility by the thickness, or 25,500/393=about 65 g. p. d. per sq. ft.

In the test on well 4/28–10G4 the pump was run for about 29 hours at a rate of 266 g. p. m. and recovery of the water level was measured for 21¼ hours. The depths to water plotted against the log of t/t' give a straight line whose slope in the equation

$$T=264q\left(\frac{log_{10}\ t/t'}{s}\right)$$

together with the discharge, q=266 g. p. m., gives a value of T=31,200 g. p. d. per ft. The casing perforations are not known, but the well penetrates 231 feet of saturated material, all in the Santa Barbara formation, and the casing is believed to be perforated throughout. Dividing T by 231 gives a permeability of 135 g. p. d. per sq. ft. If this value is averaged with that obtained from the test on well 4/28–4R4 (65 g. p. d. per sq. ft.), an approximate value of 100 g. p. d. per sq. ft. is obtained for the permeability of the upper part of the Santa Barbara formation.

Certain additional observations were made in the test on well 4/28–10G4 and used as a basis for determining the coefficient of storage of the Santa Barbara formation under artesian conditions. The coefficient of storage is defined as "the cubic feet of water discharged from each vertical column of the aquifer with a base 1 foot square as the water level falls 1 foot" (Wenzel, 1942, p. 87 footnote). The additional observations were measurements of drawdown of water level in the pumped well and in three nearby wells near the end of the pumping period. These data were applied to the Thiem formula (Wenzel, 1942, pp. 76–79 and formula 60) for computing transmissibility. They were then applied to a formula worked out by Theis (1935, pp. 519–524) but employing a graphic modification devised by Jacob.[10] The results were not entirely satisfactory as the data were inadequate in some respects. However, they give a coefficient of storage of about 0.003, which is considered to be of the correct order of magnitude. Inasmuch as the test was made on a well that penetrated only 231 feet of the formation, this value applies only to about that thickness.

Values for the permeability coefficient also were obtained by testing outcrop samples of the formation in the laboratory. Samples are collected loose and repacked under water in an apparatus such as was designed by Turner,[11] and similar to that described by Wenzel (1942, p. 60). The method is discussed in an earlier report (Upson and Thomasson, 1951).

The tests on the samples were not entirely satisfactory as difficulty

[10] Jacob, C. E., Notes on determining permeability by pumping tests under water-table conditions: U. S. Geol. Survey, duplicated manuscript p. 3, 1945.

[11] Turner, S. F., personal communication, 1944.

was encountered in packing the sands, which also contained considerable clay and silt. Tests could not be completed on some of the finer-grained samples because the material did not remain stable in the permeameter. However, for the coarser-grained samples, values of the coefficient of permeability ranging from 26 to 118 g. p. d. per sq. ft. were obtained. These values are at least of the same size as those obtained from the pumping tests, and they generally support the results of those tests.

GROUND-WATER BODIES

The ground water in the unconsolidated deposits of the Goleta basin is separated into two bodies: a shallow water body and a deep water body. The shallow body is defined as the water in the upper beds in the younger alluvium, in certain of the terrace deposits, and in the upper parts of the older alluvium. The deep water body comprises the water in the lower beds of the older alluvium and in the Santa Barbara formation. These two water bodies are separated hydraulically throughout most of the extent of the younger alluvium, and throughout at least part of the extent of the older alluvium. Also, their occurrence, manner of recharge, and of discharge differ. These features, together with the extent and degree of hydraulic separation, are discussed more fully in ensuing paragraphs.

Shallow water body.—The shallow water body occurs more or less continuously throughout the Goleta basin. Several shallow wells tap water in the alluvial deposits beneath the main central part of the Goleta alluvial plain and in the deposits capping the terrace southwest of the plain. Northeast of the plain a few wells tap water at shallow depth in the hills underlain by the older alluvium, and a few wells obtain water in alluvium or terrace deposits resting on the consolidated rocks northwest of the plain.

In most of this area, the shallow water is hydraulically separated from the deep water. Within the area of confined water of the Goleta alluvial plain (see pl. 9), near the end of March 1945 when measurements were made in all accessible wells, the shallow water level stood from 14 to as much as 40 feet above the static level of water in nearby or adjacent deep wells. Also, in well 4/28–11P1 in the area underlain by older alluvium the water level was more than 30 feet above the static level in nearby deep wells at the same time. Thus, the clay beds in the older alluvium also are sufficiently impermeable, at least locally, to prevent water from moving downward readily from the land surface.

With respect to recharge, water stands at depths of only 10 to 20 feet below the land surface and is everywhere generally unconfined. Thus it is able to receive infiltrate of rain. It also receives water by lateral seepage from the streams entering the plain and locally doubtless through downward percolation of irrigation water. Infiltration of rain may be the principal source on the main alluvial plain, as lateral seepage from the streams probably does not extend far from the stream courses and takes place chiefly during floods. Much of the water thus lost during floods drains back to the streams when the flood stages have subsided.

Of the water thus comprising the shallow water body, some is discharged downward to the deep water body in areas where there is hydraulic interconnection and some remains in the shallow body. Water that remains in the shallow body passes into the area where there is no hydraulic interconnection, percolates laterally toward the center of the basin, and discharges into the ocean at the Goleta slough, into the lower reaches of the streams such as Atascadero Creek, and into the atmosphere through evaporation and transpiration.

Deep water body.—The deep water body comprises the water in the lower beds of younger alluvium, in the older alluvium, and in the Santa Barbara formation. Thus it is extensive and deep, and it supplies essentially all the pumpage from wells in the Goleta basin.

The deep water body is laterally coincident with the Santa Barbara formation, whose extent is shown in plate 2, and therefore occurs widely outside the limits of the alluvial plain. A few wells in the hills in secs. 6 and 7, T. 4 N., R. 27 W., and in the city of Santa Barbara, tap water in the Santa Barbara formation beneath the older alluvium. The depth to the base of the deep water body beneath the alluvial plain is not known. For the part of the Santa Barbara formation that lies below the deeper water wells—that is, below a depth of about 500 feet—little detailed information is at hand as to the permeability and as to the quality of the contained water. It is inferred that more or less permeable deposits extend to about 2,000 feet below the surface of the plain, and that the water body is correspondingly thick. However, water in the deeper parts of the formation is likely to be salty or otherwise chemically unfit for use. As has been discussed (p. 28), it is believed that the initial movements on the faults in the Goleta basin began and progressed during the deposition of the Santa Barbara formation. Thus, the coastal barrier of consolidated rocks that separates the Santa Barbara formation beneath the Goleta alluvial plain from the sea has existed intermittently, if not continuously, throughout the deposition of the formation. Accordingly, sea water contained in the Santa Barbara sediments, or connate water, has had no way of draining southward from the deposits.

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The distribution of consolidated rocks (pl. 2) probably precludes westward drainage, but there may have been drainage to the east, depending on the time of movement on the faults bordering the northeastern part of the plain. Some such eastward drainage might have been accomplished during a large decline of sea level, such as has been discussed by Shepard (Shepard and Emery, 1941, pp. 145–155). But even if such a decline took place in post-Santa Barbara time it would seem that salt water would have remained in at least the lowermost few hundred feet of the formation. Therefore, the writer believes it likely that connate sea water still exists in the lower part of the Santa Barbara formation. If so, it constitutes an effective limit to the thickness, and indeed to the utility, of the deep water body of this discussion. As far as the writer is aware, there are no available data on the quality of the water at depth beneath the Goleta alluvial plain. Such data could be obtained only by test drilling or adequate sampling of the water in some oil-prospect well during drilling.

CONFINEMENT OF THE DEEP-WATER BODY

Throughout most of its extent the deep water body is under artesian pressure. Beneath most of the alluvial plain the water is confined by the fine-grained beds of the younger alluvium, and in part by clay strata within the Santa Barbara formation itself. Confinement is proved by the fact that, although no longer are there flowing wells in the area, in early years wells drilled in the vicinity of Goleta flowed at the land surface. In fact the water rose to heights of 20 feet or more above the land surface. These wells were over 100 feet deep and doubtless tapped strata in the lower part of the younger alluvium to which pressure head was transmitted from the Santa Barbara formation below. According to reports by old residents, the area of flowing wells was not large, but there is considerable evidence that confining conditions prevail over a rather wide area. Much credit is due Mr. Harry Sexton for his observations of ground-water conditions during the early days. For instance, Mr. Sexton supplied the information that there used to be an area of springs just southwest of wells 4/28–8B3 and 4/28–8B4. Springs are reported south of Atascadero Creek in the general vicinity of its junction with Maria Ygnacio Creek. These springs are thought to have been sustained by upward leakage of water through permeable deposits in or at the edge of the confining beds, because they ceased to flow when the water level in the artesian wells was lowered by pumping.

Springs that may have been artesian formerly flowed at the base of the hill on which the cemetery rests, near well 4/28–11K2. There also were springs near well 4/28–12L2. These last probably are not truly artesian, but more likely resulted from water being forced upward by the impermeable fault zone immediately to the south.

In addition to the springs, a few scattered flowing artesian wells have been reported. Well 4/28–8K1, or a well near it, flowed. Well 4/28–4K2, or one near it, was reported to have flowed when drilled. A well in the vicinity of well 4/28–11N1, or 3, also flowed when drilled. Well 4/28–14C1, owned by the La Cumbre Mutual Water Company, is said to have had a small flow when drilled.

Miscellaneous information indicates artesian conditions at other places. A well may be considered a nonflowing artesian well if the water level rises substantially when a water-bearing bed is encountered during drilling. Study of the records obtained from continuous water-stage recorders also indicates which wells tap confined water and which are water-table wells. In addition to the flowing artesian wells mentioned previously, wells classified as nonflowing artesian wells are as follows:

4/28–3M4	4/28–5R1	4/28–11P2
4/28–3Q2	4/28–8B2	4/28–11N3
4/28–4K2	4/28–8B4	4/28–12K1
4/28–4J1	4/28–8K1	4/28–12L1
4/28–4Q2	4/28–10E1	4/28–12L4
4/28–4R3	4/28–11L3	4/28–14A2

Confining conditions exist beneath nearly the full width of the alluvial plain east of Goleta, and also, at least locally, beneath parts of the older alluvium. This inference is further supported by the difference in altitude of the water level between deep and shallow wells. (See p. 90.) Thus, the area of confined water is inferred from the altitude of the initial static levels (discussed on p. 92), from the permeability of shallow materials as revealed by well logs (table 17), and from the study of the behavior of water levels when wells are drilled or pumped. Its extent is shown on plate 9. Within this area there is essentially no interchange between shallow and deep water, and hence essentially no downward percolation from the land surface to the deep water body.

Beds of impermeable material that might confine water under presure occur also in the parts of the Santa Barbara formation that crop out beyond the alluvial plain, and also in the older alluvium. Therefore, confining conditions do exist locally in those areas. For example, wells 4/28–3M4, 4/28–3Q2, and 4/28–12L4, tap confined water. However, in general the impermeable beds in those areas are discontinuous, and it is believed that outside the area of confined water, shown on plate 9, shallow water supplied by infiltration of rain or seepage from streams is able to percolate to the deep water body.

SOURCE AND MOVEMENT OF WATER IN THE DEEP WATER BODY

The direction of movement of ground water indicates the areas from which and to which the water travels and hence is a basis for determining in a general way the source and discharge of the ground water. The direction of movement is indicated by the relative head of the water at different places in the body, provided there are no impermeable barriers. Accordingly, a map of the relative head of water shows the direction of movement and thus indicates the areas of replenishment and of discharge.

Plate 9 is such a map. It shows by contours the direction of movement of water in the deep body. The contours are based on depth-to-water measurements made in all accessible wells on March 27 and 28, 1945, except for eight wells in the western part of the basin measured March 20, 1945, and wells in the city of Santa Barbara where the measurements were made May 10, 1945. The readings were subtracted from the altitude of measuring points of the wells, and the resulting altitudes of water surface plotted on the map. The contour lines, or lines of equal altitude, were drawn on the points so plotted. The altitude of the measuring points at most of the wells was determined by spirit levelling by the Geological Survey. Those in the extreme western part of the area and in secs. 6 and 7, T. 4 N., R. 27 W., in the northeastern part, were determined by aneroid barometer. The altitudes of the measuring points at wells within the city limits are from levelling by the city of Santa Barbara. At a few scattered wells altitudes were determined by spirit levelling by the engineering firm Quinton, Code, and Hill-Leeds and Barnard—these data being made available by the County.

The highest water levels are in secs. 6 and 7, T. 4 N., R. 27 W. The troughlike depression in the water table along the line between these two sections probably is due to a concentration of pumpage by numerous small wells. Thence the gradient slopes southwestward toward the alluvial plain. The gradient is southward from the canyons of San Antonio, Maria Ygnacio, and San Jose Creeks. For the extreme west end of the Goleta basin data are almost entirely lacking, but gradients appear to be toward the alluvial plain from the hills and terraces to the north and northwest. At the extreme east end of the area the gradient is southeastward toward the city of Santa Barbara. Along the entire south side of the basin the contours indicate a northward gradient.

Thus, water apparently moves toward the center of the Goleta alluvial plain from all sides. The most extensive ground-water slopes within the area of unconsolidated deposits are from the north and northeast sides of the basin eastward from San Jose Creek and indicate that most of the water is moving from the northeast side of the basin. In detail, the contours show that water is moving from the canyons of Maria Ygnacio and San Antonio Creeks, and also from the outcrop of the Santa Barbara formation in the eastern part of section 11 and adjoining sections in T. 4 N., R. 28 W. The water doubtless comprises seepage from the streams and infiltration of rain in the interstream areas, as well as on the stream valley floors. West of San Jose Creek, as is discussed elsewhere (p. 52), little water seeps from the streams, and ground water there must be supplied by infiltration of rain. The potential northward movement from the south side of the basin shown by the contours, must be supported by infiltration of rain. Water may move northwestward from the hills in the Hope Ranch, but movement from the south is probably much restricted everywhere.

The contours not only reveal the general sources of water in the deep water body, but also certain significant features in regard to both recharge and discharge of the body. With respect to recharge, the large differences in altitude of water levels within short distances are critical. These marked breaks in gradient, such as those near the north margin of the alluvial plain, reveal the presence of restrictions to the movement of the water. The breaks are believed to be caused by impermeable zones created by movement and perhaps cementation along the faults, and in part are used as evidence in determining the location of the faults (p. 27). The breaks in gradient are greatest along the southeastern part of the Modoc fault (about 100 feet) and along the eastern part of the Goleta fault (about 130 feet). These large differences in water-level altitude show that the movement of the water across part of the fault zones is restricted, and would be negligible under ordinary hydraulic gradients. It is believed that the impermeable parts of the fault zones transmit water, but that an appreciable amount of water can be transmitted across them only because of the very steep gradients that now exist. It is likely that similar impermeable zones exist along the faults bordering the south side of the basin and correspondingly restrict the movement of water from the south.

Movement of water from Maria Ygnacio Creek, however, is apparently not restricted, and water from San Antonio Creek seems to move westward north of the Goleta fault and to pass southward with the water from Maria Ygnacio Creek.

The contour map shows that the water is all moving toward the central part of the plain, and must be discharged by pumping. In times past the water under artesian pressure may have leaked upward through the confining beds and may have flowed to the sea or been evaporated and transpired. At present, however, the water level is 10 to 50 feet below the land surface—in fact it is below sea level—and these means of discharge cannot operate. Therefore, the water can be discharged only by pumping. The relatively gentle hydraulic gradients within the entire area of confined water, together with the irregular curves and the local depression contours, demonstrate this conclusion. The large depressions shown by the water-level contours are in the southeastern and southwestern parts of the area; but smaller ones occur in secs. 4, 8, and 10, T. 4 N., R. 28 W., presumably in part localized by impermeable zones along the nearby faults.

These depressions demonstrate certain details as to the source of water for different parts of the Goleta basin. Water must move into the depressions from all sides, and water cannot move past them. Therefore, the map shows that ground water at the east end of the basin, derived from San Antonio, Maria Ygnacio, and San Jose Creeks, and from infiltration of rain on the intervening hills, remains in and is pumped from the eastern part of the basin—approximately east of the town of Goleta. In fact, much of the water moving from these source areas is intercepted before moving far beneath the alluvial plain. None of this water reaches the southwestern part of the plain—west of the town of Goleta; accordingly, pumpage in that area must be supplied entirely from immediately adjacent sources.

RECHARGE TO THE DEEP WATER BODY

As indicated in the foregoing paragraphs, the water of the deep water body is derived from two sources: infiltration of rain and seepage from streams. This recharge can take place only in the area lying between the area of confined water and the consolidated rock border. The absence of downward percolation of shallow water within the area of confined water has been discussed (p. 90), and that area is outlined on plate 9. Its extent is about 7.6 square miles, or about 5,000 acres. The consolidated rocks transmit essentially no water directly to the deep body, but the area between them and the area of confined water is underlain by unconsolidated deposits which are not separated from the land surface by impermeable members. They receive water at the surface and transmit it downward to the deep water body. This area is called the recharge area.

The recharge area includes the areas of outcrop of the Santa Barbara formation north of the alluvial plain, and the western part of the outcrop in the hills southeast of the plain. The unnamed Pliocene formation that underlies the terrace deposits in part of secs. 21 and 22, T. 4 N., R. 28 W., is predominantly of compact clay and silt and doubtless transmits water very slowly, if at all. However, the adjoining southern parts of secs. 15 and 16, T. 4 N., R. 28 W., together with a matching area on the southwest side of the basin, are included in the recharge area as there is apparently no runoff, and water may percolate to the deep water body outside the edge of the younger alluvium. The recharge area also includes most of the outcrop of the older alluvium except for that in parts of secs. 1 and 2, T. 4 N., R. 28 W., and farther north where the bedrock lies at shallow depth, and rain that is absorbed apparently is discharged as local high-level springs and does not percolate directly to the deep water body. The total extent of the recharge area as thus defined in 9.3 square miles, or about 6,000 acres.

INFILTRATION OF RAIN

The Santa Barbara formation develops a fine sandy soil which absorbs a fairly high proportion of the rain that falls on the areas of outcrop. The older alluvium also absorbs most of the rain that falls on its outcrop. This is demonstrated by observations of discharge in Atascadero Creek, which drains a large part of the recharge area. Observations show (p. 48) that there is very little runoff from this stream drainage except in years of exceptional rainfall. Apparently, therefore, neary all the rain is absorbed, at least temporarily. Plants on the hills and slopes doubtless use most of this water, but an appreciable proportion percolates downward to the deep water body. A higher proportion of the rainfall is probably retained at shallow depth on the relatively clayey soil of the older alluvium. However, the outcrop of that formation has less natural vegetation than does the outcrop of the Santa Barbara formation, and hence probably a comparable proportion of absorbed rainfall can percolate downward to the deep body. Rain is also readily absorbed by the younger alluvium in the stream valleys. The alluvium there is moderately permeable and permits the downward percolation of rainfall as well as seepage from the streams to the deep water body.

Water thus penetrating below the land surface and below plant roots percolates partly downward through interconnecting lenses of permeable material, and partly laterally along the inclined beds of sand and of gravel. In the northern part of the basin especially, a large part of this recharge water is pumped from wells within the recharge area. From an evaluation of the quantity of local pumpage and from the contour map, plate 9, however, it is apparent that most of the recharge water from the northeast, and some of that water from the north, moves past the intercepting wells and passes beneath the edge of confining material to the area of confined water. In moving laterally, the water must traverse the Modoc, Goleta, and Carneros faults. The zones of very low permeability along these faults restrict the movement of the water so that at places it is backed up as behind a dam. Accordingly, at places water levels are about at the level of adjacent stream beds, although south of the faults they may be many feet lower. The effect of this feature on the recharge by seepage loss from the creeks is discussed in the next topic of this report.

SEEPAGE FROM STREAMS

Just as downward movement of infiltrate of rain can reach the deep water body only in the recharge area, so seepage from the streams can reach the deep water body only within the recharge area. As shown on the plate 9, the recharge area is broadest in the eastern part of the basin where traversed by Atascadero, San Antonio, Maria Ygnacio, and San Jose Creeks, and somewhat narrower where traversed by Carneros Creek and the streams from San Pedro and Glen Anne Canyons. Thus, recharge from the eastern streams would be expected to be more than from the western streams.

Two other factors influence the recharge from streams. One is the available thickness of water-transmitting material, and the other is the potential hydraulic gradient away from the streams. Beneath San Jose Creek and the streams to the east, the alluvium and the Santa Barbara formation are relatively thick. Accordingly, cross-sectional areas are ample to transmit water seeping from these streams. On the other hand, beneath Carneros Creek, San Pedro, and Glen Anne Canyons the Santa Barbara formation is missing and the alluvium is relatively thin. Also, confining lenses of impermeable material may extend north of the apparent edge of the area of confined water. Therefore, the cross-sectional area for transmitting water seeping from the three western streams is much smaller, and local confining beds may prohibit appreciable downward percolation of water from the streams.

The hydraulic gradient away from the streams is potentially steepest where the water table is at greatest depth below land surface; and the rate of seepage loss is potentially greatest at such places. Conversely, where the water table is about at creek level the hydraulic gradient away from the stream is gentle, and the potential rate of seepage loss is small. For example, along San Jose Creek in the western part of sec. 3, T. 4 N., R. 28 W., the water level in wells stands 12 to 24 feet below the land surface, or about at creek level. Measurements and estimates (p. 52) indicate that there is very little seepage loss from San Jose Creek north of the Carneros fault. Similarly, near Atascadero Creek static water level in well 4/28–12L4 in March 1945 was about 40 feet below land surface and probably not more than 20 feet below stream level. Also, along San Antonio Creek water levels in wells 4/28–2N2, 4/28–2P1, and 4/28–2P2 stand about at creek level most of the year. Therefore, it is inferred that there are comparably small losses from San Antonio Creek and Atascadero Creek north of the Goleta and Modoc faults, respectively.

On the other hand, in the valley of Maria Ygnacio Creek, the water levels in wells 4/28-3J1 and 4/28-3Q5 were about 87 and 81 feet, respectively, below land surface, and probably 50 or more feet below stream-bed level. Also, there is no extensive steepening of hydraulic gradient across the Goleta fault. Therefore, it is inferred that the greatest seepage loss can take place from Maria Ygnacio Creek, and by westward movement from San Antonio Creek to the valley of Maria Ygnacio Creek. Correspondingly deep water levels occur beneath the courses of Atascadero and San Antonio Creeks south of the Goleta and Modoc faults, respectively. However, the area of confined water extends beneath the channel of Atascadero Creek about to the Modoc fault, and thus water cannot percolate downward from that creek to the deep water body. On the other hand, water is able to percolate from San Antonio Creek to the deep body for a distance of about half a mile south of the Goleta fault. Thus, the greatest amount of recharge to the deep water body by seepage loss from the streams is evidently from the Maria Ygnacio and San Antonio Creeks and very little from any of the other streams. This conclusion is substantiated by measurements and estimates of seepage loss discussed in earlier paragraphs (p. 53).

QUANTITY OF RECHARGE

The quantity of recharge to the deep water body is the quantity of infiltration of rain plus the quantity of seepage loss from streams. As shown in table 1, the rainfall at Goleta during the years 1937 to 1945 ranged from a low of 14.42 inches in 1938–39 to a high of 46.08 inches in 1940–41. The average for the period was 21.25 inches. Average rainfall at Santa Barbara for the same period was practically the same (table 1); hence the long-term average rainfall at Santa Barbara (18.40 inches) is considered the approximate long-term average at Goleta. The major part of the recharge area is more than a mile northeast of the site of the Goleta rain gage, however, and is a somewhat higher terrain. Accordingly, a rounded-off value of 19 inches is taken as the long-term average rainfall on the recharge area, and 22 inches for the shorter period 1937–45.

The proportion of the rainfall that percolates to the deep water body is exceedingly difficult to estimate. However, an approximation can be obtained by the use of the computations by Blaney referred to elsewhere in this report (p. 62) and illustrated in figure 2. The land-use types included in the recharge area of the Goleta basin are land in citrus groves, clean cultivated, irrigated by usual practice; land in deciduous trees, clean cultivated; land in grass and weeds; and bare land. By inspection of aerial photographs taken in 1938 and from field observation, it is estimated that at least 85 percent of the land is in citrus groves, and that there are about 700 acres of grass and weeds. Also there are small acreages of deciduous trees, mostly walnuts, and bare land. The acreage of bare land below which deep penetration of rain in any one winter is relatively great is considered to balance the acreage of deciduous trees below which deep penetration is small. For purposes of computation the total intake area, about 6,000 acres, is considered to comprise about 5,300 acres of citrus groves, and 700 acres of grass and weeds.

Figure 2 shows curves for estimating deep penetration in these two classes of land; these curves were obtained by plotting points for seasonal rainfall and computed deep penetration from Blaney's table B (1933, p. 10). It is assumed that the data given are applicable to the Goleta basin; thus the amount of deep penetration can be approximated by applying the seasonal rainfall to the curves, and reading off the deep penetration. These figures, in inches, are readily converted to acre-feet. The data are summarized in the following table, which shows the tremendous variation of recharge from year to year. It also shows that during the years of high average rainfall, 1941–45, the average yearly recharge from rain may have been as much as 4,400 acre-feet; whereas the long-term average rainfall of 19 inches on the recharge area is inferred (fig. 2) to have supplied only about 2,600 acre-feet as the long-term average recharge.

Estimated recharge by infiltration of rain in the Goleta basin

Year	Yearly rainfall at Goleta [1] (inches)	Deep penetration of rain				Total recharge (acre-feet)
		Citrus growth		Grass and weeds		
		Inches	Acre-feet	Inches	Acre-feet	
1937–38	23.03	9.2	4,063	5.2	303	4,400
1938–39	14.42	1.9	839	0	0	800
1939–40	15.19	2.6	1,148	0	0	1,150
1940–41	46.08	28.5	12,588	17.3	1,009	13,600
1941–42	14.93	2.3	1,016	0	0	1,000
1942–43	21.16	7.6	3,357	2.1	123	3,500
1943–44	19.28	6.0	2,650	1.0	58	2,700
1944–45	15.93	3.2	1,413	0	0	1.400
Average	21.25					3,600
Average 1941–45	23.5					4,400
Long-term average	19	5.7	2,517	1	58	2,600

[1] From table 1.

Estimates of the amount of recharge from streams are based on measurements and estimates of actual seepage losses from San Antonio, Maria Ygnacio, San Jose, and other creeks. They are discussed on pages 51 to 53 of this report. It is there concluded that the total annual seepage losses from streams in the recharge area have amounted to about 700 acre-feet per year during recent wet years, but that long-term average losses are about 500 acre-feet per year.

Thus, the total recharge to the deep water body during recent wet years is estimated to have been 5,100 acre-feet per year, and over the long term about 3,100 acre-feet per year.

FLUCTUATIONS OF WATER LEVELS

ORIGINAL WATER LEVELS

Some of the first wells in the Goleta area were drilled about 1890 near the site of the town of Goleta. Water encountered at a depth of 60 to 80 feet rose to a height of 20 to 30 feet above the land surface. As the altitude of the land surface at Goleta is about 22 feet, the static head was 40 to 50 feet above sea level. The water pressure in the water-bearing beds that were less than 100 feet below the surface was soon lowered by water released through wells. These and deeper wells ceased to flow many years ago, and since then the artesian pressure has been lowered still more. For example, in wells such as 4/28–14C1, in which the artesian head was initially about at the land surface, the water level in March 1945 stood 50 to 55 feet below the land surface. In the vicinity of Goleta, in well 4/28–17H11, for example, the static level of the confined water in March 1945 was about 15 feet below land surface. Thus, the decline of artesian head beneath the Goleta alluvial plain from 1890 to 1945 was about 50 feet, or an average of about 0.9 foot per year.

WATER LEVELS DURING THE PERIOD 1928–44

Measurements of the water level in wells 4/28–12P1 and 4/28–14C1 made by employees of the La Cumbre Mutual Water Co. from 1928 to 1944 were furnished by that company for this report, and the data are shown graphically in figure 7. Figure 7 shows that the water level in well 4/28–12P1 declined progressively throughout the 17 years of record at an average rate of about 3 feet each year. There were periods of several years, of course, when the rate of decline was more or when it was less than the average; and during the spring of 1944 the water level was higher than it was in 1943. Because this well is in the angle formed by the impermeable zones of two intersecting faults, the decline of the water level probably has been greater than the average decline throughout the Goleta area. In well 4/28–14C1 (fig. 7) the decline of the water level, about 1½ feet per year on the average, has not been so great as in well 4/28–12P1. Also there have been periods of several years when there was practically no decline. For instance, from 1932 to 1937 and from 1940 to 1944 the water level each

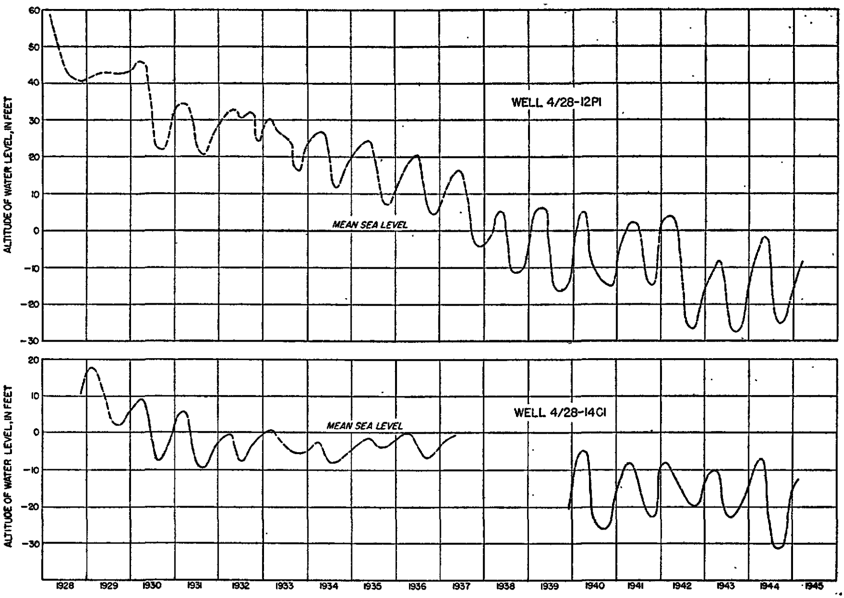

FIGURE 7.—Water levels in wells 4/28–12P1 and 4/28–14C1 when pump was idle.

spring was about the same. The record is missing during 1937–39, when one well was out of service on account of caving and another well was drilled close by to replace it. The fluctuations of water level in this well are probably fairly representative of the fluctuations throughout the area of confined water of the Goleta basin. However, because the yearly changes during the period 1941 to 1944 differ somewhat from the changes in other wells in the artesian area, which are discussed in ensuing paragraphs, the fluctuations in well 4/28–14C1 evidently reflect in part the yearly variations in draft from the well itself.

WATER LEVELS DURING THE PERIOD 1941–46

During 1941 the Geological Survey made periodic measurements of the depth to water in more than 100 wells in the Goleta area. Since 1941 periodic measurements of water level have been continued in about 40 of them. These measurements have been published annually in United States Geological Survey water-supply papers and have been released locally in duplicated form. (See p. 8.) Automatic water-stage recorders were installed in some of the wells, and charts are available for the periods shown in the following table.

Records of water-level fluctuations by water-stage recorders on wells in the Goleta basin

Well	Period of record	Well	Period of record
4/28–2N2	Dec. 6, 1944 to Dec. 13, 1945.	4/28–9A3	July 19, 1941 to Jan. 20, 1943.
4/28–3P1	Apr. 22, 1943 to May 12, 1943.	4/28–12L4	Jan. 20, 1943 to June 4 1946.
4/28–4R1	Jan. 28, 1941 to July 18, 1941.	4/29–13K2	Sept. 28, 1942 to Apr. 22, 1943.
4/28–8C2	Jan. 7, 1946 to present.		

The charts show that the water levels fluctuate widely. The levels decline rapidly when pumps are started at the beginning of each irrigation season, and in general they continue to decline until the end of the pumping season. The water levels in the recorder wells are very sensitive to the influence of nearby pumped wells and the charts show abrupt changes in water level amounting to several feet when pumps in nearby wells are started or stopped. At the end of the irrigation season the water levels start to rise and continue upward until the following spring. During this seasonal rise there are minor declines when a pump is started in a nearby well. The water levels are usually still rising in the spring when irrigation pumping starts, but then begin to decline abruptly. Hydrographs drawn from the depth-to-water measurements in 18 observation wells, made when pumps in them were idle, indicate that the average range between summer and winter water levels has been about 10 feet.

Figures 8 and 9 show fluctuations of water levels in seven observation wells maintained by the Geological Survey during the period 1941 to 1946. Figure 8 shows fluctuations in four wells in the area of confined water, and figure 9 shows fluctuations in three wells in or near the recharge area. There is some variation in water-level change from one part of the area to another. For example, as shown by the hydrographs for wells 4/28–3M2 and 4/28–4R3 (fig. 9), water levels in most wells in and near the recharge area had a steady yearly rise from 1941 to 1945 and a sizeable over-all net rise in the same period. Levels declined from 1945 to 1946 in all wells. On the other hand, water levels in wells in the area of confined water (fig. 8) rose during the first part of 1942, and then declined each year to 1946; except in well 4/28–18G2, in which the water-level peak declined from 1942 to 1943 but recovered in 1944 and 1945. Within the area of confined water the differences in yearly net change were probably due to shifting intensity of pumpage. For example, the yearly rise to 1944 and

1945 in well 4/28–18G2 probably was due to the establishment of the Marine Corps Air Base which, beginning in 1943, took out of service several wells in the western part of the area of confined water. Considering the hydrographs, as a whole, in both parts of the area, the peak in some wells was reached in 1942, in others in 1945. In some wells the peak in 1946 was somewhat higher than in 1941; in others it was lower. Thus, in the area as a whole for the period of record there was little average net change either up or down. Corresponding features are shown by the records for wells 4/28–12P1 and 4/28–14C1 (fig. 7). As shown by those records, the short period of no change seems to be a temporary leveling off superimposed on a long-term decline.

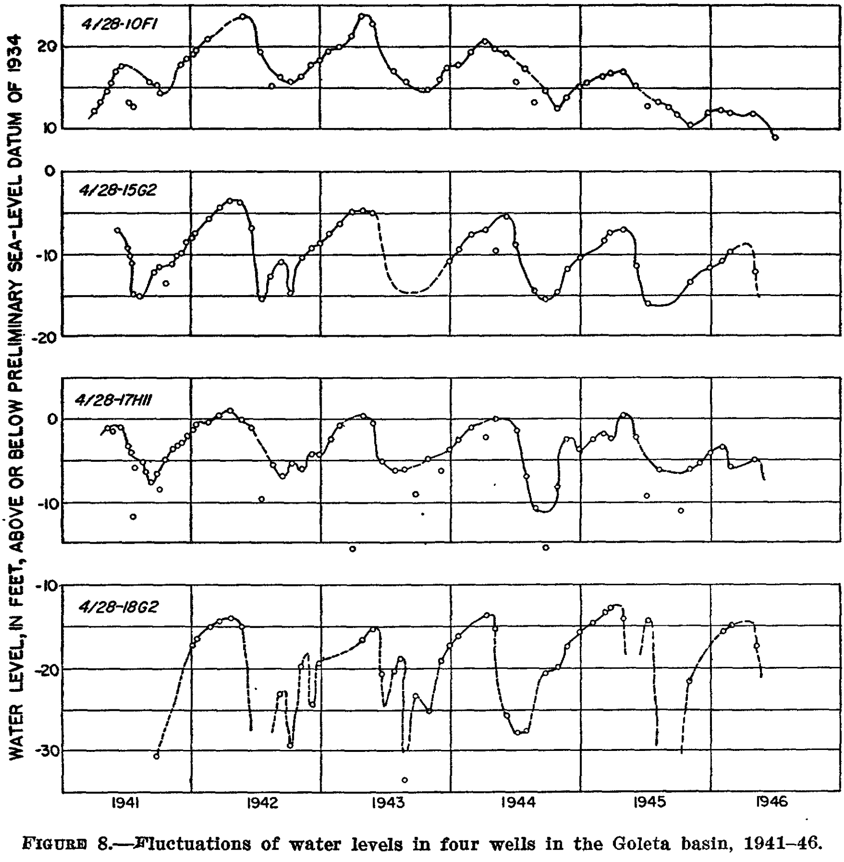

FIGURE 8.—Fluctuations of water levels in four wells in the Goleta basin, 1941–46.

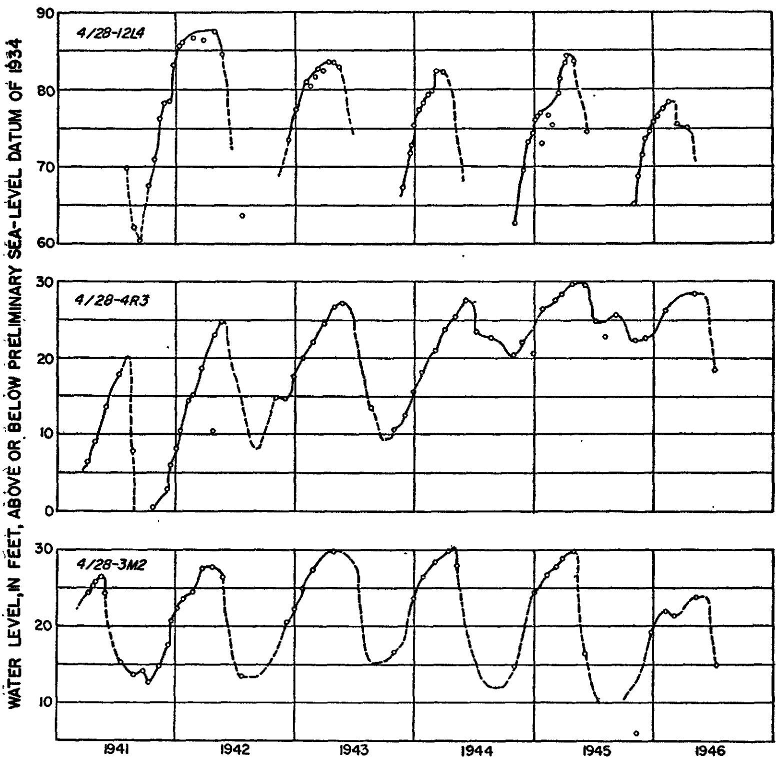

FIGURE 9.—Fluctuations of water levels in three wells in the Goleta basin, 1941–46.

PUMPAGE FROM WELLS

Water pumped from wells in the Goleta basin is mainly for purposes of irrigation, though some of it is for domestic supply and some for use at the Marine Corps Air Base. The pumpage in the extreme northeastern part of the area is largely for domestic use. The principal irrigated crops are lemons and walnuts. Orchards are planted on much of the rough ground between the valleys as well as on the flat parts of the valleys and on the alluvial plain where the valleys coalesce.

Only a small part of the water used for irrigation is pumped directly from the creeks or from reservoirs filled by the creeks during the winter. Irrigation is ordinarily not required during winter months, when most of the rain falls and the streams are flowing. Commonly no rain falls during the summer months and the streams do not flow. Thus, practically all the water used for irrigation is pumped from wells, which range in depth from 100 to 500 feet.

Nearly all the old wells were drilled with cable tools and are of straight-wall construction. During recent years wells of larger diameter and of gravel-walled construction have been put down. The yield of the wells ranges from about 25 gallons per minute for the shallow wells of small diameter to 600 or 800 gallons per minute for deep wells of large diameter and gravel-walled construction. The small wells usually have plunger-type pumps whereas those of large yield have deep-well centrifugal or turbine pumps. For the most part, electric power is used to drive the pumps. A few are driven by tractors or small gasoline engines and two pumps of large capacity are driven by engines using natural gas.

The first wells drilled in the Goleta basin were put down in about 1890 in the vicinity of the present town of Goleta. They were less than 100 feet deep and had a natural flow at the surface of the ground. They were small in diameter and, although the artesian pressure was strong enough to raise the water as much as 30 feet above the ground, the flow from each well was small. As more wells were put down the water pressure declined and it was not long before the wells stopped flowing. Deeper wells of large diameter were put down, pumps were installed, and the irrigation of fruit and nut trees became a major part of the agricultural activities in the Goleta basin. During 1938 the engineering firm, Quinton, Code, and Hill-Leeds and Barnard, made an investigation of the water resources of Santa Barbara County and included in their report a discussion of the ground-water resources of the Goleta area. On the basis of a consumptive use of one acre-foot of water per acre irrigated, it was estimated that about 6,100 acre-feet of water was pumped during 1938.[12] It was estimated that the safe yield of the water-bearing formations underlying the Goleta basin was about 4,100 acre-feet each year and that the ultimate demand would be about 16,000 acre-feet per year.

No records have been kept of the total annual pumpage in the area but a few enterprising ranchers have kept records of the pumpage from their wells and have observed the water level in the wells from time to time. During the present investigation by the Survey an attempt has been made to estimate the total annual pumpage for each year during the 10-year period from 1935 to 1944. The total annual kilowatt-hours consumed by each well pump, as shown by records of the Southern California Edison Co., have been added to obtain the total annual kilowatt-hours consumed by all well pumps in the Goleta basin. From tests made on 34 well pumps distributed throughout the irrigated area it was found that, on the average, about 350 kilowatt-hours were used to deliver 1 acre-foot of water to the irrigated fields.

[12] Quinton, and others, op. cit., p. 33.

The following table gives the amount of water pumped by electric energy based on an estimated use of 350 kilowatt-hours per acre-foot. The power records are totaled for the year ending with April, and the pumpage given is for the interval from May of one year through April of the next. Because the total of nonirrigation pumpage is small, the totals shown are practically all for the irrigation season early in each period. Here and elsewhere the yearly pumpage accordingly is listed in the earlier calendar year—in which the appropriate irrigation season occurs.

TABLE 12.—*Irrigation water pumped from wells by electric energy in the Goleta basin 1935–44*

Year	Kilowatt-hours	Acre-feet	Year	Kilowatt-hours	Acre-feet
1935	969, 000	2, 770	1940	1, 934, 000	5, 530
1936	1, 146, 000	3, 280	1941	1, 391, 000	3, 980
1937	1, 371, 000	3, 920	1942	1, 648, 000	4, 710
1938	1, 449, 000	4, 140	1943	1, 788, 000	5, 110
1939	1, 995, 000	5, 700	1944	1, 678, 000	4, 800

In addition to the water pumped by electric energy shown in the above table, there are a few wells using small pumps driven by motors of less than 2 horsepower. The average yield of those individual wells probably is less than 10 gallons a minute, and therefore only a small allowance is made for pumpage from them. Also, two wells of large capacity have pumps driven with engines using natural gas, and a few wells are pumped intermittently with energy from tractors or small gasoline engines. During 1943, 1944, and 1945, water was also pumped from wells to supply the United States Marine Corps Air Base at Goleta. Estimates have been made for these miscellaneous uses and the following table shows the estimated total annual pumpage from wells in the Goleta basin.

TABLE 13.—*Estimated total annual pumpage from wells in the Goleta basin, 1935–44*

Year	Acre-feet	Year	Acre-feet
1935	2, 900	1941	4, 100
1936	3, 400	1942	4, 900
1937	4, 000	1943	5, 500
1938	4, 300	1944	5, 400
1939	5, 900		
1940	5, 700	10-year average	4, 610

Pumpage increased gradually during the period 1935 through 1939; that in 1939 was the maximum recorded. The rate decreased to a low during 1941 and then increased again. The water-year 1940–41 was one of heavy rainfall and the pumping season was much shorter than during other years. Pumpage in 1943 was about equal to that in 1944, and was almost as high as during 1939–40. The average during the entire period 1935 to 1944 was about 4,600 acre-feet a year, and during the 4 years 1941 to 1944, in which water-level fluctuations were measured, the average was about 5,000 acre-feet a year.

In this area no data are available as to the percentage of "return" of irrigation water applied to the land. About half the irrigation is within the area of confined water and it is believed that there the amount of return of irrigation water to the deep water body is practically none. Within the recharge area, probably the amount of irrigation water return is not more than a few hundred acre-feet. Accordingly, the figures for total pumpage given in table 13 are probably also close to the net pumpage, and are so considered.

RELATION OF PUMPAGE TO FLUCTUATIONS OF WATER LEVELS

Water-level fluctuations indicate the relation of recharge to pumpage. In general, when recharge is less than pumpage water levels decline, and when recharge is greater than pumpage water levels rise. This general relationship holds whether or not either of the two variables, pumpage and recharge, is constant. Although it is possible to compute the approximate rate of recharge to the pumped area in the Carpinteria basin (p. 74), this cannot be done for the Goleta basin because about half the pumpage is from the recharge area itself.

However, if the rate of transmission to the area of confined water alone be considered more or less constant, it can be approximated. For example, figure 10 shows the relationship between annual pumpage from the area of confined water alone and average annual net change of water level over that area. On this and on figure 11, the date shown at each plotted point is that of the season in which the bulk of the pumpage took place. The corresponding water-level change is that between the two peaks: one before and one after the pumping season indicated. Pumpage from the area of confined water was determined by the same method as for the whole area, but by totaling only the kilowatt-hour consumption for wells within that area. In any one year the pumpage ranged from about 50 to 60 percent of the pumpage from the whole area. Average net water-level changes from the highest recorded level of one year to the highest recorded level of the next were determined by the same method as previously described (p. 74). For about the western one-third of the area of confined water in which no observations were made in the spring of 1941 the value for the period 1941–42 is estimated. Except-ing the value for 1943, the points on figure 10 fall nearly on a straight line which intercepts the axis of zero water-level change opposite a pumpage of about 2,350 acre-feet. Thus, the graph indicates that, had the rate been constant, the amount of water transmitted to the area of confined water each year since 1940 would have been about 2,300 acre-feet.

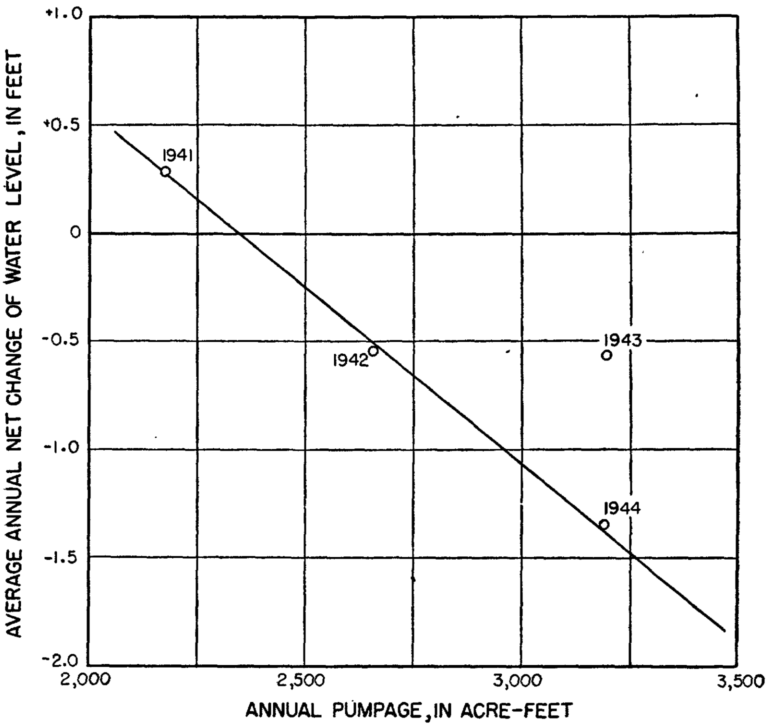

FIGURE 10.—Graph showing comparison of annual pumpage with average annual net change of water level in the area of confined water in the Goleta basin, 1941–45.

To make a similar comparison for earlier years, the record of water-level fluctations in well 4/28–14C1 (fig. 7) is used. Figure 11 shows points of yearly net change of water level in this well with corresponding annual pumpage from the area of confined water. It was necessary to estimate the water-level peaks in the years 1938 and 1939 by comparison with the curve for well 4/28–12P1. Also, as stated elsewhere (p. 102), fluctuations of water level are evidently somewhat affected by variations of yearly pumpage from the well itself. Nevertheless, it is assumed that the net changes of water level are more or less representative of the entire area of confined water. Under that assumption, again neglecting the point for the year 1943, the remaining points fairly well define a straight line which intercepts the axis of

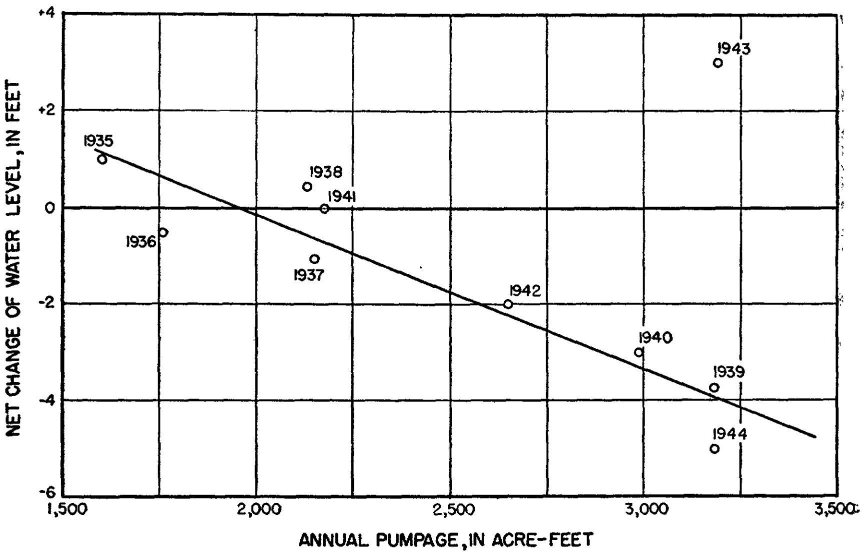

FIGURE 11.—Graph showing comparison of annual pumpage from the area of confined water in the Goleta basin with annual net change of water level in well 4/28-14C1, 1935-44.

zero water-level change opposite a yearly pumpage of about 2,000 acre-feet. If constant, then, the rate of transmission to the area of confined water since 1936 has been about 2,000 acre-feet a year. Thus, although the rate is not constant, under current conditions an average of about 2,000 acre-feet of water has been transmitted yearly to the area of confined water; and the same amount may be expected to be transmitted in the future, provided hydraulic gradients do not change appreciably.

A steepening of gradients, such as would accompany a rise of water level in the recharge area or a lowering of water level in the area of confined water, would increase the quantity transmitted; a lessening of the gradients, such as would accompany a lowering of water level in the recharge area or a rise of water level in the area of confined water, would decrease the quantity transmitted. For example, if pumpage from the recharge area were decreased, or the recharge increased, a correspondingly larger amount of water could be pumped from the area of confined water without increasing the over-all average pumping lift, and without increasing the danger of salt-water contamination.

Whereas these relationships are of value in connection with possible future operation of the ground-water basin as a reservoir, under current conditions the relation between pumpage and fluctuations of water levels in the recharge area as well as in the area of confined water affords a basis for inferences with respect to the natural yield of the basin. As has been pointed out (p. 104), there has been no pronounced over-all rise or decline of water levels for the period 1941 to 1946. Thus, the pumpage during that interval has been approximately balanced by the recharge. Data for 1945 are not assembled, but the pumpage probably is not much more than in 1944. Therefore, the average for the period is about the same, or about 5,000 acre-feet per year. This pumpage caused no decline of water levels over the whole period, but evidently caused a marked decline from 1945 to 1946. The significance of this relationship is discussed in ensuing paragraphs.

PERENNIAL YIELD OF THE GOLETA BASIN

Because there is no longer any salvageable natural discharge from the Goleta basin, its perennial yield is the quantity of recharge that is available every year for pumpage. Further lowering of water levels as such cannot increase the recharge, though if limited to the area of confined water it might increase temporarily the amount of water transmitted to the area of withdrawal. Therefore, the perennial yield is the long-term average recharge from rain and by seepage from streams, unless this can be augmented by artificial recharge.

In the foregoing paragraphs an attempt has been made to relate pumpage to fluctuations of water level on the theory that the pumpage which causes no over-all lowering of water levels is balanced by recharge. Within the period of water-level measurements, 1941–46, pumpage has averaged about 5,000 acre-feet a year and seems to have caused no marked over-all decline of water levels. Thus, during this period the perennial yield has been almost if not quite 5,000 acre-feet a year. However, it must be borne in mind that these years have been relatively wet and recharge from rain and streams probably has been considerably more than during earlier, drier years; and considerably more, also, than the long-term average of the past or of that to be expected in the future. The fact that water levels in all wells declined markedly from 1945 to 1946 probably means that there is no longer any recharge from storage held over from the preceding wet years, especially 1940–41.

Unfortunately, records of rainfall and of pumpage in the Goleta basin are not available for early years. Furthermore, it is exceedingly difficult to determine the amount of infiltration of rain. Nevertheless, a long rainfall record is available at Santa Barbara. Also, the estimate of infiltration for the years of water-level records gives a figure for recharge that, taken in conjunction with the estimate of recharge from streams, about balances the pumpage. Thus, average infiltration of rain from 1941 to 1945 was estimated to be about 4,400 acre-feet a year (table on p. 100) and seepage from streams about 700 acre-feet a year (table p. 53), making a total of 5,100 acre-feet, which about balances the average pumpage. With the evidence of little or no change in water levels, it seems that the computations of recharge from rain and from streams are fairly accurate.

Therefore, taking the average rainfall at Santa Barbara (18.40 inches for the 77-year period) and rounding it upward to an estimated 19 inches for the recharge area of the Goleta basin, it is believed that a fairly reliable figure for long-term average infiltration from rain is given by the method used for the shorter period. This gives a long-term average infiltration of 2,600 acre-feet a year (p. 100). Seepage from streams is estimated to have been about 700 acre-feet in the past 5 years and is perhaps as much as 500 acre-feet in long-term average. Thus, the long-term average annual recharge is estimated to be about 3,100 acre-feet a year. Inasmuch as this is the average amount of water that can be counted upon as available for withdrawal, it is taken as the perennial yield.

This perennial yield is only an average. Pumpage at that rate would exceed the recharge during dry years and would be less than the recharge during wet years. Continued pumpage at or above the perennial yield will cause water levels to decline, thus increasing pumping lifts, will draw water from storage, and will maintain or aggravate any tendency for contamination of the ground water from the ocean or other sources. The possibility of salt-water contamination is discussed in the following paragraphs.

QUALITY OF WATER

To appraise the quality of water in the Goleta basin, the Geological Survey collected 58 samples of water from wells for chemical analyses. Also, a number of analyses were gathered for study from various other agencies, chiefly the Bureau of Reclamation and the County Farm Advisor. Of the 58 samples collected by the Geological Survey, partial analyses (comprising determination of chloride, soap hardness, and specific electrical conductance) were made for 54 and complete analyses for 4. The results of the partial analyses are assembled in table 14 and the complete analyses made by the Survey, together with selected complete analyses (complete except for determination of iron and silica) by other agencies are assembled in table 15. The complete analyses of waters in most of the areas (excluding well 4/28–18M1) show that the chloride and hardness range from 49 to about 140 parts per million and from 474 to 630 parts per million, respectively, and that the sodium percentage ranges from 22 to 37. Hence, these waters are probably satisfactory for ordinary agricultural and domestic uses although the hardness is substantially higher than is generally desirable for domestic uses. In general, the partial analyses, which afforded more complete coverage, are consistent with the information supplied by the complete analyses. For example, in most wells the chloride concentration ranges from 37 to about 90 parts and the hardness from 350 to 550 parts. In the north marginal part of the area the chloride concentration is a little greater, ranging from 100 to 140 parts, and the hardness as high as 750 parts. In well 4/28-20A1 near Mescal Island, an abandoned oil test well, the chloride concentration is 872 parts, though the hardness is 340 parts. The water has a strong "sulfur" odor. Few data are at hand concerning this well.

TABLE 14.—*Partial chemical analyses of waters from wells in the Goleta basin*

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

Well	Date of collection	Chloride (Cl), parts per million	Soap hardness, as $CaCO_3$, parts per million	Specific conductance ($K \times 10^5$ @ 25° C.)
4/27-7J1	Oct. 29, 1941	37	350	93.2
7L6	December 1941	62	365	104
12L3	June 26, 1942	88	600	149
4/28-3M1	June 7, 1941	131	700	194
3Q1	July 31, 1942	65	425	113
3R4	Oct. 25, 1941	60	375	114
4P1	July 2, 1942	104	575	146
4R3	July 21, 1941	176	700	188
4R3	Aug. 9, 1941	132	650	178
4R4	June 3, 1942	117	650	172
5B1	Sept. 24, 1941	82	400	133
7P2	Oct. 28, 1941	28	275	79.7
8A2	June 25, 1942	72	600	138
8B1	June 10, 1942	76	450	122
8B3	Sept. 24, 1941	129	525	159
8B5	Oct. 25, 1941	99	425	139
8J2	December 1941	76	500	135
8K1	Aug. 17, 1942	72	625	144
8K2	do	67	375	117
8M1	July 5, 1942	198	575	187
9A2	June 7, 1941	155	750	202
9A2	Apr. 21, 1942	86	525	148
9B4	July 5, 1942	54	525	119
9L2	July 1, 1942	57	450	112
9P3	Oct. 28, 1941	52	400	107
9R6	do	74	440	120
10A2	Sept. 24, 1941	43	400	99.7
10E1	Oct. 25, 1941	40	325	92.8
10F1	June 24, 1942	57	475	109
10G1	Aug. 11, 1941	114	650	158
10G1	July 3, 1942	60	465	117
10G4	June 10, 1942	31	325	88.4
10H2	Sept. 24, 1941	40	390	97.7
10N1	June 7, 1941	33	500	104
10R1	Aug. 11, 1941	57	425	108
11G2	Oct. 28, 1941	74	375	116
11N1	do	54	400	109
12J2	July 8, 1942	41	400	96.2
12L3	Sept. 24, 1941	82	550	149
12P2	Apr. 21, 1942	84	425	130
12P2	July 8, 1942	73	500	126
14C1	July 2, 1942	92	515	140
15A1	July 3, 1942	57	550	115
15A3	July 29, 1942	50	375	103
15C3	June 26, 1942	21	415	89.7
15D2	Sept. 24, 1941	32	375	99.1
15D3	June 26, 1942	28	450	97.0
16H1	July 21, 1941	120	750	188
17H2	June 7, 1941	71	500	121
18G2	June 3, 1942	160	390	152
18P1	Apr. 21, 1942	82	400	118
18P1	Aug. 18, 1942	184	525	160
20A1	Aug. 9, 1941	872	340	870

TABLE 15.—*Selected chemical analyses of well and stream waters of the Goleta basin*

Number	Well or location symbol[1]	Source	Date of collection	Temperature (° F.)	Parts per million														
					Dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$
1	4/28-4R3	Caveletto and Gallagher. Drilled irrigation well 230 feet deep. Sample taken by U. S. Bur. Reclamation (No. 4); analysis by Nat. Bur. Standards (No. 59788).	Dec. 11, 1942	------	1,400	------	------	160	65	180	10	0	470	470	140	0.1	------	0	0
2	4/28-9A2	L. M. Cavaletto. Drilled irrigation well, 334 feet deep. Sample taken by U. S. Geol. Survey; analysis by G. J. Petretic, U. S. Geol. Survey (No. 27422).	Apr. 21, 1942	62	1,090	18	1.4	172	49	109	6.4	0	367	421	86	------	0.3	2.3	630
3	4/28-9P3	Mrs. D. M. Culver. Drilled irrigation well, 262 feet deep. Sample taken by U. S. Geol. Survey; analysis by M. D. Foster and L. W. Miller, U. S. Geol. Survey (No. 26558).	Oct. 25, 1941	66	738	30	.04	134	35	61	1.8	0	390	209	49	------	.4	1.2	478
4	4/28-12P2	La Cumbre Mutual Water Co. Drilled public supply and irrigation well, 500 feet deep. Sample taken by U. S. Geol. Survey; analysis by G. J. Petretic, U. S. Geol. Survey (No. 27418).	Apr. 21, 1942	70	931	36	2.2	132	42	106	9.2	0	366	309	84	------	.3	.6	502
5	4/28-18M1	Devereux Foundation School. Drilled irrigation well, 144 feet deep. Analysis by J. C. Martin.	July , 1946	------	[2] 760	------	------	365	------	280	------	0	490	430	440	------	------	------	------
6	4/28-18P1	C. A. Storke Estate. Drilled irrigation well, 180 feet deep. Sample taken by U. S. Geol. Survey; analysis by G. J. Petretic, U. S. Geol. Survey (No. 27415).	Apr. 21, 1942	66	814	22	.97	134	34	84	5.8	0	384	227	82	------	.4	.5	474

7	4/28-3H	Maria Ygnacio Creek at crossing of U. S. Highway 101. Discharge estimated 100 cfs. Sample taken by U. S. Bur. Reclamation (No. 23); analysis by Nat. Bur. of Standards, San Francisco Lab. (No. 61277).	Mar. 4, 1943	------	170	------	------	25	7.5	9.9	0.6	0	82	32	6	------	------	.9	93
8	4/28-3H	Maria Ygnacio Creek, same locality; discharge estimated 2 cfs. Sample taken by U. S. Bur. Reclamation (No. 32); analysis by Nat. Bur. Standards, San Francisco Lab. (No. 61724).	Apr. 8, 1943	------	660	------	------	------	------	------	------	2.6	230	240	35	.06	------	------	------

[1] Symbol is well number as described in text: or a location symbol only where applied to a stream locality.
[2] Calculated.

However, it had a small flow in August 1941; the water is probably from considerable depth, perhaps from the consolidated rocks. It is evidently not representative of the water tapped by most water wells, but may be representative of deep-lying high-sulfate water discussed in the following paragraphs.

In the western part of the Goleta basin, in sec. 18, T. 4 N., R. 28 W., and sec. 13, T. 4 N, R. 29 W., several wells yield water having a rather high concentration of dissolved solids, as indicated by several analyses of water made available by the Santa Barbara County Farm Advisor, and also by the reports of local residents. A representative analysis is that for well 4/28-18M1, taken in July 1946 and given in table 15. The analysis indicates essentially a calcium chloride and sulfate water; the chloride content makes up about 42 percent of the anions, with the sulfate only slightly lower than the bicarbonate. The high mineral content of the water—1,760 parts of total solids—would render its continued use dangerous to most soil types although the "percent sodium" is only 40.

The geologic conditions in the Goleta basin do not favor the possibility of contamination of the deep ground-water body by sea water. As has been described (p. 84), impermeable consolidated rocks lie along the seaward side of the Goleta basin and constitute an essentially continuous surface and subsurface barrier, broken only at the outlet of the Goleta slough and at the outlet of the smaller slough about 3 miles farther west. The surface outlets are relatively narrow but furnish ample capacity for tidal water to enter the sloughs. Both of the sloughs contain salty water which extends or has extended inland as much as 0.5 to 1 mile and might constitute a source of sea-water contamination. It is believed that in general the upper strata of the younger alluvium are sufficiently impermeable to restrain, and probably prevent entirely, the downward percolation of salty water from these sloughs, but nevertheless, it is conceivable that under a favorable hydraulic gradient salty water could percolate downward very slowly over a long period of time through the fine-grained deposits. Moreover, wells with casings perforated in both shallow and deep zones or wells with a gravel envelope to the land surface could yield some salty water derived from a shallow zone. Such wells could also constitute conduits by which shallow saline water could migrate into and contaminate deeper zones if the head relationship were favorable.

In the subsurface channels, sea water may now extend landward through the presumed tongues of coarse-grained deposits at the base of the younger alluvium beneath the surface outlets previously described. Once it has crossed the barrier of impermeable rocks, sea water could percolate downward into the underlying Santa Barbara formation. It would have to migrate landward through such tongues for only about half a mile at the Goleta slough and probably a little more than half a mile at the outlet of the slough farther west in order to reach the Santa Barbara formation. Thus, under a favorable hydraulic gradient it would be possible for salt water to reach the Goleta ground-water basin from the ocean proper through these subsurface channels, and such encroachment may be occurring at this time.

Hydraulic gradients favorable to sea-water encroachment have existed for several years in most of the Goleta basin because beneath the eastern part of the alluvial plain the static head of the deep water body is 10 to 15 feet below sea level, and beneath the western part of the alluvial plain is as much as 20 feet below sea level. (See pl. 9.) During pumping periods, the water levels beneath the plain are many feet lower near pumped wells and the hydraulic gradients landward from the sea may be temporarily much steepened. That such conditions have existed for several years is indicated by the reports of static water levels in 1938 discussed by Quinton [13] and others, which indicate levels below sea level beneath a large part of the alluvial plain at that time.

Although in recent years hydraulic gradients have existed that would be favorable to ocean-water incursion, a review of available chemical data has led to the conclusion that this source of contamination may not be in operation in the Goleta basin. The chief reason for such a conclusion is that here the wells high in chloride are also high in sulfate; furthermore, a variation in chloride from well to well is attended by an equal if not greater variation in sulfate. If fluctuations in chloride were due to mixture with ocean water, fluctuations in sulfate would be only minor—the sulfate content of ocean water is only about 13 percent of that of chloride.

For one well in the contaminated area a series of five analyses is available, covering the period 1939–43. For this well, the chloride was 248 parts in October 1939, reached a maximum of 298 in November of that year, then declined to 200 parts in January 1943. For the sample of November 1939, the sulfate was 453 parts and for that of January 1943, it declined to 200 parts. The cyclic nature of the chloride fluctuation would not, in itself, rule out ocean-water contamination, but the correspondingly greater fluctuation of sulfate would render that source extremely unlikely insofar as those analyses are concerned. Furthermore, a sample from this well, collected July 20, 1942, and probably not representative of the water normally

[13] Quinton, and others, op. cit., p. 34.

yielded, contained 715 and 91 parts of sulfate and chloride, respectively. Hence, a high sulfate water is available at least locally; its capacity to blend with native waters of fair quality is likely to be dependent on regional ground-water levels. Because accumulation of chemical data is of much help in attempting to determine sources of contamination and to predict contamination trends, recurrent sampling of wells should become a common practice in areas where contamination is a possibility. From selected wells a series of samples should also be taken—one sample as the pump is started and others after successively longer intervals until the water discharged is of constant quality. Analyses of these may indicate how the contaminant is entering the casing.

There is apparently no evidence of salt-water contamination of the ground water in the central and eastern parts of the basin, east of San Pedro Canyon. However, if sea water is moving into the basin as a result of continued maintenance of static water levels below sea level, encroachment will take place ultimately in the eastern part of the basin if current hydraulic gradients are maintained.

In addition to ocean water as a source of contamination, two other possible sources exist: saline waters locally native to the lower part of the Santa Barbara formation, and saline waters native to older Tertiary rocks, specifically those associated with petroleum deposits.

It has been shown in other areas that connate saline waters may occur in aquifers correlative with the principal water-bearing zones or immediately underlying them. In the Long Beach-Santa Ana area (Piper, Garrett, and others, in preparation), a sample collected from the bottom of a well near Huntington Beach, contained about 4,500 parts of total solids although the water yielded by the well during pumping contained only about 1,300 parts. Based on this and other evidence not here presented, the conclusion was made that the saline water in the bottom of that well was of connate origin, that an interface existed between the connate water and the slightly contaminated fresh water above, and that this interface moved up and down, probably dependent upon the pumping drawdown. The possible presence of connate saline water in the lower part of the Santa Barbara formation in the Goleta basin has been discussed (p. 91); and here, as elsewhere, it may, depending on pumping, move upward into the zones penetrated by water wells.

The other possible source of salt-water contamination is the connate brines associated with petroleum, found principally in Miocene rocks in both the Goleta and Elwood fields. Opportunity for these brines to migrate into fresh-water zones is available through tar seeps that occur in association with the outcrop of fractures; similarly these seeps may also occur beneath the Santa Barbara formation in the basin. Such brines may have invaded the lower part of that formation and, if so, might be drawn upward during times of pumping, as concluded in the case cited above. Accordingly, pending the collection of additional data such a source of contamination is considered improbable. It was pointed out earlier that in this area an increase in salinity in hitheto fresh waters is accompanied by a marked increase in sulfate. Oil-field brines, however, commonly contain only a trace of sulfate, rarely more than about 20 parts—even though the brine may have a total solids content equal to or somewhat greater than that of ocean water.

Hence, of the three possible sources of contamination outlined, the postulation of saline water locally native within or immediately underlying the stratigraphic range penetrated by water wells is the most likely. Extended sampling of wells probably would furnish the data for determining the source or sources of contamination.

TABLE 16.—*Drillers records of wells in the Carpinteria basin*

[Altitudes are above approximate mean sea level, stratigraphic correlations by J. E. Upson and L. Porter, Jr.]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
4/25-19G1. S. M. Brown. On alluvial slope. Altitude 85 feet					
[Casing perforated from 120 to 140, 160 to 180, 200 to 240, and 250 to 270 feet]					
Older alluvium:			Casitas formation—Continued		
Boulders and clay	43	43	Sand and gravel	5	114
Clay and gravel	24	67	Boulders and clay	28	142
Clay, yellow, sticky	16	83	Clay, yellow, sticky	20	162
Clay, yellow, sandy; and gravel	20	103	Boulders and gravel	5	167
Casitas formation:			Clay, yellow	35	202
Boulders and clay	6	109	Boulders and clay	37	239
			Sand, blue, and gravel	31	270
4/25-19N1. H. P. Drake. On alluvial plain. Altitude 38 feet					
Younger alluvium:			Older alluvium:		
Surface soil	41	41	Clay, yellow	121	248
Gravel, water-bearing	7	48	Rock and gravel	23	271
Clay, brown	32	80	Clay, red	13	284
Gravel, water-bearing	20	100			
Clay, sandy, brown	27	127			
4/25-19Q2. H. W. Morris. On alluvial plain. Altitude 21 feet					
[Casing perforated at 55 feet, and from 90 to 200 feet]					
Younger alluvium:			Older alluvium:		
Top soil	13	13	Clay, sandy, red	21	119
Silt, water-bearing	6	19	Sand, fine, water-bearing	3	122
Gravel	1	20	Clay, hard, red	10	132
Clay, sandy	16	36	Clay	41	173
Clay, soft, blue	10	46	Sand, fine, water-bearing	3	176
Clay, sticky, blue	34	80	Clay, sandy	10	186
Sand, fine, water-bearing	2	82	Sand and gravel, water-bearing	5	191
Clay, blue	16	98	Clay	9	200

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-19Q3. F. L. Stewart. On alluvial plain. Altitude 34 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Older alluvium:		
Surface soil	11	11	Clay, red	18	111
Clay, brown	14	25	Gravel, water-bearing	6	117
"Surface water"	3	28	Clay, yellow, and boulders	8	125
Clay, yellow	9	37	Clay, sandy, yellow	66	191
Clay, brown	39	76	Clay, brown	5	196
Clay, yellow	5	81	Gravel, water-bearing	4	200
Clay, brown	6	87	Boulders and gravel, water-bearing	25	225
Clay, yellow	4	91	Clay, red	12	237
Gravel, water-bearing	2	93			

4/25-20L2. Samuel Edwards Associates. On alluvial plain. Altitude 97 feet

[Casing perforated from 64 to 70, 98 to 104, 222 to 223, 261 to 266, 286 to 308, 317 to 330, 338 to 346, 380 to 396, and 416 to 431 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Casitas formation—Continued		
No record	50	50	Gravel, water-bearing	1	223
Older alluvium:			Clay, red, and sand	17	240
Boulders	10	60	Clay, brown, and sand	21	261
Gravel, water-bearing	4	64	Gravel, water-bearing	5	266
Gravel and clay	11	75	Sand and boulders	14	280
Clay and sand, soft	14	89	Sand, soft	6	286
Gravel and clay	9	98	Gravel, water-bearing	22	308
Sand, water-bearing	5	103	Clay, red	9	317
Casitas formation:			Gravel, water-bearing	13	330
Clay, brown	12	115	Clay, very sticky, red	8	338
Gravel and clay, hard	8	123	Gravel, water-bearing	8	346
Clay and sand, brown	15	138	Clay, yellow	30	376
Gravel and clay, brown	6	144	Clay, very sticky, brown	4	380
Clay, yellow, and gravel	18	162	Gravel, water-bearing	16	396
Clay, brown, and gravel	8	170	Clay, brown	20	416
Clay, brown, and gravel	39	209	Gravel, water-bearing	15	431
Gravel and clay, hard, brown	13	222	Clay, brown	3	434

4/25-20M2. C. P. Reynolds. On alluvial slope. Altitude 71 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Top soil	14	14	Clay, yellow	3	105
Boulders imbedded in dark soil	23	37	Clay, yellow, interbedded with gravel	4	105
Clay, yellow	5	42	Clay, yellow	3	108
Gravel, coarse, water-bearing	2	44	Sand, medium fine	1	109
Boulders in red clay	3	47	Clay, yellow, interbedded with gravel	4	113
Boulders imbedded in yellow clay	6	53	"Solid formation"	2	115
Clay, red, interbedded with fine sand	3	56	Clay, yellow, soft	4	119
Gravel, water-bearing	3	59	Gravel, water-bearing	6	125
Clay and boulders, red	8	67	Clay, soft, brown	4	129
Clay and cobbles, red	22	89	Clay	2	131
Gravel, medium, and small rock	9	98	Clay, interbedded with gravel	10	141

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-21R1. B. Moore. On alluvial slope. Altitude 127 feet

[Casing perforated 82 to 90, 120 to 150, 170 to 176, 240, 289 to 304, 314 to 318, 341, 356 to 386, and 412 to 416 feet]

	Thickness (feet)	Depth (feet)
Younger alluvium:		
Surface formation	15	15
Casitas formation:		
Clay, sandy, hard	39	54
Sand, soft, "dead"	4	58
Clay, sandy, hard	22	80
Clay, sandy; little gravel	10	90
Clay, sandy, hard	18	108
Sand, soft, "dead"	3	111
Clay, sandy, hard	6	117
Sand, soft, "dead"	20	137
Sand, "dead", soft	1	138
Sand, soft, "dead"	12	150
Clay, sandy, hard	18	168
Clay, sandy, soft	8	176
Clay, sandy, hard	57	233
Sand, "dead", yellow	6	239
Sand, "dead", yellow, soft	1	240
Clay, sandy, yellow, hard	8	248
Casitas formation—Continued		
Sand, soft, yellow, "dead"	8	256
Clay, sandy, hard, blue, brown	12	268
Clay, sandy, soft, blue, brown	36	304
Clay, sandy, hard, blue, brown	8	312
Clay, sandy, soft, light brown	6	318
Clay, sandy, hard, blue brown	21	339
Clay, sandy, soft, light brown	3	342
Clay, sandy, hard, light brown	14	356
Clay, sandy, soft, yellow	30	386
Clay, sandy, hard, brown	26	412
Clay, sandy, soft, brown	4	416
Clay, sandy, hard, brown	32	448
Clay, sandy, soft	20	468

4/25-26J1. Stanley Shepard. On surface of Shepard Mesa. Altitude 598 feet

	Thickness (feet)	Depth (feet)
Terrace deposits:		
Sand and boulders	30	30
Casitas formation:		
Sand, yellow; streaks of yellow clay	25	55
Clay, yellow; steaks of sand	20	75
Sand	10	85
Sand, hard; gravel	44	129
Shale, yellow; streaks of hard sand	22	151
Sand, hard	8	159
Clay, yellow; streaks of hard sand	26	185
Sand, hard; streaks of yellow clay	19	204
Sand, hard; gravel	16	220
Sand, hard	24	244
Sand, hard; gravel	24	268
Clay, yellow; streaks of hard sand	20	288
Clay, yellow; streaks of sand	30	318
Clay, yellow; hard sand	22	340
Clay, yellow; streaks of sand	27	367
Clay, yellow; hard sand	23	390
Sand, hard	23	413
Sand, fine, hard	1	414
Sand, hard	3	417
Sand and clay, hard	8	425
Sand and yellow clay, hard	12	437
Sand, hard	14	451
Sand, hard; streaks of yellow clay	6	457
Sand, hard; thin streaks of yellow clay	7	464
Sand, hard	11	475
Sand, hard; thin streaks of yellow clay	5	480
Sand, hard; streaks of yellow clay	7	487
Sand, hard, clay	14	501
Sand, hard	2	503
Sand and clay	12	515
Clay, yellow; thin streaks of sand	7	522
Sand, yellow, clay	23	545
Casitas formation—Continued		
Sand, yellow	10	555
Clay, yellow; streaks of sand	18	573
Clay, yellow	15	588
Sand, hard	2	590
Sand, hard, clay	18	608
Sand, hard	13	621
Sand, hard; gravel	51	672
Sand, hard	20	692
Sand, hard; gravel	8	700
Sand, yellow; streaks of red clay	47	747
Sand, hard; gravel	18	765
Sand, hard	18	783
Sand, hard; streaks of clay	10	793
Clay, yellow; gravel	34	827
Clay and sand, yellow	23	850
Shale, sandy, blue	18	868
Sand, hard	7	875
Shale, sandy, blue	25	900
Sand, hard; streaks of blue sand	25	925
Sand, hard	88	1,013
Santa Barbara (?) formation:		
Sand, blue	5	1,018
Sand, blue; streaks of hard sand	14	1,032
Shale, sandy, blue	7	1,039
Sand, hard	2	1,041
Sand, fine, blue; thin streaks of shale	5	1,046
Sand, hard, blue	4	1,050
Sand, hard	4	1,054
Sand, hard, blue	8	1,062
Sand, blue	10	1,072
Sand, hard, blue	4	1,076
Sand, blue	7	1,083
Sand, hard	4	1,087
Sand, hard, blue	6	1,093
Sand, hard	12	1,105
Sand, blue; streaks of brown shale	12	1,117
Sand, blue	27	1,144
Sand, hard	7	1,151
Sand, hard, blue	14	1,165

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-26J1. Stanley Shepard. On surface of Shepard Mesa. Altitude 598 feet—Continued

	Thickness (feet)	Depth (feet)
Santa Barbara (?) formation—Continued		
Sand, blue	9	1,174
Sand, blue; thin streaks of oil sand	1	1,175
Shell	1	1,176
Sand, blue; thin streaks of oil sand	1	1,177
Sand, blue, and shale; thin streaks of oil sand	8	1,185
Sand, hard, blue; thin streaks of oil sand	4	1,189
Sand, hard; streaks of oil sand	5	1,194
Sand, hard, blue	9	1,203
Sand, hard	1	1,204
Sand, blue	5	1,209
Sand, hard	1	1,210
Sand, hard, blue; streaks of blue sand	2	1,212
Sand, hard, blue	8	1,220
Sand, blue; streaks of coarse gravel	13	1,233
Sand, blue	9	1,242
Sand, blue; streaks of oil sand	12	1,254
Sand, gray; streaks of oil sand	9	1,263
Sand and streaks of hard blue sand	4	1,267
Sand, blue; streaks of oil sand and red clay	11	1,278
Sand, blue; showing of oil	20	1,298
Sand, blue; streaks of oil sand	2	1,300
Oil sand	17	1,317
Sespe (?) formation:		
Shale, red	17	1,334
Shale, flaky, yellow	21	1,355
Oil sand	2	1,357
Shale, red; streak of blue sand	12	1,369
Shale, red	8	1,377
Sand, gray	3	1,380
Shale, red, sandy	3	1,383
Shale, red; streaks of blue sand	20	1,403
Sand, gray	7	1,410
Sand, gray; red shale	28	1,438
Sand, gray, fine	6	1,444
Shale; streaks of sand	14	1,458
Sand, gray, fine; streaks of red shale	10	1,468
Shale, red	18	1,486
Sand, blue; red shale	12	1,498
Sand, hard	4	1,502
Shale, red	23	1,525
Shale, gray, sandy	33	1,558
Shale, red; streaks of blue sandy shale	20	1,578
Shale, red	10	1,588
Sespe formation:		
Shale, brown, sandy	10	1,598
Shale, hard, sandy	4	1,602
Shale, red, sandy	4	1,606
Shale, red	16	1,622
Shale, brown, sandy	16	1,638
Shale, brown	18	1,656
Shale, red; hard sandy brown shale	22	1,678
Shale, red; streaks of sand	13	1,691
Sand, red; streaks of shale	14	1,705
Shale, brown	3	1,708
Rock, hard	1	1,709
Sand, hard	3	1,712
Sand rock, hard	5	1,717
Sand, hard	14	1,731
Shale, red, sticky	1	1,732
Shale, red, sandy	12	1,744
Sespe formation—Continued		
Sand, fine, hard	10	1,754
Shale, brown, hard	3	1,757
Shale, brown, sandy	2	1,759
Shale, brown	14	1,773
Sand, blue-gray, sandy; streaks of hard sand	15	1,788
Shale, brown; streaks of blue and gray sand	11	1,799
Sand, gray, dark	1	1,800
Sand, gray, fine; streaks of red shale	12	1,812
Shale, brown	9	1,821
Shale, brown, sandy	5	1,826
Sand, yellow, coarse	7	1,833
Sand, yellow coarse, hard	3	1,836
Sand, yellow, hard	9	1,845
Sand, light gray	11	1,856
Sand, gray, streaks of blue shale	17	1,873
Shale; streaks of hard sand	13	1,886
Shale, brown; streaks of sandy shale	19	1,905
Shale, brown; streaks of green shale	5	1,910
Shale, brown	8	1,918
Shale, brown; streaks of sand	8	1,926
Shale, sandy	10	1,936
Shale, brown, sandy; white sticky clay	21	1,957
Shale, sandy	6	1,963
Shale, brown; streaks of sandy shale	16	1,979
Shale, brown; streaks of sand	13	1,992
Shale, brown, hard, sandy	9	2,001
Shale, brown, hard	10	2,011
Shale, brown, hard, sandy	8	2,019
Shale, hard, sandy	5	2,024
Sand, hard	7	2,031
Shale, hard, dark, sandy	13	2,044
Shale, reddish brown; streaks of gray sand	9	2,053
Shale, dark sandy	17	2,070
Sand, brown, hard	7	2,077
Sand, hard	6	2,083
Shale, hard, sandy; streaks of hard sand	5	2,088
Shale, dark, sandy	19	2,107
Shale, hard, dark sandy	9	2,116
Shale, sandy, dark	12	2,128
Shale, hard, sandy	12	2,140
Shale, dark, sandy	15	2,155
Shale, hard, dark	9	2,164
Shale, dark brown, sandy	20	2,184
Shale, dark, sandy	13	2,197
Shale, brown, hard; streaks of sand	15	2,212
Shell, hard	1	2,213
Sand, gray, hard	1	2,214
Sand, hard	3	2,217
Shale, brown	1	2,218
Shale, red, hard	9	2,227
Shale, brown, sandy	7	2,234
Shale, brown	7	2,241
Shale, brown; streaks of hard sand	11	2,252
Shale, dark	15	2,267
Shale, brown, tough; streaks of sand	9	2,276
Shale, reddish-brown; streaks of sand	6	2,282
Shale, red; streaks of sand	14	2,296
Sand, hard	14	2,310
Shale, hard, sandy	6	2,316

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
4/25-26J1. Stanley Shepard. On surface of Shepard Mesa. Altitude 598 feet—Continued					
Sespe formation—Continued			Sespe formation—Continued		
Shale, red	22	2,338	Shale, dark	17	2,568
Shale, dark	22	2,360	Shale, soft, sandy	17	2,585
Shale, reddish-brown, hard; streaks of gray sand	7	2,367	Shale, brown, dark	15	2,600
Shale, dark brown and blue	7	2,374	Shale, dark reddish-brown	11	2,611
Shale, brown; streaks of sandy blue shale	31	2,405	Shale, red	23	2,634
Shale, reddish-brown; streaks of blue shale	27	2,432	Shale, reddish-brown; streaks of blue shale	23	2,657
Shale, dark	1	2,433	Shale, brown; streaks of gray sand	28	2,685
Shale, reddish-brown; streaks of blue shale	8	2,441	Shale, gray, sandy, hard	9	2,694
Shale, dark red; streaks of blue shale	7	2,448	Shale, dark, sandy, hard	7	2,701
Shale, dark, hard	5	2,453	Sand, dark, hard	8	2,709
Shale, red, hard; streaks of blue shale	3	2,456	Sand, dark, streaks of hard sand	17	2,726
Shale, reddish-brown; streaks of blue shale	21	2,477	Shale, sandy	5	2,731
Shale, dark	16	2,493	Sand, hard	1	2,732
Shale, dark, sandy	12	2,505	Sand, gray, hard, streaks of sandy shale	6	2,738
Shale, hard, sandy	5	2,510	Sand, hard, streaks of sandy shale	8	2,746
Shale, dark, sandy	24	2,534	Sandy, gray, hard	4	2,750
Shale, dark, hard, sandy	10	2,544	Sand, hard	5	2,755
Sand, dark, hard	5	2,549	Sand, gray	9	2,764
Sand, gray, hard; reddish-brown shale	2	2,551	Sand, gray, sharp	6	2,770
			Sand, gray	4	2,774
4/25-27G2. Cate and Vosburg School. At edge of alluvial plain. Altitude 159 feet					
Younger alluvium:			Casitas formation—continued		
Loam, sandy and boulders	42	42	Clay, yellow, and boulders	4	255
Gravel, cemented	4	46	Sandstone, clay and boulders	17	272
Casitas formation:			Sandstone, hard	3	275
Boulders and clay	6	52	Clay and boulders	1	276
Clay	3	55	Clay, sandy; sand and gravel	8	284
Boulders and clay	5	60	Sandstone, hard	5	289
Sandstone, hard	14	74	Clay, sandy, boulders and gravel	3	292
Clay, sandy, and boulders	29	103	Clay and boulders	4	296
Boulders, hard	4	107	Sandstone, hard	4	300
Clay, sandy, and boulders	4	111	Gravel, cemented	6	306
Sandstone, hard	3	114	Clay, sand, gravel	5	311
Clay, sandy, and boulders	20	134	Clay, yellow, and boulders	10	321
Sandstone, soft; clay and small boulders	6	140	Clay, sandy, and small boulders	4	325
Gravel, cemented	5	145	Clay, yellow, and boulders	9	334
Clay, sandy, and boulders	6	151	Clay, yellow, and boulders	5	339
Sandstone, clay and boulders	4	155	Clay, yellow and dark; small boulders; sand and gravel	4	343
Gravel, cemented	4	159	Clay, yellow, and boulders	4	347
Sandstone, hard	3	162	Sandstone, hard	3	350
Clay, yellow, hard; and small boulders	7	169	Clay, yellow, and boulders	5	355
Sandstone, hard	8	177	Clay, sandy; red clay, sand and gravel	10	365
Clay, yellow, and boulders	4	181	Clay, yellow, and boulders	9	374
Sandstone, clay and boulders	6	187	Boulders, sand and gravel	3	377
Gravel, cemented	2	189	Gravel, cemented	1	378
Sandstone, hard	2	191	Boulders, sand and gravel; clay	5	383
Clay, yellow, and boulders	14	205	Sandstone, hard	3	386
Gravel and sand	2	207	Clay, yellow	7	393
Clay, yellow, and boulders	9	216	Clay, yellow; boulders	2	395
Gravel, cemented	2	218	Sandstone, hard	2	397
Clay, yellow, and boulders	5	223	Clay, yellow, and boulders	2	399
Clay and gravel	3	226	Sandstone, hard	4	403
Boulders and clay	3	229	Clay and boulders	10	413
Gravel, cemented	2	231	Clay, sand and gravel; boulders	19	432
Sandstone, hard	2	233	Sandstone, hard	3	435
Clay, yellow, and boulders	9	242			
Sandstone, hard	3	245			
Clay, yellow, and boulders	3	248			
Sandstone, hard	3	251			

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-27G2 Cate and Vosberg School. At edge of alluvial plain. Altitude 159 feet—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Casitas formation—Continued			Casitas formation—Continued		
Clay and boulders	10	445	Clay, sandy; soft sandstone	32	506
Clay, boulders; sand and gravel	10	455	Clay, boulders; sand and gravel	5	511
Clay and boulders	4	459	Clay, sandy; soft sandstone	21	532
Clay, sand and gravel	3	462	Clay, sandy; boulders	3	535
Clay, yellow, and boulders	3	465	Sandstone, hard	4	539
Clay, sandy, and boulders	9	474			

4/25-27L1. G. R. Bliss. On alluvial plain. Altitude 130 feet

[Casing perforated from 99 to 114, 120 to 125, and 151 to 205 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Casitas formation—Continued		
Soil	9	9	Boulders with some clay	34	185
Clay, sandy	68	77	Gravel	6	191
Clay and water	16	93	Clay and rocks	14	205
Gravel, showing clay	21	114	Clay	42	247
Casitas formation:			Boulders	13	260
Clay, red	6	120	Gravel	2	262
Gravel with some clay	5	125	Clay	6	268
Clay, red	26	151			

4/25-27R2. W. H. Yule. On alluvial plain. Altitude 132 feet

[Casing perforated from 295 to 310, 350 to 378, and 392 to 420 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Casitas formation—Continued		
Soil	14	14	Clay, brown	12	360
Clay, sandy	88	102	Gravel and boulders	18	378
Casitas formation:			Clay, green	8	386
Sand, water-bearing	2	104	Gravel and boulders	8	394
Clay	84	188	Clay, brown	7	401
Clay, hard, brown	128	316	Sandstone	3	404
Gravel and fine sand	5	321	Sand and gravel	15	419
Clay	26	347	Clay	1	420
Sand	1	348	Gravel	1	421

4/25-27R3. M. D. Knapp and E. S. Atkinson. At foot of terrace. Altitude 135 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Casitas formation:			Casitas formation—Continued		
Surface soil	6	6	Conglomerate	4	252
Clay and sand	26	32	Sand and gravel	19	271
Clay and "rock"	22	54	Sand and clay	36	307
"Rock," sand, and clay	41	95	Gravel and rock	8	315
Sand, clay, and gravel	40	135	Clay, hard	7	322
"Rock" and clay	15	150	Clay and sand	5	327
Sand and clay	22	172	Rock and sand	8	335
Gravel and sand	29	201	Clay and sand	13	348
Clay and sand	12	213	Rock	7	355
Hard rock, conglomerate	21	234	Gravel	5	360
Clay	2	236	Sand and clay	18	378
Conglomerate	10	246	Clay, hard	20	398
Gravel	2	248			

4/25-28F1. P. Hanson. On alluvial plain. Altitude 59 feet

[Casing perforated from 50 to 190 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Top soil	23	23	Adobe and silt, black	17	148
Sand and gravel	10	33	Sand and gravel	14	162
Clay, sandy, yellow	17	50	Adobe and silt, black	9	171
Sand and gravel	11	61	Sand and gravel	17	188
Adobe and silt, black	63	124	Clay, yellow	14	202
Sand and gravel	7	131	Gravel and boulders	18	220

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-25-28F3, E. W. Hoffman. On alluvial plain. Altitude 78 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Soil	4	4	Sand, coarse, and water-bearing gravel	21	183
Clay, brown	11	15	Clay, brown	32	215
Sand, brown, water-bearing	7	22	Sand, fine	5	220
Clay, brown	75	97	Sand, coarse, and water-bearing gravel	11	231
Sand, coarse, and water-bearing gravel	4	101	Clay, brown	29	260
Clay, brown	39	140			
Clay, red	22	162			

4/25-28G1. E. W. Hoffman. On alluvial plain. Altitude 87 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Soil, sandy	31	31	Boulders, sandy	14	142
Gravel, sandy	13	44	Clay, sandy	4	146
Clay	15	59	Sand and boulders	31	177
Gravel, fine	18	77	Clay, sandy	5	182
Clay, sandy	23	100	Gravel, sandy	16	198
Sand, fine	18	118	Sand	12	210
Clay and boulders	10	128	Clay, very sandy	17	227

4/25-28J1. W. C. and C. A. Catlin. On alluvial plain. Altitude 89 feet

	Thickness (feet)	Depth (feet)
Younger alluvium:		
Top soil	30	30
Gravel and sand with thin layers of hard, water-tight material	86	116

4/25-28N1. Mona Catlin. On alluvial plain. Altitude 29 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Sand and sandy surface soil	15	15	Sand, fine, and clay	22	145
Sand and gravel	17	32	Sand, fine, and clay	5	150
Clay and gravel	20	52	Sand, gravel, and clay	20	170
Clay, hard	4	56	Younger alluvium and older alluvium, undifferentiated:		
Sand, fine, and gravel	17	73	Sand, gravel, and sea shells	36	206
Gravel	23	96	Sand, fine, and clay; silt and muck	79	285
Sand, hard, and gravel	10	106			
Sand, fine; clay and gravel	17	123			

4/25—29B1. Monte Vista Dairy. On alluvial plain. Altitude 26 feet

[Casing perforated from 54 to 194 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Surface soil	9	9	Gravel and sand, loose	7	137
Clay and rocks, brown	34	43	Clay, brown	19	156
Clay, sandy	19	62	Gravel, cemented	3	159
Clay, brown	42	104	Gravel and sand, loose	7	166
Sand, silty, loose	3	107	Sand	3	169
Clay, brown	16	123	Clay, brown	17	186
Sand, silty, loose	6	129	Rocks	1	187
Clay, brown	1	130	Clay, brown	7	194

4/25-29D2. C. C. Heltman. On alluvial plain. Altitude 33 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Surface soil	4	4	Clay, brown	52	94
Sand, very fine	3	7	Gravel, water-bearing	5	99
Clay, soft, brown	17	24	Clay, brown	3	102
Sand, very fine, water-bearing	6	30	Clay, yellow	43	145
Clay, brown	6	36	Gravel, water-bearing	4	149
Gravel, no water	6	42	Clay, red, and sand	17	166

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-29D3. Stewart and Atkinson. On alluvial plain. Altitude 20 feet

	Thickness (feet)	Depth (feet)
Younger alluvium:		
Surface soil	16	16
Sand, brown	9	25
Boulders and gravel	6	31
Clay, brown, and boulders	34	65
Gravel, water-bearing	8	73
Clay, brown, and gravel	10	83
Gravel, water-bearing	22	105
Sand, clay, and boulders	27	132
Sand, and gravel, water-bearing	17	149
Sand and clay, brown	2	151
Sand and gravel, water-bearing	16	167
Older (?) alluvium:		
Sand and clay, brown	51	218
Sand and gravel, water-bearing	3	221
Sand and clay, brown	11	232
Sand and gravel, water-bearing	2	234
Sand and clay, brown	6	240
Clay, sandy, hard	23	263
Clay and sand, brown	5	268
Clay, sandy, hard	2	270
Older alluvium—Continued		
Sand and gravel, water-bearing	5	275
Boulders, hard	2	277
Clay, sandy, hard	25	302
Sand	2	304
Clay, sandy, hard	3	307
Sand	1	308
Clay, sandy, hard	2	310
Sand and gravel, water-bearing	8	318
Rock, hard	2	320
Clay, sandy, hard	2	322
Sand, water-bearing	20	342
Sand and gravel, water-bearing	8	350
Clay, sandy, hard	6	356
Sand and fossil shells, water-bearing	10	366
Clay, sandy, hard	8	374
Sand and fossil shells	16	390
Sand, gravel and rock, water-bearing	9	399
Sand	3	402
Clay, hard, sticky	4	406
Clay, sandy, hard	2	408

4/25-29E1. Santa Barbara Oil & Gas Co. On alluvial plain. Altitude 10 feet

[Log reproduced with permission of Peter Cooper Bryce.]

	Thickness (feet)	Depth (feet)
Younger alluvium and older alluvium, undifferentiated:		
Silt, black	30	30
Silt	26	56
Sand, black	4	60
Sand, reddish	10	70
Clay, black	8	78
Sand, black	7	85
Clay, sandy, brownish red	15	100
Clay, brown	25	125
Sand, blue	4	129
Clay, sandy, blue	16	145
Gravel and coarse sand, blue	27	172
Clay, sandy, blue	4	176
Sand, coarse, blue	10	186
Sand, brown	2	188
Sand, blue	8	196
Clay, sandy, brown	48	244
Clay, sandy, blue	6	250
Sand, brown	5	255
Clay, sandy, brown	4	259
Sand	9	268
Clay, sandy, blue	2	270
Clay, sandy, brown	22	292
Sand, gray, fine, loose	10	302
Sand, grading into fine gravel below	6	308
Sand	82	390
Clay, sticky; sandy in lower part	19	581
Clay, alternating hard and soft layers	15	596
Clay, sticky, blue	20	616
Gravel and sand	24	640
Casitas formation:		
Clay, sticky	12	652
Clay, alternating hard and soft layers	5	657
Gravel and clay, hard	31	688
Clay, sandy, hard	4	692
Core: massive reddish-brown, silty to muddy silt; mottled with gray and tan when dry	19	711
Casitas formation—Continued		
Clay, sticky	17	728
Gravel, interbedded with clay	51	779
Clay, alternating hard and soft layers	61	840
Clay, sticky	33	873
Clay, sandy	20	893
Clay, sticky	24	917
Clay, sandy	28	945
Clay, sticky	9	954
Clay and sand in alternating layers	40	994
Sand and gravel in alternating layers	16	1,010
Gravel	10	1,020
Clay, sticky, alternating with sand	24	1,044
Core: 2½ feet massive compact, reddish and gray clay; 1½ feet medium-grained gray sand with charred wood specks and occasional pebbles up to ⅛ inch in diameter	4	1,048
Clay, sticky, and alternating with sand	30	1,078
Sand and gravel with charred wood fragments	12	1,090
Gravel	10	1,100
Clay, sandy	30	1,130
Clay, alternating sticky and sandy layers	20	1,150
Clay, sticky	5	1,155
Gravel and boulders	15	1,170
Clay, sticky	32	1,202
Clay, sandy, hard	12	1,214
Clay, sticky, hard	16	1,230
Core: no recovery, sticky clay	10	1,240
Clay, sticky	52	1,292
Clay, sandy, hard	13	1,305
Clay, sticky, interbedded with sand	21	1,326

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-29E1. Santa Barbara Oil & Gas Co. On alluvial plain. Altitude 10 feet—Continued

	Thickness (feet)	Depth (feet)
Casitas formation—Continued		
Clay, sticky	13	1,339
Gravel	5	1,344
Clay, sticky	54	1,398
Core: compact reddish clay and silty sand	14	1,412
Core: 5 feet sandy gray clay, reddish cast, charcoal and gypsum; 1 foot coarse gray sand with pebbles up to ¾ inch in diameter, with reddish silt	15	1,427
Clay, sticky	11	1,438
Sand and gravel	12	1,450
Clay, sandy	8	1,458
Clay, sticky, interbedded with sand	31	1,489
Clay, sandy	9	1,498
Sand and gravel	8	1,506
Clay, sandy, hard	8	1,514
Clay, sticky	5	1,519
Clay, sandy	21	1,540
Clay, sticky, brown, interbedded with thin layers of sand	47	1,587
Core: sandy massive reddish-to-tan and gray mottled clay; sandy massive gray clay with pebbles up to ¼ inch in diameter; massive very sandy reddish-gray clay	18	1,605
Clay, sandy, tough streaks	32	1,637
Clay, sandy, alternating with sticky clay	38	1,675
Clay, sticky	13	1,688
Sand, interbedded with sticky clay	32	1,720
Clay, hard, tough, brown	16	1,736
Clay, sticky	6	1,742
Clay, sandy	28	1,770
Clay, hard, sandy	20	1,790
Core: no recovery; probably soft sand	15	1,805
Core: clean, fine-grained sand	10	1,815
Sand	8	1,823
Casitas formation—Continued		
Clay, sandy, alternating with tough clay	10	1,833
Clay, hard, sandy	12	1,845
Core: very fine-grained blue sand	8	1,853
Clay, sandy, hard	2	1,855
Sand, interbedded with hard layers	15	1,870
Clay, sticky	7	1,877
Core: grayish-brown silt	26	1,903
Clay, sandy	16	1,919
Clay, alternating sandy and sticky	9	1,928
Clay, sandy, alternating with sand	32	1,960
Core: sand	2	1,962
Sand and sticky clay	35	1,997
Core: clay, reddish-brown, alternating with gray, sandy clay	5	2,002
Depth correction	−6	1,996
Core: silt, sandy, reddish and gray, slightly indurated	9	2,005
Santa Barbara formation:		
Core: clay, sandy, gray, loosely cemented; contains fossil shells	4	2,009
Core: same	18	2,027
Clay, sandy	19	2,046
Clay, shale, very sandy; gray sand	4	2,050
Clay, sticky, alternating with sand	11	2,061
Clay and sand in alternating layers	31	2,092
Sand and gravel	9	2,101
Clay, alternating sandy and sticky	69	2,170
Sand and gravel	9	2,179
Clay, alternating sandy and sticky	372	2,551
Shale, silty and sandy gray very fossiliferous, and with carbonized wood fragments	18	2,569

4/25-29G2. Stewart and Atkinson. On alluvial plain. Altitude 23 feet

	Thickness (feet)	Depth (feet)
Younger alluvium:		
Surface soil	6	6
Sand, fine, water-bearing	31	37
Clay, brown	23	60
Clay, blue	32	92
Clay, brown	59	151
Clay, yellow	5	156
Sand, very fine	9	165
Younger alluvium and older alluvium, undifferentiated:		
Clay, yellow	22	187
Clay, red	41	228
Younger alluvium and older alluvium, undifferentiated—Con.		
Gravel, water-bearing	8	236
Clay, blue	34	270
Gravel, water-bearing	11	281
Clay, red	12	293
Gravel, water	4	297
Clay, brown	58	355
Sand, very fine; contains fossil shells	14	369
Gravel, water-bearing	5	374
Sand, blue	23	397

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-29H1. C. R. Sawyer. On alluvial plain. Altitude 33 feet

	Thickness (feet)	Depth (feet)
Younger alluvium and older alluvium, undifferentiated:		
Soil	3	3
Sand, alternating with gravel	17	20
Clay	18	38
Silt, loose	4	42
Clay and fine sand	8	50
Clay	47	97
Sand and gravel	2	99
Clay	16	115
Sand, fine, and gravel to 1 inch	1	116
Clay	10	126
Younger alluvium and older alluvium, undifferentiated—Con.		
Silt and fine sand	3	129
Clay	21	150
Silt, fine, loose	4	154
Sand, very fine	5	159
Sand and gravel, coarse	2	161
Clay	5	166
Sand and gravel, coarse	16	182
Clay	17	199
Gravel, coarse	33	232
Older alluvium (?):		
Clay	4	236

4/25-29M1. Western Oil Royalties Limited 1. On alluvial plain. Altitude 2 feet

[Log compiled by L. Porter, Jr., largely from core records; reproduced with permission of Peter Cooper Bryce]

	Thickness (feet)	Depth (feet)
Younger alluvium and older alluvium, undifferentiated:		
Sand, soft, blue	15	15
Sand, soft, blue; some clay	17	32
Sand, soft, blue	42	74
Sand and shell fragments	9	83
Sand and clay, hard, tough	12	95
Sand, fine, soft, blue	30	125
Sand and clay, loose, blue and brown, with shell fragments	105	230
Sand and gravel; some soft brown clay	15	245
Clay and gravel, soft, brown and blue	65	310
Clay, blue and brown; some gravel	47	357
Casitas formation:		
Clay, sticky, tough, brown; some fine sand	18	375
Clay and gravel, soft to tough, brown	104	479
Clay, soft, with hard sandy layers, brown; wood fragments	68	547
Clay and gravel, sandy layers, brown; wood fragments	275	822
Clay and sand; brown	38	860
Clay and thin sand layers, reddish-brown; some carbonized matter	97	957
Clay and sandy clay, brown, hard and tough	200	1,157
Clay and sandy clay, hard and sticky; some fine gravel	29	1,186
Clay, sandy, soft, brown; some gravel	77	1,263
Clay, brown, and fine hard sand	67	1,330
Clay, sandy, and fine sand	66	1,396
Clay, sandy, brown; fine gravel	34	1,430
Clay, sandy, brown; some gravel	81	1,511
Clay and sandy clay, soft, blue and brown	12	1,523
Clay, sandy, brown	16	1,539
Clay, brown to reddish-brown; some sandy clay and pebbles	15	1,554
Clay and sandy clay, brown; some fine gravel	85	1,639
Clay, sandy brown; some coarse sand and pebbles	15	1,654
Clay, brown, tough; some sand and pebbles	14	1,668
Santa Barbara (?)formation:		
Clay, brown, tough; some sand; "common fish bones, and fragments of molluscan shells"	12	1,680
Clay, mottled-brown, tough; some shell fragments; fine sand near bottom	13	1,693
Sand, gray, medium-grained; numerous shell fragments	17	1,710
Gravel, containing pebbles of black chert and numerous shell fragments	5	1,715
Sand, soft, brown to light gray	6	1,721
Sand, loose, medium, gray, with pebbles of black chert and shell fragments	4	1,725
Sand with pebbles, gray, fossiliferous	15	1,740
Fragments of fossil wood	5	1,745
Sand with pebbles, gray, fossiliferous	21	1,766
Gravel; large rounded pebbles of banded Monterey	1	1,767
Sand, fine, gray; some pebble and shell fragments	6	1,773
Sand, soft, gray-green, with shell fragments	2	1,775
Sand and pebbles, bluish-gray	5	1,780
Clay, tough, sticky, mottled-brown	13	1,793
Clay, sandy, dark brown	40	1,833
Clay, tough, mottled-brown	20	1,853
Clay, sandy, brown	20	1,873
Sand, soft, gray	20	1,893
Sand, soft, dark; shell fragments; bluish-gray sandy clay near base	20	1,913
Clay, sandy, with pebbles of shale	20	1,933
Sand, bluish-gray, fossiliferous	20	1,953
Sand, dark, fossiliferous; some some hard clay	20	1,973
Clay, bluish-gray	10	1,983
Clay and sand	10	1,993
Clay, soft, bluish-brown	10	2,003
Sand, coarse, hard; red-brown clay, grading down to fine sand and greenish-white sandy clay	20	2,023

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-35A2. E. H. Bates. In valley of Rincon Creek. Altitude 147 feet

[Casing perforated from 55 to 179 and 231 to 401 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Casitas formation—continued.		
Soil and sand	12	12	Clay with thin streaks of sand and few pebbles	8	187
Sand, coarse, and gravel, large boulders	26	38	Clay, sandy	6	193
Sand, coarse, and pebbles	4	42	Gravel, small pebbles	12	205
Casitas formation:			Clay and silt with few streaks of fine sand	12	217
Sand and boulders with clay	20	62	Clay	10	221
Sand, coarse, with small pebbles	4	66	Gravel and clay	4	238
"Hard sandstone boulder"	2	68	Clay, gray	7	237
Clay and gravel	7	75	Gravel, pebbly, and brown sand	3	241
Clay, brown	10	85	Clay, gray	6	247
Gravel and clay	6	91	Gravel	5	252
Gravel	9	100	Silt, hard	4	256
Clay, brown	3	103	Clay with thin streaks of sand and pebbles	9	265
Gravel and clay	8	111	Clay, gray	6	271
Clay and gravel, interbedded	8	119	Silt, gray, and clay with thin streaks of sand and pebbles	85	356
Gravel, hard, pebbly	11	130	Clay, sticky	14	370
Gravel, small, pebbly, with coarse brown sand	2	132	Gravel, small, pebbly, and coarse brown sand	12	382
Silt, brown	9	141	Clay, sticky	9	391
Gravel and clay	5	146	Silt and fine sand	2	393
Gravel, clean, with coarse sand	4	150	Clay, sticky	8	401
Clay, grayish-brown	12	162	Silt with one 6-inch streak of fine sand	12	413
Gravel, small, pebbly, with some fine sand	13	175			
Clay, sandy	4	179			

4/25-35C1. M. B. McDougall. On side of terrace. Altitude 206 feet

[Casing perforated from 116 to 159, 171 to 177, and 233 to 250 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Casitas formation:			Casitas formation—Continued		
Top soil	4	4	Clay, red and gravel	4	146
Clay, red, heavy	10	14	Clay, red, gravel and sand	11	157
Clay red, streaked with sand pan	8	22	Clay, yellow, heavy	2	159
Clay, heavy, yellow	12	34	Gravel, coarse, water-bearing	5	164
Clay, red	22	56	Clay, red, and gravel	5	169
Clay red, carrying sand boulders	14	70	"Solid formation"	4	173
Gravel dry, and red clay	9	79	Sand rock, hard	4	177
Clay, red	27	106	Adobe, black	6	183
Clay, red, carrying sand	9	115	Clay, yellow	7	190
Clay, yellow; interbedded with some pea-size gravel	4	119	Sand, red	14	204
Clay, yellow and boulders, dry formation	13	132	Clay, yellow	17	221
Sand, water	2	134	Clay, red, and gravel	12	233
Boulders in yellow clay	4	138	Gravel water-bearing	9	242
Gravel and sand, water-bearing	4	142	Clay, red, sandy	31	273
			Boulders	1½	274½
			Clay, red, sandy	15½	290

4/25-35C3. Reed Nicols. At edge of Rincon Creek valley. Altitude 222 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Casitas formation:			Casitas formation—Continued		
Surface soil	6	6	Gravel	3	149
Clay, red	12	18	Gravel, water-bearing	14	163
Clay and gravel, yellow	43	61	Clay, brown	27	190
Clay, red	25	86	Clay, red	28	218
Clay, yellow	11	97	Clay, boulders, and gravel, yellow	34	252
Clay, red	11	108	Clay and boulders, red	11	263
Clay and gravel, yellow	14	122	Clay, brown	4	267
Clay, red	16	138	Clay and gravel, red	38	305
Clay, yellow	8	146			

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

4/25-35E2. W. B. Knowlton. On terrace surface. Altitude 250 feet

[Casing perforated from 394 to 403, 412 to 420, and 484 to 493 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Terrace deposits:			Casitas formation—Continued		
Soil, hard, black	10	10	Clay, hard, dark	56	394
Clay, yellow	8	18	Santa Barbara formation:		
"Rock," mixed with yellow clay	11	29	Shells, fine "rocks" and sand; water-bearing	9	403
Casitas formation:			Sand, fine, and clay	7	410
Clay, hard, yellow	69	98	Clay, dark blue	2	412
Clay mixed with a few "rocks"	22	120	Sand, shells, small "rocks,"; water-bearing	8	420
Clay, hard, yellow	83	203	Sand, fine, light blue	51	471
Clay, blue	36	239	Clay, hard, blue	13	484
Clay, blue mixed with fine sand	51	290	"Rock," sand, clay; water-bearing	9	493
Sand, hard, blue, very fine	48	338	Clay, hard, blue	25	518

4/26-14N1. M. C. Fleischmann. In valley of Toro Creek. Altitude 180 feet.

[Casing perforated from 43 to 48, 80 to 82, 138 to 140, and 179 to 185 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Surface soil	5	5	Clay and gravel, red	20	138
Boulders and gravel	28	33	Gravel, water-bearing	2	140
Clay, red	10	43	Clay, yellow, and gravel	14	154
Surface water	5	48	Clay, yellow	25	179
Clay, yellow	5	53	Gravel, water-bearing	6	185
Boulders and gravel	20	73	Sand, yellow	22	207
Clay, yellow	7	80	Clay, yellow, and gravel	8	215
Gravel, water-bearing	2	82	Sespe formation:		
Boulders and gravel	5	87	Shale	14	229
Clay and gravel, yellow	31	118			

4/26-23H2. Mrs. W. C. Hohmann. On alluvial slope. Altitude 51 feet

[Casing perforated from 90 to 103 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Top soil, a few stones	10	10	Clay, soft, yellow	15	82
Clay, red	18	28	Clay, yellow; interbedded with sand	8	90
Clay cobbles, red	6	34	Gravel, coarse	2	92
Clay and soft rock, red	4	38	Clay, yellow	1	93
Clay with some gravel and sand, red	10	48	Sand, medium fine, yellow	1	94
Clay and sand, red, water-bearing	8	56	Clay, gravel and sand, brown	4	98
Gravel, water-bearing	2	58	Clay and cobbles, yellow	2	100
Clay, sandy, red	6	64	Clay, red; interbedded with brown cobbles and sand	5	105
Clay and rock, red	3	67			

TABLE 16.—*Drillers records of wells in the Carpinteria basin*—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
4/26-23H3. F. K. Hubbell. On alluvial slope. Altitude 52 feet. [Casing perforated from 60 to 68, 193 to 197, and 226 to 234 feet]					
Older alluvium:			Casitas (?) formation:		
Top soil	3	3	Sand, very fine, gray, water-bearing	4	197
Top soil carrying small rock	11	14	Sand, coarse	4	201
Clay, red; small amount of sand	35	49	Clay, yellow, and sand	10	211
Sand, dry, and gravel	2	51	Clay, red, sandy	7	218
Clay, red	9	60	Clay, yellow	8	226
Sand, fine, red; in red clay, surface water	8	68	Sand, coarse; small amount of coarse gravel and stone; water-bearing	8	234
Clay, red; small amount of fine sand	34	102	Clay, yellow; small amount of fine sand	6	240
Clay, red	32	134	Clay, yellow	6	246
Sand, medium fine, water-bearing	4	138	Sand, coarse, water-bearing	2	248
Clay, yellow	30	168	Clay, red, heavy	8	256
Clay, yellow; small amount of sand	11	179			
Clay, brown	2	181			
Clay, yellow	12	193			
4/26-24E3. Santa Barbara Polo Association. On alluvial slope. Altitude 38 feet. [Casing perforated from 180 to 200 feet]					
Older alluvium:			Casitas formation—Continued		
Top soil, water-bearing	35	35	Clay, brown	87	295
Clay, brown	23	58	Clay, blue	3	298
Clay, brown	52	110	Sand, blue	2	300
Clay, light sandy	70	180	Clay, brown	10	210
Sand and gravel, water-bearing	20	200	Clay, blue	10	320
Casitas formation:			Sand, blue	5	325
Sand, fine, blue	8	208			
4/26-24F3. A. F. Thurmond. On alluvial plain. Altitude 11 feet. [Casing perforated from 100 to 167 feet]					
Younger alluvium:			Older alluvium—Continued		
Soil	4	4	Sand and gravel, coarse	26	151
Adobe, black	10	14	Casitas (?) formation:		
Older alluvium:			Clay, sandy, alternating yellow and blue	274	425
Clay, sandy, yellow	81	95			
Sand and silt	30	125			
4/26-24F4. Santa Barbara Polo Association. On alluvial slope. Altitude 31 feet					
Older alluvium:			Casitas (?) formation—Continued		
Surface soil, sandy	29	29	Sand	5	258
Sand, loose	7	36	Clay, sandy	6	264
Clay, sandy, yellow	24	60	Sand	6	270
Clay, yellow	10	70	Clay	26	296
Clay, sandy, yellow	16	86	Sand and clay, loose	7	303
Boulders	2	88	Clay	7	310
Gravel, sandy	4	92	Clay	13	323
Clay, sandy, yellow	32	124	Sand, hard	4	327
Sand	10	134	Clay	7	334
Clay, sandy, yellow	7	141	Sand, hard	2	336
Sand	5	146	Clay	8	344
Clay, sandy, yellow	14	160	Clay, yellow	11	355
Clay, yellow	35	195	Sand	5	360
Casitas (?) formation:			Clay	2	362
Sand	5	200	Sand	5	367
Clay, yellow	13	213	Boulders	3	370
Sand	2	215	Clay	9	379
Clay, sandy	21	236	Sand and boulders	30	409
Sand	4	240	Clay	6	415
Clay, sandy, hard	13	253			

TABLE 17.—*Materials penetrated by water wells in the Goleta basin*

[Based on drillers' records unless otherwise indicated. Stratigraphic correlations by J. E. Upson. Altitudes with respect to preliminary sea-level datum of 1934]

4/27-6R2. Verne B. Archer. On valley floor. Altitude 295 feet

[Casing perforated from 272 to 284 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Older alluvium—Continued		
Soil	6	6	Clay, gray	4	191
Clay	2	8	Clay, red; some fine sand	11	202
Older alluvium:			Clay, sandy, yellow	7	209
Clay, brown	24	32	Sand, fine, yellow, water-bearing	2	211
Clay, yellow and brown	16	48	Sand, fine, yellow; some clay	14	225
Clay, yellow	17	65	Gravel, water-bearing	2	227
Sand and gravel; not water-bearing	3	68	Sand, fine, and clay; gravel at bottom	12	239
Clay, yellow, soft	4	72	Clay, brown, "solid"	8	247
Clay, brown, "solid"	12	84	Sand, fine, and clay, brown	5	252
Clay, yellow; some sand	12	96	Clay, brown, soft	4	256
Clay, brown, "solid"	9	105	Clay, brown	4	260
Clay, sandy, yellow	10	115	Clay and sand, brown	4	264
Clay, red, "solid"	7	122	Sand, medium	2	266
Clay, brown	12	134	Sand, grading downward into coarse sand and gravel	17	283
Sand, yellow	10	144	Sand, medium	11	294
Clay, yellow, soft	8	152	Sand, fine, brown, with clay	9	303
Clay, brown, "solid"	15	167	Clay, blue, soft	9	312
Clay, sandy, yellow	16	183			
Sand; some gravel; water-bearing	4	187			

4/27-7B2. W. E. Dickerson. On alluvial terrace. Altitude 274 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Soil	1	1	Clay and gravel, in alternating layers	6	138
Clay, red, "heavy"	15	16	Clay, fine; some sand and gravel	14	152
Clay, red, "heavy"; some sand	22	38	Clay, yellow, soft	12	164
Clay, red, "heavy"	8	46	Clay and gravel, water-bearing	12	176
Clay, yellow	12	58	Sand, "very solid"	4	180
Clay, red; some sand	40	98	Gravel and sand, water-bearing	10	190
Clay and gravel	8	106	Clay, brown	2	192
Clay, red; some sand	12	118			
Sand, fine; gravel at bottom	11	129			
Sand, "very solid"	3	132			

4/27-7G1. Lloyd Water Association. On alluvial terrace. Altitude 274 feet.

[Casing perforated from 114 to 116 and 175 to 180 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Soil	0	3	Sand, fine	8	142
Clay, red, heavy	5	8	Sand, clay, and gravel; not water-bearing	8	150
Clay, red, with some sand	62	70	Sand with some hard layers	16	166
Clay, yellow	22	92	Clay, red, "heavy"	9	175
Sand, fine, yellow	2	94	Santa Barbara formation:		
Clay, fine, alternating with sand	14	108	Sand, medium, gray, water-bearing	6	181
Clay, yellow	6	114	"Rock formation"	4	185
Sand, medium, and fine gravel	2	116	Sand, medium; some gravel and clay	5	190
Sand, gray	7	123	Clay, soft, light-colored	11	201
Clay, red, sticky	11	134			

TABLE 17.—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-2N1. W. M. Hughes. In valley of San Antonio Creek. Altitude 154 feet

[Casing perforated from 157 to 164 and 190 to 204 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Boulders and clay	40	40	Gravel, water-bearing	7	164
Santa Barbara formation:			Sand, yellow	26	190
Sand, yellow	110	150	Sand, blue, water-bearing	20	210
Clay, blue	7	157	Clay, sandy, blue	8	218

4/28-3K1. T. C. Emmons. On valley floor of Maria Ygnacio Creek. Altitude 147 feet

[Casing perforated from 68 to 361 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil, sandy	24	24	Sand, shells, fine gravel	11	224
Sand and gravel	11	35	Clay, sandy, blue	13	237
Clay, sandy, brown	3	38	Silt and shells	26	263
Clay, sandy; some gravel and boulders	45	83	Clay, blue; cemented shells	4	267
Santa Barbara formation:			Silt and shells	14	281
Sand, yellow	102	185	Sand, blue, hard	12	293
Clay, gray, sticky	2	187	Clay, blue; cemented shells	5	298
Clay, blue, sandy	14	201	Silt and shells	41	339
Clay, blue, sticky	8	209	Sand, blue, hard	7	346
Silt and shells	4	213	Silt and shells	14	360
			Clay, blue	7	367

4/28-3M7. L. W. Fowler. On valley floor of San Jose Creek. Altitude 117 feet

[Log by L. Porter, Jr., compiled from cuttings]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Clay, chocolate-brown	36	36	Silt, gray	10	163
Sand, yellow; shell fragments and pebbles	15	51	Sand, gray	15	178
Clay, brown	21	72	Silt, gray	8	186
Santa Barbara formation:			Gravel, gray, very fossiliferous	3	189
Sand, yellow, with pebbles	13	85	Clay, gray, silty	21	210
Sand, light tan	38	123	Clay, light gray	125	335
Sand, light gray	30	153			

4/28-3Q2. A. J. Haverland. On valley floor of Maria Ygnacio Creek. Altitude 120 feet

[Casing perforated from 126 to 360 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	25	25	Clay, yellow	6	170
Clay, yellow	20	45	Silt, blue, and shells	25	195
Clay with sandstone boulders	54	99	Clay, sandy, yellow	50	245
Clay, yellow	19	118	Sand, fine, yellow	35	280
Stanta Barbara formation:			Clay, sandy, blue	8	288
Clay, blue	8	126	Silt, yellow; fine gravel	6	294
Silt, yellow	22	148	Sand, fine, yellow	34	328
Sand, yellow	14	162	Clay, sandy, blue	2	330
Sand and gravel; not water-bearing	2	164	Silt, yellow	17	347
			Sand and gravel	13	360

TABLE 17.—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-4R4. L. M. Cavaletto and G. M. Gallagher. On valley floor of San Jose Creek. Altitude 91 feet

[Log by L. Porter, Jr., compiled from cuttings]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Silt, brown, sandy	22	22	Silt, gray	10	247
Sand, yellow, with pebbles	10	32	Sand, gray, fine	50	297
Silt and clay, brown	60	92	Clay, sandy, gray	3	300
Gravel, brown	5	97	Clay, silty, gray	32	332
Gravel, fine	10	107	Sand, fine, gray	45	377
Santa Barbara formation:			Clay, light brown	25	402
Silt, brown	10	117	Clay, brown	5	407
Clay, silty, light tan	10	127	Clay, gray, with shell fragments	5	412
Silt, light gray-brown	35	162			
Silt, gray	45	207	Clay, gray	5	417
Sand, gray	4	211	Silt, gray	25	442
Clay, gray	3	214	Silt, gray, with shells	10	452
Sand, gray	3	217	Silt, gray	20	472
Silt, gray	15	232	Silt, gray, with shells	25	497
Clay, gray	5	237	Silt, gray	3	500

4/28-8C1. C. S. Spizzibottiani. On Goleta alluvial plain. Altitude 67 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation:		
Soil	27	27	Sand, blue	7	111
Silt and sand	8	35	Clay, blue	125	236
Clay, brown	25	60	Sand, blue	14	250
Clay, sandy brown	20	80	Clay, blue, shells	22	272
Sand, gray	8	88	Sand, blue	2	274
Clay, brown	16	104	Clay, blue, hard	6	280

4/28-8C2. G. B. Cavalletto. On Goleta alluvial plain. Altitude 57 feet

[Casing perforated from 95 to 105 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Clay, red	38	38	Sand, coarse, yellow	15	107
Sand and gravel, water-bearing	12	50	Clay, sandy, blue	30	137
Santa Barbara formation:			Clay blue	111	248
Sand, fine, yellow	42	92	Clay, green	106	354

4/28-8Q2. Navy Department, Marine Corps Air Station. On Goleta alluvial plain. Altitude 21 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	15	15	Clay, sandy, dark	72	191
Clay, sandy	18	33	Sand, blue	8	199
Sand, brown	9	42	Clay, sandy, dark	13	212
Clay, sandy, brown	16	58	Sand, blue	2	214
Santa Barbara formation:			Clay, sandy, dark	5	219
Clay, sandy, dark	60	118	Sand, blue; small clam shells	7	226
Mud, sandy	1	119	Clay, sandy, dark	1	227
			Sand, blue, coarse	6	233

TABLE 17.—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-9A2. L. M. Cavalette. On alluvial plain. Altitude 85.5 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	25	25	Silt, with shells	18	219
Clay, sandy, yellow	13	38	Clay, blue, sticky; pebbles, wood fragments, and shells	8	227
Gravel	3	41	Silt, with shells	12	239
Sand, yellow, loose	4	45	Clay, blue, sticky, with shells	11	250
Sand, yellow, compact	7	52	Clay, blue, compact	19	269
Sand, blue	5	57	Silt, with shells	6	275
Clay, sandy, blue	9	66	Clay, sandy, blue, compact	3	278
Sand and gravel	2	68	Silt, with shells	7	285
Santa Barbara (?) formation:			"Rock ledge, solid"	9	294
Clay, sandy, blue	7	75	Clay, sandy, blue, compact	22	316
Sand, compact, blue	8	83	Clay, blue, sticky, with shells	19	335
Clay, sandy, blue	7	90	Rincon shale:		
Sand, blue, compact	4	94	Shale, brown	5	340
Clay, blue, sticky	36	130			
Santa Barbara formation:					
Silt, with shells	15	145			
Clay, blue, sticky	56	201			

4/28-9C3. Chester Rich. At edge of Goleta alluvial plain. Altitude 56 feet

[Casing perforated from 64 to 348 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	5	5	Clay, sandy, blue	21	145
Sand, brown	17	22	Sandstone, hard, blue	12	157
Santa Barbara formation:			Clay, sandy, blue	8	165
Clay, sandy, blue	4	26	Sand, blue	4	169
Clay, blue	6	32	Clay, sandy, gray	15	184
Sand, blue	16	48	Clay, blue, sticky	4	188
Sand, yellow	54	102	Clay, sandy, blue	7	195
Sand, gray, hard; contains shells	22	124	Sand, gray, blue	63	258
			Clay, blue, and shells	92	350

4/28-9E1. A. T. Spaulding. On Goleta alluvial plain. Altitude 44 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Soil	17	17	Sand and clay, brown	41	117
Clay, yellow	10	27	Santa Barbara formation:		
Clay, yellow	3	30	Sand, blue; blue clay; some gravel	173	290
Gravel and sand	4	34	Clay, blue, tough; some "shale"	20	310
Gravel and sand; yellow clay	13	47			
Sand, yellow	7	54			
Sand, yellow, mixed with clay	22	76			

4/28-9H1. J. C. VanDyke. On Goleta alluvial plain. Altitude 73 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	12	12	Sand, hard, gray-blue	6	154
Clay, sandy	9	21	Sand, blue-green, with shells	15	169
Sand and gravel	3	24	Clay, sandy, green, with shells	6	175
Clay, sandy	21	45	Sand, hard, gray-blue	16	191
Sand, yellow	10	55	Sand, gray-blue, soft	3	194
Clay, sandy, brown	8	63	Sand, gray-blue, hard	24	218
Sand and gravel	2	65	Clay, sandy, blue	3	221
Santa Barbara formation:			Sand, gray-blue, hard	17	238
Sand, gray	9	74	Clay, gray-blue, sandy	6	244
Clay, sandy, gray	10	84	Sand, hard, gray-blue	21	265
Clay, sandy, brown	5	89	Clay, sandy, blue	3	268
Sand and fine gravel	3	92	Sand, gray-blue	2	270
Sand, fine, gray	7	99	Sand, gray-blue, hard, mixed with fine gravel	3	273
Silt, black	9	108	Sand, hard, gray-blue	7	280
Sand, fine, gray	6	114	Clay, blue, sticky	60	340
Sand and gravel	3	117	Silt, fine, and shells	22	362
Clay, sandy, gray	15	132			
Sand, gravel, and shells	16	148			

TABLE 17—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-9H2. P. Bogaro. On Goleta alluvial plain. Altitude 69 feet

[Casing perforated from 250 to 265 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation:		
Soil	12	12	Sand, fine, blue	123	235
Gravel, not water-bearing	6	18	Sand, coarse, blue	15	250
Clay	25	43	Gravel	15	265
Sand, water-bearing	2	45			
Clay	67	112			

4/28-9M1. W. Soundy. On Goleta alluvial plain. Altitude 31 feet

[Casing perforated from 280 to 313 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Sand	14	14	Sand, blue	2	74
Clay, sandy, brown	24	38	Clay, blue, "slummy"	88	162
Sand and clay	12	50	Clay, blue, hard	98	260
Sand and yellow clay	9	59	Clay, sandy, blue	16	276
Sand and gravel	8	67	Sand, blue	19	295
Santa Barbara formation:			Sand, blue, and "lava rock"	18	313
Clay, blue	5	72	Clay, blue	16	329

4/28-9Q2. Rose Dearborn. On Goleta alluvial plain. Altitude 39 feet

[Casing perforated from 142 to 160 and 184 to 210 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara (?) formation—Continued:		
Soil	9	9	Boulders and sand	5	154
Clay, sandy	29	38	Sand, blue	33	187
Sand, fine, water-bearing	10	48	Gravel, water-bearing	7	194
Santa Barbara (?) formation:			Santa Barbara formation:		
Clay, sandy, blue	100	148	Gravel with shells	6	200
Gravel, water-bearing	1	149	Clay, blue	10	210

4/28-10F1. J. S. Edwards. On Goleta alluvial plain. Altitude 79.9 feet

[Casing perforated from 72 to 198 and 312 to 459 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Clay, sandy	12	12	Clay, blue, with sand and shells	186	330
Gravel and boulders	17	29	Clay, sand, and shells	37	367
Clay and gravel	32	61	Sand, shells, and gravel	35	402
Clay, yellow	10	71	Sand, clay, and sandstone	57	459
Santa Barbara formation:					
Clay, blue, and sand	73	144			

4/28-10G2. Gene Miratti. On valley floor of Maria Ygnacio Creek. Altitude 106 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation:		
Soil	20	20	Sand, yellow, with fine gravel	16	132
Sand and gravel	10	30	Sand, yellow	5	137
Clay, sandy, yellow	25	55	Sand, blue	17	154
Sand, alternating with clay	12	67	Clay, blue, and sand	39	193
Sand and gravel	34	101	Sand, very fine, yellow	7	200
Boulders	15	116	Sand, fine, yellow	15	215
			Clay, sandy, yellow and blue	21	236

TABLE 17—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-10G4. Gene Miratti. On alluvial plain. Altitude 105.1 feet

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Younger alluvium—Continued		
Soil	12	12	Gravel	2	112
Clay, brown, and rocks	48	60	Gravel, cemented	3	115
Gravel	12	72	Santa Barbara formation:		
Clay, brown	6	78	Sand, blue	72	187
Gravel, cemented	10	88	Clay, sandy, blue	7	194
Gravel	5	93	Clay, sandy, yellow	12	206
Clay, sandy	10	103	Sand, yellow, with shells	31	237
Gravel, cemented	2	105	Clay, yellow	14	251
Gravel	3	108	Sand, yellow	81	332
Gravel, cemented	2	110			

4/28-10N2. R. Broader. On alluvial plain. Altitude 59 feet

[Casing perforated from 318 to 337 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	5	5	Clay, sandy, hard	7	192
Sand	10	15	Clay, soft	4	196
Clay, brown	56	71	Clay, blue, hard	18	214
Gravel, coarse	8	79	Clay, light, blue	18	232
Clay, brown, soft	3	82	Clay, sandy, soft	13	245
Clay, hard, and gravel	7	89	Clay, sandy	27	272
Sand, blue, packed with gravel	16	105	Rock	1	273
Older alluvium (?):			Sand and clay, hard	8	281
Gravel, small	2	107	Sand and shells, hard	9	290
Clay, yellow, soft	28	135	Sand, fine, blue	23	313
Santa Barbara formation:			Sand, loose	4	317
Clay, blue, soft	32	167	Sand and gravel	23	340
Clay, blue, hard	18	185			

4/28-11P2. Mrs. Geo. Rowe. On older alluvial slope. Altitude 64 feet

[Casing perforated from 45 to 50, 60 to 70, 120 to 125, 145, 180, 195, 240 to 245, and 289 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Older alluvium:			Older alluvium—Continued		
Hard pan	18	18	Clay, red and yellow	55	174
Gravel, cemented	2	20	Clay, sandy; some water	24	198
Clay, yellow	30	50	Clay, red, with gravel and boulders; water-bearing	18	216
Clay, hard, yellow	15	65	Santa Barbara formation:		
Clay, blue	4	69	Clay, yellow, sandy	59	275
Clay, red	31	100	Sand, white; some gravel; water-bearing	14	289
Shale, blue	10	110	Clay, sandy, blue	16	305
Clay, black	9	119			

4/28-16R1. Pacific Lighting Corporation. At edge of alluvial plain. Altitude 30 feet

[Casing perforated from 37 to 47, 67 to 97, and 107 to 137 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil	4	4	"Rocks," hard; some shells	5	159
Sand	6	10	Sand and gravel	18	177
Clay, blue	14	24	Clay, sandy	8	185
Sand, clay, and gravel	16	40	Clay, blue, sticky	8	193
Clay, black	14	54	Clay, sandy, blue	7	200
Santa Barbara formation:			Clay, blue, sticky	50	250
Sand, free	41	95	Unnamed Pliocene (?) formation:		
Clay, sandy, blue; some gravel	59	154	Clay, blue, tough	360	610

TABLE 17—*Materials penetrated by water wells in the Goleta basin*—Continued

4/28-18F1. Navy Department, Marine Corps Air Station. On alluvial plain. Altitude 6 feet

[Casing perforated from 395 to 430 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Mud	50	50	Clay, sandy, blue	282	367
Sand and gravel	5	55	Sand, blue	9	376
Santa Barbara formation:			Sand, blue, with "sheets of black rock"	59	435
Sand, fine, yellow	30	85	Clay, blue, and "beach rock"	5	440

4/28-18P1. C. A. Storke Estate. On alluvial plain. Altitude 8 feet

[Casing perforated from 120 to 160 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
"Adobe"	22	22	Sandstone	2	96
Sand	2	24	Sand	22	118
Clay	6	30	Clay	2	120
Sand	2	32	Sand, blue	10	130
Clay	6	38	Clay, blue	10	140
Santa Barbara formation:			Sand, gray	8	148
Sea shells	2	40	Clay	2	150
Clay, blue	40	80	Sand, blue	7	157
Sand	14	94	Clay, blue	143	300

4/29-13D1. Mrs. Pomatto and Sons. On terrace. Altitude 39 feet

[Casing perforated from 67 to 218 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Terrace deposits:			Santa Barbara formation—Con.		
Soil	10	10	Clay and sand, gray-blue	2	165
Clay, yellow and brown	10	20	Sand, blue-gray	2	167
Boulders	9	29	Clay, blue	2	169
Santa Barbara formation:			Sand, blue-gray	2	171
Sand, yellow	3	32	Clay, sandy, gray-blue	15	186
Sand, not water-bearing	50	82	Sand, blue	2	188
Sand and gravel	3	85	Clay, gray-blue	18	206
Sand, gray, hard	14	99	Sand, blue	1	207
Sand, gray, alternating soft and hard	64	163	Clay, sandy, gray-blue	42	249

4/29-13K2. Bishop Ranch Company. On alluvial plain. Altitude 24 feet

[Casing perforated from 108 to 111, 129 to 132, 150 to 153, 171 to 174, 192 to 195, 204 to 225, 232 to 238, 253 to 259, and 267 to 330 feet]

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Younger alluvium:			Santa Barbara formation—Con.		
Soil, sandy	15	15	Clay, sandy	30	246
Clay, sandy, yellow	37	52	Sand, water-bearing	4	268
Clay, sandy, blue	5	57	Sandstone, very hard	1	269
Santa Barbara (?) formation:			Clay and sandstone	3	272
Clay, blue; some shells	11	68	Clay, sandy	5	277
Sand, fine, blue	4	72	Sand, water-bearing	2	279
Clay, sandy, blue; some shells	18	90	Sand	11	290
Clay, blue; some sand	27	117	Sand, hard	10	300
Santa Barbara formation:			Sand	5	305
Clay, shaley, blue; some fine sand	58	175	Sand, hard	25	330
Clay, blue	10	185	"Shell and rock" very hard	1	331
Clay, sandy, blue	21	206	Sand	3	334
Sand, fine	4	210	"Hard rock and shell"	1	335
Sand, very fine	18	228	Clay, sandy	17	252
Shale, very hard (possibly calcareous concretion)	1	229	Clay	4	356
Shale	4	233	"Shell and rock"	1	357
"Shell, shale, and rock" very hard (possibly calcareous concretion)	1	234	Clay	21	378

REFERENCES CITED

ARNOLD, RALPH, 1907, Geology and oil resources of the Summerland district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 321, 93 pp.

BAILEY, T. L., 1943, Late Pleistocene Coast Range orogenesis in southern California: Geol. Soc. America Bull. v. 54, no. 10, pp. 1549–1567.

BLANEY, H. F., 1930, Rainfall penetration and consumptive use of water in Santa Ana River valley and coastal plain: California Dept. Public Works, Water Resources Div., Bull. 33, pt. 1, pp. 19–24.

——— 1933, Rainfall penetration, *in* Ventura County investigations: California Dept. Public Works, Water Resources Div., Bull. 46, pp. 82–91.

BROWN, J. S., 1925, A study of coastal ground water, with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper 537, 101 pp.

CALIFORNIA DIVISION OF MINES, 1943, Geologic formations and economic development of the oil and gas fields of California, Bull. 118, pt. 3, pp. 370–425.

CONKLING, HAROLD, 1945, Utilization of ground-water storage in stream development: Am. Soc. Civil Engineers Proc., v. 71, no. 1, pp. 33–62.

GALE, H. S., and others, 1932, Southern California: Internat. Geol. Cong., Washington, 16th sess., Guidebook 15, Excursion C–1, 68 pp.

GRANT, U. S., IV, and GALE, H. R., 1931, Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions: San Diego Soc. Nat. Hist. Mem., v. 1, 1036 pp.

GRANT, U. S., IV, and HERTLEIN, L. G., 1941, Pliocene correlation chart, *in* Geologic formation and economic development of the oil and gas fields of California: California Div. Mines Bull. 118, pt. 2, pp. 201–202.

HILL, MASON L., 1932, Mechanics of faulting near Santa Barbara, Calif.: Jour. Geology, v. 40, pp. 535–556.

JENKINS, O. P., 1938, Geologic map of California: California Dept. Nat. Resources, Div. Mines.

KERR, P. F., and SCHENCK, H. G., 1928, Significance of the Matilija overturn: Geol. Soc. America Bull., v. 39, no. 4, pp. 1087–1102.

KEW, W. S. W., 1932, Los Angeles to Santa Barbara, *in* Gale, H S. and others, Southern California: Internat. Geol. Cong., Washington, 16th sess., Guidebook 15, pp. 48–68.

LA ROCQUE, G. A., JR., UPSON, J. E., and WORTS, G. F., JR., 1950, Wells and water levels in principal ground-water basins in Santa Barbara County, Calif.: U. S. Geol. Survey Water-Supply Paper 1068, 459 pp.

MEINZER, O. E., WENZEL, L. K., and others, 1943, Water levels and artesian pressure in observation wells in the United States in 1941, part 6, Southwestern States and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 941, pp. 141–168.

——— 1944, Water levels and artesian pressures in observation wells in the United States in 1942, part 6, Southwestern States and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 949, pp. 176–238.

——— 1945, Water levels and artesian pressure in observation wells in the United States in 1943, part 6, Southwestern States and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 991, pp. 153–177.

PIPER, A. M., GALE, H. S., THOMAS, H. E., and ROBINSON, T. W., 1939, Geology and ground-water hydrology of the Mokelumne area, California: U. S. Geol. Water-Supply Paper 780, 230 pp.

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PIPER, A. M., GARRETT, A. A. and others, (in preparation), Chemical character of native and contaminated ground waters in the Long Beach-Santa Ana area California; U. S. Geol. Survey Water-Supply Paper 1136.

REED, R. D., 1933, Geology of California, 355 pp., Tulsa, Am. Assoc. Petroleum Geologists.

SAYRE, A. N., and others, 1947, Water levels and artesian pressure in observation wells in the United States in 1944, part 6, Southwestern States and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 1021, pp. 129–164.

——— 1949, Water levels and artesian pressure in observation wells in the United States in 1945, part 6, Southwestern States and Territory of Hawaii: U. S. Geol. Survey Water-Supply Paper 1028, pp. 146–154.

SCOFIELD, C. S., and WILCOX, L. V., 1931, Boron in irrigation waters: U. S. Dept. Agr. Tech. Bull. 264.

SHEPARD, F. P., and EMERY, K. E., 1941, Submarine topography off the California coast: Geol. Soc. America Special Papers, no. 31, 166 pp.

SMITH, J. P., 1912, Geologic range of Miocene invertebrate fossils of California: California Acad. Sci. Proc., 4th ser., v. 3, pp. 161–182.

SONDEREGGER, A. L., 1930, Water supply from rainfall on valley floors: Am. Soc. Civil Engineers Trans., v. 94, pp. 1242–1268.

THEIS, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophys. Union Trans., no. 16, pp. 519–524.

TROXELL, H. C., and others, 1942, Floods of March 1938 in southern California: U. S. Geol. Survey Water-Supply Paper 844, 399 pp.

UPSON, J. E., and THOMASSON, H. G., JR., 1951, Geology and water resources of the Santa Ynez River basin, Santa Barbara County, Calif.: U. S. Geol. Survey Water-Supply Paper 1107, 189 pp.

WENZEL, L. K., 1942, Methods for determining permeability of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 887, 192 pp.

WILLIS, BAILEY, 1925, Fault map of Santa Barbara district, California, *in* A study of the Santa Barbara earthquake of June 29, 1925; Seismol. Soc. America Bull., v. 15, pp. 255–278.

WILMARTH, M. G., 1938, Lexicon of geologic names of the United States: U. S. Geol. Survey Bull. 896, pts. 1 and 2, 2396 pp.

WOODRING, W. P., 1932, Plate 2 *in* Internat. Geol. Cong., Washington, 16th sess., Guidebook 15.

WOODRING, W. P., STEWART, RALPH, and RICHARDS, R. W., 1940, Geology of the Kettleman Hills Oil field, California: U. S. Geol. Survey Prof. Paper 195, 170 pp.

WOODRING, W. P., BRAMLETTE, M. N., and LOHMAN, K. E., 1943, Stratigraphy and paleontology of Santa Maria district, California: Am. Assoc. Petroleum Geologists Bull., v. 27, no. 10, pp. 1335–1360.

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