Ground-Water Reconnaissance of the Santa Barbara-Montecito Area, Santa Barbara County, California

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1859-A

Prepared in cooperation with the Santa Barbara County Water Agency

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By K. S. MUIR

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

GROUND-WATER RECONNAISSANCE OF THE SANTA BARBARA-MONTECITO AREA, SANTA BARBARA COUNTY, CALIFORNIA

By K. S. Muir

ABSTRACT

This is the third interpretive report prepared by the U.S. Geological Survey in cooperation with the Santa Barbara County Water Agency on the ground-water resources of areas along the south coast of the county. The two previous reports—one by J. E. Upson in 1951 and another by R. E. Evenson, H. D. Wilson, Jr., and K. S. Muir—were on ground-water conditions in the Goleta and Carpinteria basins. The Santa Barbara-Montecito area is between those two basins—the Goleta basin on the west and the Carpinteria basin on the east. This area of about 30 square miles extends from the Pacific Ocean on the south to the Santa Ynez Mountains on the north. The city of Santa Barbara and the towns of Montecito and Summerland are within the area.

The Santa Barbara-Montecito area is a low-lying flat section of the coastal plain. Farther inland are highlands of consolidated rock and terrace deposits. The highlands are areas of uplift, folding, and faulting, and the lowlands are structural depressions. Most of the urban development in the area has been in the lowlands. The unconsolidated deposits that have partly filled the structural depressions make up the ground-water reservoir of the Santa Barbara-Montecito area. They include the Santa Barbara Formation of Pliocene and Pleistocene age, the Casitas Formation of Pleistocene age, and the alluvium of late Pleistocene and Recent age. These deposits underlie an area of about 20 square miles and have a maximum thickness of about 2,000 feet.

The consolidated rocks of Tertiary age that underlie and form the boundaries of the ground-water reservoir contain ground water in fractures and in sandstone beds. However, the consolidated rocks are not an important source of ground water.

In 1959, a year the ground-water basins were full and ground water in storage was at a maximum, storage in the Santa Barbara area was 184,000 acre-feet, and storage in the Montecito area was 97,000 acre-feet. By 1964, in response to below-average recharge and continued withdrawal by pumping, the quantity of ground water in storage in the Santa Barbara area had decreased to 178,000 acre-feet. Because of a reduction in pumpage, there was little change in storage in the Montecito area between 1959 and 1964.

Deep percolation of rain, seepage from streams, and subsurface inflow from consolidated rocks are the main sources of recharge to the ground-water reservoir in the Santa Barbara-Montecito area. The most important discharge is by pumping.

The long-term perennial yield of the ground-water reservoir of the Santa Barbara area is estimated to be 1,700–2,000 acre-feet. Present data are insufficient to accurately determine the perennial yield of the reservoir in the Montecito area, but it is estimated to be about 2,500 acre-feet.

Most ground water in the Santa Barbara-Montecito area is suitable for general use. However, ground water in some of the consolidated rocks and in the shallow unconsolidated deposits adjacent to the coast is too saline for most uses. Seawater intrusion has occurred in the Santa Barbara area and the western part of the Montecito area. The intrusion, however, is limited to the upper part of the nearshore shallow alluvial deposits and contaminates only wells which were constructed without a near-surface seal.

INTRODUCTION

PURPOSE AND SCOPE

The Santa Barbara County Water Agency is making plans to insure sufficient water for the future needs of the county. A knowledge of the hydrologic conditions in the county, therefore, is necessary. The purpose of this report is to provide hydrologic information for the Santa Barbara-Montecito area (fig. 1).

The scope of this investigation includes a study of the geology of the area, with particular reference to the water-bearing deposits, a determination of the areal extent and thickness of the ground-water reservoir, the quantity and chemical quality of water in storage, and, as data permit, inflow to and outflow from the aquifers in the area.

The investigation was made by the U.S. Geological Survey, in cooperation with the Santa Barbara County Water Agency, under the general supervision of Walter Hofmann, district chief in charge of water-resources investigations in California, and under the immediate supervision of L. C. Dutcher, chief of the Garden Grove subdistrict.

LOCATION AND GENERAL FEATURES

The Santa Barbara-Montecito area is on the south coast of Santa Barbara County (fig. 1, pl. 1) between two ground-water basins—the Goleta basin on the west and the Carpinteria basin on the east. It is predominantly an urbanized area of about 30 square miles, extending from the Pacific Ocean on the south to the foothills of the Santa Ynez Mountains on the north. The city of Santa Barbara and the towns of Montecito and Summerland are the major population centers. Lemon growing near Montecito and Summerland is the primary agricultural activity.

The water supply for the Santa Barbara-Montecito area is obtained from two sources: Ground water pumped from local wells and surface water impounded behind dams on the Santa Ynez River. The impounded water is delivered to users along the south coast by three tunnels cut through the Santa Ynez Mountains.

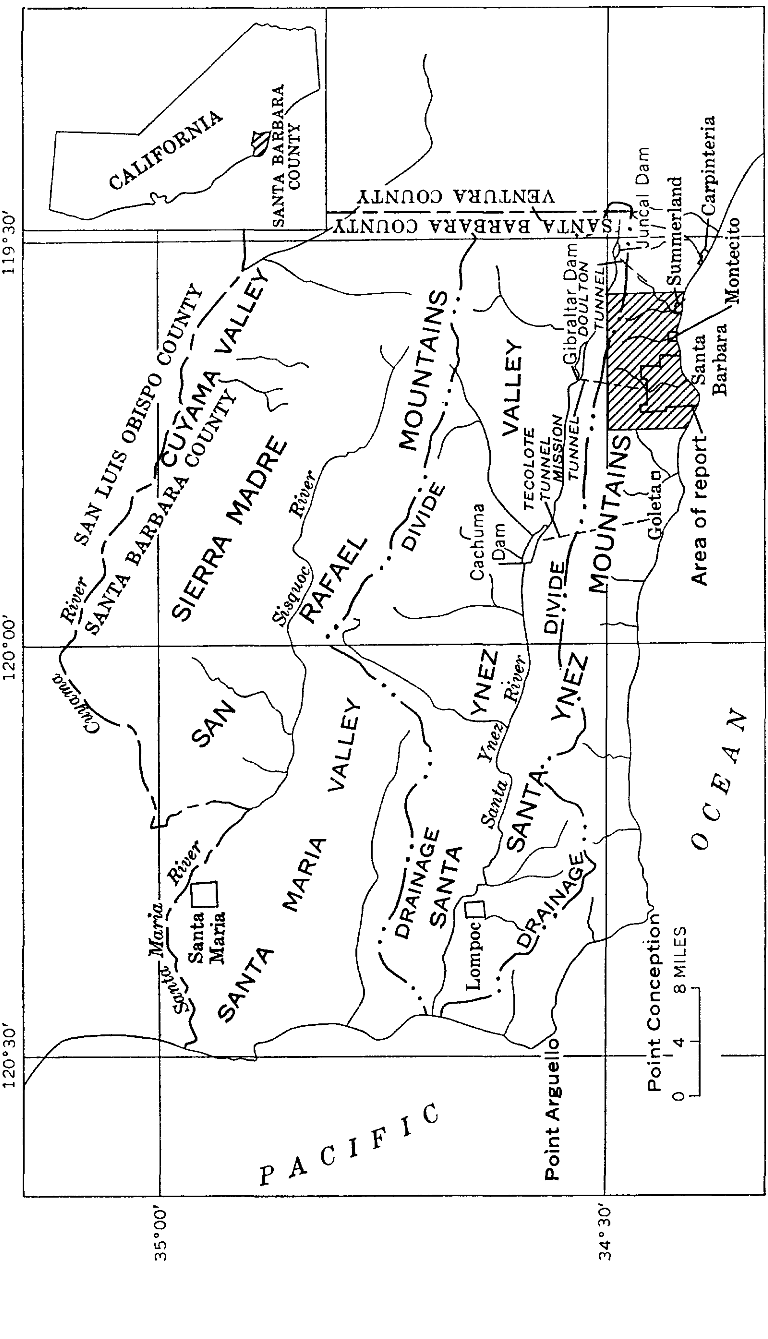

FIGURE 1.—Index map of Santa Barbara County showing the Santa Barbara-Montecito area.

PREVIOUS INVESTIGATIONS AND ACKNOWLEDGMENTS

This is the third interpretive report describing the ground-water resources of areas along the south coast of Santa Barbara County. The two previous reports described the Goleta and Carpinteria basins (Upson, 1951; Evenson and others, 1962).

The cooperation and assistance of the city of Santa Barbara Water Department, the Montecito County Water District, and the Southern California Edison Co. in supplying data on water levels, pumpage, and chemical quality of ground water are gratefully acknowledged.

WELL-NUMBERING SYSTEM

Wells and springs are numbered according to the rectangular system of subdivision of public land. Where the land has not actually been surveyed, appropriate subdivisions are projected. A well number, such as 4N/27W–15R1, has two parts. The part that precedes the hyphen indicates the township and range (T. 4 N., R. 27 W.). The numbers following the hyphen indicate the section (sec. 15); 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 4N/27W–15R1 is the first well listed in the SE¼ SE¼ sec. 15, T. 4 N., R. 27 W., San Bernardino meridian and base line.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

GEOGRAPHIC FEATURES

CLIMATE

The Santa Barbara-Montecito area has distinct wet and dry seasons. About 95 percent of the rainfall occurs between November and May. The average rainfall at Santa Barbara, based on 97 years of record, is 17.79 inches. The rainfall pattern is not uniform; the bordering foothills receive more rain than the low-lying coastal area. Troxell and others (1942, p. 48–49) estimated that along the coast of southern California rainfall increases 3 inches for each 1,000-foot increase in altitude. Nearly all ground-water recharge and surface-water flow in the Santa Barbara-Montecito area are derived from rain that falls directly on the area. However, a small part of the imported water from the Santa Ynez River may recharge the ground water.

Seasonal temperatures are moderate. Winter temperatures average 55°F; summer temperatures, 65°F. There is little or no frost during the winter months.

Fog and high humidity are common in the morning during the summer months. Winds, which usually blow from the west or southwest, normally dissipate the fog by midday.

LANDFORMS AND DRAINAGE

LOWLANDS

The Santa Barbara-Montecito area (pl. 1) consists of a low-lying, nearly flat alluviated plain and the adjacent highlands. The lowlands are underlain by unconsolidated deposits that range in thickness from several hundred to several thousand feet; the highlands are underlain by consolidated rock and terrace deposits. The main part of the city of Santa Barbara is in the western part of the low-lying plain, and the town of Montecito is in the eastern part.

Seven main creeks carry runoff from the area. These creeks, where they flow across consolidated rocks in their headwater reaches, have gradients of about 800 feet per mile. The gradients decrease where the stream courses reach areas underlain by alluvium, but even there the gradients are steep—about 200 feet per mile. The stream gradients conform closely to the land-surface gradients across the low-lying areas. Several of the creeks are perennial in their upper reaches, but all are intermittent where they cross the alluvium.

BORDERING MOUNTAINS

The Santa Ynez Mountains, which adjoin the area on the north, are made up of a series of complexly folded and faulted consolidated rocks of Tertiary age. They rise steeply from the edge of the coastal plain, and several miles inland have altitudes of nearly 4,000 feet above sea level.

Erosion has formed deep gulleys and sharp ridges and has left little or no soil to mantle the mountains. Brush and grass are the principal ground cover.

GROUND-WATER RESOURCES

THE GROUND-WATER RESERVOIR

In the Santa Barbara-Montecito area there is close similarity between geologic structure and topography: Mission Ridge, the Summerland area, and La Mesa have been uplifted along faults (pl. 1); the central part of the city of Santa Barbara and the Montecito area are in structural depressions. The unconsolidated deposits that partly fill these structural depressions form the ground-water reservoir of the Santa Barbara-Montecito area. The deposits include the Santa Barbara Formation, the Casitas Formation, and alluvium ranging in age from Pliocene to Recent (pls. 1 and 2). These deposits underlie an area of about 20 square miles and have a maximum thickness of about 2,000 feet along the north sides of the Lavigia and Mesa faults.

The consolidated rocks that underlie and form the boundaries of the ground-water reservoir contain ground water in fractures and in sandstone beds. However, these formations yield ground water to wells slowly and are important mainly as a source of recharge by subsurface flow to the unconsolidated deposits.

The crustal movements that formed the structural depressions in the Santa Barbara and Montecito areas began in late Pliocene time. Folding and faulting at that time created basins in which detrital material eroded from adjacent highlands subsequently was deposited. This detrital material makes up the Santa Barbara and Casitas Formations, which are the major aquifers of the ground-water reservoir (pl. 2). The Santa Barbara Formation was deposited in a marine environment; the Casitas Formation, in a nonmarine environment.

In middle or late Pleistocene time, renewed crustal movements once again caused uplifting, faulting, and folding of the consolidated rocks. At the same time, vertical movements along the faults in some areas displaced the Santa Barbara and Casitas Formations several thousand feet (pl. 2). The general boundaries of the ground-water basins of the area were established by these movements.

Since middle Pleistocene time several advances and retreats of the ocean, caused both by worldwide changes of sea level and by crustal movements, have occurred, as have renewed movements along the preexisting faults. The deposition of alluvium and the formation of terraces accompanied these events.

GEOLOGY

In this report, the geologic formations are divided into two groups: The consolidated rocks of Tertiary age and the unconsolidated deposits of Quaternary age. This division is based on water-bearing properties. The consolidated rocks, represented on the geologic map and geologic sections (pls. 1 and 2) as one unit, are important mainly because they delineate the boundaries of the unconsolidated deposits.

Plate 1 shows the outcrop pattern of the formations; plate 2 shows their stratigraphic and structural relations; and table 1 summarizes their sequence, general character, and water-bearing properties.

CONSOLIDATED ROCKS

Consolidated rocks of Tertiary age underlie the Santa Barbara Formation (pl. 2). They have been uplifted to form the prominent

TABLE 1.—*Stratigraphic units of the Santa Barbara-Montecito area*

Period	Epoch	Formation	General character	Water-bearing properties
QUATERNARY	Recent	Alluvium. Includes younger alluvium, older alluvium, and terrace deposits, undifferentiated.	Unconsolidated gravel, sand, silt, and clay. Underlies the alluvial plains and extends into adjoining stream canyons. Marine terraces are found along the seaward side of La Mesa and at Summerland.	Alluvium is permeable and yields moderate quantities of water to wells. Terrace deposits are above zone of saturation, and contain little water.
		Unconformity		
	Pleistocene	Casitas Formation	Unconsolidated yellow-brown to red gravel, sand, silt, and clay. Also contains some cobbles and boulders. It is continental in origin. The formation probably underlies part of the Montecito area. It crops out at Summerland and near the Santa Barbara cemetery.	Yields moderate quantities of water to wells.
TERTIARY AND QUATERNARY	Pliocene and Pleistocene	Santa Barbara Formation	Unconsolidated gravel, brown sand, silt, and clay, with discontinuous conglomerate beds at the base. Also includes a few calcareous clay beds. The formation is marine in origin and fossiliferous. It underlies most of the area.	Yields moderate quantities of water to wells. It is the major aquifer of the area.
		Unconformity		

TABLE 1.—*Stratigraphic units of the Santa Barbara-Montecito area*—Continued

Period	Epoch	Formation	General character	Water-bearing properties
TERTIARY	Eocene to Miocene	Sedimentary rocks. Include Monterey Shale, Rincon Shale, Vaqueros Sandstone, Sespe Formation, and Tejon Formation, undifferentiated.	Consolidated sandstone, siltstone, mudstone, and shale. The formations are both continental and marine in origin. They underlie the entire area. Pyroclastic material, conglomerate, and limestone occur interspersed throughout the deposits.	Yield water from fractures and from sandstone units. The water-bearing properties of these formations are largely unknown.

highlands of La Mesa, of Mission Ridge, and of the Summerland area. These rocks form continuous outcrops in the foothills of the Santa Ynez Mountains (pl. 1). The consolidated rocks also crop out on the ocean floor about a quarter of a mile offshore east of Stearns Wharf. The outcrop extends to an area east of Fernald Point (pl. 1). Uplift has probably occurred along an east-west-trending fault in this area.

The consolidated rocks, which range in age from Eocene to Miocene, are sedimentary rocks predominantly marine in origin. From oldest to youngest, they are the Tejon Formation, the Sespe Formation, the Vaqueros Sandstone, the Rincon Shale, and the Monterey Shale. The base of the Tejon Formation is not exposed in the mapped area, so its relation to the underlying rocks is unknown. An unconformity exists between the consolidated rocks of Tertiary age and the overlying unconsolidated younger deposits.

The total thickness of the consolidated rocks is about 15,200 feet—two-thirds consists of shale, mudstone, and siltstone, and one-third is composed predominantly of sandstone. Pyroclastic material, conglomerate, and limestone are interspersed through the deposits. Fossils are common in the marine beds.

The consolidated rocks in the Santa Barbara-Montecito area are water bearing. Ground water is contained in the fractures and in the sandstone units. However, the rocks are not considered a good source of ground water because the occurrence and location of the fractures in the more consolidated parts of the rocks are difficult to determine, and the sandstone units have low specific yields and release ground water to wells slowly.

Direct evidence of ground water in the consolidated rocks is found in the seepage from unlined parts of tunnels which penetrate thick sections of these rocks in the Santa Ynez Mountains (fig. 1). Ground-water seepage into Mission Tunnel, through which surface water stored behind Gibraltar Dam on the Santa Ynez River is brought to the city of Santa Barbara, is about 1,000,000 gpd (gallons per day). This tunnel has a total length of 19,560 feet, of which 9,800 feet is unlined. Doulton Tunnel, through which surface water is brought from Juncal Dam to the Montecito area, has a ground-water inflow of 300,000 gpd through an unlined 7,000-foot section of the tunnel. Cold Springs Tunnel (pl. 1) was excavated by the city of Santa Barbara specifically to develop a source of water from the consolidated rocks. This tunnel, 3,300 feet of which is unlined, penetrates 5,000 feet of sandstone and shale, and the flow averages about 120,000 gpd.

Data furnished by the city of Santa Barbara indicate that ground-water inflow to the tunnels responds to the long-term variation of the rainfall—more inflow during wet periods and less during dry periods.

A few wells in the area obtain water from the consolidated rocks and have small yields and large drawdowns. Well 4N/27W–20E1 penetrated 380 feet of the Vaqueros Sandstone and was perforated through an interval of 200 feet; it yielded 175 gpm (gallons per minute) with a drawdown of 350 feet. The pumping level in this well stabilized at 70 feet below the land surface when a pumping rate of 75 gpm was maintained.

UNCONSOLIDATED DEPOSITS

SANTA BARBARA FORMATION

The Santa Barbara Formation underlies most of the Santa Barbara-Montecito area. This formation, of Pliocene and Pleistocene age (Woodring and others, 1940, p. 111), is composed of massive unconsolidated brown marine sand, silt, and clay (pl. 2). The sand consists of medium-grained well-rounded quartz with some interbedded conglomerate and calcareous clay. There is an extensive outcrop of calcareous clay in sec. 20, T. 4 N., R. 27 W.

The Santa Barbara Formation lies unconformably on the consolidated rocks of Tertiary age and in most of the area underlies the alluvium. In the Montecito area, however, the Santa Barbara Formation grades upward into the Casitas Formation of Pleistocene age (State of California, 1954).

The Santa Barbara Formation has a maximum thickness of about 2,000 feet on the north side (downthrown side) of the Lavigia fault in sec. 20, T. 4 N., R. 27 W., and on the north side (downthrown side) of the Mesa fault in sec. 22, T. 4 N., R. 27 W. It thins toward the north. Beneath the central part of the city of Santa Barbara (pl. 2) the formation is about 400–500 feet thick.

CASITAS FORMATION

The Casitas Formation, of Pleistocene age, underlies part of the Montecito area. It consists mainly of unconsolidated continental deposits of generally yellowish-brown to red gravel, sand, silt, and clay, but cobbles and boulders also occur.

The Casitas Formation has a gradational contact with the underlying Santa Barbara Formation and is unconformably overlain by the alluvium. It is not present beneath the city of Santa Barbara and crops out only at Summerland and near the Santa Barbara cemetery (pl. 1). It has a maximum thickness of about 500 feet.

ALLUVIUM

The alluvium, as mapped, includes the terrace deposits, older alluvium, and younger alluvium of Upson (1951, p. 24–25). It rests unconformably on all older deposits and consists of gravel, sand, silt, and clay, of late Pleistocene to Recent age. Cobbles and boulders occur throughout the deposits (pl. 2) which are extensive over most of the area. The maximum thickness is about 500 feet.

WATER-BEARING PROPERTIES

The Santa Barbara Formation, the Casitas Formation, and the alluvium have similar water-bearing properties. All three have vertical variations in lithology in which coarse-grained beds that yield water freely to wells alternate with fine-grained beds that do not. Good yields can be obtained only from those wells that penetrate many of the coarse-grained beds. Consequently, most wells are perforated in all the saturated coarse-grained deposits that are penetrated, down to and including those of the Santa Barbara Formation.

Ground water in the Santa Barbara Formation, Casitas Formation, and alluvium is locally under artesian pressure. Several wells flowed in 1963; well 4N/27W–15Q8 flowed at a rate of about 2 gpm, and well 4N/26W–8P2 flowed at a rate of 15–20 gpm. Pumped yields of 500–1,000 gpm and specific capacities of 3–6 gpm per foot of drawdown are common.

The electric logs on plate 2 graphically illustrate variations in the water-bearing characteristics of the deposits in the Santa Barbara-Montecito area: a high resistivity on electric logs of these deposits indicates coarse-grained water-bearing beds, and a low resistivity indicates fine-grained beds. Plate 2 shows that beneath the city of Santa Barbara, within the alluvium, there are two water-bearing zones distinct enough to permit delineation, each about 50 feet thick, with the upper zone at a depth of about 250 feet below sea level and the lower zone at about 350 feet below sea level. Plate 2 shows (1) that in addition to the two distinct water-bearing zones shown on plate 2, there are other water-bearing beds with interspersed fine-grained deposits; (2) that the lithology of the alluvium and Santa Barbara Formation are similar; (3) that the Santa Barbara Formation seems to have a coarse-grained basal zone; and (4) that in general the water-bearing deposits underlying the Montecito area (pl. 2) are coarser grained than those underlying the city of Santa Barbara. Data are insufficient to permit a delineation of any continuous water-bearing zones in the Montecito area.

GROUND-WATER STORAGE CAPACITY

Ground water is stored in the interstices of the unconsolidated deposits of the alluvium, Casitas Formation, and Santa Barbara Formation. The interstices are filled with water below the zone of saturation; the quantity of water contained depends upon the porosity of the deposits. However, the quantity of water in the pore spaces and the quantity that will be released to wells are not everywhere equal. Only the water that will drain from the pore spaces by gravity is available for use. The specific yield of a rock or soil with respect to water has been defined by Meinzer (1923, p. 28) as the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. The water that remains in the pore spaces after gravity drainage is held there mainly by surface tension. The total quantity of ground water in storage that is available for use by man (storage capacity) is equal to the volume of saturated material times its specific yield.

To compute the storage capacity of the water-bearing deposits, the area was divided into five storage units as shown in figure 2. The boundaries of these storage units are in part determined by faults that impede the movement of ground water. Higher water levels usually occur on the upgradient sides of the faults than on the downgradient sides.

The western boundary of storage unit 2 and the boundary between storage units 1 and 4 are formed by ground-water divides. The city of Santa Barbara overlies most of storage units 1, 2, and 3, and the Montecito area overlies storage units 4 and 5. The surface areas of the five storage units are listed in table 2. The arrows in figure 2 show the direction of ground-water movement southward toward the ocean.

After dividing the area into storage units, the saturated material in each unit was assigned a value for specific yield based on the classification by Evenson and others (1962) for the adjacent Goleta and Carpinteria basins. This classification is summarized in the following table.

Types of material according to drillers' terms	Assigned classification	Assigned specific yield (percent)
Gravel, gravel and sand, boulders	Gravel	25
Sand, fine sand	Sand	20
Silt, packed sand, hard sand, sandy clay; soil.	Sand and clay	7
Clay and gravel, hard sand and gravel, cemented gravel.	Clay and gravel	5
Clay, adobe, shale	Clay	1

Generally, in ground-water basins adjacent to the ocean, storage computations are limited to zones above sea level because of possible sea-water intrusion if ground-water levels decline to or below sea level. However, in the Santa Barbara-Montecito area, usable storage in the deposits below sea level can be computed because an east-west-trending fault just offshore (pls. 1, 2; figs. 2, 3) acts as an effective barrier to the movement of sea water into the lower part of the fresh-water aquifers under present hydrologic conditions. The estimated storage capacities of the units given in table 2 and shown in section in figure 3 are conservative because only a minimum thickness of saturated deposits is used. The saturated thickness used is the interval between the highest recorded static ground-water level and the lowest recorded pumping level—the zone of maximum recorded water-level fluctuation. In figure 3 the top of each unit represents the highest recorded static water levels within the unit, and the bottom of each unit represents the lowest recorded pumping levels within the unit. Ground-water storage estimates were limited to this one zone because under present pumping demands no draft will occur in any lower zones in the foreseeable future.

In calculating the volume of storage capacity available, the saturated thickness of each unit was divided into a series of depth zones, and an average specific yield for each zone was computed. The storage units were divided into these depth zones to facilitate future storage-change calculations. The ground-water storage capacity in each zone was computed by multiplying the average specific yield of the zone by its volume. Table 2 lists the ground-water storage capacity in each depth layer within the different storage units, the storage capacity for each unit, and the total capacity of all five

TABLE 2.—*Estimated ground-water storage capacity in the Santa Barbara-Montecito area*

Storage unit	Depth zone (in feet above or below sea level)	Surface area of depth zone (acres)	Volume of depth zone (acre-ft)	Weighted average specific yield of depth zone (percent)	Number of well logs	Ground water storage capacity (acre-ft)	
						By depth zone	Total
Santa Barbara area							
1	+50 to sea level	[1] 2,040	102,000	17.5	7	17,800	
	Sea level to −50	4,200	210,000	9.9	27	21,000	108,800
	−50 to −100	4,200	210,000	10.9	25	23,000	
	−100 to −200	4,200	420,000	11.2	25	47,000	
2	+100 to +50	1,700	85,000	7.5	23	6,400	
	+50 to sea level	1,700	85,000	10.4	19	8,800	
	Sea level to −50	1,700	85,000	11.4	10	9,700	48,900
	−50 to −100	1,700	85,000	8.2	8	7,000	
	−100 to −200	1,700	170,000	10.0	7	17,000	
3	+50 to sea level	[1] 1,270	63,500	10.8	14	6,900	
	Sea level to −50	2,000	100,000	11.4	13	11,400	26,500
	−50 to −100	2,000	100,000	8.2	10	8,200	
Subtotal							184,000
Montecito area							
4	Sea level to −50	2,000	100,000	10.1	9	10,100	
	−50 to −100	2,000	100,000	8.7	8	8,700	29,000
	−100 to −150	2,000	100,000	10.2	7	10,200	
5	+250 to sea level	2,300	575,000	11.8	6	67,800	67,800
Subtotal							97,000
Total							281,000

[1] Area between 0 to 100-ft land-surface contour not included in +50-foot to sea-level depth zone.

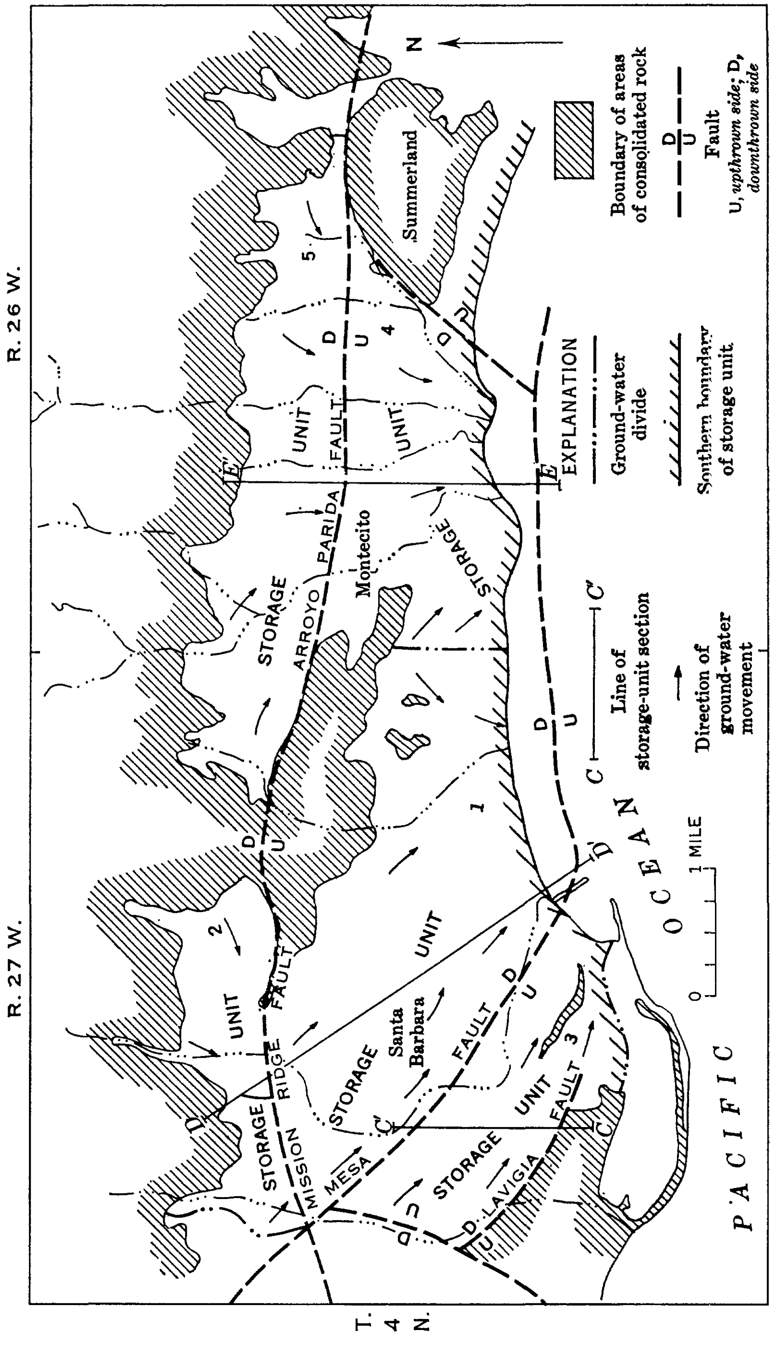

FIGURE 2.—Ground-water storage units, direction of ground-water movement, and major faults which control the movement and storage of ground water. Sections shown in figure 3.

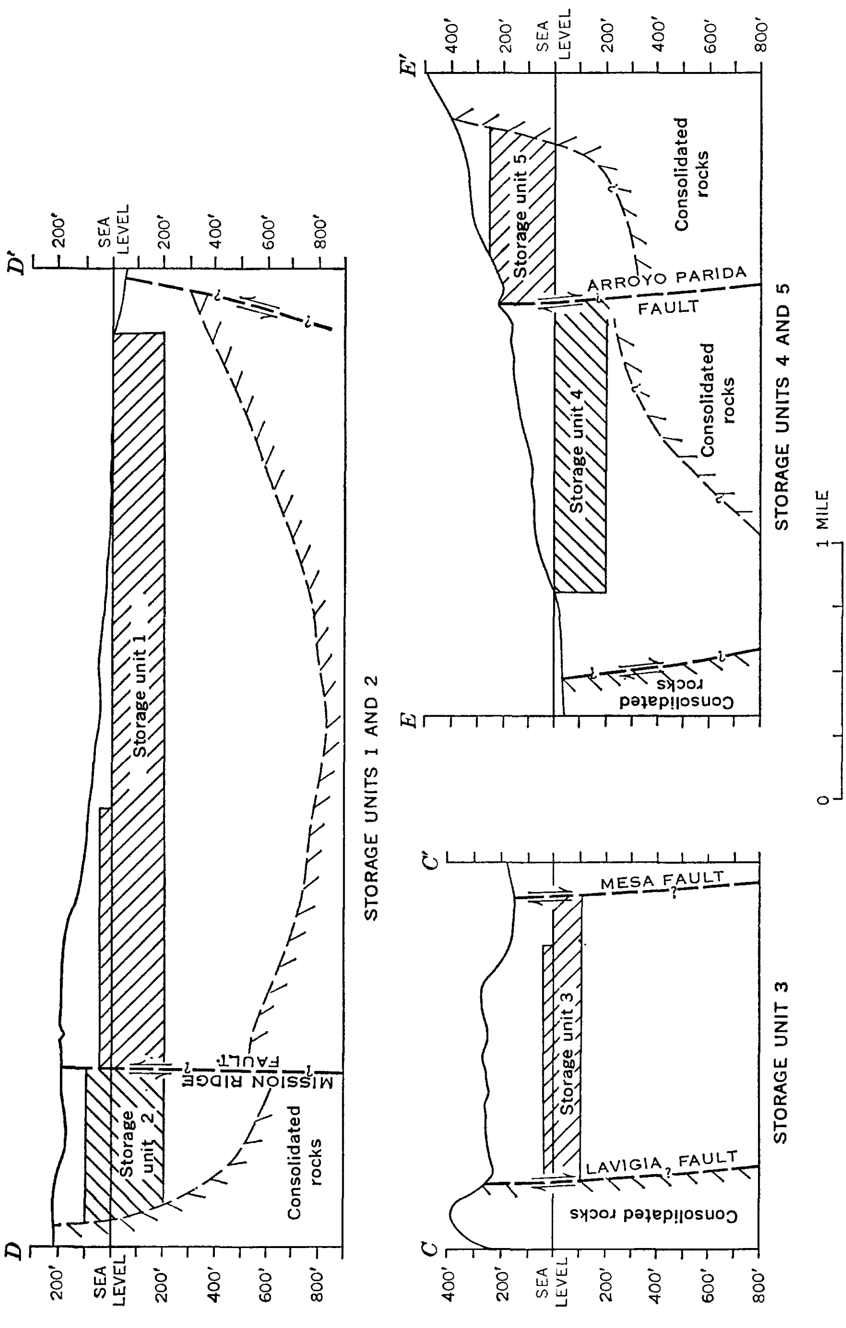

FIGURE 3.—Sections showing thickness of storage units. See figure 2 for lines of sections.

storage units, which also was the ground water in storage for 1959—a year for which ground-water storage was at a maximum throughout most of the area.

Ground water in storage units 1, 2, and 3 is available for use by wells in the area of the city of Santa Barbara (fig. 2). In 1959 the ground water in storage in this area was about 184,000 acre-feet. By 1964, in response to below-average recharge and continued withdrawal, a decline of water level indicated the quantity of ground water in storage had decreased to about 178,000 acre-feet, which is the lowest on record.

In the Montecito area wells pump ground water from storage units 4 and 5, and in 1959 ground water in storage was about 97,000 acre-feet. There was very little change in storage between 1959 and 1964.

GROUND-WATER INVENTORY

The hydrologic equation states that all water that enters an area during any period of time must, during the same period, either go into storage, be evaporated therefrom, be exported therefrom, or flow out either on the surface or underground. If, as in this report, the hydrologic equation is applied only to the inflow and outflow of a ground-water basin, it is called a ground-water inventory. A ground-water inventory is just what the term implies—it is the inventory of all items of inflow and all items of outflow for a ground-water basin. An analysis of the inventory makes it possible to estimate perennial yield and allows those responsible for the management of a ground-water basin to plan the future use of the water resources.

The first step in making a ground-water inventory is to select the time span for the inventory. The period selected should reflect average long-term climatic conditions. In the Santa Barbara-Montecito area the periods selected were (1) 1868 to 1964, (2) 1944 to 1964, and (3) 1949 to 1959. The first period represents long-term climatic conditions, the second spans a prolonged period of generally less than average rainfall (a time of minimum inflow), and the third covers a period when there was little or no change in the quantity of ground water in storage (inflow equaled outflow over the 11-year period) within the basin.

Pertinent items of the ground-water inventory are listed below.

Inflow

Infiltration of rain.
Seepage from streams.
Subsurface inflow from consolidated rocks.
Water imported from the Santa Ynez River.
Infiltration of irrigation water.

Outflow

Pumpage.
Subsurface discharge to ocean.
Evapotranspiration.

INFLOW

Infiltration of rain, seepage from streams, and subsurface inflow from consolidated rocks are the main items of inflow into the ground-water basin. Water imported from the Santa Ynez River by diversion through the Mission, Tecolote, and Doulton Tunnels supplies nearly all the municipal water for the Montecito area and the majority of the municipal water for the city of Santa Barbara. Little of this water enters into the ground-water inventory because it is a piped supply which, after use, is discharged to the ocean as sewage. About 700–750 acres, primarily in citrus, is irrigated with imported water. There is some inflow into the ground-water basin from infiltration of irrigation water, but the quantity is small—about 150 acre-feet per year (50 acre-feet in the Santa Barbara area and 100 in the Montecito area).

INFILTRATION OF RAIN

The major source of recharge to the ground-water reservoir in the area is infiltration of rain that falls directly on areas of unconsolidated deposits (pl. 1). Measurements and work by Blaney (1933) in neighboring Ventura County were used in this study to estimate the quantity of rain that becomes ground water. Climate, soils, geology, and vegetative cover in the two areas are similar. Blaney tabulated the quantities of rain that became ground water, depending upon type of vegetative cover and seasonal precipitation, for several locations in Ventura County for a period of 5 years. Upson (1951, p. 63, fig. 2), using Blaney's data, graphically related seasonal rainfall to depth of penetration on lands covered with several different types of vegetation. Infiltration of rain on the Santa Barbara-Montecito area was estimated from the curves shown on Upson's graph.

The area of infiltration of rain includes storage units 2, 4, and 5 (fig. 2). It includes also that part of storage unit 1 that lies above an altitude of 250 feet above sea level and that part of storage unit 3 that lies above an altitude of 100 feet. Below those altitudes, storm sewers, city streets, and buildings prevent significant infiltration of rain. In the Santa Barbara area (storage units 1, 2, and 3), the infiltration area includes about 3,400 acres, of which 1,300 acres is covered with grass and weeds and 2,100 acres with a citrus-type cover. In the Montecito area (storage units 4 and 5) there are 4,300 acres, all with a citrus-type cover. The areas classified as having a citrus-type cover are those that have a scattering of citrus trees, lawns, home gardens, avocado trees, and miscellaneous deciduous trees; only about 200 acres in the Santa Barbara area and about 550 acres in the Montecito area are planted in commercial citrus groves.

The rainfall recorded at Santa Barbara was used in estimating infiltration from rain. The rainfall that infiltrated in the Santa Barbara-Montecito area for the periods 1868–1964, 1944–64, and 1949–59 is given in table 3.

TABLE 3.—*Estimated recharge, in acre-feet, in the Santa Barbara-Montecito area by infiltration of rain for the water years (October 1–September 30) 1868–1964, 1944–64, and 1949–59*

Period	Average rainfall at Santa Barbara (inches)	Land in grass and weeds		Land with citrus-type cover				Total average yearly recharge
		Santa Barbara area (1,300 acres)		Santa Barbara area (2,100 acres)		Montecito area (4,300 acres)		
		Total recharge	Average yearly recharge	Total recharge	Average yearly recharge	Total recharge	Average yearly recharge	
1868–1964	17.79	17,680	180	87,200	900	178,750	1,840	2,900
1944–64	15.55	2,360	110	12,820	610	26,340	1,250	2,000
1949–59	16.96	1,810	160	8,680	790	17,780	1,620	2,600

The Santa Ynez foothills, an area of brush-covered consolidated rocks, including 8,600 acres near Santa Barbara and 7,500 acres near Montecito, is a secondary area of infiltration. The infiltration on these brushlands is estimated, on the basis of Blaney's (1933) work, to be 10 percent of the amount of rain greater than 18 inches.

The rainfall used in these calculations is that recorded at Santa Barbara, plus an estimated additional 3 inches per 1,000 feet in altitude (Troxell and others, 1942, p. 48 and 49, fig. 5). The average altitude of this brushland is about 1,700 feet above sea level.

The following table lists the estimated average yearly infiltration from rain on brushlands for the three selected periods of time:

Because some of the infiltration on brushland is stored in the fractures and sandstone beds of the consolidated rocks, the quantity recharging the ground-water reservoir was not included in the estimate of total inflow used elsewhere in this report.

Period	Average yearly infiltration, in acre-feet, of rain on brushlands		
	Santa Barbara area	Montecito area	Total
1868–1964	360	310	670
1944–64	260	230	490
1949–59	350	300	650

SEEPAGE FROM STREAMS

In the Santa Barbara-Montecito area seepage occurs along the lower reaches of the streams in the areas where they flow across unconsolidated deposits (pl. 1). Where streams flow across consolidated rocks, the steep stream gradients and the flash-flow characteristics of the streams prevent large seepage losses.

Seepage loss from streams is usually estimated from the decrease in streamflow between two gaging stations. The establishment of gaging stations on all creeks in the area was not economically feasible; therefore, indirect methods were used to estimate runoff and seepage loss.

Streamflow data collected from San Jose Creek in the adjacent Goleta basin were used to estimate runoff in the Santa Barbara-Montecito area. San Jose Creek was chosen because the stream has been gaged continuously since 1941, because the stream-gaging site is near the contact between the consolidated rock and the unconsolidated deposits, because the drainage area is underlain by consolidated rocks, and because the stream gradient (about 700 ft per mile) and the altitude of the drainage area are similar to those of streams in the Santa Barbara-Montecito area. The streamflow characteristics probably are also similar. Thus, runoff measured at the present gaging site on San Jose Creek should be a good index of the expectable runoff (dependent upon drainage area) from areas of consolidated rock along the Santa Barbara-Montecito part of the south coast of Santa Barbara County; that is, of the quantity of surface water that is available for seepage from the streams.

The runoff from each stream in the Santa Barbara-Montecito area was estimated by using the drainage area-runoff ratio from the San Jose Creek drainage basin. Near Santa Barbara, runoff occurs in a network of streams which drain San Roque, Barger, Mission, Lauro, Rattlesnake, and Sycamore Canyons. The combined drainage-basin area of these streams in the area of consolidated rock is about 14 square miles. Near Montecito, streams in Cold Spring, Hot Spring, San Ysidro, Romero, and several unnamed canyons have a combined consolidated rock drainage area of about 12.5 square miles. San Jose Creek has a drainage basin of 5.5 square miles. Stream runoff from the drainage areas adjacent to Santa Barbara and Montecito is assumed for each area to be about 2.5 times that of San Jose Creek.

Seepage-loss estimates in the Santa Barbara-Montecito area are based on ground-water recharge data for the adjacent Carpinteria and Goleta basins (Thomasson, in Upson, 1951, p. 43–45, 51–53; Evenson and others, 1962, p. 54, 92). Data from those basins are considered to be applicable for extrapolation and use in the Santa Barbara-

Montecito area, and they indicate that seepage from streams averages about 14 percent of the runoff.

The following table lists the average yearly recharge (calculated on the basis of the assumptions described above) from seepage in the area during the two selected periods for which streamflow data were available.

These estimates of ground-water recharge are based only on estimates of runoff from the areas of consolidated rocks and are conservative. Some runoff undoubtedly originates in areas underlain by unconsolidated deposits and eventually percolates to ground water, but the quantity cannot now be estimated.

Period	Average yearly recharge, in acre-feet, from seepage loss in the Santa Barbara-Montecito area		
	Santa Barbara area	Montecito area	Total
1944–64	360	360	720
1949–59	450	450	900

SUBSURFACE INFLOW FROM CONSOLIDATED ROCKS

There is subsurface inflow from the consolidated rocks that form the boundary of the ground-water reservoir in the Santa Barbara-Montecito area. The quantity cannot be determined directly. A relation probably exists, however, between water levels and inflow from the consolidated rocks. When water levels are high in the ground-water basin, inflow from the consolidated rocks probably decreases slightly; conversely, when water levels are low, inflow probably increases slightly. Indirect estimates, based on the ground-water inventory for the period 1949–59 during which quantities of ground water in storage did not change, suggest that subsurface inflow to the Santa Barbara area from the consolidated rocks is about 300 acre-feet per year. Data are not available for a similar estimate for the Montecito area. However, it probably is about the same as in the Santa Barbara area—300 acre-feet per year.

OUTFLOW

Of the items of outflow, pumpage is the most important. Subsurface discharge to the ocean probably is small because ground-water levels adjacent to the coast are, and have been in the past, at or near sea level, resulting in nearly flat ground-water gradients toward the ocean. Evapotranspiration is also small. Water levels in most places are too deep (more than 20 ft below land surface) for transpiration of ground water to be effective. Where water levels are closer to the land surface, the area is either covered by urban structures or all native vegetation has been removed.

PUMPAGE

Withdrawal of ground water by pumping from wells is the major outflow from the ground-water reservoir in the Santa Barbara-Montecito area. All other forms of outflow are insignificant.

Withdrawal of ground water from wells began to supplement local surface-water sources in the early 1800's. These local surface-water supplies varied considerably from year to year in direct relation to the rainfall. Water shortages always followed winters of low rainfall. In an attempt to develop a more dependable source of water, wells were drilled. Later it became obvious that local sources of water would not be sufficient to supply the demands of an expanding population. With this realization, surface-water supplies were developed by building several dams on the Santa Ynez River (fig. 1). Today, Juncal, Gibraltar, and Cachuma Dams impound water which is supplied to users in the area.

However, even now during years of low rainfall, all sources of surface water are heavily drawn upon and water is in short supply. During such drought years, water users depend heavily on ground-water supplies. The city of Santa Barbara and the Montecito County Water District have wells on which they rely to avoid water shortages during drought years. The Montecito County Water District uses its water wells only when the surface-water supplies are low. On the other hand, in recent years the city of Santa Barbara has been using more and more ground water. The city has done this, not so much to supplement the surface-water supply, but to utilize an available local source of low-cost ground water.

The following table lists the quantity of ground water pumped by the city of Santa Barbara and the Montecito County Water District for 1947–64. No records are available for years prior to 1947. Pumpage shown for each individual year is the amount of water pumped during the 12-month period beginning May 1.

Municipal pumping in the Santa Barbara-Montecito area, 1947–64

Year	Pumpage (acre-ft)		
	City of Santa Barbara	Montecito County Water District	Total [1]
1947	336	76	410
1948	3, 471	298	3, 770
1949	4, 243	407	4, 650
1950	3, 987	450	4, 440
1951	2, 745	108	2, 850
1952	1, 002	82	1, 080
1953	1, 497	179	1, 680
1954	891	102	990
1955	413	102	520
1956	220	34	250
1957	1, 480	37	1, 520
1958	81	0	80
1959	81	18	100
1960	2, 961	0	2, 960
1961	2, 961	0	2, 960
1962	2, 535	0	2, 540
1963	2, 941	0	2, 940
1964	2, 888	0	2, 890

[1] Rounded to the nearest 10 acre-ft.

The quantity of water pumped for irrigation, domestic, stock, and industrial uses in the Santa Barbara-Montecito area is small compared with the pumpage for municipal use. Pumping of this type has declined in recent years and by 1964 probably did not exceed about 200 acre-feet per year in either the Santa Barbara area or in the Montecito area.

PERENNIAL YIELD

The term "perennial yield" has many definitions, all of which are based on one premise: the long-term dependability of the water supply, as expressed by the balance of the items of the ground-water inventory. The perennial yield of the ground-water reservoirs in the Santa Barbara-Montecito area is the rate at which water can be pumped from wells year after year without decreasing ground water in storage to the point where the pumping lift would become economically infeasible or where water of poor quality would begin to intrude into the reservoir. In this area the intrusion of water of poor quality probably would occur first.

The ground-water storage units of the Santa Barbara-Montecito area have a capacity of about 280,000 acre-feet. The ground water can be depleted by pumping until one of the above limiting conditions is approached. When this occurs, then only as much water can be pumped as will be equal to the long-term average inflow to the reservoir minus the quantity which must flow to the ocean annually to maintain a barrier against sea-water intrusion. This is the perennial yield of the aquifer.

The perennial yield for the area of this report cannot be estimated with a high degree of accuracy because of a lack of complete data on inflow, outflow, and aquifer transmissibilities and because ground water within the reservoir is not static, which means that the natural inflow-outflow relations of the reservoir system probably will continue to change with time. Pumping ground water from wells is one item that can change these relations. If pumping causes water levels to decline, the decline in turn may cause subsurface inflow or influent seepage from creeks to increase.

For convenience the perennial yield of the ground-water reservoirs in the Santa Barbara-Montecito area can be estimated in two parts. One of these reservoirs underlies the area of Santa Barbara (fig. 2, storage units 1, 2, and 3), and the other the Montecito area (fig. 2, storage units 4 and 5). Each of these reservoirs has a perennial yield independent of the other.

An approximation of the perennial yield for the reservoir in the area of Santa Barbara can be estimated by referring to the 11-year period 1949–59 during which net ground-water storage seems to have remained about constant. During that period, inflow was equal to outflow. Thus, the average perennial yield for the area would be equal, at least, to the average pumping draft, or about 1,700 acre-feet per year. Average annual inflow for the period 1949–59 was estimated to be 1,800 acre-feet, as compared with the long-term estimated average annual inflow of 2,000 acre-feet per year for the period 1868–1964. Also on the basis of these estimates, the ground-water outflow to the ocean required to prevent sea-water intrusion seems to be about 100–300 acre-feet per year. Because there is no evidence of sea-water intrusion into the area during the period 1949–59, the long-term perennial yield for the Santa Barbara area probably is more than 1,700 acre-feet per year but less than 2,000 acre-feet per year.

A summary of the inflow-outflow relations in the Santa Barbara and Montecito areas for the periods 1868–1964, 1949–59, and 1944–64 are summarized in the following table.

Ground-water inventory for Santa Barbara and Montecito

[All values rounded]

	Average (acre-ft per year)					
	1868–1964		1949–59		1944–64	
	Santa Barbara	Montecito	Santa Barbara	Montecito	Santa Barbara	Montecito
Inflow						
Infiltration of rain (p. A18)	1, 100	1, 800	1, 000	1, 600	700	1, 200
Seepage from streams (p. A20)	[1] 500	[1] 500	400	400	400	400
Subsurface inflow from consolidated rocks (p. A20)	300	300	300	300	300	300
Infiltration of irrigation water (p. A17)	100	100	100	100	100	100
Total	2, 000	2, 700	1, 800	2, 400	1, 500	2, 000
Outflow						
Pumpage:						
Municipal (p. A22)	(2)	(2)	1, 500	100	(2)	(2)
Other (p. A22)	(2)	(2)	200	200	(2)	(2)
Subsurface discharge to ocean (p. A23)	100–300	100–300	100–300	100–300	100-300	100–300
Total	(3)	(3)	1, 800–2, 000	400–600	(3)	(3)

[1] Estimated from long-term rainfall-runoff relation.
[2] No records prior to 1947.
[3] No estimate possible.

The perennial yield of the Montecito area is not determinable with data now available. Only small-scale development of ground water has occurred within the area and apparently has not altered appreciably the natural inflow and outflow. Theoretically, the perennial yield of the Montecito area equals the average long-term inflow, which is about 2,700 acre-feet per year, minus the outflow that is required to maintain ground-water levels high enough to prevent sea-water intrusion. If the quantity of outflow required to prevent sea-water intrusion is about equal to the quantity of outflow from the Santa Barbara area (about 100–300 acre-ft per year), the perennial yield of the Montecito area may be approximately 2,500 acre-feet per year.

If, during any period, pumpage equals perennial yield and inflow is less than the long-term average, ground water in storage will decline. This occurred in the Santa Barbara area during the drought years 1944–64 when inflow averaged only about 1,500 acre-feet per year.

To obtain the full perennial yield from the Santa Barbara-Montecito area, careful placement of wells and proper pumping techniques will be required. Also, estimates of perennial yield are always subject to refinement as additional information becomes available during use of the reservoir system.

CHEMICAL QUALITY

The source of most potable ground water is rain. Most dissolved mineral matter in streams and ground water is added to the rain after it has reached the land surface and begins to run over or percolate through the rock materials which mantle the earth. As it moves, the ground water dissolves a small quantity of all material with which it comes in contact. This dissolved material is carried along with the water in a number of physical and chemical forms. The value of a water supply depends, in part, upon the character and quantity of this dissolved-mineral matter and the use for which the water is intended.

Most ground water in the Santa Barbara-Montecito area is of suitable quality for ordinary domestic and industrial uses. Notable exceptions are ground water in some of the consolidated rocks of Tertiary age and water from several wells adjacent to the ocean. Water from those sources has a total dissolved-solids content of 1,000–17,500 ppm (parts per million) and is too saline for most needs in the area.

Some water in the deeper parts of the ground-water basin in the Santa Barbara area presumably is of poor quality. This is suggested by the electric log from well 4N/27W–16E1 (pl. 2), which records a large negative departure on the self-potential curve and a low resistivity through the interval 490–570 feet below sea level. On an electric log this combination generally indicates saline water.

Most of the ground water pumped in the area is used for domestic purposes. According to the drinking-water standards of the U.S. Public Health Service (1962), which are commonly used to evaluate domestic water supplies used on interstate carriers, dissolved solids should not exceed 500 ppm. However, if water of this quality is not available, a dissolved-solids content of 1,000 ppm is permitted.

The following table lists the approximate concentrations of nitrate (NO_3), sulfate (SO_4), and chloride (Cl) in samples of ground water from the area, and the limits recommended by the U.S. Public Health Service (1962). These particular ions were chosen for inclusion in the table because they serve as an index of the quality of the ground water.

Area	Parts per million		
	Nitrate	Sulfate	Chloride
Santa Barbara	<10	100–150	<100
Montecito	<25	150–250	150
Recommended limit	45	250	250

The range in total dissolved solids in ground-water samples for the Santa Barbara area is about 450–650 ppm and for the Montecito area about 600–1,000 ppm. Although the water is, in general, of good quality, hardness is objectionably high in both areas. It ranges from 250 to 500 ppm. Hem (1959, p. 147) stated that hardness of a domestic water supply does not become objectionable until it reaches about 100 ppm. Hardness is undesirable in domestic water supplies because of its scale-forming and soap-consuming properties which are caused by carbonate and bicarbonate salts, principally magnesium and calcium.

Ground water from some wells near the Mesa fault (pl. 1) contains dissolved hydrogen sulfide gas. This gas probably originates in the underlying consolidated rocks of Tertiary age and moves upward toward the surface along the fault. There has been no pumping of ground water near the Mesa fault for many years.

SEA-WATER INTRUSION

Where there is heavy pumping from wells along the coast, the possibility of sea-water intrusion must always be considered as a potential source of contamination to aquifers in the area. The intrusion of sea water into coastal aquifers can occur in two ways: by horizontal migration into the aquifer at depth or by lateral movement through shallow deposits adjacent to the ocean with subsequent downward migration. Either way, the water level or head of water in an aquifer at the coast, in relation to sea level, is the controlling factor that determines if sea water intrusion will occur. If ground-water levels in the reservoir system adjacent to the coast are near or below sea level, sea-water intrusion is likely to occur.

Static ground-water levels near the coast in the area of Santa Barbara and the western part of the Montecito area have been below sea level since 1960. Sea water apparently has intruded as the water level has declined. The intrusion is not extensive and seems to be limited to the shallow deposits directly adjacent to the coast. Only wells less than 50 feet deep and deep wells which have been constructed without sealing off the near-surface water-bearing zones have been affected. Water from observation well 4N/27W–22A1 (pl. 1), which is 31 feet deep, had a chloride concentration of 17,500 ppm in 1962. In contrast,

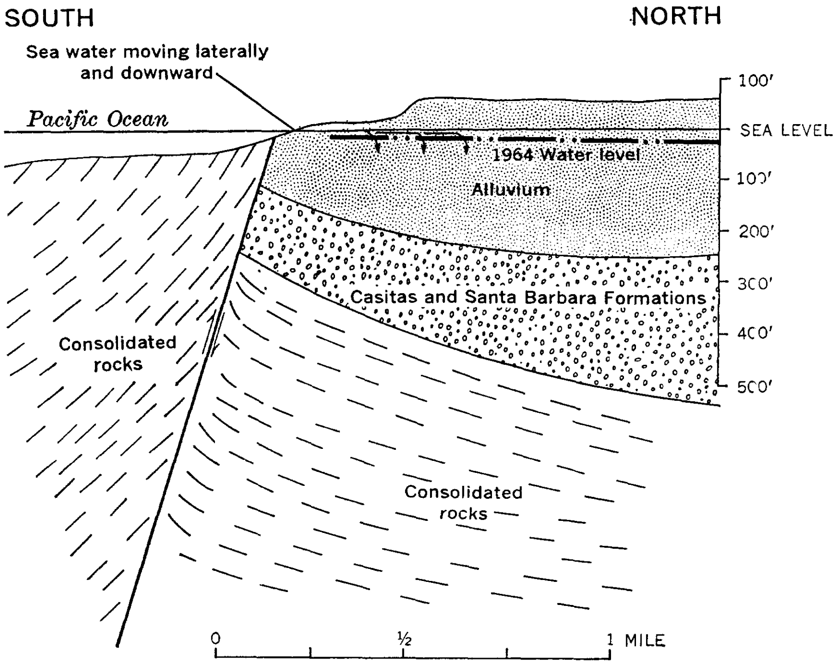

FIGURE 4.—Geology and direction of movement of sea water into the ground-water reservoir in the vicinity of sec. 19, T. 4 N., R. 26 W.

water from well 4N/27W–24D2 (pl. 1), which was completed to a depth of 473 feet and sealed from the shallow aquifers with cement between the surface and a depth of 116 feet, had a chloride concentration of about 200 ppm in 1962. Water from well 4N/26W–19D2 (pl. 1), which is 487 feet deep, had a chloride concentration of about 2,000 ppm in 1964; when this well was drilled no cement seal was provided through the shallow aquifers.

The rather limited data that are available suggest that no direct horizontal migration of sea water has occurred at depth into the main aquifers. The possibility that horizontal migration could occur seems remote because there is no direct connection between the deeper water-bearing zones and the ocean. Consolidated rocks of Tertiary age have been uplifted on the south side of an offshore fault (pls. 1 and 2), and these serve as an effective salt-water barrier.

The sketch shown in figure 4 illustrates the near-shore geologic conditions in the vicinity of sec. 19, T. 4 N., R. 26 W., and the probable direction of movement of sea water into the ground-water reservoir.

CONCLUSIONS

1. The unconsolidated deposits of Quaternary age (alluvium, Casitas Formation, and Santa Barbara Formation) make up the ground-water reservoirs in the Santa Barbara-Montecito area.

2. In 1959 ground water in storage in the Santa Barbara area was about 184,000 acre-feet. By 1964, in response to below-average recharge and continued withdrawal, the quantity of ground water in storage had decreased to about 178,000 acre-feet, the lowest on record.
3. In 1959 ground water in storage in the Montecito area was about 97,000 acre-feet. Water levels indicate little change in the quantity of ground water in storage from 1959 to 1964.
4. For the ground-water reservoir in the Santa Barbara area, the calculated perennial yield is between 1,700 and 2,000 acre-feet per year.
5. Data are insufficient to make a firm estimate of perennial yield for the Montecito area. However, the long-term perennial yield may be about 2,500 acre-feet per year.
6. Most ground water in the area is suitable for ordinary domestic and industrial uses.
7. Locally, sea-water intrusion has occurred as ground-water levels declined below sea level adjacent to the coast. The intrusion is limited to the upper parts of near-shore shallow alluvial deposits. Ocean water has contaminated only those deep wells which were constructed without a cemented seal between the casing and shallow aquifers.

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Base from U.S. Geological Survey Goleta, 1950, Santa Barbara, 1952, and Carpinteria, 1952

Geology by K. S. Muir modified from Upson (1951, pl. 1,2) and Dibblee, unpublished geologic map of the central Santa Ynez mountains and vicinity. Surveyed in 1963–64

MAP SHOWING MAJOR GEOLOGIC FEATURES AND LOCATION OF WATER WELLS SANTA BARBARA–MONTECITO AREA, SANTA BARBARA COUNTY, CALIFORNIA

SCALE 1:24 000

CONTOUR INTERVALS 20 AND 50 FEET
DATUM IS MEAN SEA LEVEL

GEOLOGIC SECTIONS OF THE SANTA BARBARA-MONTECITO AREA, SANTA BARBARA COUNTY, CALIFORNIA

SCALE 1:24 000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

VERTICAL EXAGGERATION × 10

288-767 O - 68 (In pocket)