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HYDROLOGIC INVENTORY OF THE LOMPOC SUBAREA, SANTA YNEZ RIVER BASIN, SANTA BARBARA COUNTY, CALIFORNIA, 1957-62

By

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With a section on

PERENNIAL SUPPLY

By

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By R. E. Evenson

ABSTRACT

Hydrologic data collected during the climatically near-average 6-year period of inventory 1957-62 provide the basis for making estimates of supply to and demand from the Lompoc subarea of the Santa Ynez River basin and changes in the quantity of water stored in the deposits of the basin. The hydrologic inventory presents gains or accretions to the water supply, as inflow, equated with loss by water demands, as outflow. The difference is the ground-water storage change. Items of inflow include precipitation, surface and subsurface inflow, irrigation return, and sewage effluent. Items of outflow include surface and subsurface outflow, evapotranspiration, and water pumped for irrigation and other uses.

Ground-water storage changes occurred as depletions of the shallow water body beneath the eastern and central parts of the Lompoc plain and beneath the upland part of the Lompoc subarea to the north and east. The estimated annual depletion of storage averaged 3,000 acre-feet.

A near balance between inflow and outflow is indicated by a calculated difference of 5,000 acre-feet of accretion and an observed depletion of ground water in storage of about 3,000 acre-feet. The difference of 8,000 acre-feet between the two values, considering the magnitude of total inflow and outflow--110,000 and 105,000 acre-feet, is not significant. For the period of inventory, more water was discharged from the basin by flow in the Santa Ynez River than by pumping from wells.

The near balance between inflow and outflow for a period of near-average climatic conditions, in general, substantiates a previous estimate that perennial pumpage is as much as about 20,000 acre-feet. However, water in storage will be depleted if the progressive change in the ratio of irrigation pumpage to other pumpage continues. Even though the hydrologic balance is maintained, changes in chemical quality of the ground water, due to recycling of irrigation water and inflow of poor-quality connate water from the consolidated rocks, indicate that chemical equilibrium has not been reached. Perennial supply under the 1957-62 conditions of inventory is estimated to be between 24,000 and 26,000 acre-feet.

INTRODUCTION

Santa Barbara County (fig. 1) is in the coastal part of southern California and includes the Santa Ynez and San Rafael mountain ranges. Between these two ranges and associated foothills is the Santa Ynez River basin, which has been divided on the basis of hydrology into five subareas.

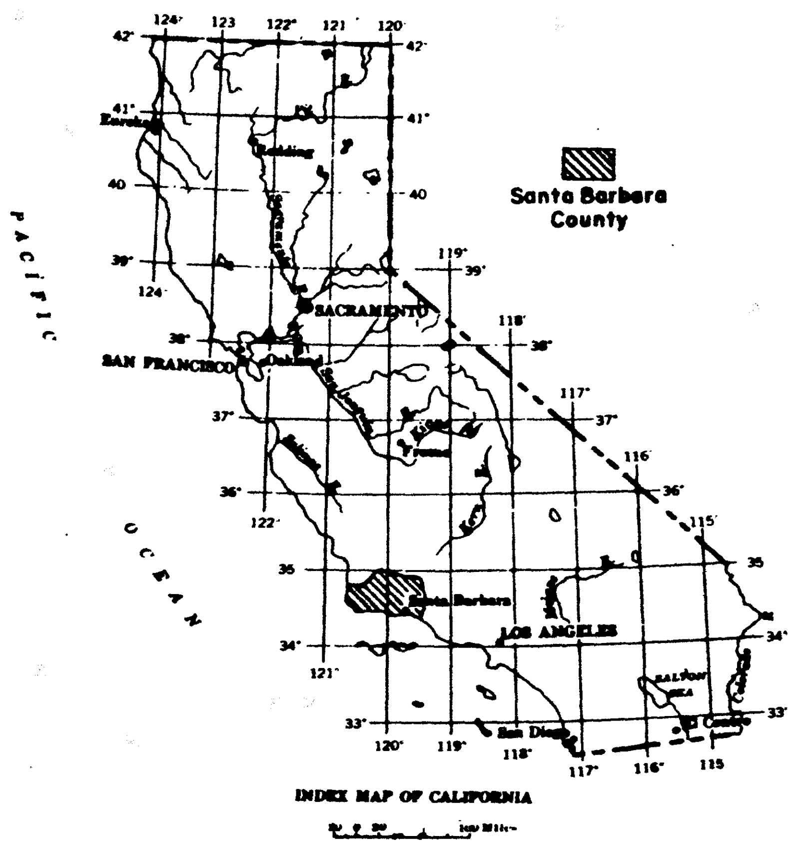

FIGURE 1.--Index map showing Santa Barbara County, California.

The Lompoc subarea is the westernmost of the five subareas (fig. 2) and includes the drainage area between Robinson Bridge and the Pacific Ocean and between the Purisima Hills and the Santa Ynez Mountains. Most of the flat valley floor, known as the Lompoc plain, is irrigated agricultural land that includes more than 8,000 acres of truck and field crops and pastureland. On either side of the plain are upland areas covered with brush and weeds. In 1956 the establishment of Vandenberg Air Force Base on the site of Camp Cooke Military Reservation (fig. 3) resulted in significant changes in land use in the Lompoc subarea. As population has increased, some irrigated agricultural land and some brushland have been converted to housing developments. Modification of irrigated agricultural land by these developments will

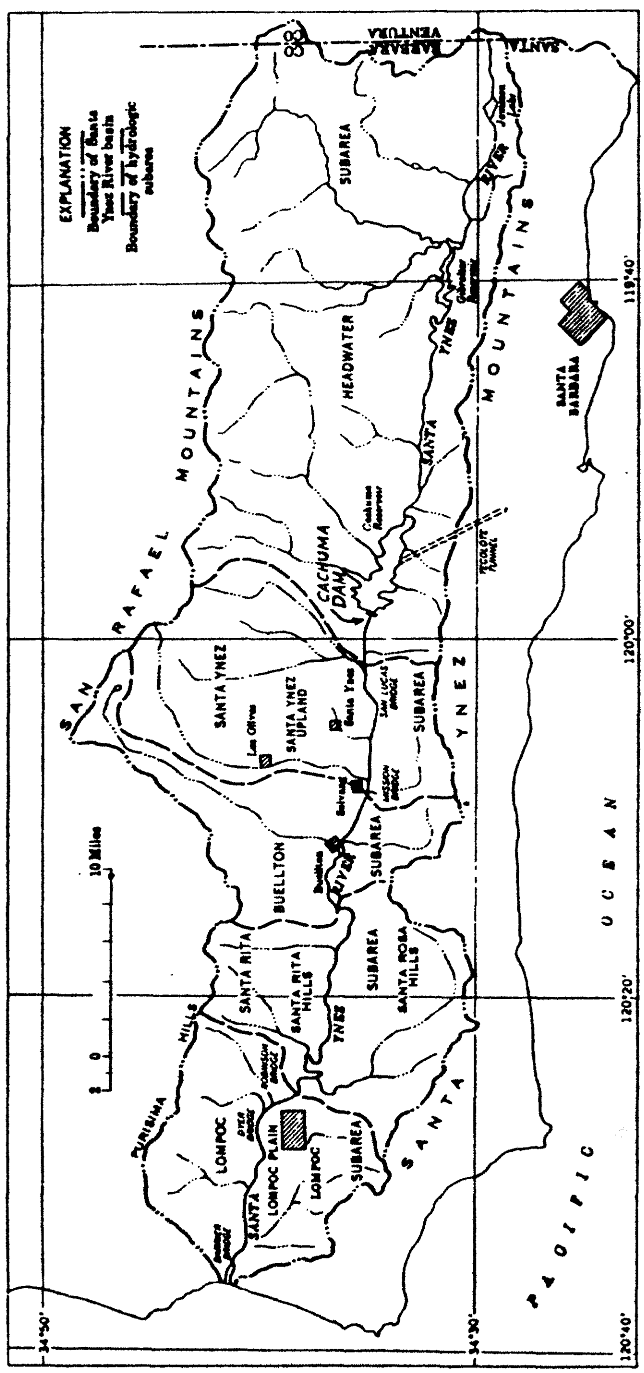

FIGURE 2.--Sketch map of the Santa Ynez River basin showing the hydrologic subareas.

undoubtedly change the hydrologic regimen and may have a serious effect on the water supply of the Lompoc subarea. As the cultural developments are completed, a smaller quantity of irrigation-return water will be available to recharge the ground-water body.

Regulation of the Santa Ynez River by Cachuma Dam and reservoir has already altered the hydrologic regimen of the basin. Cachuma Dam, completed in 1953, impounds floodwaters in a 210,000-acre-foot reservoir. Water is diverted from the reservoir through Tecolote Tunnel to supply the several south-coast communities near Santa Barbara. Water rights downstream from the dam are protected by a contract, which includes a requirement for a minimum flow of 1 second-foot at the H Street Bridge (fig. 3) near Lompoc when water is being diverted from the river into the reservoir.

This report was prepared by the U.S. Geological Survey, Water Resources Division, in cooperation with the Santa Barbara County Water Agency, under the general supervision of Walter Hofmann, district chief, Menlo Park, Calif.

Purpose and Scope

On the basis of data available in 1959, Wilson (1959, p. 104-106) estimated the quantity of water that probably could be pumped perennially from the Lompoc subarea of the Santa Ynez River basin. However, he pointed out that, for an accurate estimate, more data were necessary--data relative to (1) the rechargeable storage capacity and permeability of the water-bearing deposits, (2) the rate of replenishment of the water-bearing deposits, (3) the quantity of irrigation-return water, and (4) the deep percolation of rain.

In 1956 the Agricultural Research Service, U.S. Department of Agriculture, initiated a study to determine the contribution of rain and irrigation-return water to the ground-water supply of the Lompoc subarea. Their final report, summarizing the data, was released in 1963 (Blaney and others, 1963).

The purpose of this report is to evaluate the hydrologic inventory, using the additional data now available, and to appraise the perennial supply of the subarea. The scope includes the presentation of up-to-date information on the elements of the hydrologic inventory--items of water inflow, items of water outflow, changes in ground-water storage--and estimates of perennial supply.

Well-Numbering System

The well-numbering system used by the Geological Survey in California indicates the location of wells according to the rectangular system for the subdivision of public lands. For example, in the number 7N/34W-27L1, which was assigned to a well near Lompoc, the part of the number preceding the slash indicates the township (T. 7 N.); the number following the slash the range (R. 34 W.); the digits following the hyphen the section (sec. 27); and the letter following the section number the 40-acre subdivision of the section as indicated on the diagram below. Within each 40-acre tract the wells are numbered serially as indicated by the final digit of the well number. Thus, well 7N/34W-27L1 was the first well in the NE¼SW¼ sec. 27 to be listed. The entire area is north and west of the San Bernardino base line and meridian.

D	C	B	A
E	F	G	H
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Acknowledgments

Thanks and appreciation are expressed to residents of the Lompoc subarea who permitted access to their land and facilitated collection of the hydrologic data on which this report is based.

Officials at Vandenberg Air Force Base, Point Arguello Naval Missile Facility, city of Lompoc, Union Sugar Co., Union Oil Co., Federal Correctional Institution, and Pacific Gas and Electric Co. were courteous and helpful in providing data and in permitting access to their land.

Paul R. Nixon, G. Paul Lawless, Fred J. Libbey, E. J. Wiedmann, and Robert L. McCormick, all of the Agricultural Research Service at Lompoc, were extremely helpful in freely providing cooperation and consultation.

Previous Work

Upson and Thomasson (1951) described the geology and water resources of the Santa Ynez River basin, including the Lompoc subarea, analyzed hydrologic conditions, and estimated a minimum perennial yield of 10,000 acre-feet on the basis of the limited data available for 1935-44.

Wilson (1959, p. 105) appraised ground-water conditions in the basin, revised the previous estimates of perennial yield on the basis of data for 1945-52, and concluded that "...estimated storage depletions are inconsistent with ground-water withdrawals and estimates of the known sources of recharge." The inconsistency probably was the result of error in the computations of evapotranspiration, deep penetration of rain, and irrigation-return water, because the computations were based on data interpolated from other areas

(Wilson, 1959, p. 105). Wilson (1959, p. 106) inferred that "during a drought of as much as 11 years' duration, the Lompoc basin might be able to support an average yearly pumpage of about 25,000 acre-feet."

A report by Evenson (1961) described a method of estimating the quantity of water pumped for agriculture, based on electric-power consumption in the Santa Ynez River valley.

Evenson and Miller (1963) described in detail the geology and ground-water feature of the southwestern part of the Lompoc subarea and made some revisions in previous geologic and hydrologic interpretations.

Blaney, Nixon, Lawless, and Wiedmann (1963) summarized the results of research studies made from 1956 to 1963 to provide basic data on evapotranspiration and to determine the deep penetration of precipitation. The results of that research are a major contribution to the analysis of the hydrologic inventory for the Lompoc subarea. The total quantity of recharge to the ground-water supply was estimated as the difference between water evaporated and water applied--precipitation as well as irrigation water.

Evenson (1964) made a study of changes in ground-water quality in the Lompoc subarea and concluded that the changes were mainly the result of mixing of native water with (1) recycled irrigation water and (2) poor-quality connate water.

Summary of Geology and Hydrology

The Lompoc subarea is a structural basin about 12 miles long and 10 miles wide adjacent to the Pacific Ocean (fig. 3). Consolidated rocks of Miocene, Pliocene, and older age--mainly shale, mudstone, and alternating layers of sandstone--form the flanks of the ground-water basin. These extensively folded and faulted rocks also underlie the Santa Ynez Mountains, the Santa Rita Hills, and Burton Mesa. Unconsolidated deposits that include marine and continental deposits of Pliocene and Pleistocene age and younger alluvium and river-channel deposits of Recent age fill the basin to depths as great as 1,000 feet below land surface.

An extensive upland of low foothills, north of the Lompoc plain and east of Santa Lucia Canyon, is formed by unconsolidated marine and continental deposits of Pliocene and Pleistocene age. These deposits, as described by Upson and Thomasson (1951, pl. 4), dip slightly toward the Lompoc plain and fill a structural trough in the underlying consolidated rocks.

Ground water in the Lompoc subarea, as described by Upson and Thomasson (1951, p. 120-162), is contained principally in aquifers--permeable deposits that comprise the unconsolidated sediments of the basin--and occurs in a shallow water body, contained in a zone of permeable alluvial deposits, generally is unconfined and separated from the deep water body by an impermeable zone of fine-grained sand, silt, and clay. Locally, the shallow water body is in hydraulic continuity with the deep water body.

The deep water body is the main water-bearing zone and includes (1) a highly permeable aquifer in the lower part of the younger alluvium and (2) less permeable interconnected aquifers in the underlying or adjoining unconsolidated marine and continental deposits of Pliocene and Pleistocene age. Younger alluvium and river-channel deposits underlie the flat valley floor and are about 185 feet thick, at both The Narrows and the coast.

The deep water body is overlain and semiconfined throughout much of the area by predominantly impermeable deposits in the upper part of the younger alluvium. On the north and south sides of the Lompoc plain, water occurs in semiperched lenses in the consolidated deposits.

Water in the deep water body moves westward. Some is discharged by pumping from wells, and some is discharged through a narrow natural submarine outlet offshore from the mouth of the Santa Ynez River. Near the western end of the Lompoc plain, water from the shallow water-bearing zone is discharged into a swamp and two drainage ditches which are tributary to the Santa Ynez River. Evaporation and transpiration from swamp areas and from areas of phreatophyte growth account for a significant quantity of water discharged from the shallow zone.

The source of water in the aquifers is rain that falls on the outcrops of the permeable deposits and percolates underground, either directly or through stream channels. In addition, recent studies indicate that connate water probably is migrating locally from the consolidated rocks of Tertiary age into the fresh-water aquifers (Evenson, 1964, p. 47). Also, part of the applied irrigation water returns to the ground-water body.

Water in storage in the unconsolidated deposits of the ground-water basin is almost 300,000 acre-feet, which could be used without danger of sea-water contamination of the fresh-water supply (Wilson, 1959, p. 59; Evenson and Miller, 1963, p. 15). During years of deficient or below-average recharge, water is withdrawn from storage. During years of above-average recharge, the quantity of water in storage is increased. The cyclic periods have not been uniform in recent years; however, data show that in the past one wet year usually was adequate to replenish the water that was withdrawn from storage during preceding dry years. Thus, the cyclic utilization of ground water in storage is of major significance to the hydrology of the Lompoc subarea.

Effects on water quality due to pumping from that part of the main water-bearing zone beneath the Lompoc plain are of particular significance in the cyclic utilization of ground water in storage. These effects include: (1) Little or no change in water quality as a result of a favorable salt balance maintained by recharge from percolation of precipitation and stream runoff; (2) gradual increase in chloride and sulfate concentrations over a period of years as a result of recycling irrigation water; (3) a subsequent decrease in chloride and sulfate concentrations as a result of dilution by recharge water from percolation of above-average precipitation and stream runoff following a time lag of several years; and (4) increases in chloride concentration associated with little change in sulfate concentration, probably the result of localized inflow of connate water from the consolidated rocks. An earlier report (Evenson, 1964, fig. 7) shows graphically the changes in chloride and sulfate concentrations in water from selected wells in the main water-bearing zone.

HYDROLOGIC INVENTORY

The hydrologic inventory accounts for all items of gain to the water supply (inflow) and all items of loss by water demands (outflow). The inventory for the Lompoc subarea for the 6-year period 1957-62 may be expressed in equation form as follows:

Inflow - outflow = Change in quantity of ground water in storage.

Items of inflow include precipitation, surface inflow, subsurface inflow, water from wells applied for irrigation, and sewage effluent. Items of outflow include surface outflow, subsurface outflow, evapotranspiration, and water pumped for irrigation and other uses.

Previous studies of the Lompoc subarea relating to the hydrologic inventory specifically included irrigation-return water, deep penetration of rain, and seepage loss from streams as items of inflow directly affecting the ground-water inventory (Wilson, 1959, p. 86). This hydrologic inventory is based on total inflow and outflow for the subarea, using the estimates of consumptive use of water made by Blaney and others (1963, p. 17-21).

Estimates are made of deep penetration of rain on the irrigated land, seepage loss from streams, and irrigation-return water only to compare estimates of ground-water recharge for the 1957-62 period with those made previously.

The items of inflow and the items of outflow are estimated for each agricultural year, beginning May 1, 1957, and the ground-water storage change for the 6-year period is based on water-level change from the spring-high water level of 1957 to the spring-high water level of 1963.

Items of Inflow

Precipitation

Precipitation occurs chiefly as rain, from September through March, and some also results from frequently occurring fog and dew. Precipitation is accounted for in the hydrologic inventory by three general processes: (1) Some is returned to the atmosphere by evapotranspiration, (2) some runs off directly as streamflow, and (3) some percolates into the ground as deep penetration of rain. For this hydrologic inventory, the studies by Blaney and others (1963, p. 23, 29-44) provide the basis for determining the total volume of rainfall on the Lompoc plain and for estimating potential recharge from deep penetration of rain on the upland parts of the Lompoc subarea bordering the plain, both to the north and to the south.

Lompoc plain.--Precipitation on the Lompoc plain is distributed over about 13,500 acres of irrigated and uncultivated land. The uncultivated land contains willows, cottonwoods, brush, grass, tules, and other native vegetation adjacent to the Santa Ynez River. During the rainy season, from about September through March, most of the irrigated land lies fallow. Precipitation data for the Lompoc plain are based on records obtained from U.S. Weather Bureau rain gages at five sites within the Lompoc plain (Blaney and others, 1963, p. 23). The weighted mean annual precipitation, shown in table 1, averaged 13.5 inches for the 6-year period, compared to the 42-year long-term annual average of 14.6 inches (Wilson, 1959, p. 11). For the period 1957-62 the average annual volume of precipitation was 15,000 acre-feet.

TABLE 1.--*Precipitation on the Lompoc plain, 1957-62*

Year starting May 1	Weighted mean precipitation (inches)[1]	Volume of precipitation (acre-feet)
1957	22.9	25,800
1958	8.4	9,500
1959	9.4	10,600
1960	7.9	7,800
1961	20.0	22,500
1962	12.5	14,100
Average (rounded)	13.5	15,000

[1]Blaney and others, 1963, p. 24, table 4.

The percentage of precipitation that infiltrates to recharge the ground-water basins is dependent on the intensity and frequency of storms, as well as on the total volume of water applied, including rain and irrigation water. Potential recharge to ground water from precipitation on the irrigated area during the late autumn and winter, when the land lies fallow, is estimated by transposing recharge data for a bare plot in the upland area (Blaney and others, 1963, p. 40 and 50). The assumption made is that potential recharge for the fallow area is typical for both fallow and irrigated parts of the whole plain, because areas of land with a high potential for recharge probably compensate for areas with a low potential (Upson and Thomasson, 1951, p. 126). Figure 3a shows the relation of precipitation to potential recharge, as determined by data on a bare plot (Blaney and others, 1963, p. 40 and 50).

For the period of inventory, annual precipitation (table 2) on the irrigated area averaged 8,500 acre-feet, of which 3,500 acre-feet was estimated to percolate to the ground-water body. The balance of 5,000 acre-feet was lost to the atmosphere by evapotranspiration from the irrigated area.

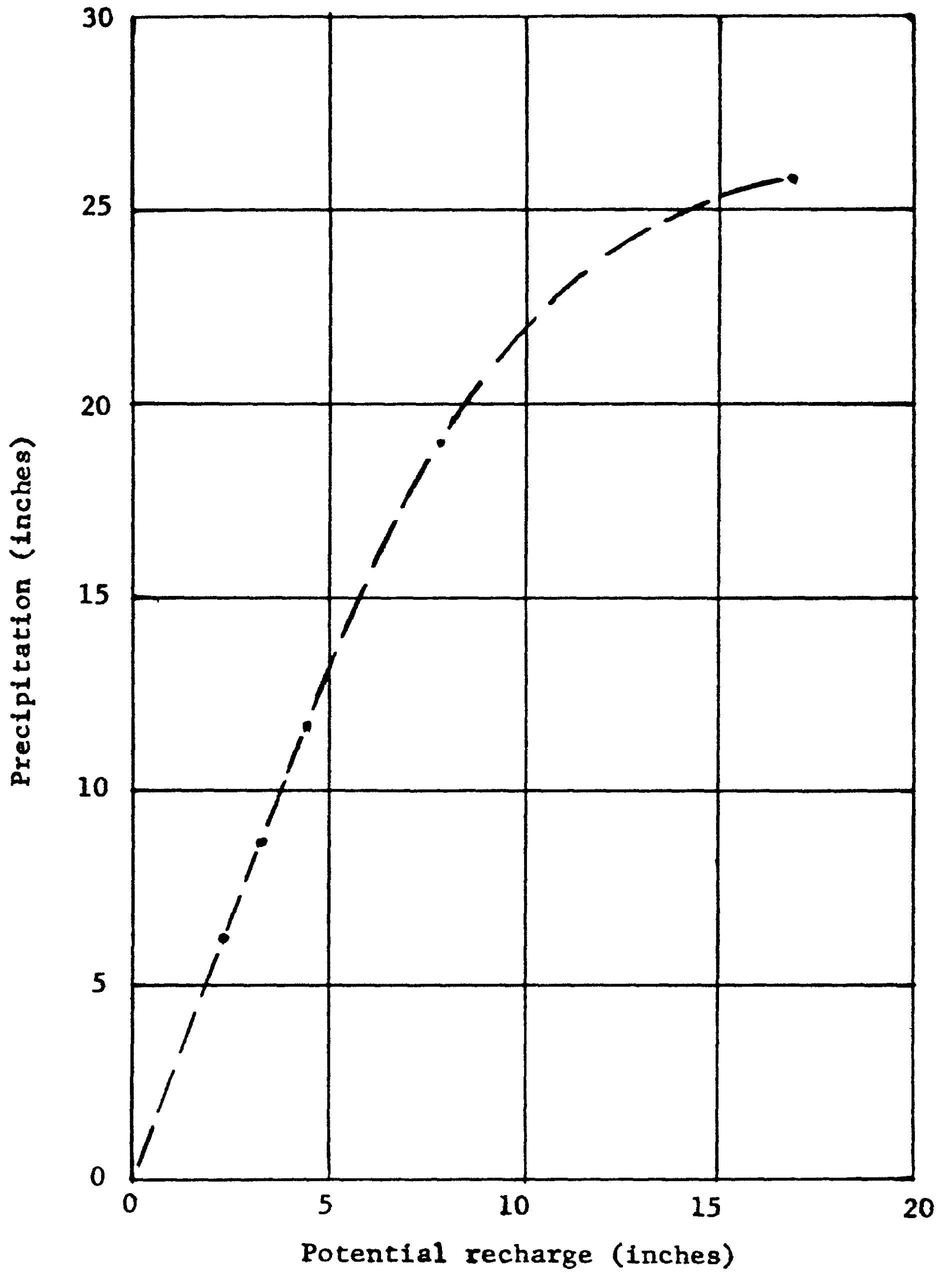

FIGURE 3a.--Graph showing relation of precipitation to potential recharge for a bare plot on permeable soil.

TABLE 2.--*Estimated potential recharge to ground water from precipitation, 1957-62*

Year starting May 1	Irrigated area (acres)[1]	Precipitation (inches)[1]	Potential recharge (inches) (fig. 3a)	Volume of precipitation on irrigated area (acre-feet)[1]	Potential deep percolation of precipitation (acre-feet)
1957	8,100	22.9	11.0	15,500	7,500
1958	7,900	8.4	3.2	5,500	2,100
1959	7,800	9.4	3.5	6,100	2,200
1960	7,300	7.9	3.0	4,800	1,800
1961	7,200	20.0	7.5	12,000	4,500
1962	7,000	12.5	4.7	7,300	2,800
Average (rounded)		13.5		8,500	3,500

[1]Blaney and others, 1963, p. 24, table 4.

Upland area.--Precipitation on the upland area of unconsolidated deposits, both to the north and to the south of the Lompoc plain (29,200 acres), is chiefly distributed by deep penetration of rain (recharge) and by evapotranspiration (discharge). Runoff from the upland area for this inventory was negligible.

Estimates of long-term potential recharge, based on precipitation and soil-moisture data, were made by Blaney and others (1963, p. 29-44). Soil-moisture measurements provided the data to indicate "amounts of consumptive use and amounts of water which drained downward out of the soil profiles," although the relative amounts of each were estimated on the basis of rates and patterns of moisture extraction by plants (Blaney and others, 1963, p. 31). Briefly, these estimates are based on the classification of soils according to their ability to absorb rain, the vegetative cover, and the precipitation for the 49-year period of record 1914-62.

For the 49-year period, average precipitation on the upland areas of the Lompoc plain was estimated to be 34,000 acre-feet per year, of which 2,600 acre-feet was potential recharge to ground water and 31,400 acre-feet was returned to the atmosphere by evapotranspiration.

Surface Inflow

Surface inflow to the Lompoc subarea consists of the streamflow of the Santa Ynez River at The Narrows and the streamflow entering the valley from the south. Streamflow also enters the valley from the north; but the quantity has not been estimated because it is not significant to the hydrologic inventory. This streamflow occurs only during heavy storms and moves rapidly out to the ocean through the Santa Ynez River.

Inflow from the Santa Ynez River is measured at a gaging station at The Narrows, and inflow from the tributary streams on the south is estimated on the basis of the streamflow (discharge) in Salsipuedes Creek (Wilson, 1959, p. 84-85). The estimated discharge of tributary streams south of the Lompoc plain--the creeks in San Miguelito, San Pascual, Rodeo, and Lompoc canyons--is based on the discharge of Salsipuedes Creek for the inventory period. The drainage areas of these streams and the drainage area of Salsipuedes Creek have similar topography, vegetation, precipitation patterns, and geology. The streams south of the Lompoc plain collectively have about 25 percent less drainage area and, therefore, an estimated 25 percent less discharge than Salsipuedes Creek.

Table 3 summarizes the quantity of streamflow from the Santa Ynez River and from streams south of the Lompoc plain for the period 1957-62. The inflow ranged from a minimum of 1,400 acre-feet in 1960 to a maximum of 138,200 in 1957, and averaged about 50,000 acre-feet per year--about one-half of the unregulated long-term average.

TABLE 3.--*Surface-water inflow, in acre-feet, from major streams tributary to the Lompoc subarea, 1957-62*

Year starting May 1	Santa Ynez River at The Narrows	Estimated flow from streams south of Lompoc plain	Total (rounded)
1957	121,420	16,800	138,200
1958	35,322	3,100	38,400
1959	1,707	1,200	2,900
1960	878	500	1,400
1961	86,731	16,600	103,300
1962	9,359	4,000	13,400
Average (rounded)	42,600	7,000	50,000

Seepage loss.--The seepage loss from streams in the Lompoc subarea is the surface-water inflow of the Santa Ynez River at The Narrows (42,600 acre-feet) plus the inflow from streams south of the Lompoc plain (7,000 acre-feet) less the surface-water outflow of the Santa Ynez River at the Barrier Bridge (35,000 acre-feet). These quantities are shown in tables 3 and 5. The average seepage loss for the 6-year period was about 14,600 acre-feet per year--7,600 for the Santa Ynez River and 7,000 for tributary streams.

The streamflow of the Santa Ynez River is measured at four gaging stations within the Lompoc subarea--narrows, H Street, and 13th Street near Lompoc; and barrier, near Surf. Table 5 shows the streamflow at each station for the 6-year period 1957-62. The table shows that significant losses occur between The Narrows and H Street, and small losses occur downstream from H Street to the Barrier Bridge.

TABLE 5.--*Streamflow of the Santa Ynez River, in acre-feet, at four gaging stations in the Lompoc subarea, 1957-62*

Year starting May 1	Santa Ynez River at			
	Narrows near Lompoc	H Street near Lompoc	13th Street near Lompoc	Barrier, near Surf
1957	121,420	110,923	109,887	107,420
1958	35,322	37,047	31,907	28,730
1959	1,707	241	138	171
1960	878	164	362	67
1961	86,731	82,476	82,691	70,421
1962	9,359	--	3,173	2,732
Average (rounded)	42,600	--	38,000	35,000

Subsurface Inflow

Subsurface inflow, or underflow of ground water, through The Narrows into the Lompoc subarea is determined by the cross-sectional area, the permeability of the saturated deposits, and the hydraulic gradient. The saturated cross-sectional area did not change appreciably during the inventory period, the permeability is a constant, but the hydraulic gradient varied during the period of inventory. For the period 1935-44 the ground-water levels were high, and an average hydraulic gradient of 8 feet per mile resulted in an average underflow of 600 acre-feet per year (Upson and Thomasson, 1951, p. 80). However, as the use of ground water in the Lompoc subarea has increased, the water levels were lowered in heavily pumped areas downstream from The Narrows, and the hydraulic gradient through The Narrows has steepened. Thus, for the period 1947-51, the gradient averaged 20 feet per mile, and the annual underflow averaged 1,500 acre-feet (Wilson, 1959, p. 83).

The hydraulic gradient for the period of this study is similar to that for 1947-51; hence, the estimated subsurface inflow was about the same, or an average of 1,500 acre-feet per year.

Irrigation Return

An estimate of irrigation-return water was one of the primary objectives of the studies by the Agricultural Research Service (Blaney and others, 1963, p. 1); however, these estimates could not be made directly because irrigation practices varied from crop to crop, from farm to farm, and from one irrigation to the next. Preliminary data showed that irrigation efficiencies ranged from 47 to 75 percent (Blaney and others, 1963, p. 20), thereby indicating substantial quantities of irrigation-return water.

The average annual irrigation-return water, determined by subtracting the percolation of precipitation and the evapotranspiration from the water applied for irrigation and the rainfall on the irrigated area and as shown by the following table, is 9,700 acre-feet.

		Annual average (acre-ft)	
Water applied for irrigation	(table 6)	21,400	
Rainfall on the irrigated area[1]	(table 2)	8,500	
Total			29,900
Less:			
Percolation of precipitation	(table 2)	3,500	
Evapotranspiration	(table 9)	16,700	
Total			20,200
Irrigation-return water			9,700

[1]Blaney and others, 1963, table 4, p. 24.

All water applied for irrigation in the Lompoc subarea is pumped from wells, and estimates of the quantity applied are based on the electric power consumed for agricultural use, principally by electric pumps. A detailed description of the method used to make these estimates is given in an earlier report (Evenson, 1961). Briefly, the quantity of water pumped from a well is dependent on the power consumed, total lift, and efficiency of the pumping plant. Records of power consumed for agricultural use in the Lompoc subarea have been supplied by the Pacific Gas and Electric Co. Table 6 shows the estimated water applied for irrigation in the Lompoc subarea for the period 1957-62.

TABLE 6.--*Estimated water applied for irrigation in the Lompoc subarea, 1957-62*

Year starting May 1	Pumpage--estimated water applied for irrigation (acre-feet)	Year starting May 1	Pumpage--estimated water applied for irrigation (acre-feet)
1957	26,500	1960	22,000
1958	18,900	1961	18,700
1959	22,100	1962	20,200
Average, 1957-62: (rounded)			21,400

Evapotranspiration by alfalfa, pasture, seed, and vegetable crops was determined by the Agricultural Research Service from measurements of soil-moisture depletion at selected sites. Moisture depletion was determined in 1957 by standard laboratory analysis of soil samples, and in succeeding years repeated field sampling was done by a neutron-scattering soil-moisture meter. The estimated evapotranspiration from the irrigated area of the Lompoc plain, as shown in table 9, averaged 16,700 acre-feet per year. Of this total, 5,000 acre-feet per year has been shown to be lost during the winter months when the precipitation occurred, and 11,700 acre-feet per year was lost during the irrigation period and was from pumped ground water.

TABLE 9.--*Estimated evapotranspiration (consumptive use) from the irrigated area of the Lompoc subarea, 1957-62*

(Blaney and others, 1963, p. 24)

Year starting May 1	Estimated evapotranspiration (acre-feet)	Year starting May 1	Estimated evapotranspiration (acre-feet)
1957	17,500	1960	16,200
1958	17,800	1961	15,700
1959	17,300	1962	15,700
Average (rounded)			16,700

Sewage Effluent

Sewage-treatment plants of the city of Lompoc and the Federal Correctional Institution discharge effluent into the Santa Ynez River; Vandenberg Air Force Base discharges sewage effluent by evaporation ponds and by an outfall pipe to the Pacific Ocean.

Sewage effluent from the city of Lompoc is metered at the treatment plant, and table 7 lists the record for the 6-year period of inventory. The effluent is discharged into the south side of the Santa Ynez River, approximately half a mile upstream from Dyer Bridge. Periodic observation during the period of inventory, at times of no flow in the river, indicated no effluent farther than about a mile downstream from the point of discharge. Sewage effluent from the Federal Correctional Institution is considered negligible compared to the effluent from the city of Lompoc.

TABLE 7.--*Metered sewage effluent, city of Lompoc, 1957-62*

(Records by the city of Lompoc)

Year	Sewage effluent (acre-feet)	Year	Sewage effluent (acre-feet)
1957	465	1960	849
1958	558	1961	881
1959	816	1962	882
Average: (rounded)			700

Items of Outflow

Surface Outflow

Surface outflow to the Pacific Ocean from the Lompoc subarea is measured at the stream gage--Santa Ynez River at barrier, near Surf. Surface-water outflow at this site ranged from 67 acre-feet in 1960 to 107,420 acre-feet in 1957 and averaged about 35,000 acre-feet for the 6-year period (table 8).

TABLE 8.--*Surface-water outflow from the Lompoc subarea, 1957-62*

Year starting May 1	Santa Ynez River at barrier, near Surf (acre-feet)	Year starting May 1	Santa Ynez River at barrier, near Surf (acre-feet)
1957	107,420	1960	67
1958	28,730	1961	70,421
1959	171	1962	2,732
Average (rounded)			35,000

Subsurface Outflow

Upson and Thomasson (1951, table 18, p. 80) calculated subsurface outflow (underflow) from the main water body to the ocean to be about 500 acre-feet per year on the basis of an estimated cross-sectional area of 110,000 square feet and a permeability of 4,000 gallons per day per square foot, and an average seaward hydraulic gradient of about 5 feet per mile. Wilson (1959, p. 81) on the basis of a gradient reduced from 5 to 3 feet per mile, lowered the estimate from 500 to 300 acre-feet per year. The gradient during the period 1957-62 also was about 3 feet per mile.

The estimated cross-sectional area has been reduced as a result of data from test drilling near the mouth of the river. Alluvial fill comprised of river channel deposits and younger alluvium, at this point is about 200 feet thick--the lower 125 feet is saturated gravel and sand; the upper 75 feet is mostly clay--the width of the material, normal to the direction of ground-water movement, is about 400 feet. Therefore, the cross-sectional area of the aquifer is approximately 50,000 square feet--about half the previous estimate. Accordingly, the subsurface outflow to the ocean for the 1957-62 period of inventory was about 150 acre-feet per year.

Evapotranspiration

Evapotranspiration (consumptive use) is defined as the total water transpired by plants, evaporated from soils and water surfaces, and evaporated from plant surfaces (Blaney and others, 1963, p. 11). As previously described, the average annual evapotranspiration was 31,400 acre-feet by native vegetation on the upland areas and 16,700 acre-feet from the irrigated area.

For the uncultivated area of the Lompoc plain evapotranspiration by native riparian vegetation along the Santa Ynez River was estimated by the U.S. Bureau of Reclamation to be about 6,700 acre-feet for 1959 and 5,800 acre-feet for 1962 (oral commun., 1964). The basis for this estimate was the acreage and density as determined from the aerial photographs and from computed rates of water use by cottonwoods, willows, brush, tules, and other natural vegetation. For the period of inventory the average annual evapotranspiration by native riparian vegetation was about 6,000 acre-feet, or about twice the previous estimate by Wilson (1959, p. 86).

From the preceding data, the total average annual evapotranspiration from the Lompoc subarea is estimated to be 54,100 acre-feet--31,400 acre-feet from the upland areas, 16,700 acre-feet from the irrigated areas, and 6,000 acre-feet from the uncultivated area of the Lompoc plain. Of the 16,700 acre-feet of evapotranspiration from the irrigated areas, 11,700 acre-feet was pumped ground water applied to the irrigated area. This value is reflected in the value for irrigation return (table 11). Therefore, the adjusted average annual evapotranspiration is 42,400 acre-feet.

Total Pumpage for All Uses

Total pumpage of water for all uses, including irrigation, is listed in table 10.

Water pumped from wells for uses other than irrigation--industrial, public supply, and military--is in large part metered.

The period of this inventory is 1957-62. However, pumpage estimates for the period 1953-56 are included to provide continuity with table 7 of Wilson (1959, p. 82). Although there is a difference of a month between table 10 of this report and table 7 of Wilson's, it is not significant to the inventory.

TABLE 10.--*Estimated pumpage, in acre-feet, from wells for all uses in the Lompoc subarea, 1953-62*

Year starting May 1	Irrigation pumpage	Other pumpage	Total
1953	14,000	1,500	15,500
1954	14,200	1,500	15,700
1955	18,000	1,500	19,500
1956	19,500	1,400	20,900
1957	26,500	1,500	28,500
1958	18,900	3,200	22,100
1959	22,100	6,400	28,500
1960	22,000	7,600	29,600
1961	18,700	8,800	27,500
1962	20,200	8,700	28,900
Average (rounded) 1957-62:	21,400	6,000	27,400

Ground-Water Storage Change

Wilson (1959, p. 58-60) estimated the ground-water storage capacity in five storage units of the Lompoc subarea. In each storage unit the volume of saturated deposits above a selected datum was multiplied by the estimated average specific yield of the unit to obtain the storage capacity.

Changes in the quantity of ground water in storage in the main aquifers of the Lompoc subarea beneath the Lompoc plain are estimated on the basis of observed changes in water levels in the shallow water body or in wells tapping the water table. A water-level decline indicates depletion of and a water-level rise indicates replenishment of the main aquifers. During the period of inventory (1957-62), ground-water storage changes have been observed beneath the eastern and central parts of the Lompoc plain and beneath the upland part of the Lompoc subarea to the north and east; no storage change has been noted beneath the western part of the Lompoc plain or beneath the upland part of the Lompoc subarea to the south. A detailed description of storage changes in the Lompoc subarea through 1952 is given by Wilson (1959, p. 60-78).

Water-level changes in wells perforated in confined aquifers (approximately the main water-bearing zone beneath the western two-thirds of the plain) represent pressure changes rather than significant changes in the quantity of water in storage. The hydrograph of well 7N/34W-27L1 (fig. 4) is typical of fluctuation in the recharge area, and the hydrograph of well 7N/35W-26J4 (fig. 4) is typical of fluctuation in the confined aquifers.

Changes in the quantity of ground water in storage beneath the eastern and central parts of the Lompoc plain (largely storage units 3 and 4, Wilson, 1959, p. 59) are estimated on the basis of water level in the shallow water body, recorded in eight wells for the period May 1957 to May 1963. Changes in water level ranged from an average decline of 4.5 feet over an area of about 9,800 acres to a rise of 2.5 to 3 feet over an area of about 2,300 acres. Estimated specific-yield value for the zone of water-level fluctuations within the larger area was about 12 percent; within the smaller area, about 18 percent. The estimated net decrease in the quantity of water in storage beneath the Lompoc plain from 1957 to 1963 was 4,100 acre-feet, only about 700 acre-feet per year.

Water-level decline in wells in the upland part of the subarea north and east of the Lompoc plain (fig. 5) has been consistent and uniform for the period of record; however, extensive upland areas have no water-level records available. The decrease in the quantity of ground water in storage for this area previously was estimated to be 2,400 acre-feet per year (Wilson, 1959, p. 75). The same value has been used in this report; consequently, the decrease in the quantity of ground water in storage in the upland area is about 14,400 acre-feet for the period of inventory.

Thus, for the 6-year period, the estimated total net depletion of the quantity of ground water in storage in the Lompoc subarea was about 18,000 acre-feet, an average of 3,000 acre-feet per year.

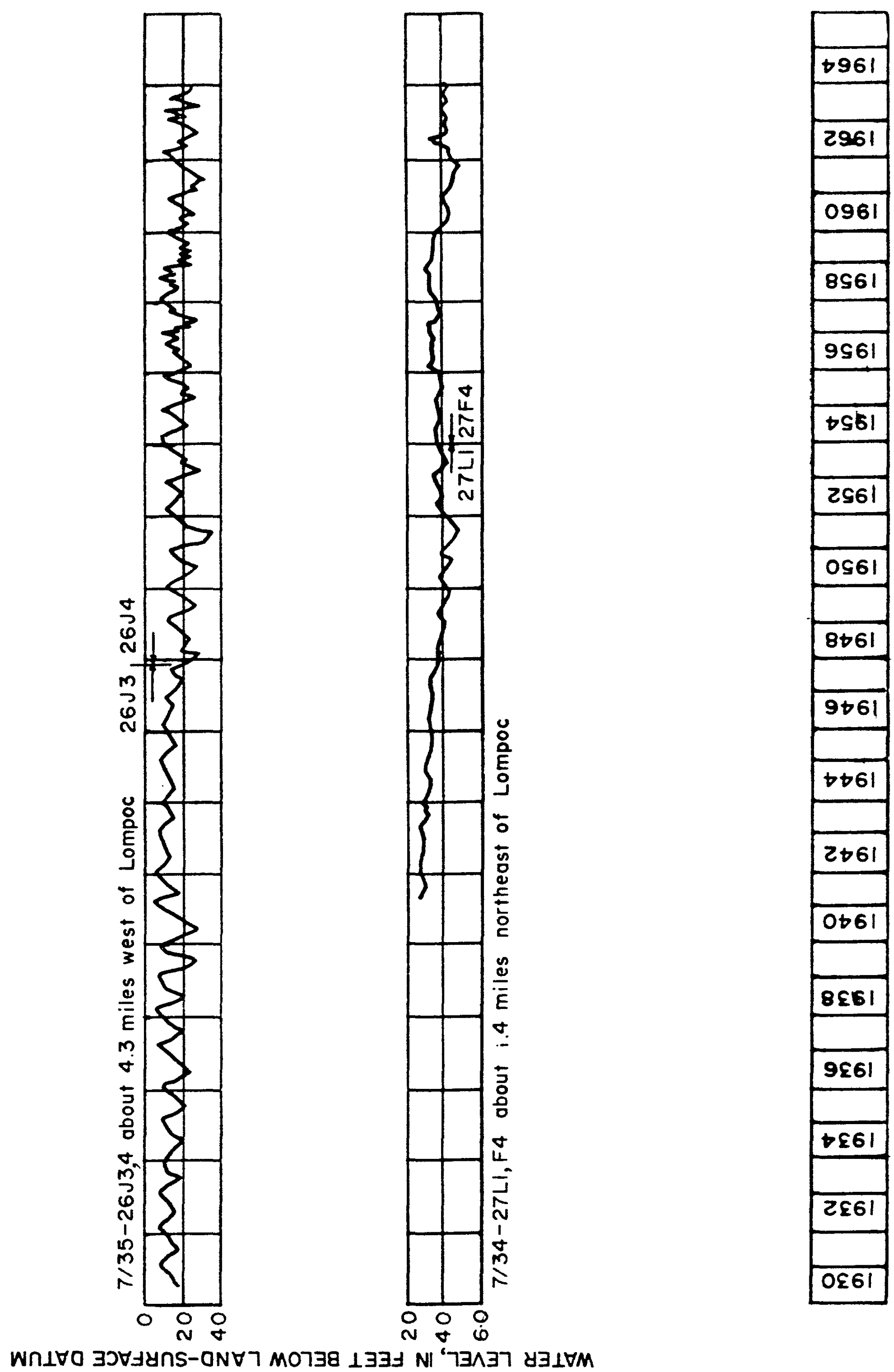

FIGURE 4.--Fluctuations of water level in two wells in the Lompoc subarea.

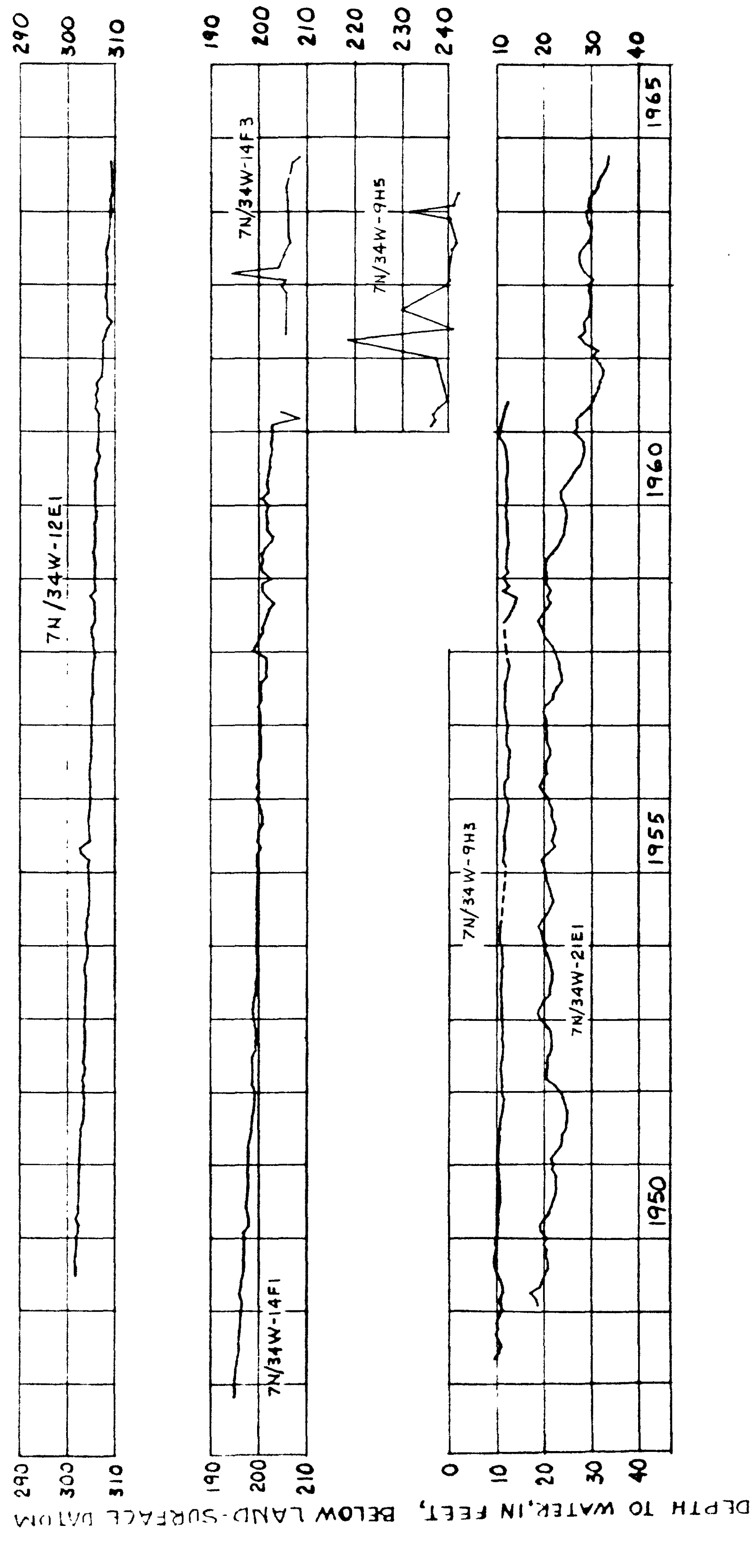

FIGURE 5.--Fluctuations of water level in six wells in the Lompoc subarea.

Hydrologic Equation

The elements of the hydrologic inventory for the Lompoc subarea are summarized in the equation shown in table 11. A near balance of the equation is indicated by an observed depletion of the quantity of ground water in storage, approximately 3,000 acre-feet, as compared to a calculated difference (indicating accretion) of 5,000 acre-feet. The difference of 8,000 acre-feet between the two values, considering the magnitude of the items of inflow and outflow--110,000 and 105,000 acre-feet--is not significant. However, it does indicate that errors in estimates of inflow, outflow, and storage depletion are not large, or are, at least, largely compensating.

TABLE 11.--*Summary of the hydrologic inventory, Lompoc subarea, 1957-62*

(May 1, 1957, to April 30, 1963)

Items of water inflow		Annual average (acre-feet)[1]
Santa Ynez River at The Narrows	(table 3)	42,600
Inflow from tributary streams	(table 3)	7,000
Subsurface inflow at The Narrows	(page 13)	1,500
Precipitation on Lompoc plain	(table 1)	15,000
Precipitation on upland part of Lompoc subarea	(page 11)	34,000
Irrigation return	(page 14)	9,700
Sewage effluent	(table 7)	700
Total water inflow		110,000

Items of water outflow		Annual average (acre-feet)[1]
Santa Ynez River outflow	(table 8)	35,000
Subsurface outflow to the ocean	(page 17)	150
Evapotranspiration from the Lompoc subarea	(page 17)	42,400
Water pumped from wells (gross)	(table 10)	27,400
Total water outflow		105,000

Inflow-	+110,000
Outflow=	-105,000
Difference, calculated	+5,000
Difference, indicated by change in quantity of ground water in storage	-3,000

[1]All values rounded to three significant figures.

For the 1957-62 period of inventory, the average precipitation (13.5 inches) is nearly 10 percent less than the 42-year average (14.6 inches) cited by Wilson (1959, p. 11). Therefore, this estimated inflow for the 6-year period is probably somewhat less than the long-term inflow.

One of the principal facts shown by the hydrologic equation is that the Santa Ynez River discharges more water from the basin than is pumped from wells. Although neither uniform nor consistent, the discharge indicates that, even with Cachuma Dam in operation, the Santa Ynez River has not been adequately regulated to salvage all the water.

Considering only recharge to the ground-water supply, several significant comparisons can be made between data for the 1935-44 and 1947-51 inventory periods and data for the 1957-62 inventory period, as shown in table 12. For those periods, average precipitation was 19.3 inches (Upson and Thomasson, 1951, p. 161), 7.9 inches (Wilson, 1959, p. 11), and 13.5 inches (Blaney and others, 1963, table 4, p. 24).

TABLE 12.--*Comparison of average annual recharge estimates*

	1935-44[1] (acre-feet)	1947-51[2] (acre-feet)	1957-62 (acre-feet)
Recharge (acre-feet)			
1. Santa Ynez River by underflow	600	1,500	1,500
2. Santa Ynez River seepage loss	2,500	500	7,600
3. Inflow from tributary streams	5,400	700	7,000
4. Infiltration of precipitation on Lompoc plain	4,800	[3] 0	3,500
5. Infiltration of precipitation on upland part of Lompoc subarea	([4])	[3] 900	2,600
6. Irrigation return	1,500	3,200	9,700
7. Sewage effluent	([4])	800	700
Total	14,800	7,600	32,600

[1]Upson and Thomasson (1951, p. 160).
[2]Wilson (1959, p. 86, table 8).
[3]Wilson (1959, p. 85).
[4]Omitted, not a significant item.

Table 12 shows that the total surface and subsurface inflow (items 1, 2, and 3) for 1957-62 amounted to almost twice the 1935-44 estimates--largely because of the additional storage space available as a result of lower ground-water levels and steeper ground-water gradients. Infiltration of precipitation (items 4 and 5) estimated for 1957-62 on the basis of limited field data, were not estimated for 1935-44 but were greater than for 1947-51.

Irrigation return (item 6) is indirectly estimated for 1957-62, but is about 3 to 6 times larger than the previous estimates. Thus, total estimated recharge for the near-normal climatic period (1957-62) is more than twice that for the above-normal 1935-44 period and more than four times that for the below-normal 1947-51 period.

The hydrologic equation for 1957-62, is also significant in that the ground-water inventory shows (1) an average annual pumpage from wells of 27,400 acre-feet resulted in (2) an estimated annual average depletion in storage of about 3,000 acre-feet. In general, this substantiates an earlier estimate by Wilson and Worts that a perennial pumpage in excess of 20,000 acre-feet (Wilson, 1959, p. 93) can be sustained.

There are, however, two limiting factors that were not recognized in deriving previous estimates of perennial pumpage for the Lompoc subarea. One of these factors is the progressive change in the ratio of irrigation pumpage to other pumpage, and the other is the change in ground-water quality.

A progressive change in the ratio of irrigation pumpage to other pumpage (table 10) is largely the result of additional water supplies required for municipal, industrial, and military developments, coupled with a reduction in irrigated acreage. As these developments are completed, a smaller percentage of water will be available as irrigation-return water, and the quantity of outflow may be larger. If the progressive change continues, more water will be withdrawn from storage to maintain the balance of the hydrologic equation.

Changes in ground-water quality in the main water-bearing zone of the Lompoc subarea are the result of mixing of the native water with (1) recycled irrigation water and (2) high chloride-low sulfate connate water from the consolidated rocks (Evenson, 1964, p. 54). The changes in ground-water quality indicate that chemical equilibrium has not been attained, even though an approximate balance in the hydrologic equation has been established. Continued monitoring of the water quality is necessary to determine future changes.

PERENNIAL SUPPLY

By R. E. Evenson and G. F. Worts, Jr.

Perennial supply for this study is considered to be the quantity of ground-water that can be withdrawn year after year without depleting the quantity of ground water in storage to such an extent that withdrawal at this rate is no longer feasible because of increased pumping costs or deterioration of water quality.

The fact that the hydrologic equation is in near balance for a period of near-average climatic conditions is an indication that the quantity of water pumped from wells is not significantly in excess of the replenishment to the ground water. Therefore, the previous estimate by Wilson and Worts (Wilson, 1959, p. 93) that perennial pumpage is somewhat in excess of 20,000 acre-feet is, in general, substantiated. Because of near-average climatic conditions, a slight refinement of the previous estimate can be made, using the items of the hydrologic equation in table 11. Perennial supply can be estimated as being equal to the average annual recharge less the unrecoverable water losses, which include evapotranspiration by native riparian vegetation and outflow to the ocean, or it can be equal to the average annual pumpage less the change in ground-water storage.

Perennial supply estimated by the recharge method is 26,000 acre-feet--32,600 acre-feet of recharge less 6,000 acre-feet of water loss by evapotranspiration of riparian vegetation less 150 acre-feet by subsurface outflow to the ocean. Perennial supply estimated by the pumpage method is 24,400 acre-feet--27,400 acre-feet of water pumped from wells, less 3,000 acre-feet decrease in the quantity of water in storage, less 150 acre-feet by subsurface outflow to the ocean. Thus, perennial supply under 1957-62 conditions is between 24,000 and 26,000 acre-feet.

As pumpage continues to increase, more water will be taken from storage in the main water-bearing zone. The principal result of this will be having storage space available to salvage more of the natural discharge from the Lompoc subarea. For the period 1957-62 the natural discharge of the Santa Ynez River at barrier, near Surf, was 35,000 acre-feet per year, and evapotranspiration losses averaged 6,000 acre-feet per year. Thus, even with the pumpage averaging 27,400 acre-feet per year, natural water losses from the basin were more than 40,000 acre-feet per year.

Wilson and Worts (Wilson, 1959, p. 91) proposed the limiting equation for perennial pumpage. Although a quantitative solution was derived by them, still remaining to be refined are two major elements of that equation: (1) Total unrecoverable water losses--these losses probably could be reduced to less than the 40,000 acre-feet per year for the period of this inventory, provided that wells are drilled near the river to provide greater opportunity for salvage of surface outflow (the largest natural loss) to the ocean; and (2) the maximum rechargeable and usable storage capacity, estimated to be 110,000 acre-feet (Wilson, 1959, p. 91). Only after substantial additional cultural development has occurred in the subarea can the necessary data be obtained to determine the perennial supply.

SUMMARY AND CONCLUSIONS

The hydrologic inventory is nearly in balance for a period of near-average climatic conditions and shows that the Santa Ynez River discharges more water from the basin than is pumped from wells. Estimates of items of recharge for 1935-44 compared with 1957-62, indicate increases in recharge from streamflow and irrigation-return water for 1957-62. The ground-water inventory shows that average pumpage from wells of 27,400 acre-feet resulted in an average depletion in the quantity of ground water in storage of 3,000 acre-feet, thus substantiating estimates that perennial yield is in excess of 20,000 acre-feet. Two factors that may limit perennial supply are (1) reduced recharge as more water is used for domestic and industrial supply and less for irrigation and (2) the changes in ground-water quality that result from recycled irrigation water and from mixing native water with connate water high in chloride but low in sulfate content. Complete chemical equilibrium has not been attained for the Lompoc subarea, and existing data are insufficient to accurately define ultimate equilibrium conditions. However, perennial supply for the Lompoc subarea is estimated to be between 24,000 and 26,000 acre-feet.

Effective water-resources management of the ground-water basin will require judicious planning for conjunctive use of both surface and ground water so that chemical equilibrium is attained. Such management must recognize that (1) limited circulation within the ground-water basin, because of geologic restrictions to the natural subsurface discharge, results in the recycling of ground water and, in addition, (2) poor-quality connate water from the consolidated rocks migrates into the basin, probably in relation to low or high water levels and artesian pressures (Evenson, 1964, p. 53).

Test drilling, now in progress, will provide additional data on sea-water intrusion, hydraulic gradients near the ocean, and the cross-sectional area of and the quality of water in the main water-bearing zone.

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GPO 972-876

U. S. GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
SANTA BARBARA COUNTY WATER AGENCY

FIGURE 2

66-42

Base map from U. S. Geological Survey Water-Supply Paper 1467

Geology mainly from Upson (Upson and Thomasson, 1951) and from Evenson and Miller (1963)

EXPLANATION

Qrc

River-channel deposits

Coarse sand and gravel in flood channel of the Santa Ynez River

Qyal

Younger alluvium

Clay, silt, sand, and gravel, beneath the alluvial plains and low terraces along the Santa Ynez River and including sand dunes along the coast

Recent — QUATERNARY

QTu

Unconsolidated marine and continental deposits

Sand, clay, and some gravel, includes terrace deposits, Orcutt Sand, Paso Robles Formation, Careaga Sand

Pliocene and Pleistocene

Boundary of consolidated rocks, undifferentiated

Mainly shale and mudstone of Miocene and Pliocene age, with alternating layers of sandstone

Miocene and Pliocene — TERTIARY

Contact

—?— D/U —

Probable fault

U, upthrown side; D, downthrown side

Queried where inferred

o C1

Well

MAP SHOWING GEOLOGY AND LOCATION OF SELECTED WELLS, LOMPOC SUBAREA, SANTA YNEZ RIVER BASIN, CALIFORNIA, 1957-62

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

1 0.5 0 1 2 3 KILOMETERS