GROUND-WATER RESOURCES IN THE LOMPOC AREA SANTA BARBARA COUNTY CALIFORNIA

U.S. GEOLOGICAL SURVEY

Open-File Report 76-183

PREPARED IN COOPERATION WITH THE CALIFORNIA WATER RESOURCES CONTROL BOARD

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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SANTA BARBARA COUNTY, CALIFORNIA

By G. A. Miller

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Menlo Park, California
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CONVERSION FACTORS

Factors for converting English units to metric units are given below to four significant figures. However, in this report the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	*Multiply by*	*Metric*
acres	4.047×10^{-1}	ha (hectares)
acre-ft (acre-feet)	1.233×10^{-3}	hm^3 (cubic hectometres)
ft (feet)	3.048×10^{-1}	m (metres)
ft/d (feet per day)	3.048×10^{-1}	m/d (metres per day)
ft^3/s (cubic feet per second)	2.832×10^{-2}	m^3/s (cubic metres per second)
ft/mi (feet per mile)	1.894×10^{-1}	m/km (metres per kilometre)
gal/min (gallons per minute)	6.309×10^{-2}	l/s (litres per second)
in (inches)	2.540×10	mm (millimetres)
Mgal/d (million gallons per day)	3.785×10^3	m^3/d (cubic metres per day)
mi (miles)	1.609	km (kilometres)
mi^2 (square miles)	2.590	km^2 (square kilometres)

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ABSTRACT

Water supplies in the Lompoc plain are pumped from highly permeable gravel and sand, which make up the main water-bearing zone. The history of ground-water quality in the Lompoc area shows little change in the Lompoc upland and the Lompoc terrace, but an increase in the concentration of dissolved solids in the main water-bearing zone beneath the Lompoc plain. Most water pumped from this zone is used for irrigation and contains dissolved solids in concentrations ranging from less than 500 to more than 3,000 milligrams per litre. The average concentration is about 1,500 milligrams per litre. The total hardness is more than 1,000 milligrams per litre, and most of this water contains more than 750 milligrams per litre sulfate; the most abundant ions are calcium, sodium, sulfate, and bicarbonate.

Changes in ground-water quality seem largely related to irrigation return, to inflow of native water of poor quality, to discharge of sewage effluent, and, in the shallow water-bearing zone, perhaps to the oxidation of sulfide minerals.

Average annual recharge to ground water in the plain from the Santa Ynez River, local tributaries, underflow, and infiltration of rain is about 14,000 acre-ft (acre-feet) or 17 hm^3 (cubic hectometres).

Discharge of ground water from the Lompoc plain is by pumping, evapotranspiration, streamflow, and underflow to the ocean. Pumpage during 1972 was about 23,000 acre-ft (28.4 hm^3), less than half of which probably returned to the main water-bearing zone.

Ground water in storage is about 220,000 acre-ft (270 hm^3) in the Lompoc plain area, more than 100,000 acre-ft (120 hm^3) in the Lompoc terrace area, and more than 400,000 acre-ft (490 hm^3) in the Lompoc upland area. During the period 1941-72, the aggregate depletion of storage in the three areas was about 60,000 acre-ft (74 hm^3).

Management alternatives to improve water quality in the main water-bearing zone of the Lompoc area include increasing the quantity of water available for recharge by importing water and salvaging more runoff and treated sewage effluent, by coordinating future releases from Lake Cachuma, by providing additional storage space in the aquifer by selective pumping, by changing patterns of water use, by selective pumping and transport of highly mineralized ground water from the area, and by pumping ground water of favorable quality from older aquifers or adjacent basins.

An adequate continuing water-quality monitoring program to evaluate changes would provide pertinent information for the prudent utilization of water resources.

INTRODUCTION

Purpose and Scope

The original purpose of this investigation, which was made in cooperation with the California Water Resources Control Board, involved the preparation of a salt balance for the ground-water system of the Lompoc plain. Because of the lack of data to do this accurately, the scope of work was modified by agreement with the cooperator to emphasize the present status of, and historical changes in, ground-water quality and the evaluation of management alternatives to maintain and improve its quality.

This report:

1. Describes the occurrence and movement of ground water beneath the Lompoc plain and in the adjacent hydraulically connected Lompoc terrace and Lompoc upland.

2. Discusses causes of present and potential changes in ground-water quality as they are related to (a) past conditions, (b) present conditions, and (c) probable future conditions.

3. Discusses general suitability of ground water for various uses, based on generally recognized quality standards.

4. Discusses possible management alternatives to improve ground-water quality.

5. Outlines a water-quality monitoring program.

Location and General Features

The Lompoc area occupies a coastal valley in western Santa Barbara County, Calif. (fig. 1). The nearly flat, alluvium-floored valley is bordered on the north by the Purisima Hills, on the east by the Santa Rita Hills, on the south by the Lompoc Hills, and on the west by the Pacific Ocean (figs. 1 and 2). It includes the Lompoc plain, the Lompoc terrace, and the Lompoc upland, which make up the Lompoc subarea of the Santa Ynez River basin as described by Upson and Thomasson (1951, p. 24-47). The altitude of the east end of the valley floor is about 120 ft (35 m) above sea level; the valley slopes westward toward the ocean to an altitude of a few feet above sea level near Surf. The Santa Ynez River, the major stream in the area, heads in the Santa Ynez Mountains about 60 mi (95 km) east of Lompoc and drains an area of about 800 mi^2 (2,070 km^2). The river is not perennial across the entire plain; flow is maintained by ground water near the ocean. Several small streams, some with perennial flow, enter the valley from the Lompoc Hills; no perennial surface flow enters the valley from the terrace area.

Lompoc (population about 24,000 in 1970), the largest town in the area, was settled in the 19th century as a farming and ranching community. Vandenberg Village and Mission Hills (fig. 2) are space-age communities that were established during the late 1950's-early 1960's. Vandenberg AFB (Air Force Base) is a large Strategic Air Command installation with allied facilities of the National Aeronautics and Space Agency.

Important aspects of the economy include truck farming and associated food processing, flower raising (both seed and cut flowers), mining and processing of the largest deposit of diatomite in the United States, a Federal prison, and the Lompoc oil field.

Almost all the water used in the area is pumped from wells, the major part pumped from beneath the Lompoc plain for agricultural purposes. The city of Lompoc, Vandenberg AFB, Vandenberg Village, and Mission Hills pump some ground water for municipal use. Locally, a few small springs and perennial streams supply water for limited uses.

The local climate is a modified Mediterranean type; almost all precipitation occurs as rain during the period October-April. Coastal fog is common in the valley throughout the year. The average precipitation at Lompoc during the period 1952-72 was 13 in (330 mm), ranging from a low of 6.42 in (163 mm) in 1956 to a high of 29.29 in (744 mm) in 1952.

The graph of cumulative departure from average precipitation at Lompoc (fig. 3) illustrates the periods of generally above-average and below-average precipitation from 1951 to 1972. The periods of above-average precipitation are shown by a rising line, and the periods of below-average precipitation by a declining line. Mean annual temperature at Lompoc is about 57°F (13.9°C). Killing frosts on the valley floor are extremely rare.

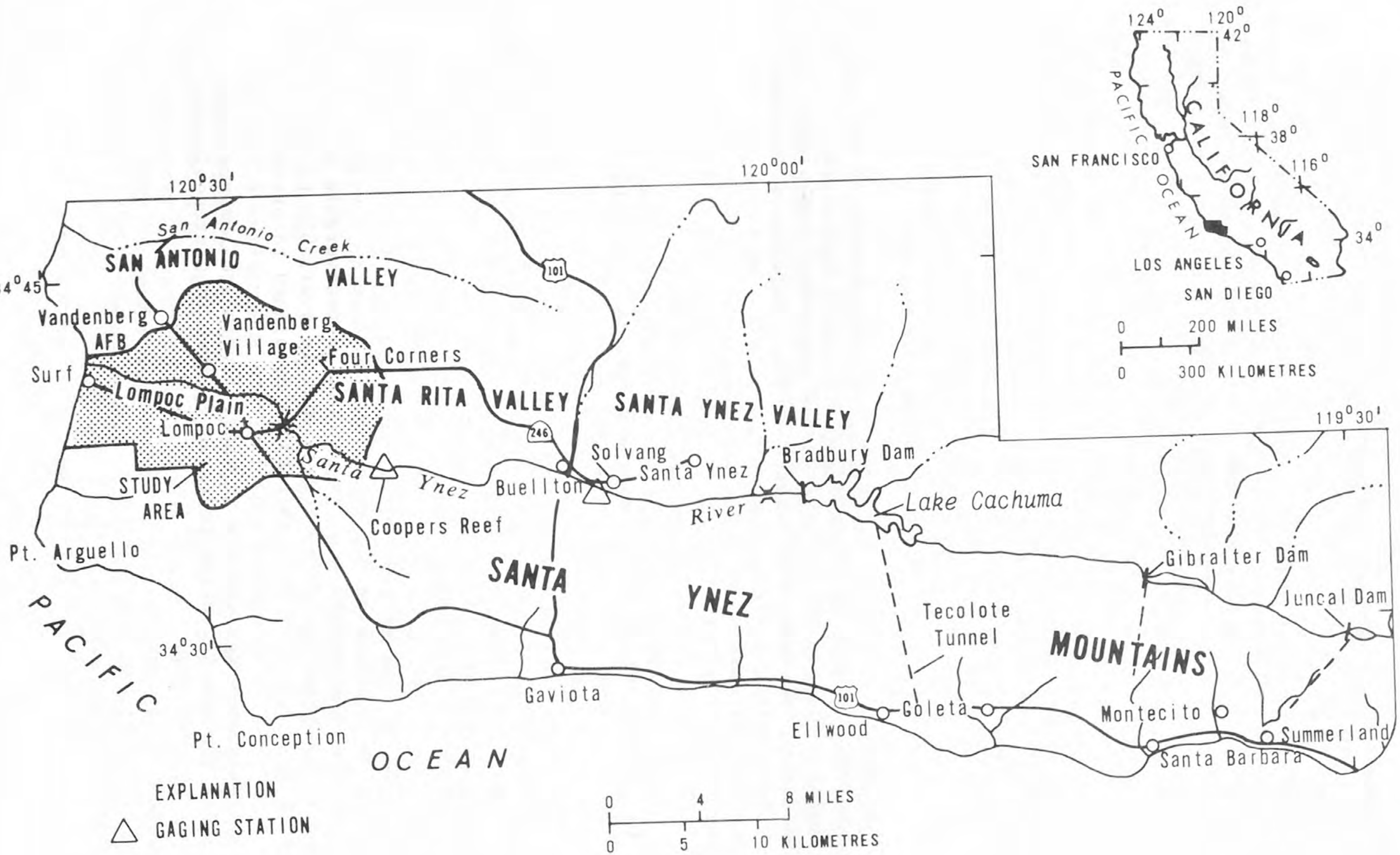


FIGURE 1.--Index map.

Field and Laboratory Methods

Although about 60 small-diameter, shallow exploratory test wells had previously (1941-66) been augered on the Lompoc plain by the U.S. Geological Survey, fewer than 10 were found during this study. This necessitated the augering of an additional 15 test wells, ranging in depth from 5 to 100 ft (1.5 to 30 m) in the area. Some holes were cored and most were cased with plastic pipe equipped with sand point screens. Of the 15 test holes, 8 were located to investigate the effects of a sheet-piling barrier near Surf, 2 were in the terrace deposits north of the Lompoc plain, and the remaining 5 were in the eastern and central parts of the plain.

Prior to 1971, almost 1,500 water analyses, from measurements of electrical conductance to chemical determination of all major and some minor constituents, were available for study in the Lompoc area. The earliest chemical data for water from several wells in the plain are for 1935. About 98 percent of the water samples in the area were collected after 1940. The analyses were of water from more than 300 wells, most of which are on the plain; only one analysis, however, was available from most wells. Almost all these wells are perforated in the main water-bearing zone.

During 1971-73 about 80 additional samples of ground water from wells were collected for chemical analysis by the Geological Survey. Most of the samples of ground water were collected in the spring of 1972. In addition, several analyses of ground water pumped during this same period were obtained from the California Department of Water Resources, the city of Lompoc, the U.S. Bureau of Reclamation, Vandenberg AFB, and from other pumpers in the area.

Samples of raw water taken for general analysis during this study were divided in the field into three separate 250-ml (millilitres) samples each as follows: (1) One filtered through a 0.45-micrometre filter for the determination of silica, chloride, fluoride, boron, and nitrate; (2) a second one, filtered as above and acidified to a pH of about 3 using double-distilled, reagent-grade nitric acid, for the determination of iron, calcium, magnesium, sodium, and potassium; and (3) a third one untreated for the determination of bicarbonate, sulfate, pH, and electrical conductivity.

In addition, several samples of ground water were filtered and chilled for shipment to the laboratory for the determination of phosphorus and a few 1-litre samples were filtered and acidified for determination of heavy metals. One sample of streambed material was taken for the determination of pesticides and insecticides.

The specific conductance of water from about 40 additional wells was measured in the field using a portable, bridge-type conductivity meter.

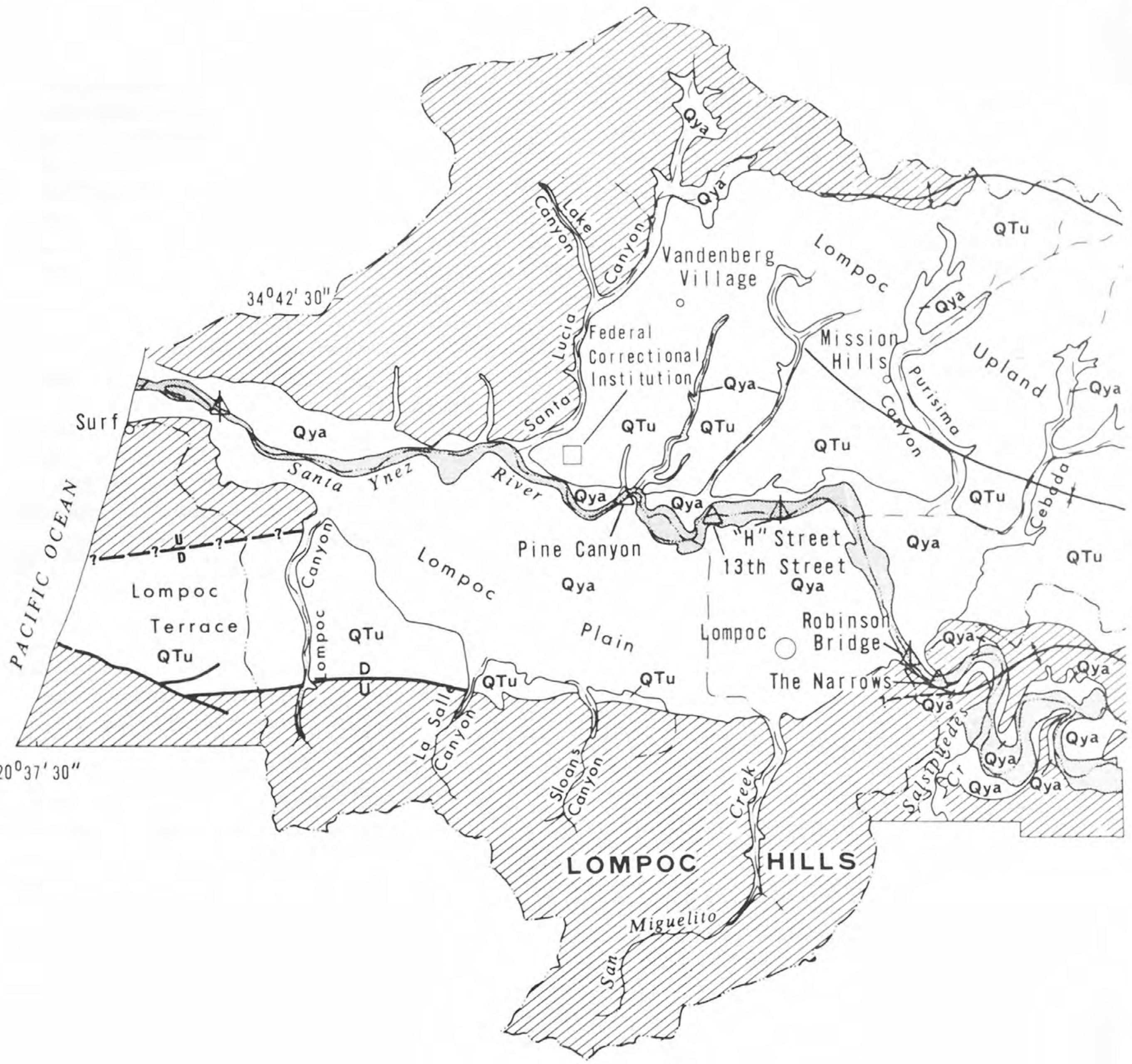
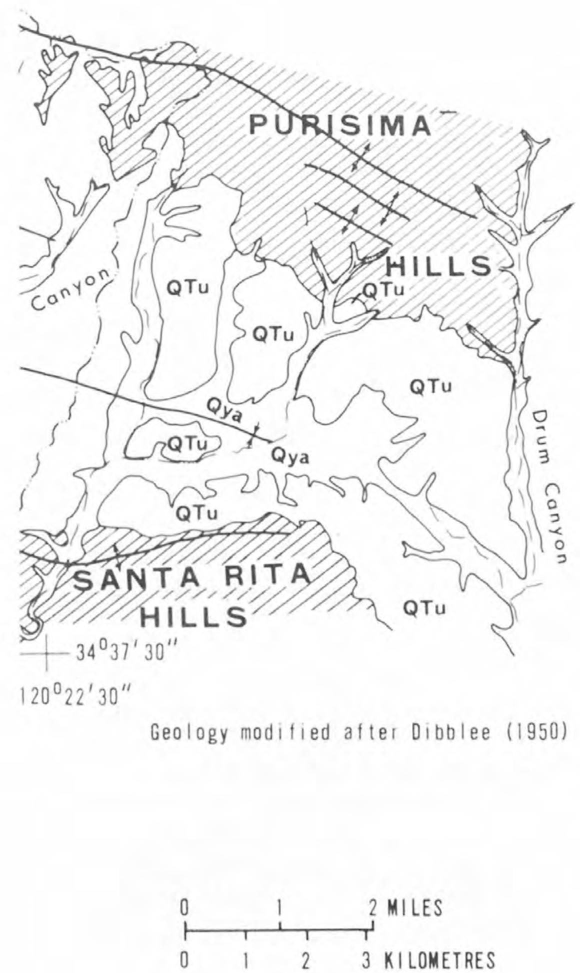


FIGURE 2.--Generalized geology of Lompoc area.



EXPLANATION

RIVER-CHANNEL DEPOSITS OF HOLOCENE AGE--Sand and gravel in flood channel of Santa Ynez River

Qya — YOUNGER ALLUVIUM OF HOLOCENE AGE--Sand, gravel, silt, and some clay; beneath Lompoc plain upper member predominantly sand and silt; lower member predominantly gravel and sand

QTu — TERRACE DEPOSITS, ORCUTT SAND, PASO ROBLES FORMATION, AND CAREAGA SAND OF PLIOCENE AND PLEISTOCENE AGE--Sand, gravel, silt, and some clay

CONSOLIDATED ROCKS OF TERTIARY AGE--Mostly sandstone, shale, diatomite, and mudstone of the Monterey, Sisquoc, and Foxen Formations

DRAINAGE DIVIDE

GEOLOGIC CONTACT

FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

GAGING STATION

FORMER GAGING STATION

FIGURE 2.--Continued.

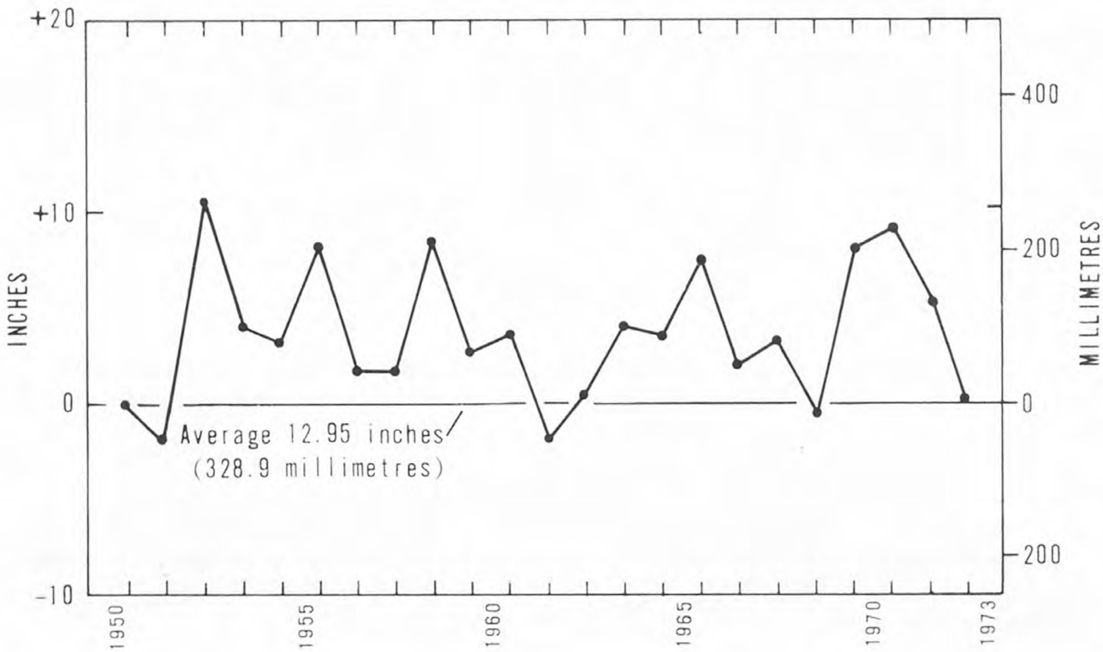


FIGURE 3.--Cumulative departure from average precipitation at Lompoc, 1951-72.

Fifteen water samples from the Santa Ynez River were analyzed by the Geological Survey during the period 1971-73, and 15 samples from local tributaries were analyzed during 1972-73. During this same period, the spring and summer of 1973, the channel-geometry characteristics of all the major local tributaries were measured in order to estimate annual streamflow. The depth to water was measured in about 80 wells during March 1972. Additional concurrent water-level measurements were obtained from the U.S. Bureau of Reclamation.

Previous Work and Acknowledgments

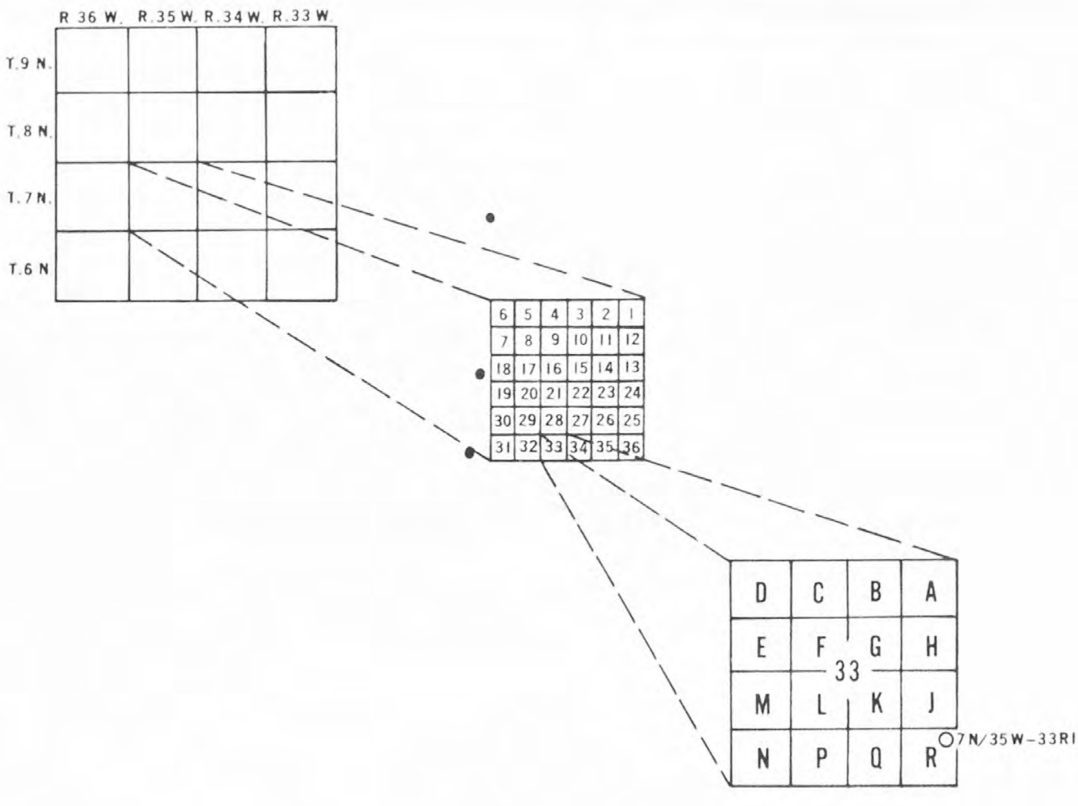
Several studies provided background data and interpretations that were relied upon in the present study. Dibblee (1950) and Woodring and Bramlette (1950) mapped the geology of the area; the work of Upson and Thomasson (1951), Wilson (1959), and Evenson and Miller (1963) provided a basic understanding of the geologic and hydrologic framework of the area. Blaney, Nixon, Lawless, and Wiedmann (1963) studied the water resources and climate as related to agriculture, and Evenson (1965, 1966) described the changing quality of ground water and made a hydrologic inventory in the Lompoc plain. LoBue (1968) investigated waste discharges in the Lompoc area, and Nishimura (1972) reported on the occurrence of nitrate in ground water. Reports by the engineering firms of Brown and Caldwell (1972) and of Converse, Davis and Associates (1972) furnished information on waste-water management and data on the shallow ground-water zone. Several annual reports on ground water in Santa Barbara County by the Geological Survey contain data on water quality in the area. Additional unpublished data are in the files of the Survey.

The California Department of Water Resources, Southern District, and the U.S. Bureau of Reclamation provided water-quality data; the city of Lompoc, Vandenberg AFB, the Mission Hills Water Co., and Vandenberg Village Utility Co. kindly furnished hydrologic data. The author expresses his gratitude to the many farmers who provided information on crops and fertilizer use and made possible the collection of water samples and other field data. Mr. Robert M. Alexander, a local well driller, provided data on specific wells and information on the general geohydrologic conditions. Dr. James Rhoads of the U.S. Salinity Laboratory, Riverside, Calif., graciously provided assistance and laboratory facilities for the determination of soil conductivities. Mr. Robert A. Fellows of Union Oil Co., Orcutt, Calif., furnished geologic data on the deep aquifers in the area, and Mr. Eldon J. Lomnes of the Johns-Manville Co. furnished hydrologic data and assisted in sampling wells in San Miguelito Canyon. Mr. Paul R. Nixon of the U.S. Department of Agriculture kindly allowed the author to use his unpublished hydrologic data. Several colleagues of the Geological Survey provided noteworthy assistance during the course of the study: Mark W. Busby in the channel-geometry studies, John R. Freckleton during test augering and data collection, and Charles O. Morgan in automatic data processing and computer programing.

Well- and Spring-Numbering System

Wells and springs in California are numbered according to their location in the rectangular system for subdivision of public land. For example, for well 7N/35W-33R1, that part of the number preceding the slash indicates the township (T. 7 N.); the number following the slash indicates the range (R. 35 W.); the number following the hyphen indicates the section (sec. 33); the letter following the section number indicates the 40-acre (16-ha) subdivision of the section according to the lettered rectangle in the diagram below.

The final digit is a serial number for wells in each 40-acre (16-ha) subdivision. The numbering of springs in this report is the same as for wells except that an S is used between the 40-acre (16-ha) subdivision letter and the final digit as shown in the following: 7N/34W-24ES1. The final digit is omitted when used as a location number, for example, for water-sampling points along streams. The area covered by the report lies entirely in the northwest quadrant of the San Bernardino base line and meridian.



Where a Z has been substituted for the letter designating the 40-acre (16-ha) tract, the Z indicates that the well is plotted from unverified location descriptions.

GROUND-WATER GEOLOGY

Water-Bearing Units

The geologic units (fig. 2) consist of two categories, based on their water-bearing characteristics: (1) Consolidated rocks of Tertiary age, largely sandstone, shale, mudstone, and diatomite that contain ground water mostly in fractures, and yield water to wells at rates of from a few gallons to several hundred gallons per minute; and (2) unconsolidated deposits of Pliocene and younger age, largely sand, gravel, silt, and some clay. These deposits contain ground water in the interstices and yield water to wells at rates of from several hundred to more than 1,000 gal/min (63 l/s). In general, the chemical quality of water in the unconsolidated deposits is better than in the consolidated rocks.

Consolidated rocks that are important hydrologically are, from oldest to youngest, the Monterey Shale of Miocene age, the Sisquoc Formation of Miocene and Pliocene age, and the Foxen Mudstone of Pliocene age. Dibblee (1950, p. 34-35), Woodring and Bramlette (1950, p. 18-42), and Upson and Thomasson (1951, p. 31-32) described these rocks in detail. The aggregate thickness of these units is as much as several thousand feet (Dibblee, 1950, p. 34-35).

The character of water-bearing units is summarized in table 1.

The Monterey Shale typically is a thin-bedded, silica-cemented to cherty, diatomaceous shale. The cherty beds commonly are fractured, in particular along the crests of folds and in fault zones. Local areas of potable ground water occur where streamflow recharges the shale. Several wells that tap the Monterey Shale, in canyons south of the Lompoc plain, yield small quantities of water for domestic supplies, and a few industrial-supply wells in San Miguelito Canyon yield as much as several hundred gallons per minute from the Monterey Shale (Eldon J. Lomnes, oral commun., 1972). Brine occurs in the formation, as indicated by test-well data (Evenson, 1965, p. 7) and by brine that accompanies petroleum production in the Lompoc oil field.

Ground water occurs in the Sisquoc Formation in fractures and as interstitial water in diatomaceous rock. A few domestic wells of low yield produce water from the Sisquoc Formation in some of the canyons south of the Lompoc plain. Brackish water occurs in the Sisquoc Formation near the south edge of the plain west of Lompoc Canyon, in the Lake Canyon area, and probably in other local areas.

The top of the Foxen Mudstone generally coincides with the base of the productive aquifer system in the area and in most places marks the base of the fresh ground water. It acts as a confining bed separating the generally brackish water in the underlying rocks from fresh water in overlying unconsolidated deposits.

TABLE 1.--*Summary of water-bearing units*

[Modified from Upson and Thomasson, 1951, p. 28-29]

Geologic age		Geologic unit and map symbol	Thickness (feet)	General character	Water-bearing properties
Quaternary	Holocene	River-channel deposits Qrc	30-40	Coarse to fine sand with some gravel lying in channel of Santa Ynez River	Permeable, not tapped by wells in Lompoc plain; in upstream areas yields 500-1,000 gallons per minute to wells
Quaternary	Holocene	Younger alluvium Qya	0-180	Gravel, sand, silt, and some clay underlying Lompoc plain and tributary streams. Includes channel deposits of tributaries. Comprises two members; lower member largely gravel and sand; upper member largely fine sand and silt	Permeable lower member is principal source of water in Lompoc plain and makes up most of main water-bearing zone; yields 1,000 gallons per minute or more to many wells; upper member slightly to moderately permeable; tapped by a few domestic wells
Quaternary and Tertiary	Pleistocene and Pliocene	Terrace deposits, Orcutt Sand, Paso Robles Formation, and Careaga Sand QTu	Aggregate thickness several thousand feet; maximum total thickness locally about 1,500 feet	In large part unconsolidated gravel, sand, silt, and some clay; local outcrops somewhat indurated; generally poorly sorted except for Careaga Sand which consists largely of moderately well to very well sorted very fine sand with local gravel lenses near the base	Moderately permeable, thick section yields from several hundred to about 1,000 gallons per minute to several wells
Tertiary	Pliocene and Miocene	Foxen, Sisquoc, Monterey, and older formations	Several thousand	Shale, mudstone, diatomite, and sandstone	Slightly permeable to almost impermeable, fractured zones, yield a few gallons to a few hundred gallons per minute to wells. Tapped by few wells, generally brackish water.

Unconsolidated deposits that are of most importance hydrologically are the Careaga Sand of Pliocene age, the Paso Robles Formation of Pliocene and Pleistocene(?) age, the Orcutt Sand and terrace deposits of Pleistocene age, and the younger alluvium and river-channel deposits of Holocene age. The Careaga Sand, Paso Robles Formation, and Orcutt Sand are not extensively tapped by wells but contain large quantities of water in storage. They occur chiefly beneath the Lompoc terrace, beneath the alluvium throughout the eastern two-thirds of the Lompoc plain, and beneath the Lompoc upland.

The Careaga Sand is a fine- to coarse-grained sand of marine origin. Lenses of permeable, fossiliferous sand and gravel occur locally at the base. The abundance of very fine, well-sorted loose sand has resulted in sanding problems in several wells that are cased using large perforations and a gravel-pack finish. The unit is as much as 700 ft (210 m) thick in the Purisima Hills northeast of Lompoc and 600-700 ft (180-210 m) thick in the Lompoc Canyon area (Evenson and Miller, 1963, p. 9). Most of the Careaga Sand is below the water table. Several wells tap both the Careaga and the overlying formations in the Lompoc terrace, Lompoc upland, and east of the plain in the Santa Rita Valley. Many of these wells yield several hundred gallons per minute. According to Upson and Thomasson (1951, p. 34) the hydraulic conductivity (permeability) of the Careaga Sand in this area is about 9 ft/d (3 m/d). The Careaga Sand underlies the alluvium beneath much of the Lompoc plain (Upson and Thomasson, 1951, pl. 5) and transmits water to the intensively pumped lower member of the alluvium (Wilson, 1959, p. 58). Water from most wells that tap the Careaga Sand is generally of better quality than that in the alluvium beneath the Lompoc plain.

The Paso Robles Formation, consisting of poorly sorted sand, gravel, silt, and clay, probably was deposited as a series of coalescing alluvial fans. The formation is as much as 700 ft (210 m) thick in the Santa Rita Valley but thins westward and apparently is not present beneath the western part of the Lompoc plain (Dibblee, 1950, p. 47; Upson and Thomasson, 1951, p. 35, pls. 4, 5). The Paso Robles Formation contains large quantities of water of usable quality north and east of the Lompoc plain and probably transmits ground water to the alluvium as underflow in the eastern part of the plain. Municipal supply wells at Vandenberg Village and Mission Hills and irrigation wells in Cebada Canyon and in Santa Rita Valley derive much of their water from the Paso Robles Formation. Upson and Thomasson (1951, p. 38) reported that wells that tap the Paso Robles Formation yield from less than 200 gal/min (13 l/s) to more than 1,000 gal/min (63 l/s) of water in the Santa Ynez Valley.

The Orcutt Sand crops out as a thin mantle over much of the Lompoc upland. The Orcutt Sand underlies the younger alluvium beneath the southern and southwestern parts of the Lompoc plain (Upson and Thomasson, 1951, p. 40, pl. 5), where it is tapped by wells. Most of the Orcutt is above the water table, but it readily accepts recharge from precipitation and locally contains perched ground water in the Lompoc upland. This perched water discharges in small seeps and springs and contains the lowest known concentration of dissolved solids of all ground water in the area.

Deposits of sand and gravel that may be buried terrace deposits underlie the alluvium along most of the south edge of the Lompoc plain (Upson and Thomasson, 1951, p. 41, pl. 5), where they are tapped by many wells that yield several hundred gallons per minute. Correlative deposits also mantle terraces in the southern part of the Lompoc upland. These surficial deposits range in thickness from 0 to 150 ft (45 m) and are similar in hydrologic character to the Orcutt Sand.

As much as 180 ft (55 m) of younger alluvium of Holocene age (Upson and Thomasson, 1951, p. 43) underlies the Lompoc plain. The material is separated into a lower and upper member and consists largely of sand and gravel, with locally abundant silt and some clay. The deposits constitute the major aquifer in the plain. The lower member of the younger alluvium, which is as much as 110 ft (30 m) thick, is the most utilized aquifer in the plain. It consists of sand and gravel that commonly yields as much as 1,000 gal/min (63 l/s) of water to wells. This unit and the buried terrace deposits along the south side of the plain are referred to herein as the main water-bearing zone.

The upper member of the younger alluvium consists of fine sand, silt, and some clay and ranges in thickness from about 75 to more than 100 ft (22 to 30 m) and is herein termed the shallow zone. The unit acts as a leaky confining layer over the main water-bearing zone. It is thicker and contains more silt and clay toward the west end of the plain (Upson and Thomasson, 1951, p. 146, pl. 5). Several test holes augered 50-100 ft (15-30 m) into the upper member of the younger alluvium penetrated mostly fine sand. Several wells of low yield have been drilled in the upper member for domestic supplies in the plain. The water in the shallow zone is of marginal quality for many uses.

River-channel deposits 30-40 ft (9-12 m) thick (Upson and Thomasson, 1951, p. 49) lie in the active channel of the Santa Ynez River. These loose deposits of sand and gravel are partly saturated but are not tapped by wells in the Lompoc plain. In upstream areas these deposits yield 500-1,000 gal/min (32-63 l/s) to wells. They transmit seepage during floods as recharge to the younger alluvium.

Geologic Structure

The younger alluvium beneath the Lompoc plain may be undisturbed by folding and faulting. The alluvium rests on the south limb of the Santa Rita syncline (Dibblee, 1950, pl. 7). The Careaga Sand and older rocks crop out at several places along the south edge of the plain where they dip steeply (20°-50°) to the north perhaps along a fault zone that borders the plain (Evenson, 1965, p. 7). The base of the younger alluvium slopes westward (downstream) throughout most of the plain. Figures 4 and 5 are diagrammatic sections across the plain.

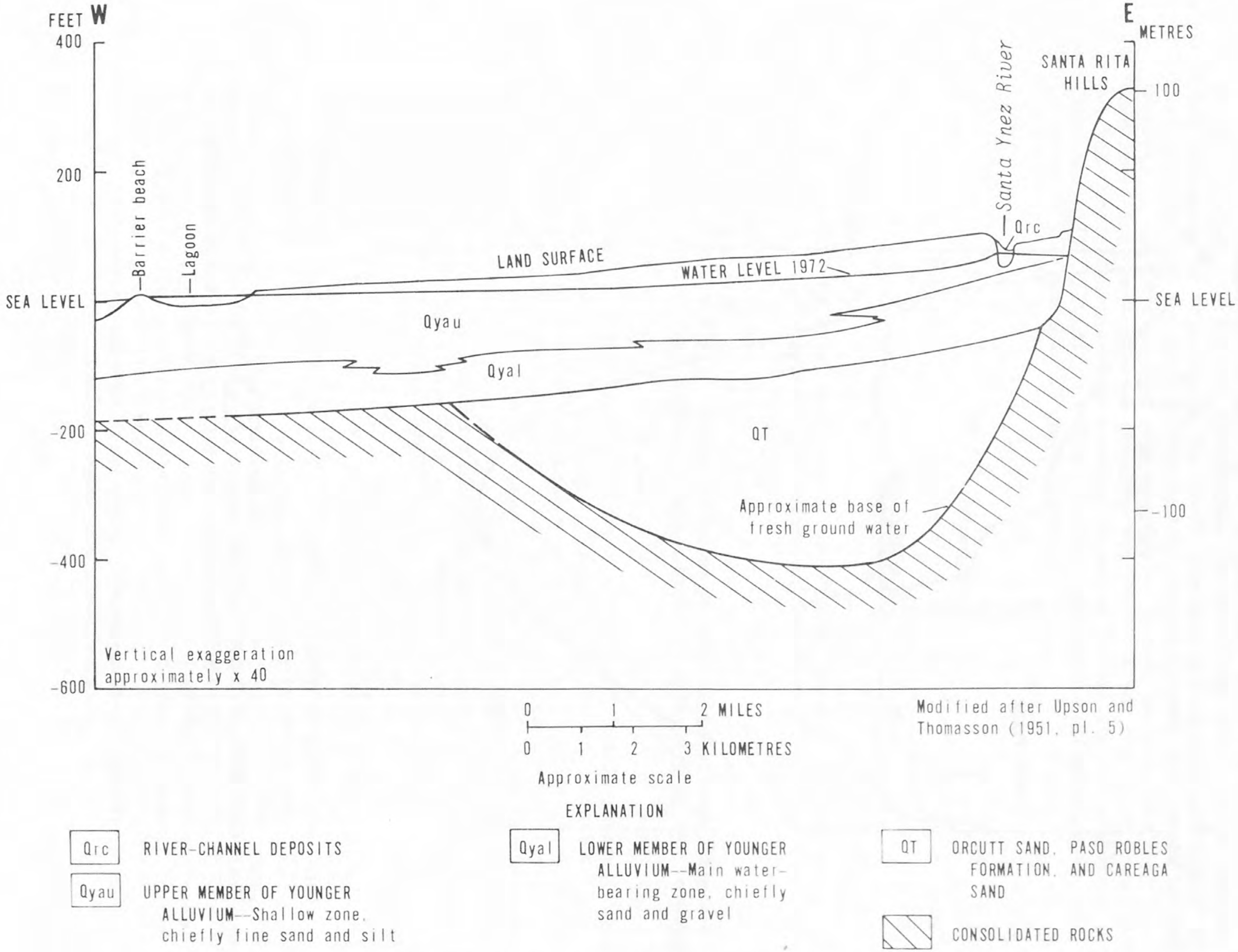


FIGURE 4.--Diagrammatic east-west section across Lompoc plain.

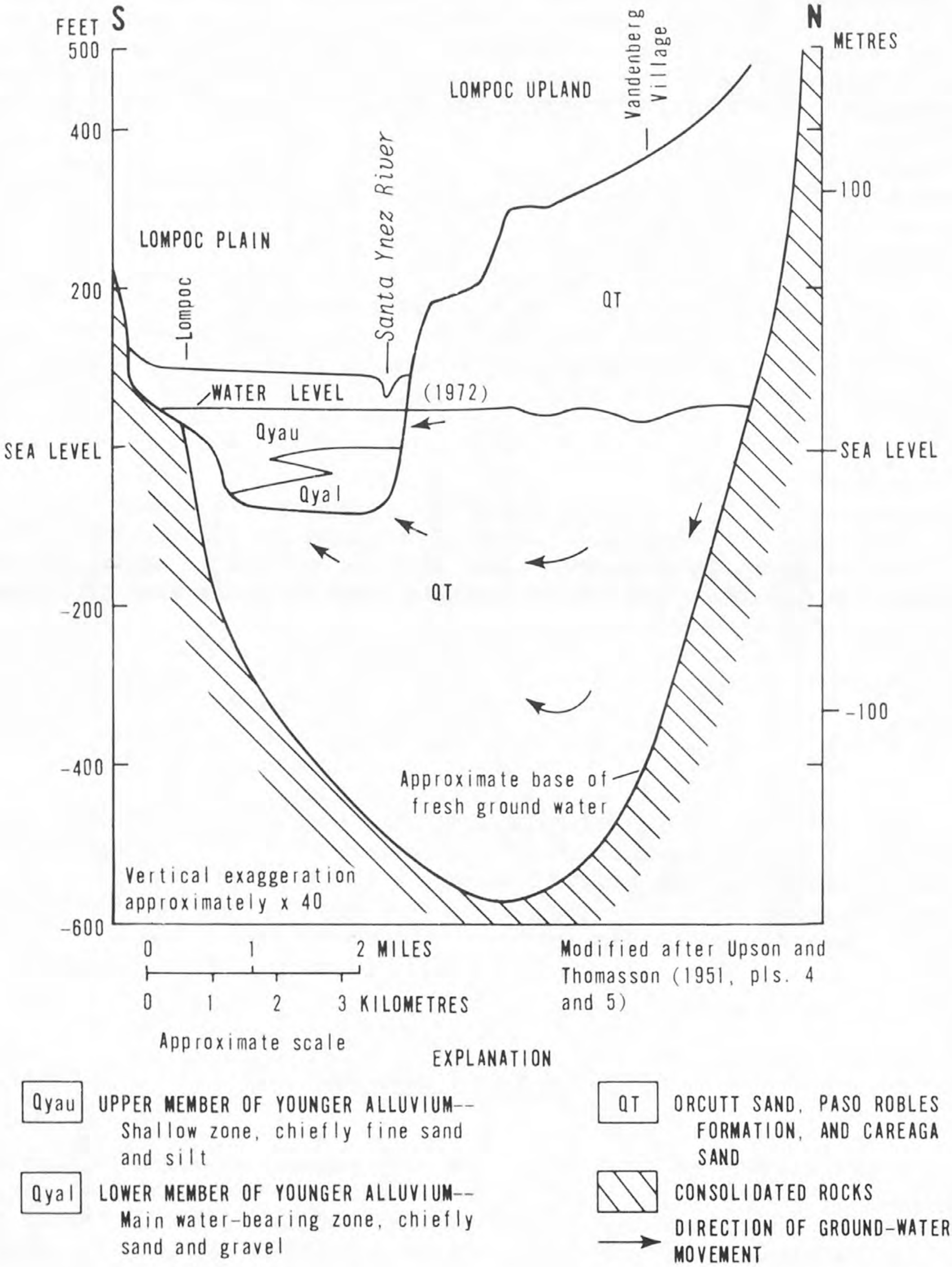


FIGURE 5.--Diagrammatic north-south section across Lompoc plain and Lompoc upland.

The Lompoc terrace is made up of a generally south-dipping wedge of unconsolidated Pliocene and Pleistocene deposits that are in fault contact with consolidated rocks along the south boundary and perhaps along part of the north boundary of the basin. The aquifer system beneath the Lompoc upland consists of the Careaga Sand and Paso Robles Formation that have been downwarped into an east-west trending syncline. A few faults of local extent cut the unconsolidated water-bearing deposits in this area (Upson and Thomasson, 1951, pl. 3), but none of these are known to form significant barriers to the movement of ground water.

HYDROLOGY

Surface Water

The Santa Ynez River is normally dry throughout most of the reach across the Lompoc plain. Perennial flow occurs in two areas: (1) Near the west end of the plain where ground water and some irrigation tail water discharge into the river; and (2) where sewage effluent from the city of Lompoc sewage-treatment plant flows in the reach from 7N/34W-29G (fig. 6) to the vicinity of sec. 24, T. 7 N., R. 35 W. Large flows occur only during floods, almost always during the winter months. These floods provide part of the recharge to the alluvium beneath the plain.

The regimen of flow has been altered since Upson and Thomasson (1951, p. 55-91) and Wilson (1959, p. 11-16) described the river. Bradbury Dam (formerly called Cachuma Dam), completed in 1953 on the river about 30 mi (48 km) upstream from the Lompoc plain, was designed to divert almost 30,000 acre-ft (37 hm^3) of water annually from the Santa Ynez drainage basin to the Santa Barbara coastal area. This diversion plus an annual evaporation from the lake of about 10,000 acre-ft (12 hm^3) or more (Busby, 1973; U.S. Bureau of Reclamation, 1971; 1972) and the streamflow regulation by Lake Cachuma have tended to diminish the flow at Lompoc during floods that originate in the upstream area (fig. 7). Also, pumping of ground water along and adjacent to the river between the dam and the Lompoc plain has contributed to lowered ground-water levels near the channel, allowing more seepage of floodwater and thus lessening the flow that reaches Lompoc.

Figure 8, a flow-duration curve, shows some aspects of the character of streamflow at three gaging stations on the Santa Ynez River near where it enters and where it crosses the Lompoc plain. The nature of the flow duration at all three stations is similar for flows above about 100 ft^3/s (2.8 m^3/s). At progressively lower flows to about 5 ft^3/s (0.1 m^3/s), the diminished duration at the two downstream stations probably is due to seepage losses to the underlying ground-water reservoir.

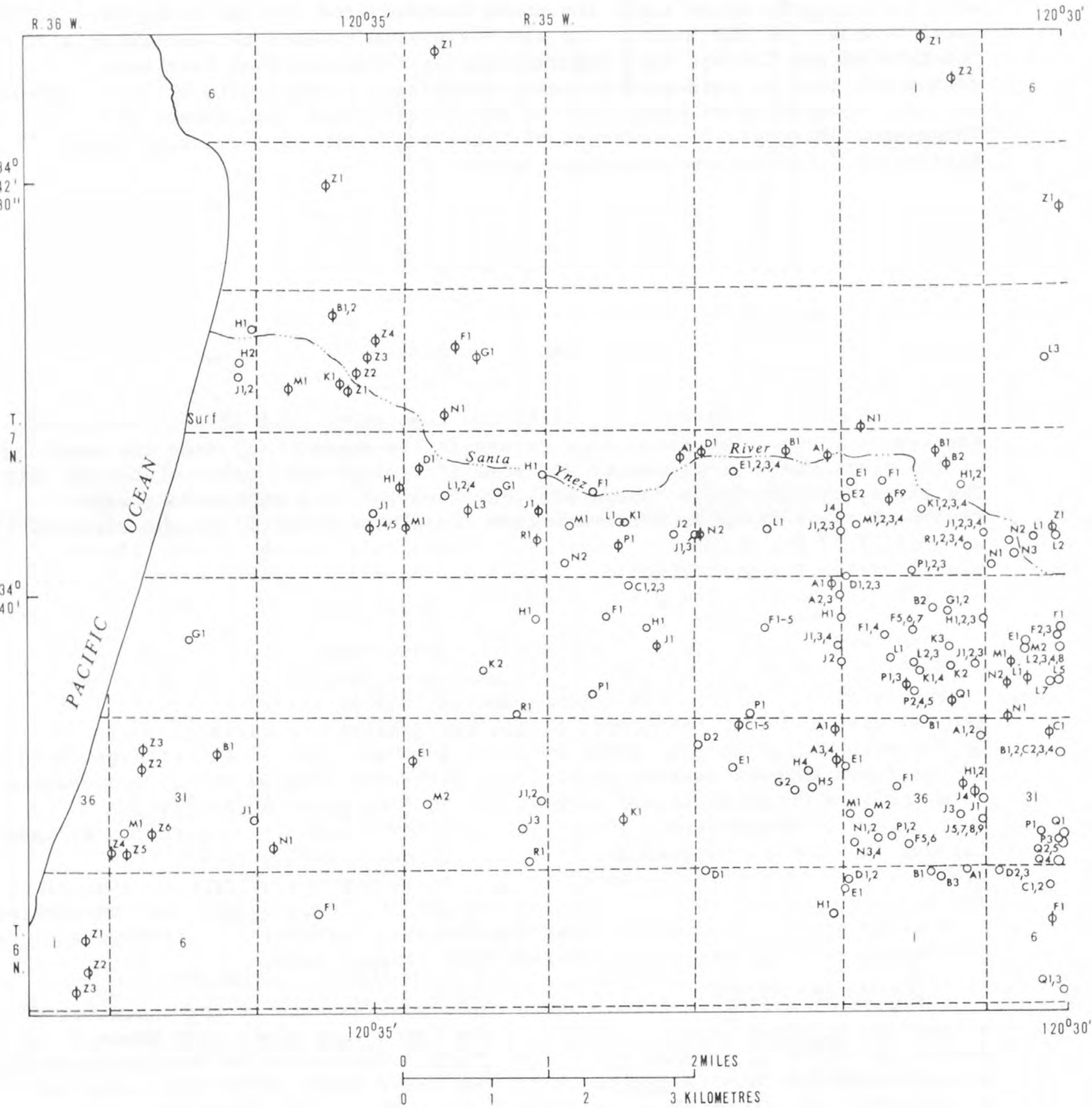


FIGURE 6.--Location of selected wells and springs.

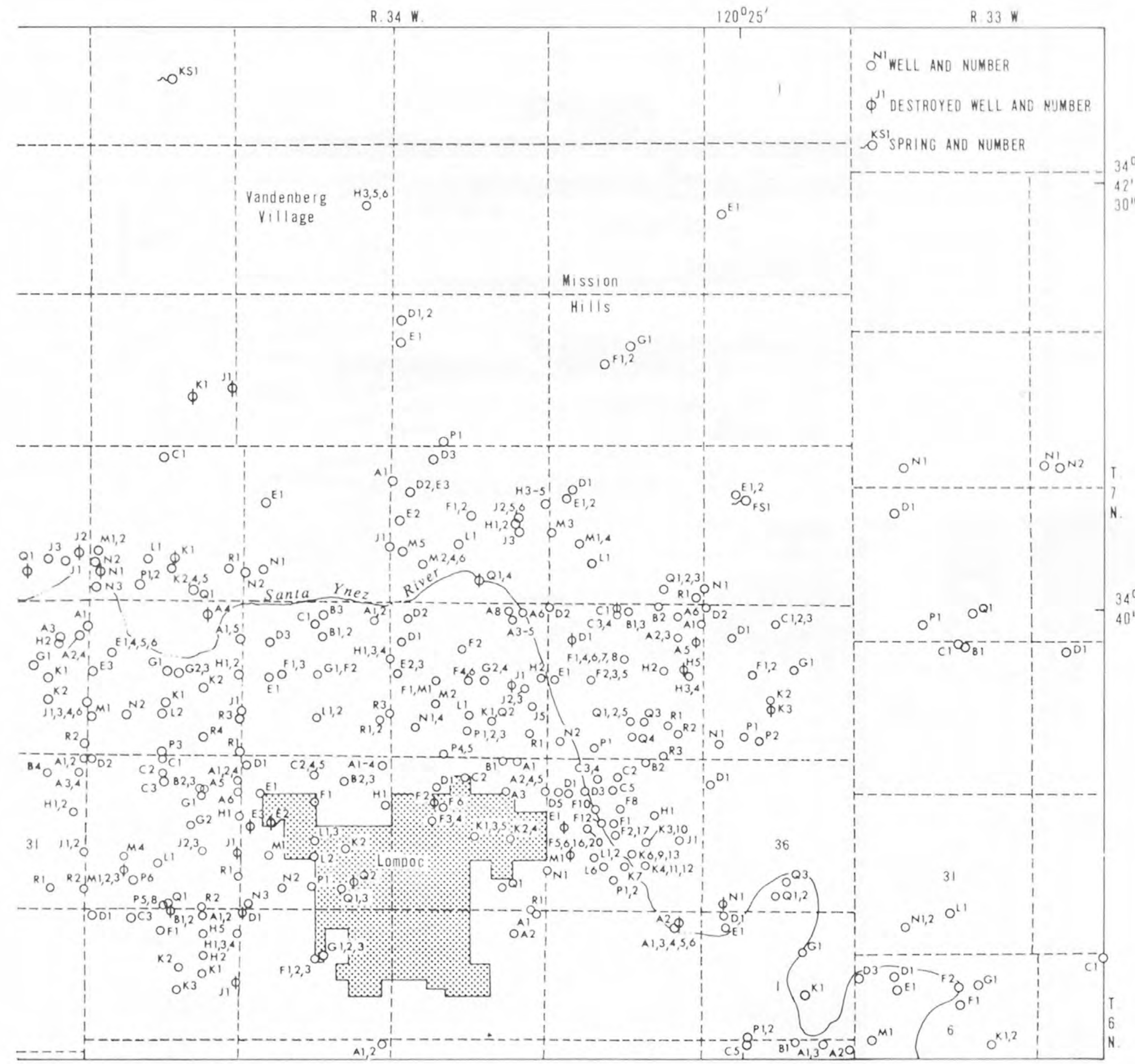
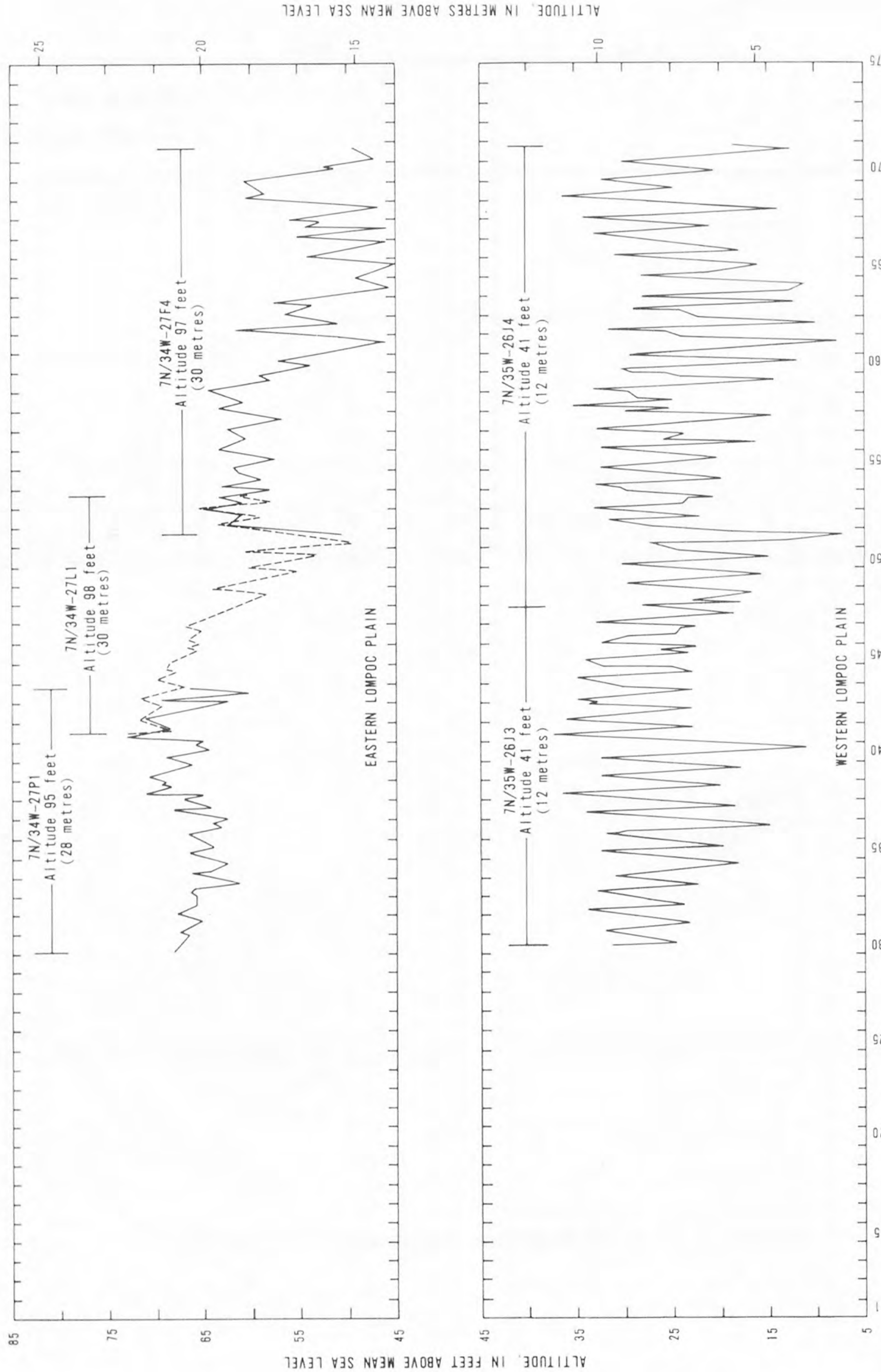


FIGURE 6.--Continued.


ALTITUDE, IN FEET ABOVE MEAN SEA LEVEL
ALTITUDE, IN METRES ABOVE MEAN SEA LEVEL
7N/34W-27P1
Altitude 95 feet
(28 metres)
7N/34W-27L1
Altitude 98 feet
(30 metres)
7N/34W-27F4
Altitude 97 feet
(30 metres)
EASTERN LOMPOC PLAIN
7N/35W-26J3
Altitude 41 feet
(12 metres)
7N/35W-26J4
Altitude 41 feet
(12 metres)
WESTERN LOMPOC PLAIN
85
75
65
55
45
45
35
25
15
5
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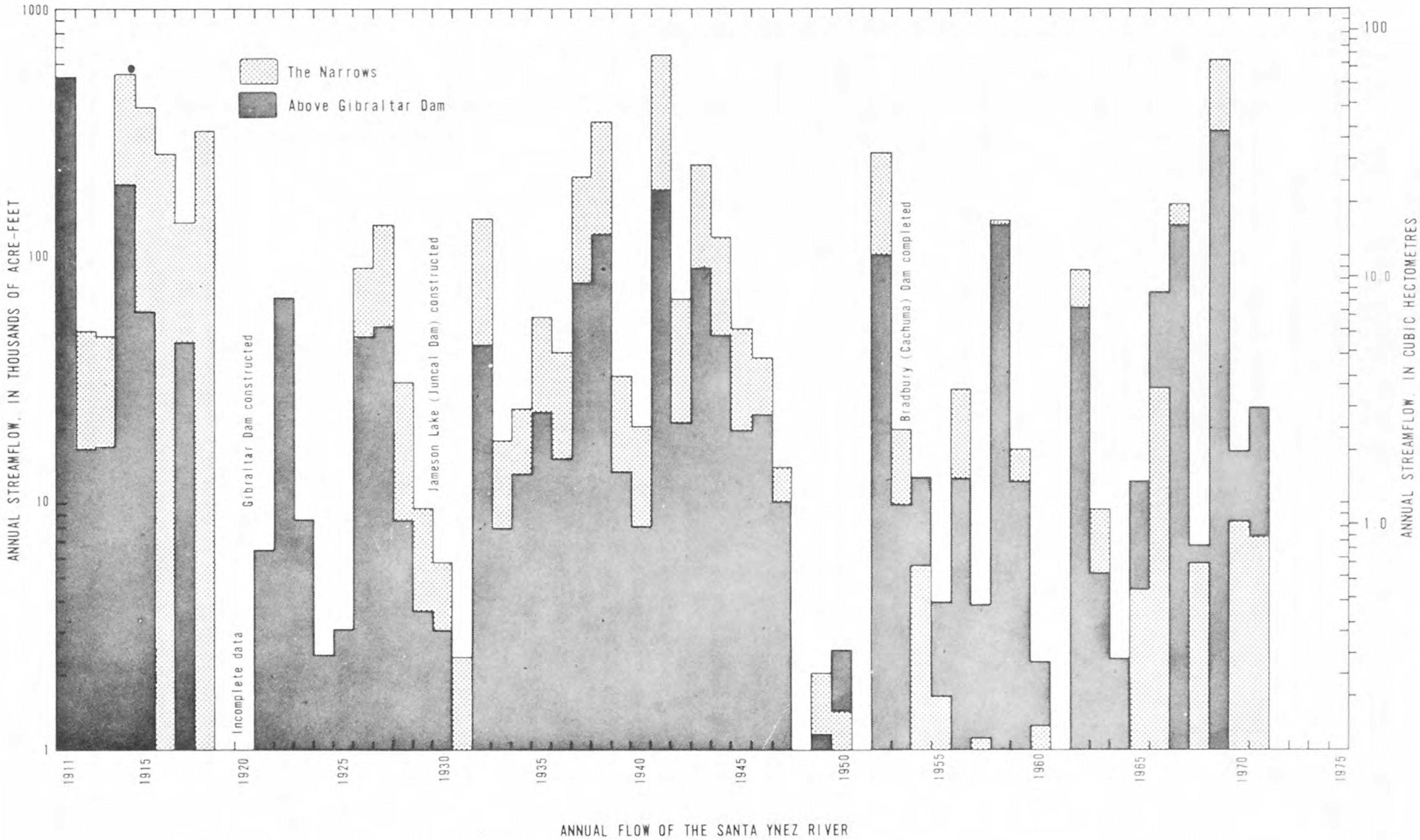


FIGURE 7.--Hydrographs of selected wells in the main water-bearing zone in Lompoc plain, 1929-71, and annual streamflow of the Santa Ynez River, 1911-71.

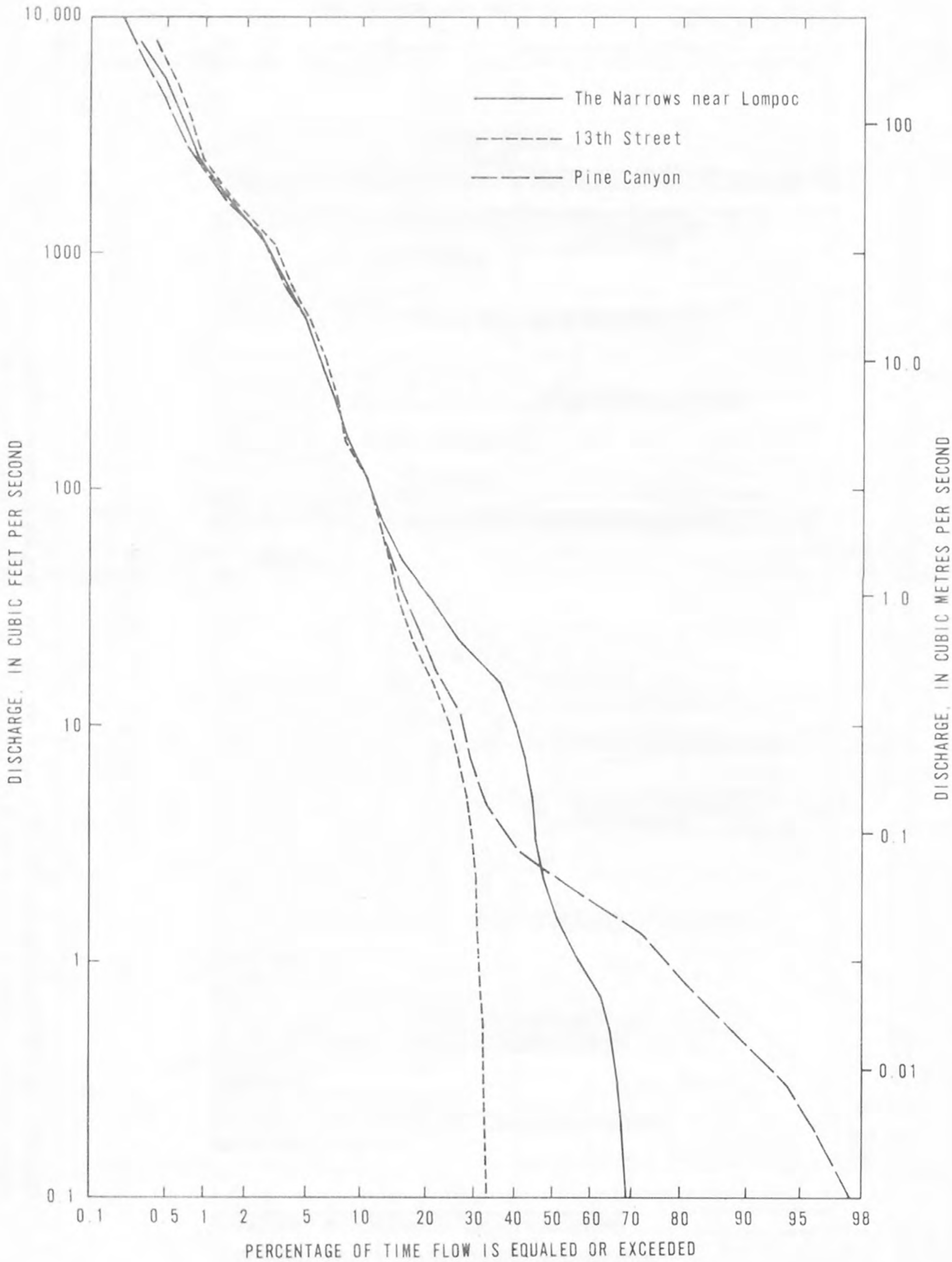


FIGURE 8.--Flow-duration curves at three gaging stations on the Santa Ynez River near Lompoc, water years 1965-71.

Most of the local tributary flow originates in the hills of consolidated rock south of the plain. Low flows reach the plain throughout most or all of the year from a few of these tributaries. The estimates of local tributary inflow, based largely on channel geometry (Hedman, 1970), are shown in table 2.

Storm runoff from urban areas within the city of Lompoc and the communities of Vandenberg Village and Mission Hills is appreciable. On the basis of results obtained from studies in the upper Santa Ana River basin, California (Durbin, 1974), using an adaptation of the Stanford Watershed Model (Crawford and Linsley, 1966), mean annual runoff was estimated to be 500 acre-ft (0.6 hm^3) from Lompoc, 150 acre-ft (0.2 hm^3) from Vandenberg Village, and 30 acre-ft (0.04 hm^3) from Mission Hills.

TABLE 2.--*Estimated mean annual inflow to Lompoc plain from selected local tributaries*

Tributary name or location	Mean annual flow in acre-feet[1]	Remarks
San Miguelito Creek	410	Channel features well defined over 300-ft reach.
Sloans Canyon	180	Moderately well-defined channel features measured at three sites in 1/8-mi reach.
La Salle Canyon	100	Channel features moderately well to fairly well defined in 1/4-mi reach.
Lompoc Canyon	180	Measured at south edge of Lompoc terrace ground-water basin; channel features well defined.
Santa Lucia Canyon	210	Estimated from scattered channel features in southern 2-mi reach and from runoff-area estimates.
Purisima Canyon	260	Channel features moderately well defined at Mission La Purisima Concepcion and at community of Mission Hills.
Cebada Canyon	260	Measured in 1/4-mi reach 3/4 mi east of Four Corners; channel features poorly to moderately well defined.
Foothill areas south of plain	190	Estimated from runoff-area data derived from adjacent streams with channel-geometry measurements, combined with data from gaged streams in the area.
Foothill areas north of plain	570	Do.
Total	2,400	

[1]Based largely on channel geometry.

Ground Water

Occurrence

The lower member of the younger alluvium and the contiguous buried terrace deposits make up the main water-bearing zone, which is the most utilized aquifer in the Lompoc area. The upper member of the younger alluvium and the river-channel deposits, the shallow zone of Upson and Thomasson (1951, p. 146) and Wilson (1959, p. 57), was considered by them to be separate from the main zone beneath most of the plain. However, in the eastern and southern parts of the plain hydraulic continuity occurs between the shallow and main zones, and vertical interchange of water occurs.

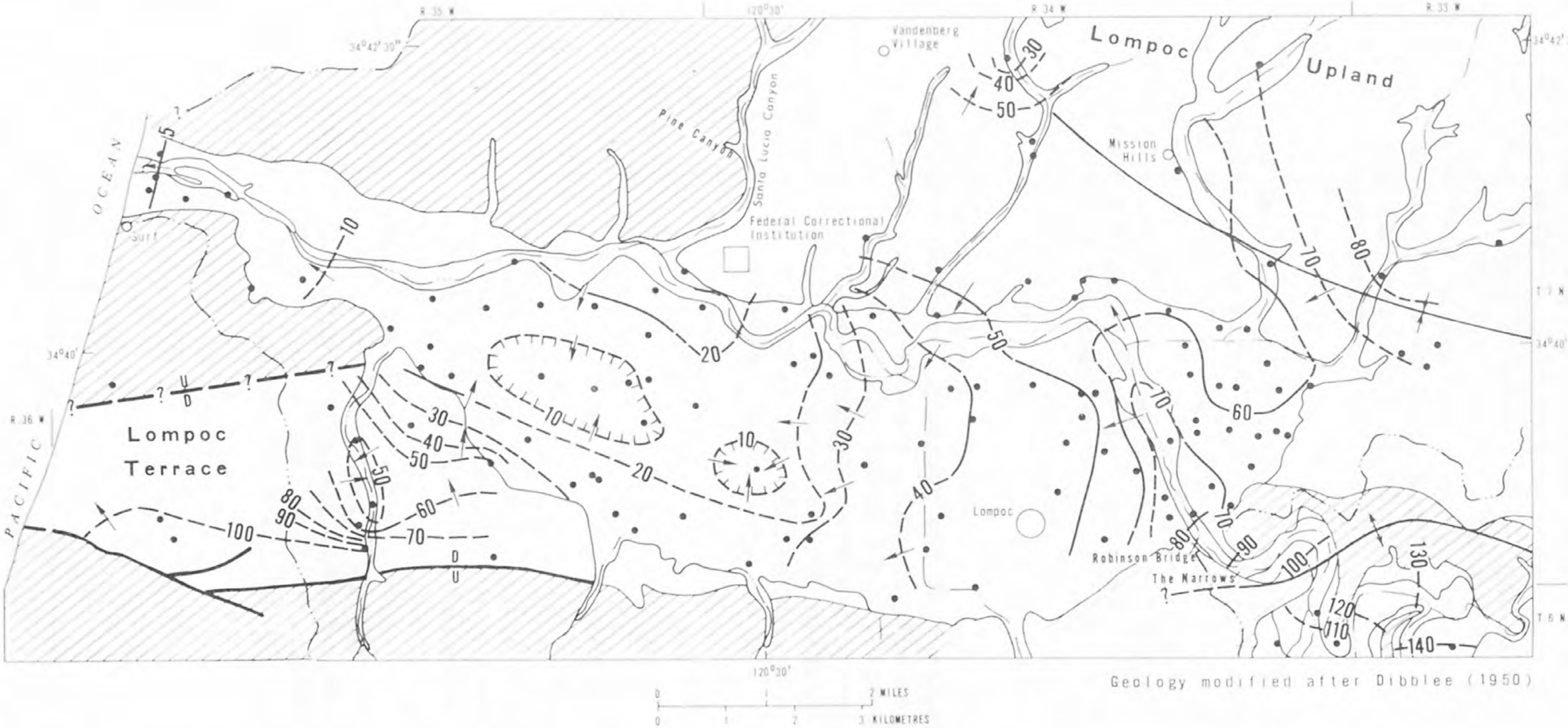
The Careaga Sand and Paso Robles Formation are chief aquifers in the Lompoc terrace and the Lompoc upland. These aquifers contain most of the ground water in storage in the area.

Locally, perched ground water occurs in the Orcutt Sand beneath the Lompoc upland. The water level in test wells and at springs that tap these perched aquifers is commonly more than 100 ft (30 m) higher than levels in the underlying Paso Robles Formation and Careaga Sand.

Fresh water occurs in the major aquifers generally to the base of the unconsolidated deposits, as shown in figures 4 and 5.

Movement

The general pattern of ground-water movement in the Lompoc area probably has not changed significantly since the steady-state condition that existed prior to man's use of water for irrigation. The areal pattern of ground-water movement in the main water-bearing zone beneath the Lompoc plain in March 1972 was from east to west (fig. 9), in a pattern very similar to that during the early 1940's as described by Upson and Thomasson (1951, pl. 7, p. 121-155). Movement of ground water in the Lompoc terrace was generally northward toward the Lompoc plain (fig. 9, and Evenson and Miller, 1963, fig. 2, p. 17). Ground-water movement in the Lompoc upland was generally from the south toward the plain (Upson and Thomasson, 1951, pl. 7). The general gradient in the main water-bearing zone beneath the plain during March 1972 ranged from more than 20 ft/mi (3.8 m/km) east of Lompoc to about 10 ft (3 m) in 5 mi (8 km) in the west-central part of the plain. The general pattern has been modified locally, as is described in the following paragraphs.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

DRAINAGE DIVIDE

GEOLOGIC CONTACT

FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

WATER-LEVEL CONTOUR--Shows altitude of water level. Dashed where approximately located. Contour interval 5 and 10 feet (1.5 and 3 metres). Datum is mean sea level. Arrows indicate approximate direction of ground-water movement

• DATA POINT

FIGURE 9.--Altitude of water level in the main water-bearing zone in Lompoc plain, March 1972.

During most years many irrigators begin pumping in late March or April. The winter months of 1971-72 were much drier than average, and the irrigators began pumping in January and February. The 1972 contours (fig. 9) show two distinct depressions related to pumping in the central-western part of the plain. The mound along the Santa Ynez River below Robinson Bridge may be caused in part by underflow into the plain along the river and in part by a residual from the previous year. At this time about 3,500 acre-ft (4.3 hm^3) of water as seepage from streamflow entered the ground-water reservoir as computed from losses in the reach between the gage near The Narrows and the gage near Pine Canyon.

Flow patterns in the Lompoc upland and Lompoc terrace have changed in response to pumping from wells within the areas, and from wells in the plain. A depression in the contours in the Lompoc upland (fig. 9) is related to the northern well field at Vandenberg Village (7N/34W-9H5, 9H6). Water levels in test well 7N/34W-12E1 in the Lompoc upland (fig. 10) have declined steadily since the well was drilled in 1948. Two supply wells (7N/35W-33J2 and 33J3) pumping from the Lompoc terrace since about 1958-60 have created a water-level depression of about 25 ft (8 m) (fig. 9) when compared to 1958 levels (Evenson and Miller, 1963, fig. 2).

In the plain, water-level contours and water-level data from closely spaced wells of different depth indicate that the hydraulic head is generally lowest in the highly pumped main water-bearing zone, somewhat higher in the underlying older aquifers (where present), and highest in the shallow zone. Thus water moves upward from the underlying aquifer into the main zone and irrigation return and rainfall infiltration move downward by leakage from the shallow zone. The head differences are greatest during the irrigation season because of pumping from the main zone and the application of irrigation water to the shallow zone.

Recharge

Sources of recharge to the aquifer system beneath the Lompoc plain include seepage from streams, ground-water underflow through the alluvium-filled channel beneath the Santa Ynez River, underflow through some of the alluvium-filled tributary valleys, underflow through aquifers that underlie the Lompoc upland and Lompoc terrace and extend under the plain, underflow through older consolidated formations, and infiltration of precipitation through shallow aquifers. Return flows of water pumped for various purposes, largely excess irrigation water and sewage outflow, are also considered recharge. A diagrammatic flow chart of these important components of recharge is shown in figure 11.

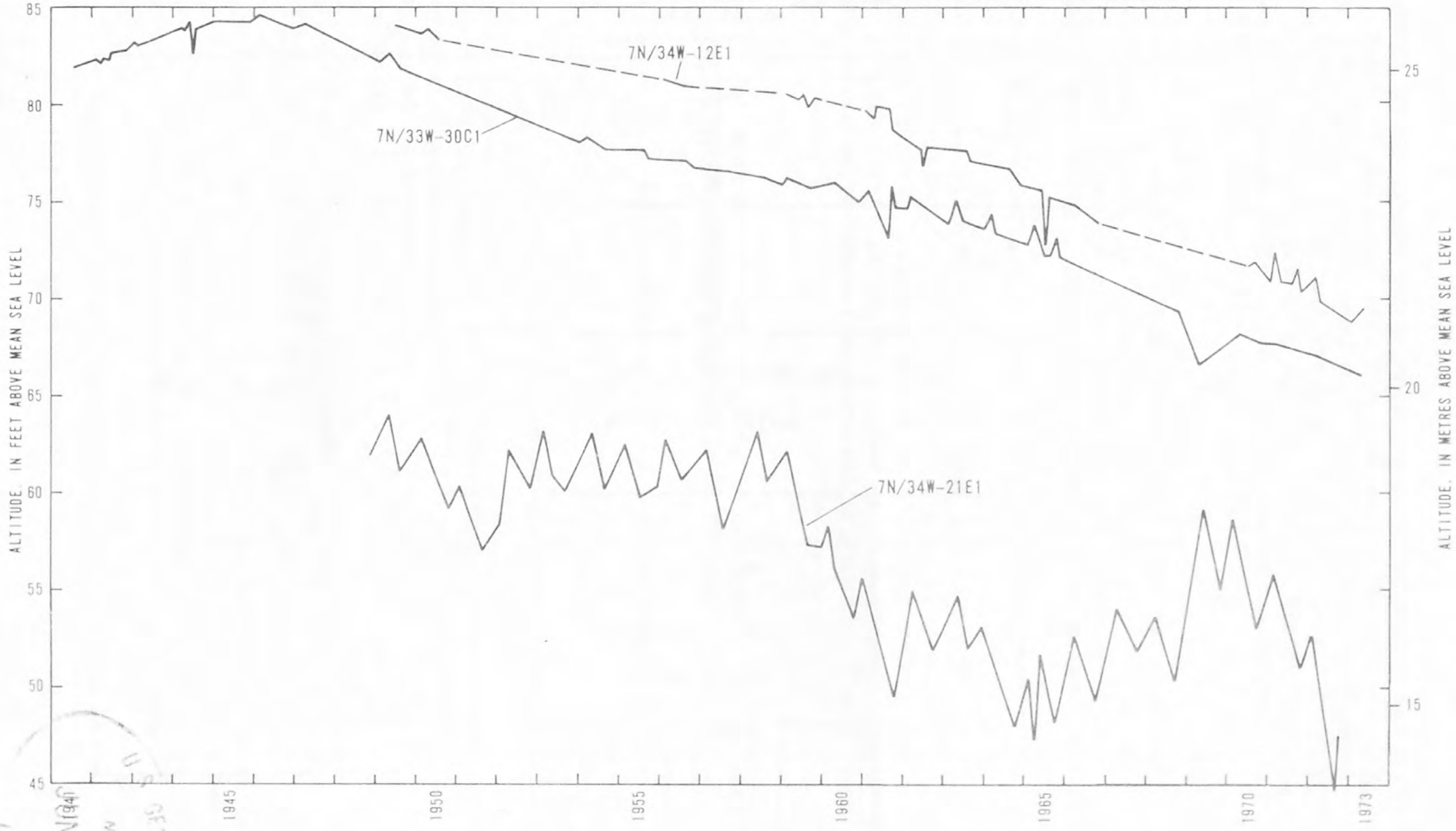


FIGURE 10.--Hydrographs of selected wells in Lompoc upland, 1941-73.

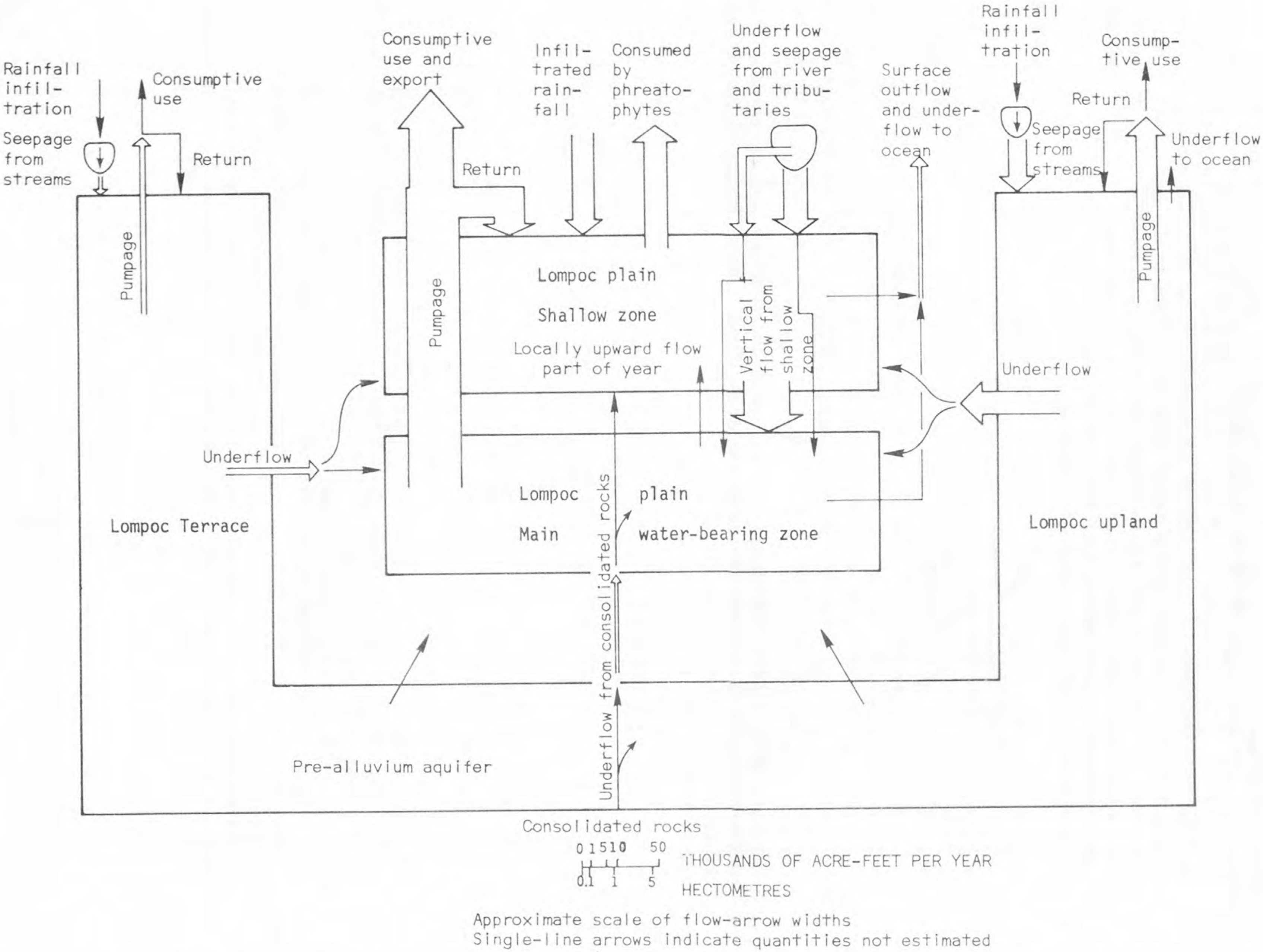


FIGURE 11.--Diagrammatic hydrologic sectional flow chart of Lompoc area, 1972 conditions.

Seepage from streams

Seepage in the Lompoc plain area occurs principally along the 2.2-mi (3.5-km) reach of the Santa Ynez River below Robinson Bridge (fig. 2) (Upson and Thomasson, 1951, p. 95) and, to a somewhat lesser but probably significant extent, between this reach and the gage near Pine Canyon (fig. 2). The river has been gaged for many years at or near Robinson Bridge in the reach before the stream enters the plain and at several downstream sites. Little tributary inflow enters the river between these gages.

Upson and Thomasson (1951, p. 95-97) and Wilson (1959, p. 83-84) estimated that the average annual recharge from the river was 2,200 acre-ft (2.7 hm^3) during the early and middle 1940's and only 500 acre-ft (0.6 hm^3) during 1947-51. However, they pointed out the uncertainties and weaknesses of utilizing computed losses between the upstream and downstream gages to estimate seepage. Evenson (1966, p. 12) estimated that seepage from the river during 1957-62 averaged about 7,600 acre-ft (9 hm^3) annually.

Table 3 shows differences in flow past the various gage sites that were operated at the east end of the plain for several periods during 1951-72. During most of 1955-71, seepage losses in the reach between The Narrows and the gage at 13th Street generally equaled or exceeded 400 acre-ft (0.5 hm^3) per month before appreciable flow occurred at the 13th Street gage.

TABLE 3.--*Recharge to Lompoc plain as estimated from differences in flow at various gage sites on the Santa Ynez River*

Gaged reach	Time period	Average annual difference in flow (rounded) (acre-feet)
The Narrows to H Street	1951-62	2,700
The Narrows to 13th Street	1955-72	3,700
The Narrows to near Pine Canyon	1965-72	[1]3,100+
Robinson Bridge to H Street	1947-60	2,100
Robinson Bridge to 13th Street	1955-60	4,200
Estimated annual average, The Narrows to near Pine Canyon, under 1972 conditions		3,000

[1]Low flow at gage near Pine Canyon made up largely of sewage effluent discharged about 1 mi upstream, which decreases the difference in flow between the gages. Difference between gages, uncorrected for estimated sewage volume past downstream gage, 2,100 acre-ft per year.

The average annual recharge from the river under 1972 conditions could exceed the 3,000 acre-ft (3.7 hm^3) shown in table 3 (Evenson, 1966, p. 12; U.S. Bureau of Reclamation, written commun., 1968). More definitive streamflow data are needed to determine the rate of seepage losses during high flows, combined with an intensive water-level measuring program in the area of recharge to better determine the effects on the ground-water levels.

Seepage to ground water from local tributaries that enter the Lompoc plain from the south was estimated by Wilson (1959, p. 84-85) to be at least 700 acre-ft (0.9 hm^3) annually during the drier-than-average period 1947-51. Upson and Thomasson (1951, p. 127) estimated that, during the wetter-than-average period 1942-44, the average recharge from this source was approximately 5,400 acre-ft (6.7 hm^3). They also noted that flow in these southern streams rarely reached the river, because almost all flow percolates into the alluvium. The results of studies during 1973 utilizing channel-geometry techniques (table 2) suggest that the mean annual flow in local tributaries that potentially contribute recharge to the plain totals about 2,400 acre-ft (3 hm^3) annually.

The channels of San Miguelito, Sloans, La Salle, and to some extent Cebada Canyons were lined with concrete across much of the Lompoc plain during the early 1960's as a flood-control measure, thereby shunting the streamflow to the Santa Ynez River. A small quantity of seepage from these streams probably still occurs, both near the head of the lined channels near the edge of the plain and in the Santa Ynez River downstream from their confluences. However, the average annual recharge may have been reduced by as much as 1,000 acre-ft (1.2 hm^3) and is estimated to be 1,200 acre-ft (1.5 hm^3).

Underflow

Most of the underflow to the plain occurs from three sources: (1) Through the channel deposits of the Santa Ynez River; (2) through the channel deposits of local tributaries; and (3) through aquifers that underlie the adjacent Lompoc terrace and Lompoc upland.

Upson and Thomasson (1951, p. 80) estimated that for 1935-44 the average annual underflow of the Santa Ynez River at The Narrows was 600 acre-ft (0.7 hm^3). Underflow to the plain from local tributaries is minor and is a small percentage of the total recharge. Most of the underflow probably enters from the alluvium-filled valleys of San Miguelito, Sloans, and La Salle Canyons. In addition to underflow in the alluvium, some underflow from a fracture zone in consolidated rocks in San Miguelito Canyon probably enters the plain. The aggregate annual underflow from all tributaries in 1972 is estimated to be 200 acre-ft (0.2 hm^3).

Underflow through the older alluvial aquifers of the Lompoc upland and Lompoc terrace occurs both laterally along the edge of the alluvium where it is in contact with the older deposits and vertically from beneath the plain (Upson and Thomasson, 1951, p. 152).

Underflow from the older aquifers, chiefly the Careaga Sand, to the main water-bearing zone beneath the Lompoc plain was estimated by Upson and Thomasson (1951, p. 153-155) to be 2,500 acre-ft (3 hm^3) annually. Lowered water levels beneath the Lompoc plain have since appreciably steepened the gradient from the older aquifers towards the plain, causing a greater rate of underflow as discussed by Wilson (1959, p. 74-75).

Underflow from the Lompoc upland to the plain occurs along an irregular section from the vicinity of well 7N/33W-19P1 westward almost to Santa Lucia Canyon. The annual underflow in 1972 along this section was estimated to be 4,000 acre-ft (5 hm^3). This is twice the underflow estimated by Upson and Thomasson (1951, p. 154).

Underflow from the Lompoc terrace to the plain occurs along a section about 2.5 mi (4 km) long from the mouth of Lompoc Canyon eastward about to La Salle Canyon. Historical water-level data in the area, although not adequate to determine the gradients accurately, suggest that the underflow from the terrace to the plain may be about 300-500 acre-ft (0.4-0.6 hm^3) annually, or about the same as estimated by Upson and Thomasson (1951, p. 154). Recent water-level data available along this section during 1972 suggest that the gradient is less than during the earlier studies and that the annual underflow may be about 50 acre-ft (0.06 hm^3).

Infiltration

Recharge to the plain from precipitation was estimated to be 2,000 acre-ft (2.5 hm^3) annually during the period 1935-44 by Upson and Thomasson (1951, p. 125-126). Other data obtained from areas adjacent to the plain (Blaney and others, 1963, tables 8, 9, and 11) indicate that for the 50-year period 1914-63, an average of 2,600 acre-ft (3.2 hm^3) annually infiltrated to aquifers underlying the Lompoc upland.

Studies by G. P. Lawless and P. R. Nixon (written commun., 1967) suggest that on the Lompoc upland during 1957-67, the percentage of rainfall that infiltrated to depths below the normal root zone may be computed by a formula similar to: Infiltration in inches = 0.845 x (precipitation in inches minus 4.15). Assuming that this rate of infiltration of rain can be applied to the approximately 7,000 irrigated acres (2,800 ha) on the plain, the annual rainfall pattern during the period 1951-72 suggests that the average annual recharge from infiltration of precipitation may be about 4,000 acre-ft (5 hm^3).

Most of the recharge from infiltration of precipitation becomes part of the water stored in the shallow zone, much of which eventually moves downward toward the main water-bearing zone.

Upson and Thomasson (1951, p. 125) estimated that 60 percent of the applied irrigation water on the Lompoc plain is evapotranspired, 25 percent runs off, and 15 percent returns to the shallow ground-water zone. Blaney, Nixon, Lawless, and Wiedmann (1963, table 4) in a later, more detailed study estimated that during the period 1957-62 an annual average of 44 percent of the total applied water (including rainfall) returned to the ground-water system.

Brown and Caldwell (1972, p. 33-38) estimated that the volume of treated effluent discharged from the Lompoc sewage plant into the normally dry channel of the Santa Ynez River about 2 mi (3.2 km) northwest of Lompoc during 1971 was 2.1 Mgal/d (7.95×10^3 m^3/d or 6.4 acre-ft/d) or almost 2,350 acre-ft (2.9 hm^3). This volume includes an unknown but probably small quantity of storm runoff that leaked into the system. Assuming that the storm-runoff portion of the sewage effluent during that drier-than-average year was 50 acre-ft (0.06 hm^3), the sewage effluent represents about 62 percent of the approximately 3,700 acre-ft (4.5 hm^3) pumped by the city during 1971.

Prior to 1969 Vandenberg AFB discharged its sewage effluent, which included some ground water pumped from the adjacent San Antonio Basin to the north (Muir, 1964), to sewage ponds in the western part of the plain near the southwest corner of sec. 15, T. 7 N., R. 35 W. Floods during January and February 1969 damaged these ponds, and since that time the effluent has reportedly been discharged to the ocean by an outfall line.

The Federal Correctional Institution discharges its sewage effluent in part as irrigation water and in part to the 0.75-mi (1.20-km) reach of Santa Lucia Canyon downstream from the sewage-treatment plant. No data are available about the volume of effluent during 1972, but it probably amounts to at least 10 percent more than the 224 acre-ft (0.27 hm^3) discharged annually in 1966-67 (LoBue, 1968, table 5), or about 250 acre-ft (0.30 hm^3).

Discharge

The principal discharge from the aquifers in the Lompoc area is by pumping, mostly for irrigated agriculture. Some discharge in the western part of the plain is by underflow to the ocean; by evapotranspiration from marshy areas, phreatophytes, and the Surf lagoon; and by surface outflow. These components of discharge are shown in figure 11.

Pumpage

Data collected by the Geological Survey indicate that an average of about 21,000 acre-ft (25 hm^3) was pumped annually for irrigation during the period 1957-62, and an annual average of about 15,000 acre-ft (18 hm^3) was pumped during the period 1963-67. During the latter period fewer acres were in irrigated agriculture, and the average annual rainfall was about 1 in (25 mm) greater, which may account for the reduction in pumpage. Annual pumpage by the city of Lompoc averaged about 2,600 acre-ft (3.2 hm^3) during 1960-64, 3,300 acre-ft (4.1 hm^3) during 1965-69, and 3,700 acre-ft (4.6 hm^3) during 1970-71. Vandenberg AFB pumped an average of about 3,800 acre-ft (4.7 hm^3) annually from wells in the Lompoc plain during 1971-73, and the Federal Correctional Institution pumped about 190 acre-ft (0.2 hm^3) during 1968. Other miscellaneous users probably pump a few hundred acre-feet annually. The estimated total pumpage from the plain during 1972 was 23,000 acre-ft (28.4 hm^3).

Underflow to ocean

Underflow of ground water to the Pacific Ocean from the Lompoc area was discussed by Upson and Thomasson (1951, p. 80-81), by Wilson (1959, p. 80-81), and by Evenson (1966, p. 16-17). Evenson estimated that the average annual underflow past the Barrier Bridge near Surf during the period 1957-62 was 150 acre-ft (0.18 hm^3). The saturated thickness there has remained constant, and the gradient during 1972 was about the same as when Evenson estimated the underflow. Thus, the underflow to the ocean during 1972 is estimated to be 150 acre-ft (0.18 hm^3).

Evapotranspiration

Upson and Thomasson (1951, p. 134) estimated that the average annual evapotranspiration during the period 1937-44 along the Santa Ynez River channel and in the western part of the Lompoc plain amounted to 5,100 acre-ft (6.3 hm^3). Wilson (1959, p. 80) estimated that the average annual total evapotranspiration had decreased to 3,000 acre-ft (3.7 hm^3) by the period 1947-51, mainly because ground-water levels had declined about 20 ft (6 m) since 1944 in the eastern part of the plain, thus reducing use by phreatophytes. The U.S. Bureau of Reclamation (1973, p. 9) estimated that in 1971 there were 2,150 acres (870 ha) of phreatophytic vegetation of varying density in the area that used about 3,200 acre-ft (3.9 hm^3) of water.

Surface outflow

Ground water in the western part of the plain seeps into the channel of the Santa Ynez River and results in perennial base flow in most of the reach within about 3 mi (4.8 km) of the ocean. The rate of base flow during the past few decades has decreased as ground-water levels declined. Upson and Thomasson (1951, p. 133) estimated that during the wetter-than-average period 1941-44 the discharge of ground water to the river and thence to the ocean averaged 1,500 acre-ft (1.8 hm^3) annually. Wilson (1959, p. 79-80) estimated that during the drier-than-average period 1947-51 the outflow was 100 acre-ft (0.12 hm^3) annually. Gaged and estimated outflow of ground water in the river at the former gage site at the Barrier Bridge near Surf during 1961-65 averaged about 200 acre-ft (0.24 hm^3) annually and ranged from less than 150 acre-ft (0.18 hm^3) during the drier-than-average year 1961 to almost 400 acre-ft (0.5 hm^3) during the wet year 1962. Average annual outflow under 1972 conditions is estimated to be 100 acre-ft (0.12 hm^3).

Water-Level Changes

Water levels in wells rise or fall in response to changes in recharge and discharge. In the Lompoc area the most significant fluctuations in water level and concomitant changes in storage occur in response to pumpage from wells and to infiltration during wet periods.

From the 1940's to 1972, water levels in wells that tap the main water-bearing zone beneath the western part of the Lompoc plain declined 5-10 ft (1.5-3 m), and beneath the eastern part declined 15-30 ft (4.5-9 m). Data on several deep wells in the Lompoc upland indicate that water levels have declined as much as 15 ft (4.5 m) since 1948. Water levels declined about 15 ft (4.5 m) near the Vandenberg Village and Mission Hills well fields since the early 1960's. Water levels in wells in much of the Lompoc terrace declined from a few feet to 12 ft (3.6 m) during the period 1959-72.

Figure 7 shows water-level fluctuations, based mostly on monthly measurements, in several wells that tap the main water-bearing zone. The hydrograph of water levels in the eastern Lompoc plain (fig. 7) shows that a net decline of about 20 ft (6 m) occurred during 1929-72. The water-level fluctuations during the period ranged from about 23 ft (7 m) in 1941 to about 53 ft (16 m) in 1965.

A rapid decline in water levels occurred during 1945-51, in response to a drier-than-average period and to an increase in pumping. Water levels rose about 10 ft (3 m) following the wet year of 1952 and remained about 35-40 ft (10-12 m) below land surface until about 1958. An irregular but general decline to depths of about 45-50 ft (13-15 m) occurred during 1959-68, followed by a rise of more than 10 ft (3 m) in 1969. The rise of water levels in 1969 was about the same as in 1952, although almost 620,000 acre-ft (760 hm^3) of flow in the river entered the plain in 1969 compared with about 260,000 acre-ft (320 hm^3) in 1952. This tends to support the conclusion of Upson and Thomasson (1951, p. 95-99, 152-153) and Wilson (1959, p. 83-84) that the recharge to ground water by seepage losses from the river is limited, even during wet years.

The hydrograph of water levels in wells 7N/35W-26J3 and 26J4 (fig. 7), in the western, more confined part of the aquifer, also shows an overall downward trend and a general decline of about 10 ft (3 m) during the period 1930-72.

A hydrograph of water levels in well 7N/34W-12E1 (fig. 10), which taps the Careaga Sand in the Lompoc upland (Wilson, 1959, p. 73), shows a steady decline totaling about 4 ft (1.2 m) during the period 1948-61 or about 0.35 ft (0.1 m) per year. This decline is in part in response to a generally drier-than-average period and in part in response to a lowering of water levels in the Lompoc plain, which steepened the hydraulic gradient toward the plain (Wilson, 1959, p. 70). The decline during 1962-72 was about 11 ft (3.3 m) or 1 ft (0.3 m) per year. The beginning of the steeper decline occurred at about the time that well fields were being established at Vandenberg Village and at Mission Hills and may reflect the pumpage from these areas.

Hydrographs of water levels in wells in the Lompoc terrace (fig. 12) show a general decline in water level of less than about 5 ft (1.5 m) during the period 1958-73.

Ground-Water Storage

Storage capacity

Total ground water in storage, as discussed herein, refers to volume computed using specific yield. All this water may not be recoverable by pumping. The quantity of usable water in storage that is available to be pumped by wells is dependent on such diverse factors as a need to prevent seawater intrusion, the minimum acceptable pumping rate and maximum acceptable lift, well spacing, change in water quality as water levels are lowered, and land subsidence. Table 4 shows the estimated ground water in storage in the Lompoc area.

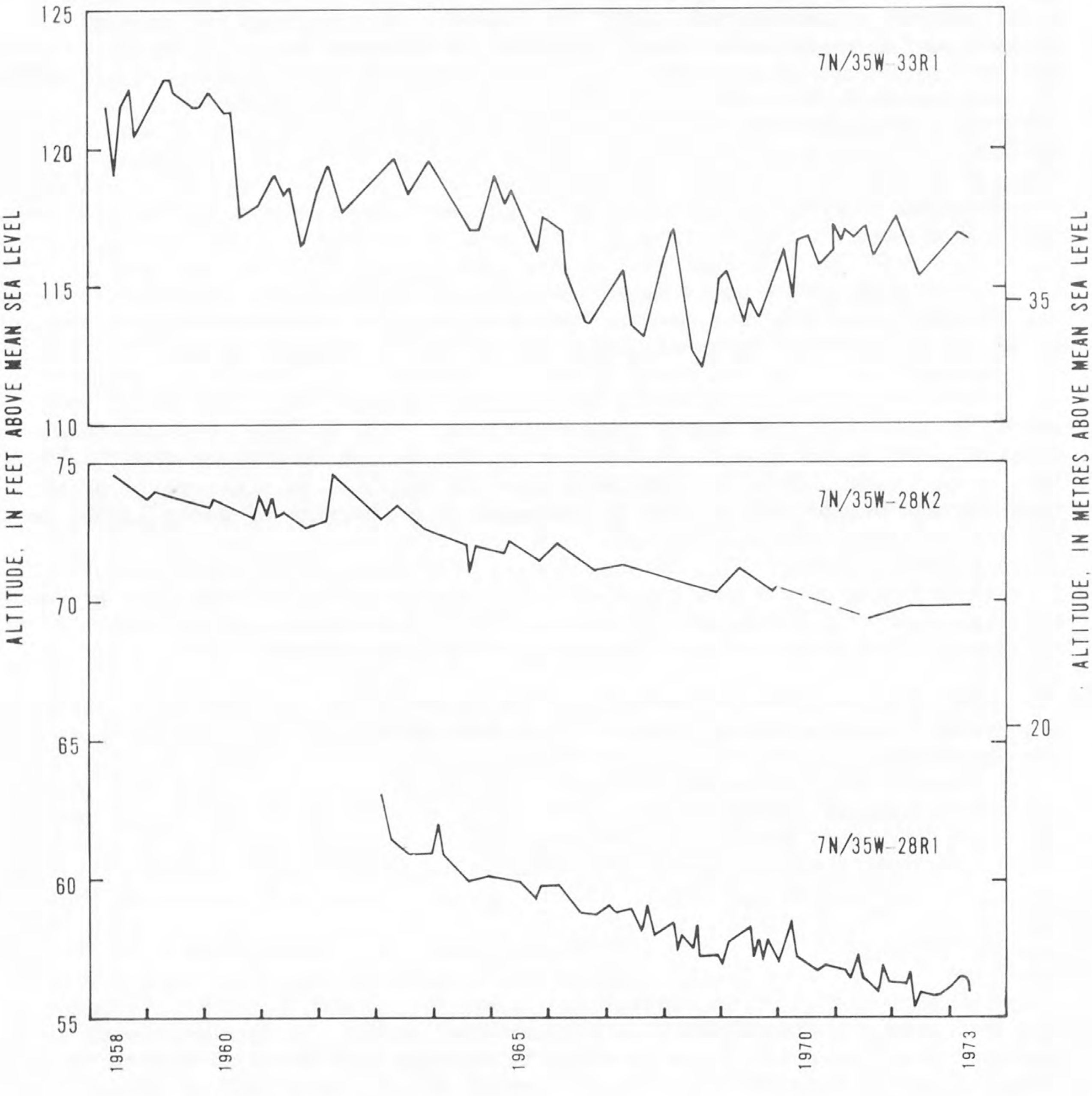


FIGURE 12.--Hydrographs of selected wells in Lompoc terrace, 1958-73.

TABLE 4.--*Estimated ground water in storage in Lompoc area*

[Acre-feet, rounded]

Lompoc plain	Lompoc terrace	Lompoc upland	Total
80,000 (main zone) ($98\ hm^3$) 135,000 (shallow zone) ($166\ hm^3$)	100,000 ($120\ hm^3$)	400,000 ($490\ hm^3$)	720,000 ($880\ hm^3$)

Changes in storage

The general decline of water levels in the Lompoc area indicates that a net decrease in storage has occurred since 1941. The change in head has induced more rapid flow of ground water from the adjacent Lompoc terrace and Lompoc upland. This increased underflow, along with pumping, has caused an appreciable decrease in ground water in storage in all three areas.

In the Lompoc plain, on the basis of an average decline in water level of 17 ft (5.2 m) and an estimated average specific yield of 16 percent in the dewatered zone from 1941 to 1972, the decrease in storage is estimated to be 38,000 acre-ft ($47\ hm^3$).

During 1958-72 the ground water in storage in the Lompoc terrace, based on water-level changes in several wells and based on a specific yield of 12 percent, decreased about 1,000 acre-ft ($1\ hm^3$).

Similarly, about 25,000 acre-ft ($30\ hm^3$) of decrease in storage occurred beneath the Lompoc upland during the period 1946-72.

WATER QUALITY

Surface-Water Quality

Historical data on the chemical quality of surface water in the area are sparse; most of the data to support the conclusions reached herein were collected during 1971-73.

Lake Cachuma

Figure 13 shows graphically some aspects of water quality of Lake Cachuma in the headwater area of the Santa Ynez River during the period 1958-73 when several large storms occurred. During this period the concentration of dissolved solids in the lake water increased. It ranged from about 430 to 650 mg/l and averaged about 500 mg/l. Similarly the concentration of sulfate increased from about 200 to 300 mg/l and along with increases in calcium and magnesium seems to account for most of the increase in both dissolved solids and specific conductance. The most apparent increase occurred during and after 1969, following a near-record series of storms. Except for 1969, the concentration of dissolved solids was in general inversely related to lake stage.

Santa Ynez River

Large regional storms commonly produce runoff from the Santa Ynez River and its tributaries below Lake Cachuma. Thus runoff contains concentrations of dissolved solids ranging from about 200 to 700 mg/l; the most prevalent constituents are calcium, sodium, sulfate, and bicarbonate.

Table 5 lists results of a reconnaissance water-quality study of the river and several of its tributaries made April 12, 1973, about 3 weeks after a storm. The water progressively increases in specific conductance in a downstream direction and probably is somewhat poorer in quality than during higher discharge. During periods when flow in the river originates largely from base flows of less than 1 to a few cubic feet per second in the Salsipuedes Creek, the concentration of dissolved solids in the 2-mi (3.2-km) reach above Robinson Bridge ranges from about 500 to more than 1,000 mg/l.

In contrast, at base flows of less than 0.5 ft^3/s (0.01 m^3/s) of the Santa Ynez River, three samples of water taken during 1971-72 in the reach within 3 mi (4.8 km) of the lagoon at Surf contained 1,740 to 2,070 mg/l of dissolved solids and averaged about 1,900 mg/l.

Local Tributaries

During the period 1972-73 water from most of the local tributaries in the Lompoc area was sampled for chemical analysis, and supplemental field measurements were made of specific conductance. Table 6 is a summary of the results.

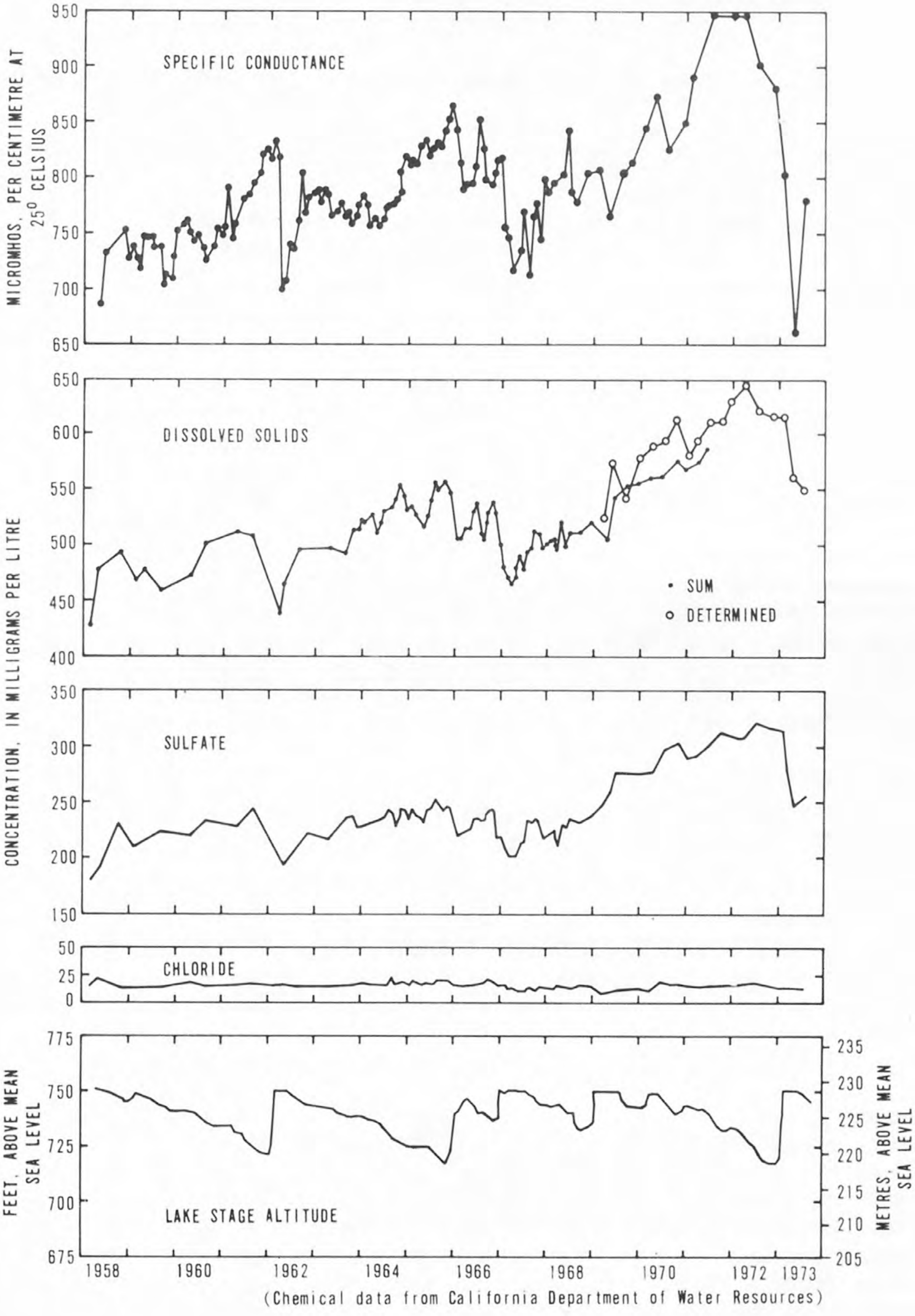


FIGURE 13.--Selected water-quality constituents and lake stage of Lake Cachuma, 1958-73.

TABLE 5.--*Reconnaissance of water quality in the Santa Ynez River and in several tributaries, April 12, 1973*

[Underlined data indicate measurements on the Santa Ynez River]

Location or name	Estimated discharge (cubic feet per second)	Water temperature (°C)	Specific conductance (micromhos at 25°C)
Tributary 0.5 mile east of DeVaul Canyon at Highway 154	1	14.0	640
DeVaul Canyon at Highway 154	2	15.0	480
Tequepis Canyon at Highway 154	4	15.0	470
Santa Ynez River at Refugio Road	100	18.0	800
Alamo Pintado Creek at Highway 154	.5	23.0	1,620
Santa Ynez River at Alisal Road	100	18.0	850
Alisal Creek at Santa Ynez River	3	19.0	1,030
Nojoqui Creek at Santa Rosa Road	5	22.5	970
Santa Ynez River at Buellton	100	18.5	920
Tributary 5.5 miles west of Highway 101 on Santa Rosa Road	2	19.5	1,720
Tributary 8.0 miles west of Highway 101 on Santa Rosa Road	1	18.0	2,310
Santa Ynez River at about 120°22'30" west longitude	100	19.5	980
Salsipuedes Creek at Santa Rosa Road	15	19.0	1,300
Santa Ynez River at Robinson Bridge	>100	20.0	1,030
Santa Ynez River at gage near Pine Canyon	100	21.0	1,060
Santa Ynez River at Renwick Avenue	<100	20.5	1,050

TABLE 6.--*Summary of chemical-quality data on streamflow of local tributaries, Lompoc area*

Stream and location	Date	Water temper-ature (°C)	Specific conductance (micromhos at 25°C)	Dissolved solids (milligrams per litre)	Estimated flow (cubic feet per second)	Remarks
San Miguelito Canyon, 6N/34W-4K	11-14-72	12.5	589	383	3.9	Major ions Ca, SO_4.
Do.	3-14-73	10.2	1,260	[1]820	5.1	Rain on 3-11.
Canyon at 6N/34W-5K	1-16-72	14.5	397	224	.5	Downstream from sanitary landfill. Major ions Na, SO_4, HCO_3, Cl.
Sloans Canyon, 6N/34W-6F	1-16-73	13.0	482	281	15	Major ions Na, Ca, HCO_3, SO_4.
Do.	3-14-73	9.0	1,150	[1]670	5	Rain on 3-11.
La Salle Canyon, 7N/35W-36N	1-16-73	12.5	485	287	20	Major ions Na, HCO_3.
Do.	3-14-73	9.0	1,570	[1]940	1	Rain on 3-11.
Lompoc Canyon, 7N/35W-28R	1-18-73	12.5	104	68	3.3	Major ions Na, HCO_3, Cl. Runoff during storm.
Lake Canyon, 8N/35W-26R	5-24-72	14.0	2,000	[1]1,100	.005	Marshy area feeds stream.
Lake Canyon, 8N/35W-36K	5-24-72	15.0	2,200	[1]1,200	.1	Inlet to small lake.
Lake Canyon, 7N/34W-6P	5-24-72	20.0	4,000	[1]2,200	--	Large lake at mouth of Lake Canyon.
Santa Lucia Canyon, 7N/34W-5N	3-13-73	15.0	911	505	.02	Rain on 3-11. Major ions Na, HCO_3, Cl.
Santa Lucia Canyon, 7N/34W-18	3-13-73	16.0	1,430	808	1.5	Major ions Na, Cl, HCO_3.
Davis Canyon, 7N/34W-16H	3-12-73	14.0	1,510	867	.20	Rain on 3-11. Major ions Na, Cl.
Purisima Canyon, 7N/34W-14F	11-14-72	17.0	394	241	.17	Major ions Na, SO_4, Cl.
Cebada Canyon, 7N/33W-18P	3-12-73	14.0	1,150	744	.05	Major ions Na, SO_4. Rain on 3-11.
Cebada-Purisima drain, 7N/34W-27A	6-8-72	18.5	702	432	.09	Major ions Na, HCO_3, Cl.

[1]Estimated from specific conductance-dissolved solids relation based on complete chemical analyses of nearby ground water.

The concentration of dissolved solids in those tributaries that seem to contribute significant recharge to the plain ranges from less than 100 mg/l in Lompoc Canyon during storm runoff to more than 2,000 mg/l for base flow in Lake Canyon.

On the basis of the lined or unlined and sandy or clayey channels and the estimated annual discharge from the tributaries, the average concentration of dissolved solids in the flow that becomes ground-water recharge is estimated to be 300 mg/l.

The major constituents in the water from tributaries that drain consolidated rocks south of the plain are sodium, calcium, bicarbonate, and sulfate, whereas those from northern tributaries that drain the sandy Lompoc upland are chiefly sodium, chloride, and bicarbonate. Runoff from the urbanized area of Lompoc is low in dissolved solids; the specific conductance of street runoff near the center of town on January 18, 1973, was 100 micromhos, suggesting that the water probably contained about 50-70 mg/l of dissolved solids.

Ground-Water Quality

In the following discussion, the chemical quality of ground water in the main and shallow zones beneath the Lompoc plain is described first in terms of selected constituents. Water quality in the Lompoc terrace and the Lompoc upland is later discussed in a similar way, but in less detail. The analytical results on the samples of ground water collected were interpreted considering the various depths of wells, the zones of perforation, the possible integration of water from several water-bearing zones, and the effect of long periods of non-pumping on water quality.

Lompoc Plain--Main Water-Bearing Zone

Specific conductance

The specific conductance of natural water is a commonly used parameter to describe the general quality of water (Hem, 1970, p. 96-103; Evenson, 1965, p. 9) because it is readily measured using field equipment and is related, although not in a simple manner (Hem, 1970, p. 96-103), to the concentration of dissolved solids. In the Lompoc area the concentration of dissolved solids can be estimated by multiplying the specific conductance by a factor ranging from 0.55 to 0.9. This relation in the Lompoc plain is illustrated by figure 14, and the general areal distribution in 1972 of specific conductance of water from wells perforated in the main water-bearing zone is shown in figure 15.

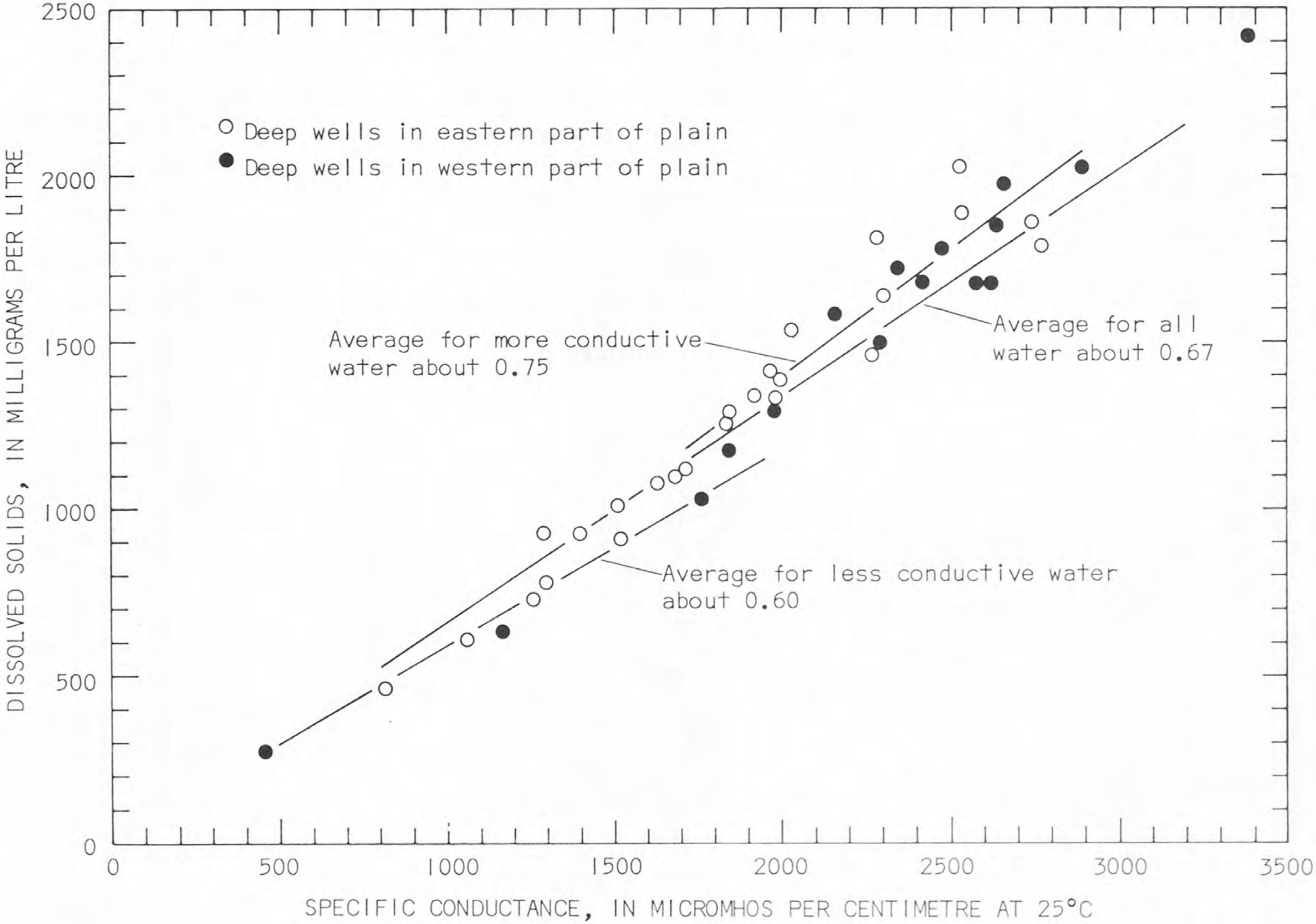


FIGURE 14.--Relation of dissolved solids to specific conductance, ground water in the main water-bearing zone in Lompoc plain, 1972.

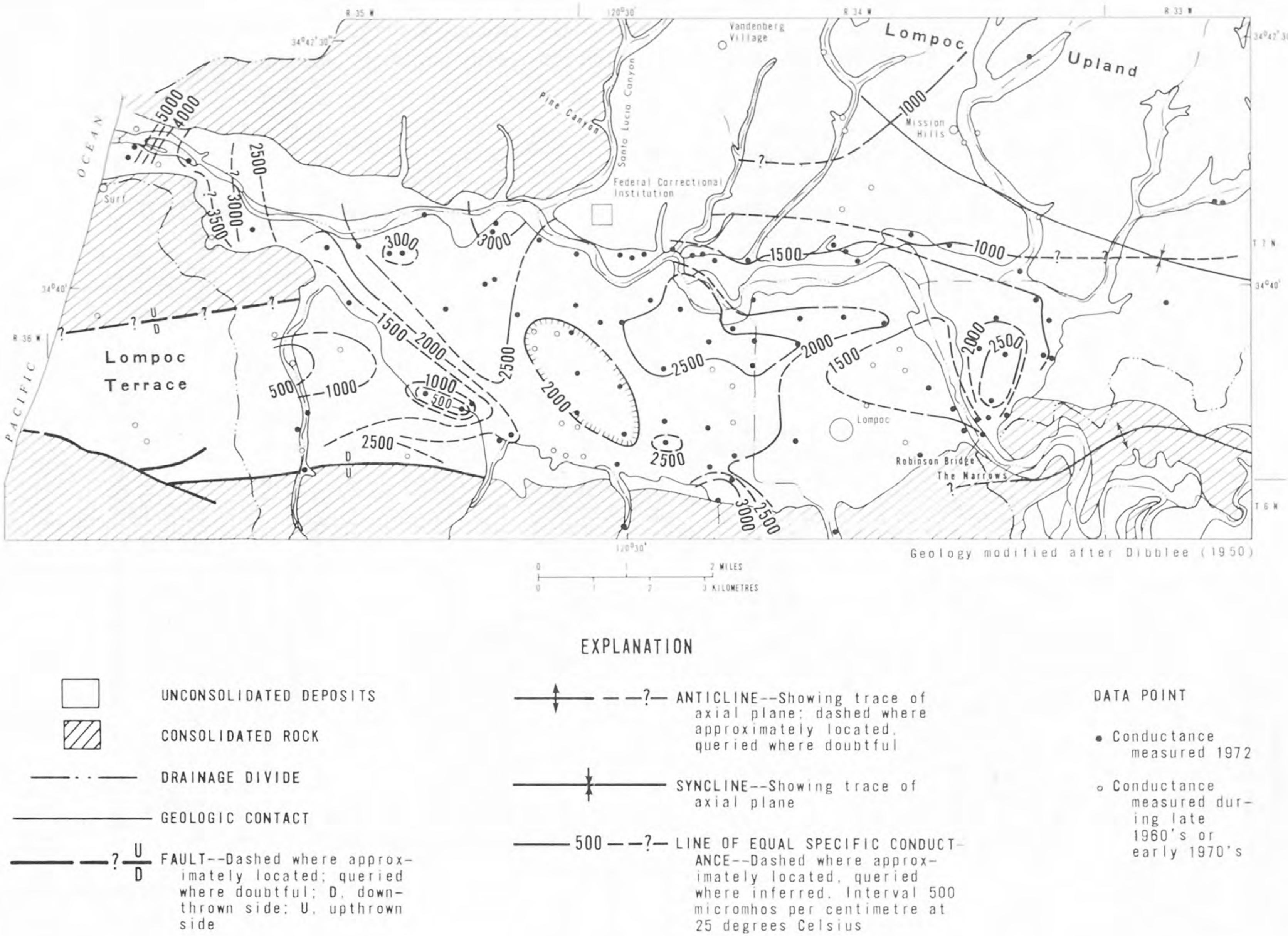


FIGURE 15.--Specific conductance of water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.

The least conductive ground water in the plain is in a small area about 4 mi (6 km) west of Lompoc and may be related to recharge from the shallow part of the Lompoc terrace. The most conductive water is in the western 1-2 mi (1.5-3 km) of the plain near the coast.

The overall pattern of specific conductance in the plain is one of a somewhat irregular but general increase from east to west, and an increase from the boundaries of the Lompoc terrace and the Lompoc upland toward the plain. The pattern is similar, but of higher overall conductance, to that during 1961 (Evenson, 1965, pl. 1). An area of below-average specific conductance (about 1,200-1,500 micromhos) north and east of Lompoc seems to reflect recharge from the Santa Ynez River. The central part of the plain about 2 mi (3 km) northwest of Lompoc contains an area of more than a square mile where the conductance exceeds 2,500 micromhos; this area is generally downgradient from, and is much larger than, an area of similar water outlined during 1961 by Evenson. This increase in the size of the area of more conductive water reflects a general increase of 300-400 micromhos in several wells in the southern part of the area, and an increase of about 1,800 micromhos in water from one well in the northern part. All the area within the 2,500-micromho line (1972) except a small strip along the Santa Ynez River has been in irrigated agriculture for several decades, and highly conductive irrigation-return water seems to be the most reasonable cause for most of the increase since 1961.

Dissolved solids

The general pattern of dissolved solids in the main water-bearing zone beneath the plain is somewhat similar to that of specific conductance. The concentration of dissolved solids ranges from less than 500 mg/l to more than 3,000 mg/l, and the water is very hard. The major anions are sulfate, bicarbonate, and chloride, and the major cations are calcium, sodium, and magnesium. Figure 16 shows the distribution of dissolved solids during 1972.

The concentration of dissolved solids is generally about 1,000-1,500 mg/l in the eastern part of the plain, less than 1,000 mg/l at the boundaries with the Lompoc terrace and upland, and 1,500-3,000 mg/l in the western part of the plain. Local areas of anomalously high dissolved solids generally coincide with the areas of high conductance.

Hardness

The term "hardness," as used herein, refers to total hardness and is calculated from the concentrations of calcium and magnesium and expressed as milligrams per litre of $CaCO_3$ (Hem, 1970, p. 224). Ground water in the main water-bearing zone beneath the plain is classified generally as very hard (more than 180 mg/l) by almost any standard (Hem, 1970, p. 225; Bean, 1962).

EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

DRAINAGE DIVIDE

GEOLOGIC CONTACT

FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

500 ? LINE OF DISSOLVED SOLIDS CONCENTRATION--Dashed where approximately located, queried where inferred. Interval 500 milligrams per litre

DATA POINT

- 1972 data
- 1972 electrical conductivity data used to estimate dissolved solids
- Pre-1972 data

FIGURE 16.--Dissolved solids in water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.

Figure 17 shows the distribution of hardness throughout the Lompoc plain. The hardness of water in the axial part of the plain exceeds 1,000 mg/l over an area about 6 mi (9.6 km) long by about 1 mi (1.6 km) wide. A small area along the south edge of the plain about 5 mi (8 km) west of Lompoc contains soft to moderately hard water. This area seems to be surrounded by much harder water and may reflect locally the natural softening by cation exchange or recharge of softer water from the shallow part of the Lompoc terrace.

Sulfate

The concentration of sulfate (fig. 18) ranges from less than 100 mg/l in two elongate areas where underflow from the Lompoc terrace and the Lompoc upland enters the plain to more than 750 mg/l in two moderately large areas in the axial part of the plain and in a small area about 1.5 mi (2.4 km) southwest of Lompoc. The pattern of distribution in the plain seems to be largely unrelated to point sources, except for the one small area about 1.5 mi (2.4 km) southwest of Lompoc and another in the same direction 3 mi (4.8 km) from Lompoc near the edge of the plain where the anomalously high concentration of sulfate may be related to inflow of water from the adjacent consolidated rocks.

Chloride

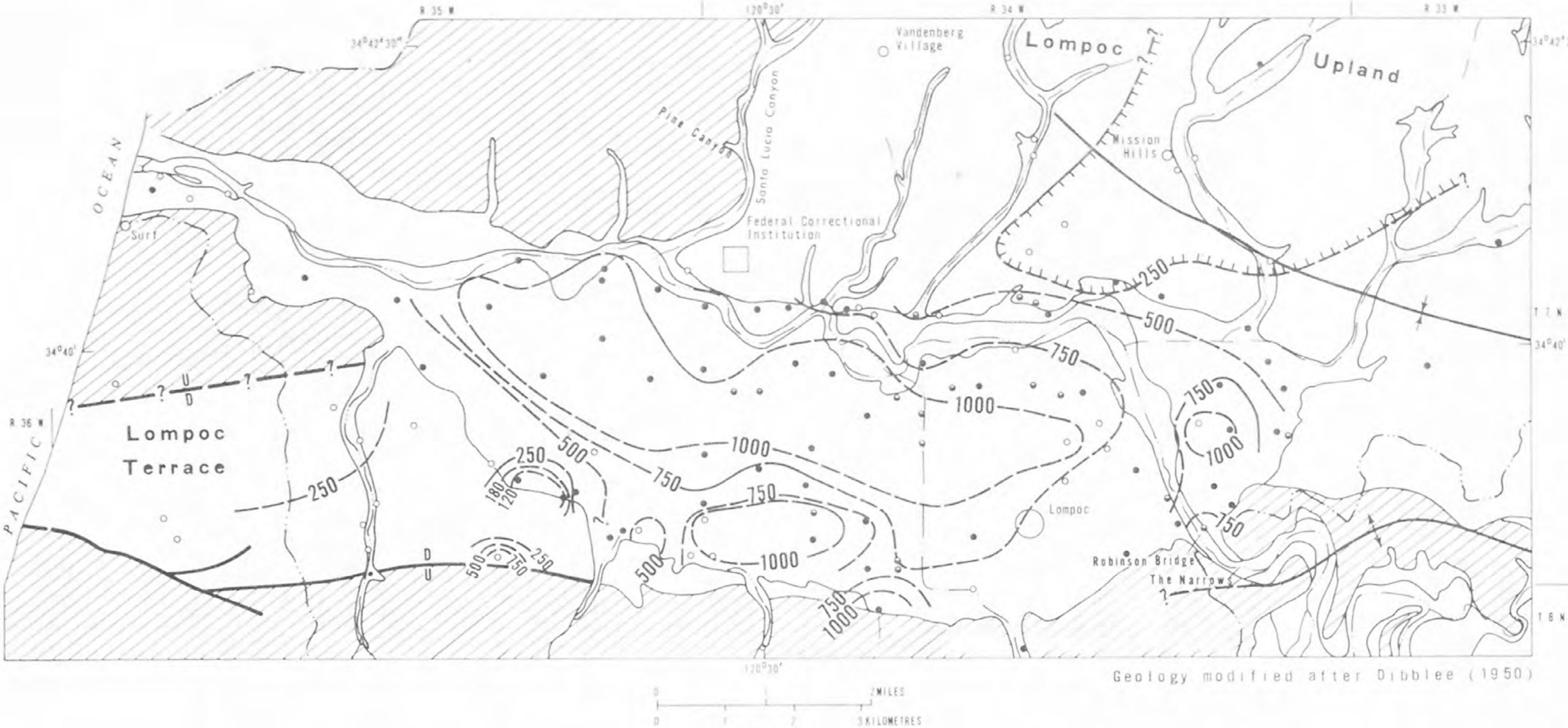
The distribution of chloride in wells perforated in the main water-bearing zone of the Lompoc plain is shown in figure 19. High concentrations of chloride occur in wells at the coastal end of the plain and near the mouth of Santa Lucia Canyon. High chloride also occurs in the area 2 mi (3.2 km) northwest of Lompoc and in the area 2 mi (3.2 km) east of Lompoc. The latter was attributed by Evenson (1965, p. 18) to a mixture of connate water from older strata and irrigation-return water.

Nitrate

The pattern of occurrence of nitrate in wells in the main water-bearing zone (fig. 20) is erratic and cannot be explained from existing information. The range in concentration during 1972 was from 0 to more than 80 mg/l; beneath much of the plain it was less than 1 mg/l.

Other major constituents

The distribution of calcium and magnesium is related to that of hardness. Calcium is the most abundant cation in water from most wells in the main water-bearing zone, and its general pattern of distribution is similar to that of hardness and sulfate. The concentration of calcium ranges from about 40 to 330 mg/l and averages about 180 mg/l. The concentration in the western part of the plain is about 30 mg/l higher than in the eastern part. The lowest concentrations occur adjacent to the Lompoc terrace and the Lompoc upland.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

DRAINAGE DIVIDE

GEOLOGIC CONTACT

FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

250 — — ?— LINE OF EQUAL HARDNESS--Dashed where approximately located, queried where inferred. Interval variable, in milligrams per litre

DATA POINT

- • 1972 data
- ∘ 1972 electrical conductivity data used to estimate hardness
- ∘ Pre-1972 data

FIGURE 17.--Total hardness of water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.

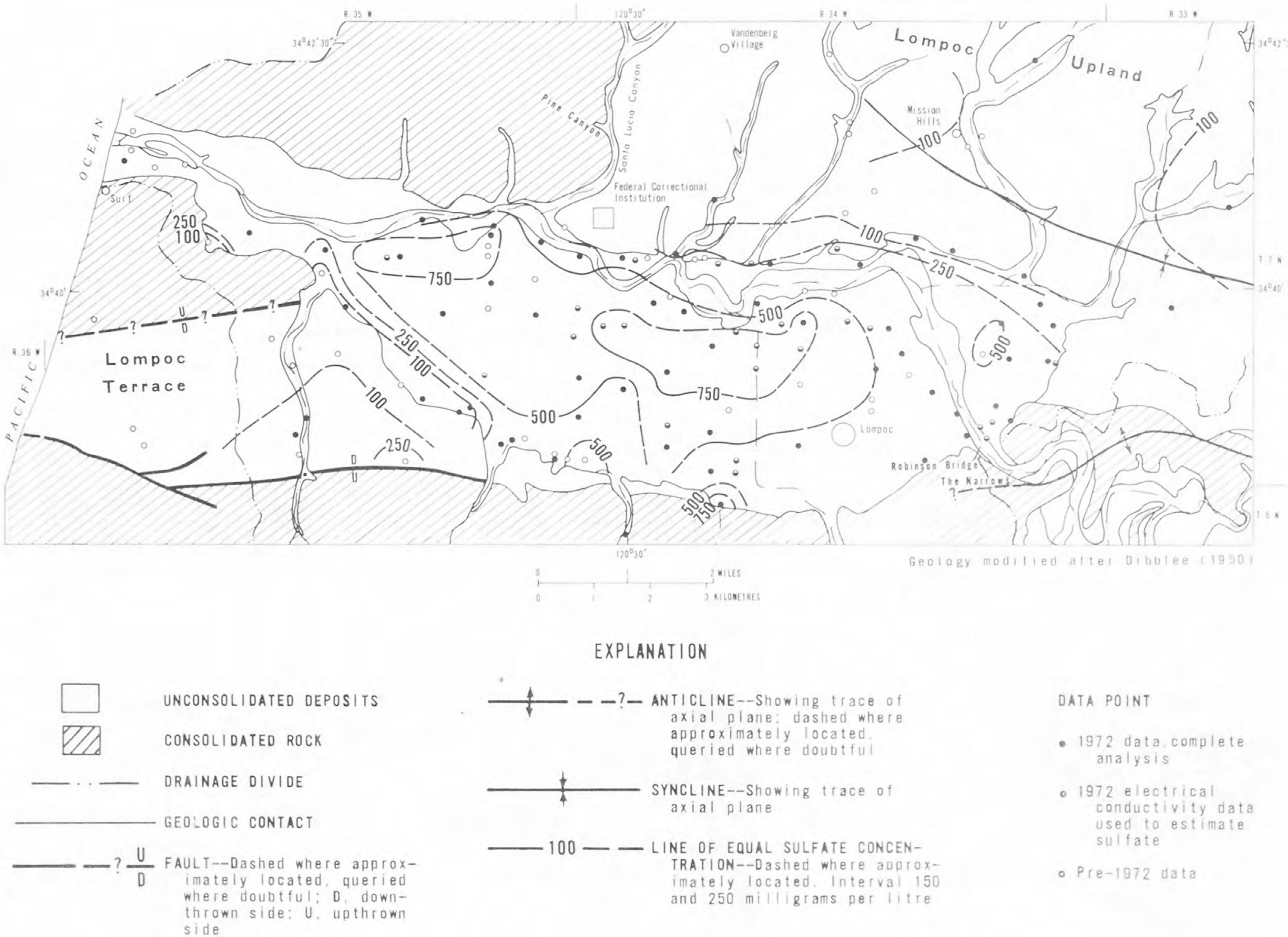
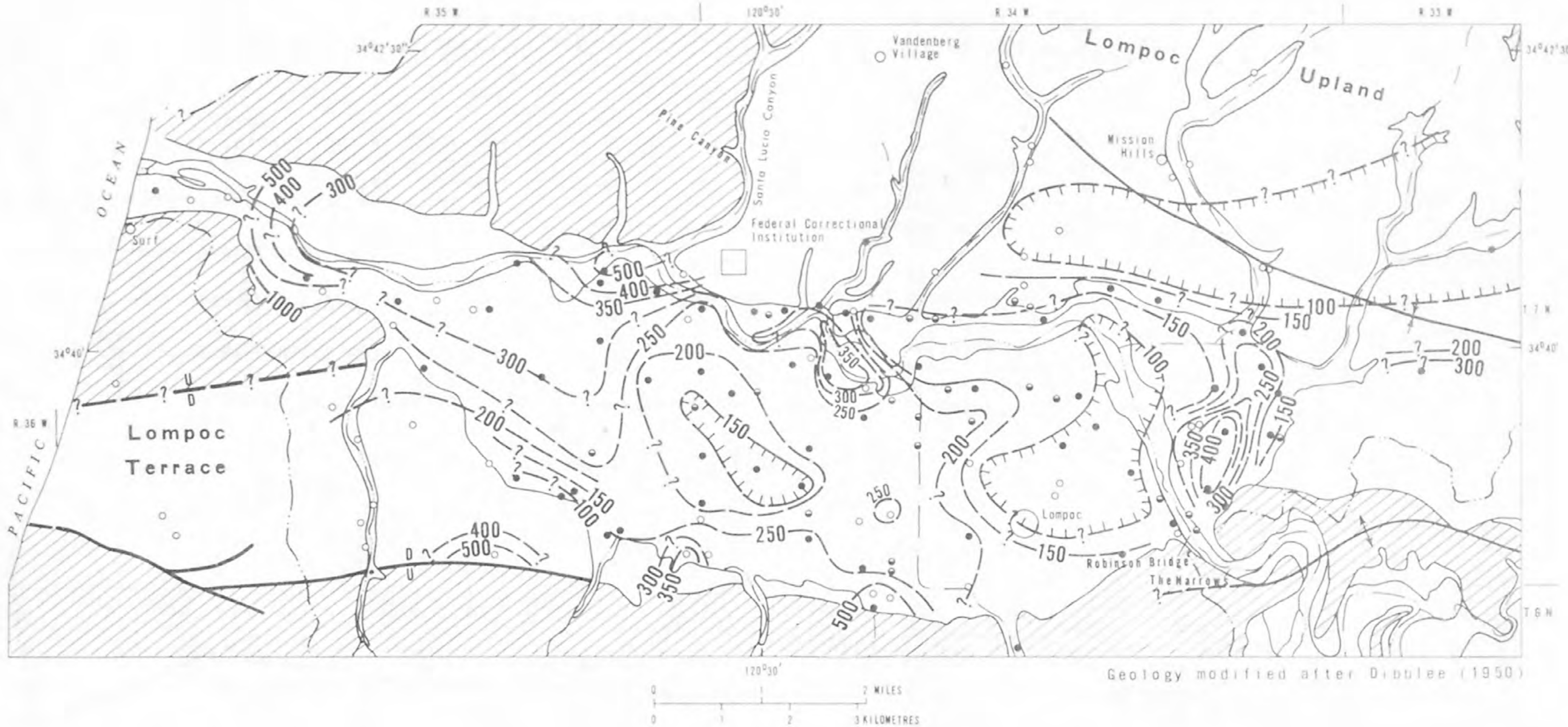


FIGURE 18.--Concentration of sulfate in water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.



EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

DRAINAGE DIVIDE

GEOLOGIC CONTACT

FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

250 — ? — LINE OF EQUAL CHLORIDE CONCENTRATION--Dashed where approximately located, queried where inferred. Interval variable, in milligrams per litre

DATA POINT

- • Water sampled in 1972
- ○ Estimated from electrical conductivity measured in 1972-73
- ○ Water sampled prior to 1972

FIGURE 19.--Concentration of chloride in water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.

EXPLANATION

UNCONSOLIDATED DEPOSITS

CONSOLIDATED ROCK

DRAINAGE DIVIDE

GEOLOGIC CONTACT

? U/D FAULT--Dashed where approximately located, queried where doubtful; D, downthrown side; U, upthrown side

?— ANTICLINE--Showing trace of axial plane; dashed where approximately located, queried where doubtful

SYNCLINE--Showing trace of axial plane

— 10 — ? — LINE OF EQUAL NITRATE CONCENTRATION--Dashed where approximately located, queried where inferred. Interval variable, in milligrams per litre

DATA POINT

• Water sampled in 1972

o Water sampled prior to 1972

FIGURE 20.--Concentration of nitrate in water from wells perforated in the main water-bearing zone in Lompoc plain, 1972.

Sodium is the second most abundant cation in the main water-bearing zone beneath the plain. The concentration ranges from about 60 mg/l in areas adjacent to the Lompoc terrace and the Lompoc upland to about 400 mg/l. The concentration of sodium in the western part of the plain tends to be about 20 mg/l higher than in the eastern part. The average concentration throughout the plain is about 170 mg/l.

The concentration of magnesium commonly is from one-fourth to one-half that of calcium, the higher ratio generally occurring where the water is high in sulfate. It ranges from about 30 to 170 mg/l and averages about 100 mg/l. In a few wells the concentration of magnesium is about equal to calcium.

Potassium commonly occurs in concentrations from about 2 to 8 mg/l and averages about 6 mg/l. In general, the higher concentrations occur in areas of high dissolved solids and high sulfate.

The alkalinity of water in the main water-bearing zone beneath the plain is accounted for almost entirely by bicarbonate, which occurs in concentrations from about 220 to more than 800 mg/l and averages about 450 mg/l. The concentration of bicarbonate in the western part of the plain is about 80 mg/l greater than in the eastern part. Bicarbonate is the second most common constituent.

Minor constituents

Iron, boron, and fluoride together commonly make up less than 1 percent of the dissolved solids in water in the main water-bearing zone.

The concentration of iron in water from most wells in the plain ranges from about 20 to 200 μg/l (micrograms per litre). In general, the concentration of iron exceeds 1,000 μg/l in an axial part of the plain. Concentrations in excess of 5,000 μg/l occur in an area about 2 mi (3.2 km) northwest of Lompoc and in a small area about 1 mi (1.6 km) southwest of the Federal Correctional Institution, near well 7N/35W-25D3.

Boron occurs in the main water-bearing zone in concentrations from less than 100 μg/l to about 1,000 μg/l. In general, concentrations of boron in excess of 500 μg/l occur in the axial part of the valley. The concentration of boron is about 1,000 μg/l in a small area about 1 mi (1.6 km) northeast of Lompoc. Past analyses of water from wells in this area show that the concentration of boron has commonly exceeded 1,000 μg/l. Sewage effluent discharged to the riverbed northwest of the city of Lompoc contained 1,000 μg/l of boron in a sample taken June 8, 1972, and data in LoBue (1968, p. 82) indicate that during the period 1957-66 the effluent contained as much as 2,800 μg/l boron and averaged about 1,000 μg/l boron. The boron content in water from wells 7N/34W-29E1 and 29E4 (fig. 6) increased from about 400 μg/l in 1935 to 600 μg/l in 1972.

Fluoride occurs in the main water-bearing zone in concentrations that are commonly in the range of 0.2 to 0.5 mg/l. No particular pattern seems evident in the areal distribution of fluoride concentrations throughout the plain except that, in a general way, lower concentrations occur in much of the northeastern part, adjacent to the Lompoc upland.

Trace constituents

Several samples of water from the area and a sample of sediment from the lagoon near Surf were analyzed for trace constituents which commonly occur and which can affect the suitability of water supplies for drinking purposes. The samples were collected from:

1. Well 7N/34W-29E4 (table 7, fig. 6), an irrigation well 176 ft (53.5 m) deep, perforated in the main water-bearing zone about 2,500 ft (760 m) west of and downgradient from the Lompoc sewage-treatment plan;

2. Well 7N/34W-29G3 (table 8, fig. 6), a test hole 50 ft (15.2 m) deep on the west (downgradient) side of the Lompoc sewage-treatment plant;

3. Well 7N/35W-25D3 (table 7, fig. 6), a domestic well in the western part of the plain that is perforated only near the base of the main water-bearing zone, from 168 to 178 ft (51.2 to 54.2 m); and

4. Bottom sediment near the upstream end of the lagoon near Surf (table 9).

TABLE 7.--*Analyses of selected trace and minor constituents in water from two wells*

Well number	7N/34W-29E4	7N/35W-25D3
Well depth	176 ft	--
Perforated interval	about 100-170 ft	168-178 ft
Date sampled	6-13-73	6-13-73
Constituent	Concentration, in micrograms per litre	
Manganese	1,400	[1]460
Arsenic	2	0
Barium	200	0
Cadmium	1	0
Chromium, hexavalent	0	0
Cobalt	0	1
Lead	50	50
Lithium	50	80
Mercury	0.1	0.1
Selenium	0	--
Strontium	2,000	1,400
Zinc	40	30

[1]Sampled May 9, 1973.

TABLE 8.--*Analysis of selected trace and minor constituents in water from well 7N/34W-29G3*[1]

Constituent	Micrograms per kilogram
Aluminum	390
Manganese	350
Bromide	1,830
Antimony	1.0
Arsenic	1.8
Cobalt	.7
Copper	2.8
Mercury	.5
Lanthanum	.9
Strontium	6,700
Zinc	83

[1]Perforated 49- to 50-foot depth; sampled November 27, 1972.

TABLE 9.--*Analysis of insecticides from bottom sediment near mouth of Santa Ynez River (7N/35W-17K)*[1]

Constituent	Concentration in micrograms per kilogram
Aldrin	<0.2
Chlordane	<1.0
DDD	<.2
DDE	1.1
DDT	2.3
Diazinon	<.2
Dieldrin	<.2
Endrin	<.2
Heptachlor	<.2
Heptachlor epoxide	<.2
Lindane	<.2
Malathion	<.2
Methyl parathion	<.2
Parathion	<.2
PCB	≤2

[1]Sampled November 27, 1972.

The results of the analyses from this reconnaissance indicate that the concentration of most trace constituents in these samples is below generally accepted limits. However, the concentrations of lead in samples from wells 7N/34W-29E4 and 7N/35W-25D3 (50 μg/1) are equal to the suggested limits set by the Environmental Protection Agency (1972). In addition, one analysis of well water furnished by the city of Lompoc indicates that chlorinated hydrocarbons, if present, were below the limits of detection.

Lompoc Plain--Shallow Zone

Water in the shallow zone, which under much of the plain consists largely of a mixture of water from irrigation return and rainfall infiltration, typically contains dissolved solids in concentrations that range from about 1,500 to 3,500 mg/1 and averages almost 2,000 mg/1. The highest concentration of dissolved solids, based on limited areal distribution of samples, occurs in the central and northern part of the plain. The major constituents in most samples of the shallow water are calcium, sodium, sulfate, and bicarbonate.

Sulfate is the most abundant constituent in water from most of the shallow wells. For example, in wells 7N/34W-27F6 and 29H1 (fig. 6) the concentration of sulfate is about 3 times and 5 times that of bicarbonate, the next most abundant ion.

In the eastern and central part of the plain, where the greatest decline in water levels has occurred and where the shallow zone consists largely of sand and silt, the water quality is different from that in the western part of the plain. The difference is mainly in the concentration of sulfate.

The highest concentration of dissolved solids in the shallow zone seems to be in irrigated areas. The concentration of dissolved solids is 3,030 mg/1 in well 7N/34W-20Q1 (fig. 6) in the irrigated area, compared to 1,410 mg/1 in well 7N/34W-20P2 in the nonirrigated area. The concentration of chloride is the same in the two wells (280 mg/1), but the concentration of sulfate in the water beneath the irrigated area is almost 4 times that beneath the unirrigated area.

The concentration of many of the constituents in water from the shallow zone in irrigated areas is commonly twice or more than that in the main water-bearing zone. For example, in the eastern half of the plain the average concentration of the major cations, chloride, and dissolved solids in the shallow zone is almost twice that in the main water-bearing zone. The concentration of sulfate is about 3 times that in the main zone. Chemical analyses of water from several shallow wells and from nearby deep wells are shown in table 10.

TABLE 10.--*Comparison of water chemistry in selected shallow wells with nearby deep irrigation wells, Lompoc plain*

[Concentrations in milligrams per litre, except iron and boron in micrograms per litre]

Well number	Depth (feet)	Date sampled	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (sum)	Hardness as $CaCO_3$	Noncarbonate hardness	Percent sodium (Na)	Specific conductance (micromhos at 25°C)	pH	Temperature (°C)	Boron (B)
7N/34W-20Q1 (Shallow)	62	6- 9-72	35	2,500	420	160	310	7.8	650	0	1,500	280	0.1	0.3	3,030	1,700	1,200	28	3,750	7.4	17.0	260
7N/34W-20K4 (Deep)	174	11-14-68	46	180	140	34	82	2.4	310	0	240	110	.1	.3	818	1,500	240	27	1,240	7.7	21.0	180
7N/34W-27F6 (Shallow)	68	11- 2-72	28	100	260	180	360	4.1	550	0	1,500	160	.9	6.2	2,770	1,400	940	36	3,480	7.9	18.0	1,600
7N/34W-27F4 (Deep)	172	5-25-72	41	2,200	190	100	110	4.4	490	0	470	130	.4	.4	1,290	890	480	21	2,000	7.4	18.0	610
7N/34W-29H1 (Shallow)	73	8- 2-72	21	140	440	270	240	7.1	390	0	2,000	300	.4	.2	3,470	2,200	1,900	19	3,950	7.8	17.0	600
7N/34W-29K2 (Deep)	([1])	5-29-67	--	--	260	140	160	5.0	430	0	900	210	.8	0	2,060	1,200	--	22	2,410	7.8	--	480
7N/34W-31C4 (Shallow)	62	8- 4-72	27	720	150	160	170	1.9	480	0	700	200	.7	.2	1,650	1,000	640	26	2,340	7.5	16.5	850
7N/34W-31C2 (Deep)	([1])	7-11-72	40	340	160	84	89	2.2	540	0	320	120	.3	0	1,080	740	300	21	1,630	7.6	16.0	250
7N/35W-22J4 (Shallow)	30	11- 2-72	29	50	250	170	210	2.6	810	0	560	410	.4	.5	2,030	1,300	660	26	3,000	7.5	19.0	820
7N/35W-22J1 (Deep)	180	6- 8-72	40	3,300	270	140	190	9.5	540	0	750	350	.2	.1	2,020	1,300	800	25	2,900	7.0	18.0	500
7N/35W-25F6 (Shallow)	19	8- 3-72	17	500	330	100	140	4.0	470	0	770	240	1.3	.34	1,870	1,200	850	20	2,570	7.4	16.0	560
7N/35W-25F5 (Deep)	175	8- 2-72	40	2,500	250	110	150	5.1	530	0	710	190	.3	0	1,720	1,100	650	23	2,350	7.3	18.0	640
7N/35W-26A4 (Shallow)	46	5- 9-73	29	12,000	430	270	450	6.8	680	0	1,600	650	.6	2.1	3,790	2,200	1,600	31	4,490	7.3	17.0	1,100
7N/35W-25D3 (Deep)	178	5- 9-73	32	9,600	280	130	210	9.0	580	0	680	310	.3	2.1	1,950	1,200	760	27	2,670	7.4	17.1	760

[1]Irrigation wells perforated in main water-bearing zone, estimated 160-180 feet deep.

Lompoc Terrace

Ground water in the Lompoc terrace typically contains from about 500 to 700 mg/l of dissolved solids, and the major constituents in water from most wells are chloride, bicarbonate, and sodium. Sulfate, in contrast to that in ground water in the nearby plain, is generally present in concentrations of less than 100 mg/l.

Figure 18 shows a general decrease in sulfate in a downgradient direction from south to north across the central part of the terrace near Lompoc Canyon.

Several of the wells along the north edge of the terrace contain less than 50 mg/l sulfate. This trend, and the odor of hydrogen sulfide that is common when many of the wells are pumped, suggests that sulfate reduction (Hem, 1970, p. 169-170) may be occurring as ground water moves northward from recharge areas along the south side of the terrace.

A few small seeps and springs, some that flow intermittently, discharge water from local shallow, perched zones in the terrace deposits. This water (Evenson and Miller, 1963, table 7) typically contains from about 300 to 500 mg/l of dissolved solids.

Lompoc Upland

Ground water in the Lompoc upland area generally is of better chemical quality than in the Lompoc plain area. The concentration of dissolved solids in water from wells in the upland ranges from about 400 to almost 1,000 mg/l and averages about 600 mg/l. The major constituents are bicarbonate, chloride, sulfate, and sodium.

The temperature of ground water in the major aquifer system beneath the Lompoc upland ranges from about 22° to 26°C which is 2° to 10°C higher than in other nearby areas. This is roughly 10°C higher than the mean annual air temperature at Lompoc (57°F, 13.9°C). The long residence time of the water in the relatively deep basin and the local geothermal gradient probably cause the increased temperature. Data from several oil wells in the area indicate that temperatures as high as 70°C exist in consolidated rocks at depths of less than 5,000 ft (1,500 m).

Perched ground water of good to excellent chemical quality occurs at shallow depths in much of the Lompoc upland. Several small springs and seeps discharge along canyon walls.

The water at two springs, 7N/34W-5KS1 and 7N/34W-24FS1 (fig. 6) (Purisima Spring) which probably are representative of the shallow water, contains about 220 mg/l of dissolved solids. The major ions in water from these springs are sodium, chloride, and bicarbonate, and the total hardness ranges from 21 to 36 mg/l.

Suitability of Ground Water for Use

Ground water beneath the Lompoc plain is presently used for irrigation and municipal, domestic, and industrial supply.

Irrigation use

The suitability of water for irrigation may depend on a combination of conditions, but of primary importance is the nature of the soil and the quality of the water.

Soils in the Lompoc plain are mostly of the Mocho-Metz-Camarillo association (Shipman, 1972), which are sandy- to silty-clay loams that generally are moderately well drained and have infiltration rates classed as medium. Their permeability combined with general depths of water table from 15 to 50 ft (5 to 15 m) below land surface over most of the plain tends to prevent water logging and salt buildup.

The water from most irrigation wells within the plain contains from about 1,000 to 2,500 mg/l of dissolved solids, and the specific conductance ranges from about 2,000 to 3,000 micromhos (fig. 15). Specific conductance is a commonly used index of the general suitability of water for irrigation. When specific conductance is used with potential salinity (concentration of chloride plus half the concentration of sulfate, Doneen, 1962, p. 3) and soil permeability, a convenient guide for the classification of suitability of irrigation water is derived.

The potential salinity of irrigation water in the Lompoc plain that is more conductive than 2,000 micromhos is roughly equal to the specific conductance multiplied by 0.0058, and for less conductive water the multiple is 0.0052. Although no attempt was made in this study to correlate the potential salinity with the details of soil type, in general the potential salinity of irrigation water seems to increase from east to west across the plain while the soil permeability decreases in this direction. This combination is additive (Richards, 1954, p. 31, 72). Considering the three classes shown in table 11, most of the irrigation supplies in the plain would fall in classes 2 and 3--the categories of good to unsuitable (LoBue, 1968; Wilson, 1959).

Other criteria that commonly are applied to the classification of irrigation water include the concentration of boron, the percent sodium, and the sodium-adsorption ratio. Boron in small quantities is necessary for most plant growth, but concentrations in irrigation water greater than 1-2 mg/l are injurious to many crops. The maximum concentration of boron found in irrigation water in the plain is about 1 mg/l, the minimum concentration is about 0.1, and the average is about 0.45 mg/l. Concentrations in this range do not seem to be injurious to most crops grown in the area. Table 12 is a general list of crops and their tolerance for boron (Wilcox, 1960).

TABLE 11.--*Tentative classification of irrigation water in the Lompoc area*

[From Doneen, 1962, p. 3]

Effect on soil	Class 1 Excellent to good		Class 2 Good to injurious		Class 3 Injurious to unsuitable	
	Potential salinity (epm)	Specific conductance (micromhos at 25°C)	Potential salinity (epm)	Specific conductance (micromhos at 25°C)	Potential salinity (epm)	Specific conductance (micromhos at 25°C)
Minimal leaching; slow percolation rates	3.00	500	3.00- 5.00	500- 800	>5.00	>800
Some restricted leaching; deep percolation slow	5.00	800	5.00-10.00	800-1,700	>10.00	>1,700
Maximum leaching; deep percolation rapid	7.00	1,200	7.00-15.00	1,200-2,500	>15.00	>2,500

TABLE 12.--*Limits of boron in irrigation water for crops of different degrees of boron tolerance*

[From Wilcox, 1960]

Tolerant	Semitolerant	Sensitive
4.0 p.p.m. of boron	*2.0 p.p.m. of boron*	*1.0 p.p.m. of boron*
Athel *(Tamarix aphylla)*	Sunflower (native)	Pecan
Asparagus	Potato	Walnut (black and Persian, or English)
Palm *(Phoenix canariensis)*	Cotton (Acala and Pima)	Jerusalem artichoke
Date palm *(P. dactylifera)*	Tomato	Navy bean
Sugar beet	Sweetpea	American elm
Mangel	Radish	Plum
Garden beet	Field pea	Pear
Alfalfa	Ragged robin rose	Apple
Gladiolus	Olive	Grape (Sultanina and Malaga)
Broadbean	Barley	Kadota fig
Onion	Wheat	Persimmon
Turnip	Corn	Cherry
Cabbage	Milo	Peach
Lettuce	Oat	Apricot
Carrot	Zinnia	Thornless blackberry
	Pumpkin	Orange
	Bell pepper	Avocado
	Sweetpotato	Grapefruit
	Lima bean	Lemon
2.0 p.p.m. of boron	*1.0 p.p.m. of boron*	*0.3 p.p.m. of boron*

The occurrence of high concentrations of sodium in irrigation water tends to cause poor tilth and to lower the permeability of fine-grained soils. The use of the sodium-adsorption ratio (SAR) of an irrigation supply as an index of its suitability is generally preferable to the use of percent sodium (U.S. Salinity Laboratory Staff, 1954, p. 72).

Another common method of classifying irrigation water, shown in figures 21 and 22, is to use the SAR and specific conductance. Most of the irrigation water from the main water-bearing and shallow zones of the plain is classed as high to very high salinity-low sodium; water sampled from the Lompoc upland and the Lompoc terrace is also classed as high salinity-low sodium.

The yield of many crops declines significantly when salt in the soil reaches certain levels. Figure 23 shows some representative responses of different crops to changes in soil-extract salinity. Many of the crops are grown on the Lompoc plain, and the yield of several is sensitive to changes in soil salt. Most of the irrigation on the Lompoc plain is by flooding furrows, and more water is usually applied than transpired by the crops. This practice helps leach salt from the soil and reduces its effect on crop growth.

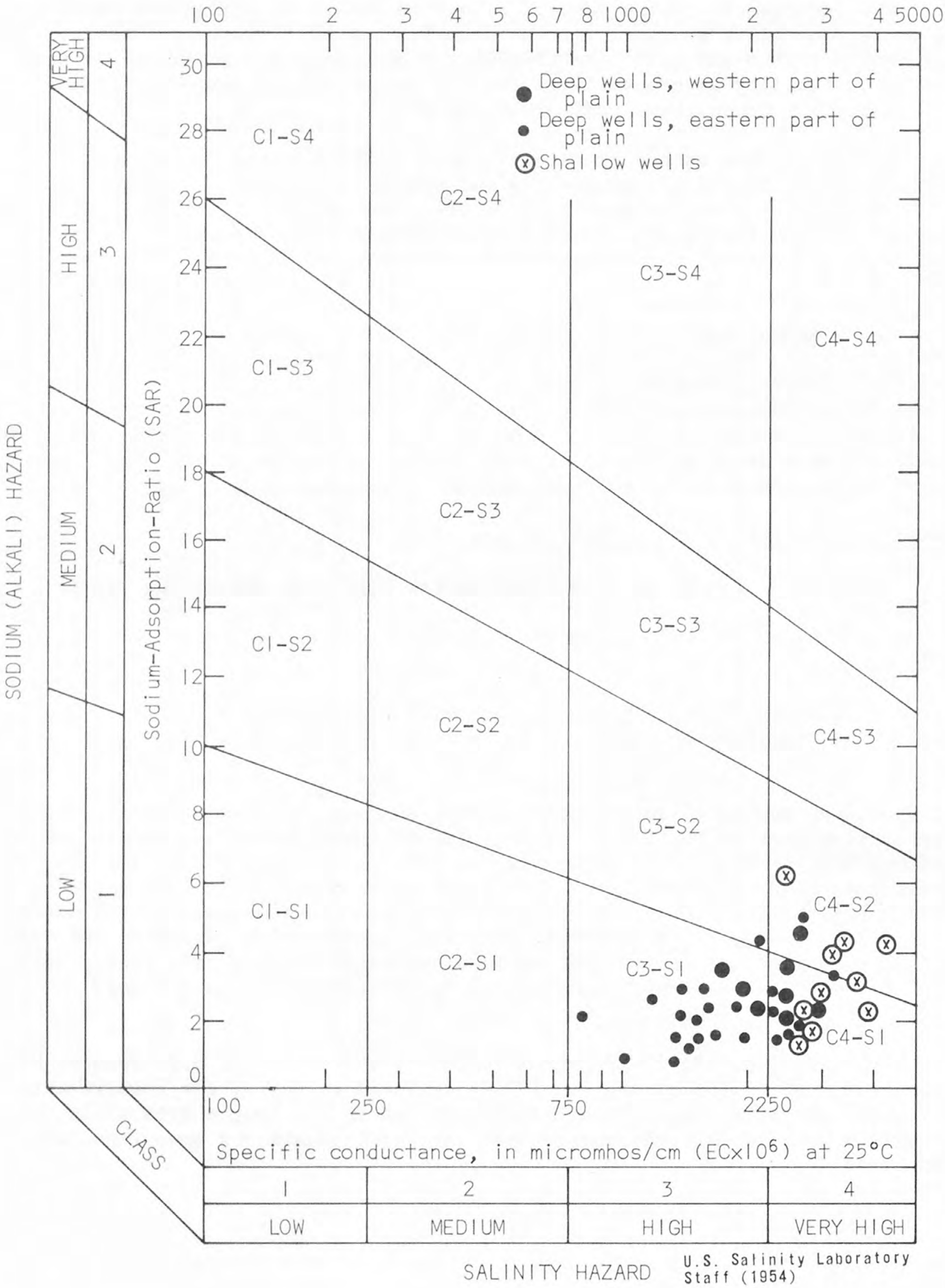
Municipal, domestic, and industrial use

The principal qualities of ground water that most affect its use for municipal, domestic, and industrial supply are hardness and dissolved solids, but the presence of iron, manganese, and other minor constituents may also affect its use.

Several standards for classifying water for its suitability as a supply are in use (California Department of Health, 1973; Environmental Protection Agency, 1972).

Most of the water supply derived from the main water-bearing zone beneath the eastern part of the Lompoc plain, with the exception of dissolved solids and sulfate, is within the water-quality criteria recommended by the Environmental Protection Agency (1972) and by the California Department of Public Health (1973) for many of the individual constituents. In the western part of the plain, the concentrations of dissolved solids, sulfate, chloride, and iron commonly exceed the recommended standards. Water from supply wells in the Lompoc terrace and Lompoc upland is within the limits for most individual constituents.

Hem (1970, p. 333-336), McKee and Wolf (1963), and the U.S. Federal Water Pollution Control Administration (1967) reviewed in detail the requirements for many industrial uses. Most water supplies in the Lompoc area would require some form of treatment to meet the requirements for many types of industry.



100 2 3 4 5 6 7 8 1000 2 3 4 5000
Deep wells, western part of plain
Deep wells, eastern part of plain
Shallow wells
C1-S4
C2-S4
C3-S4
C4-S4
C1-S3
C2-S3
C3-S3
C4-S3
C1-S2
C2-S2
C3-S2
C4-S2
C1-S1
C2-S1
C3-S1
C4-S1
SODIUM (ALKALI) HAZARD
Sodium-Adsorption-Ratio (SAR)
VERY HIGH
HIGH
MEDIUM
LOW
4
3
2
1
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
100 250 750 2250
CLASS
Specific conductance, in micromhos/cm (ECx10⁶) at 25°C
1 2 3 4
LOW MEDIUM HIGH VERY HIGH
SALINITY HAZARD
U.S. Salinity Laboratory Staff (1954)

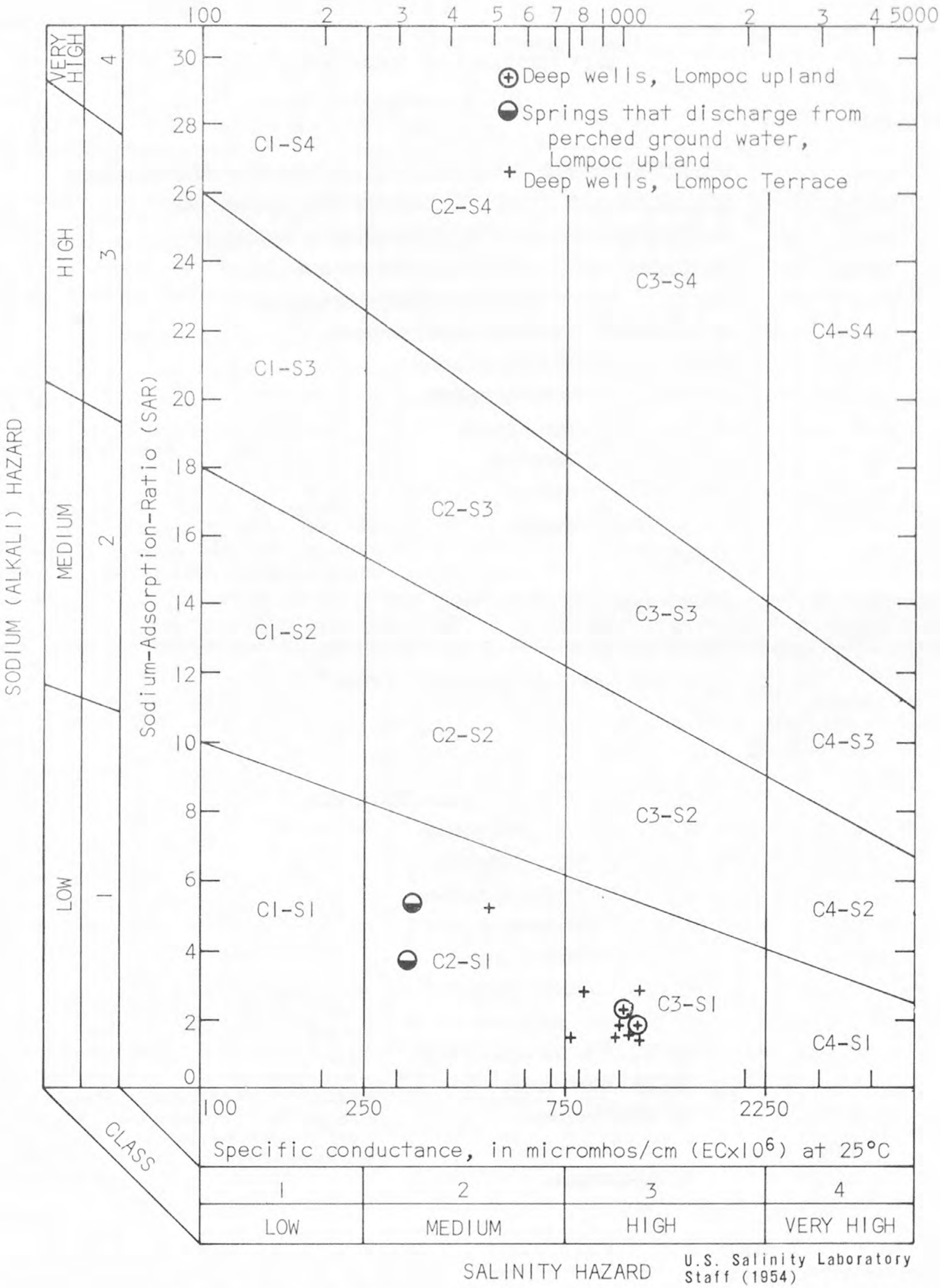
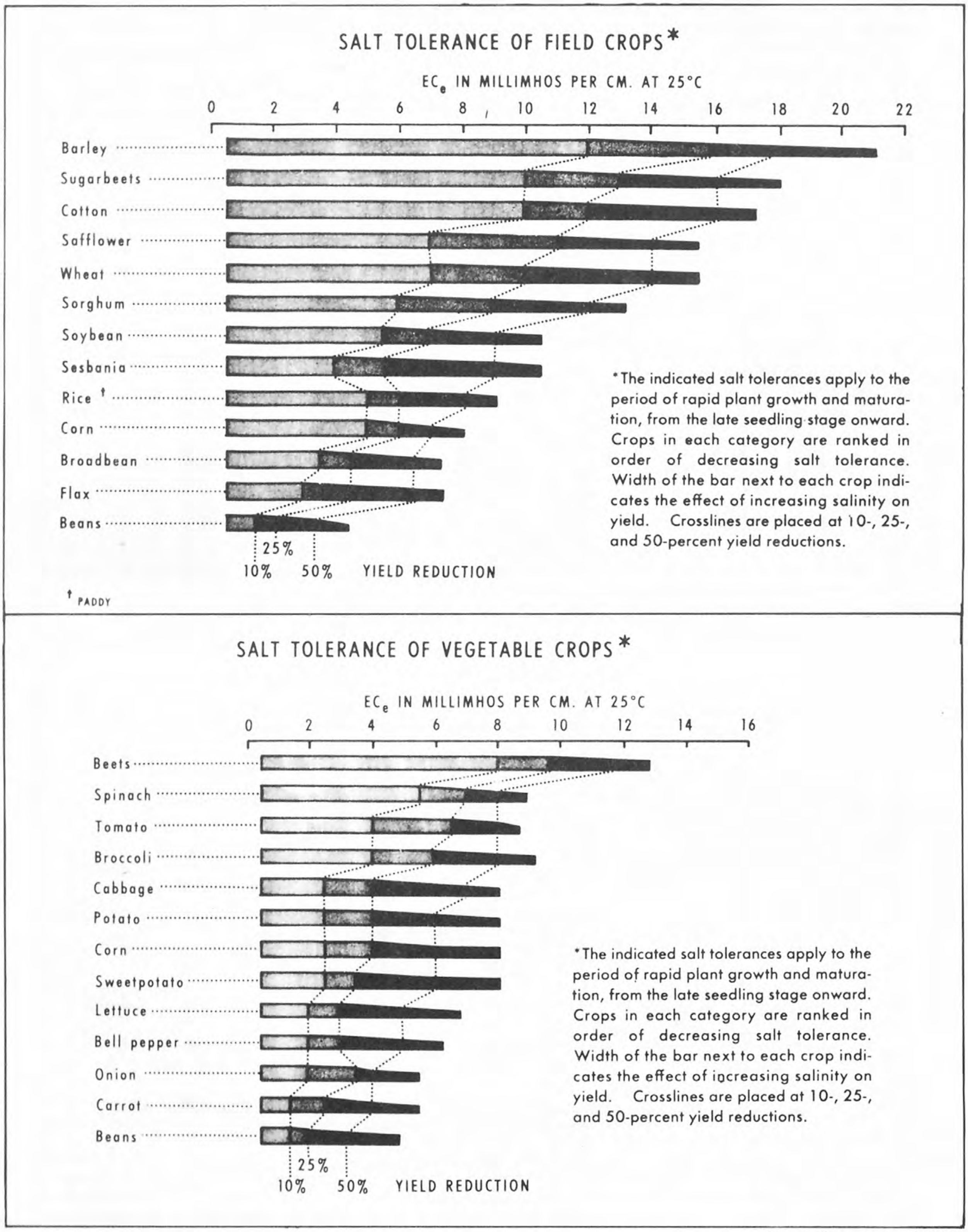


FIGURE 22.--Classification of irrigation water in Lompoc upland and Lompoc terrace.



From Bernstein (1964)

FIGURE 23.--Relation of soil salts to yield of selected crops.

Changes in Ground-Water Quality

The history of water-quality changes in the Lompoc area may be summarized as follows:

In the Lompoc plain a trend toward increasing dissolved solids in ground water apparently began during the mid-1930's. This is reflected by the generally increasing concentration of sulfate and chloride from 1935 to 1973 in selected wells that tap the main water-bearing zone beneath the plain. It is also shown for the period 1961-72 by the changes in specific conductance and concentration of chloride as contoured in figures 24 and 25.

Water quality of ground water in the Lompoc terrace and Lompoc upland has changed very little in historic time.

Apparent causes of changes

The apparent causes of most of the changes in the chemical quality of ground water in the area are closely related to man's activities. Return flow of excess irrigation water, subsurface and surface inflow of native water, and discharge of sewage effluent are important factors that have influenced the quality of ground water in the area. Other potential causes are the disposal of water-softener residue and the later effects of recharge from a reservoir on the Santa Ynez River proposed by the U.S. Bureau of Reclamation.

Irrigation-return flow.--Irrigation-return flow, enriched in dissolved solids by the evaporation and leaching processes, enters the unsaturated zone over most of the plain and moves downward to the water table in the shallow water-bearing zone.

The chemical quality of water in the shallow water-bearing zone prior to the beginning of irrigated farming is not well documented but probably was similar to that in the main water-bearing zone. Four samples taken in 1935 from the shallow zone in the eastern part of the plain contained from about 350 to 460 mg/l of sulfate, from 80 to 215 mg/l of chloride, and from 860 to 1,350 mg/l of dissolved solids.

The water quality in the shallow water-bearing zone in 1972, after a half century of recharge by irrigation return, was much higher in dissolved solids, notably sulfate, than the underlying water in the main water-bearing zone. For example, at shallow well 7N/34W-27F6 the sulfate/chloride ratio is 9.4 (SO_4, 1,500 mg/l; Cl, 160 mg/l) compared to 3.6 (SO_4, 470 mg/l; Cl, 130 mg/l) in nearby deep irrigation well 27F4. Little enrichment of nitrogen, potassium, and phosphorous, the major constituents in most commercial fertilizers, was apparent.

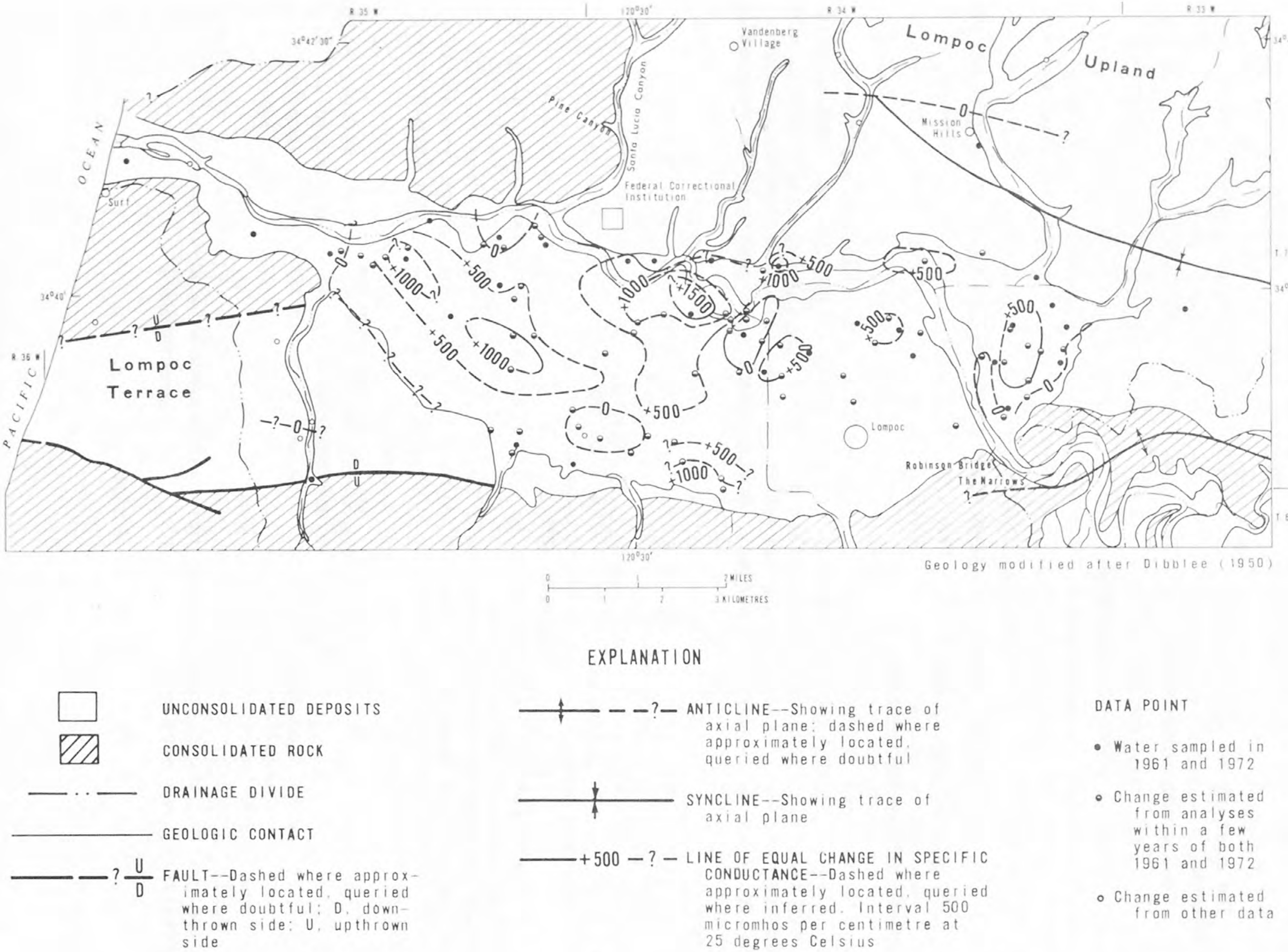


FIGURE 24.--Change in specific conductance in water from wells perforated in the main water-bearing zone in Lompoc plain, between 1961 and 1972.

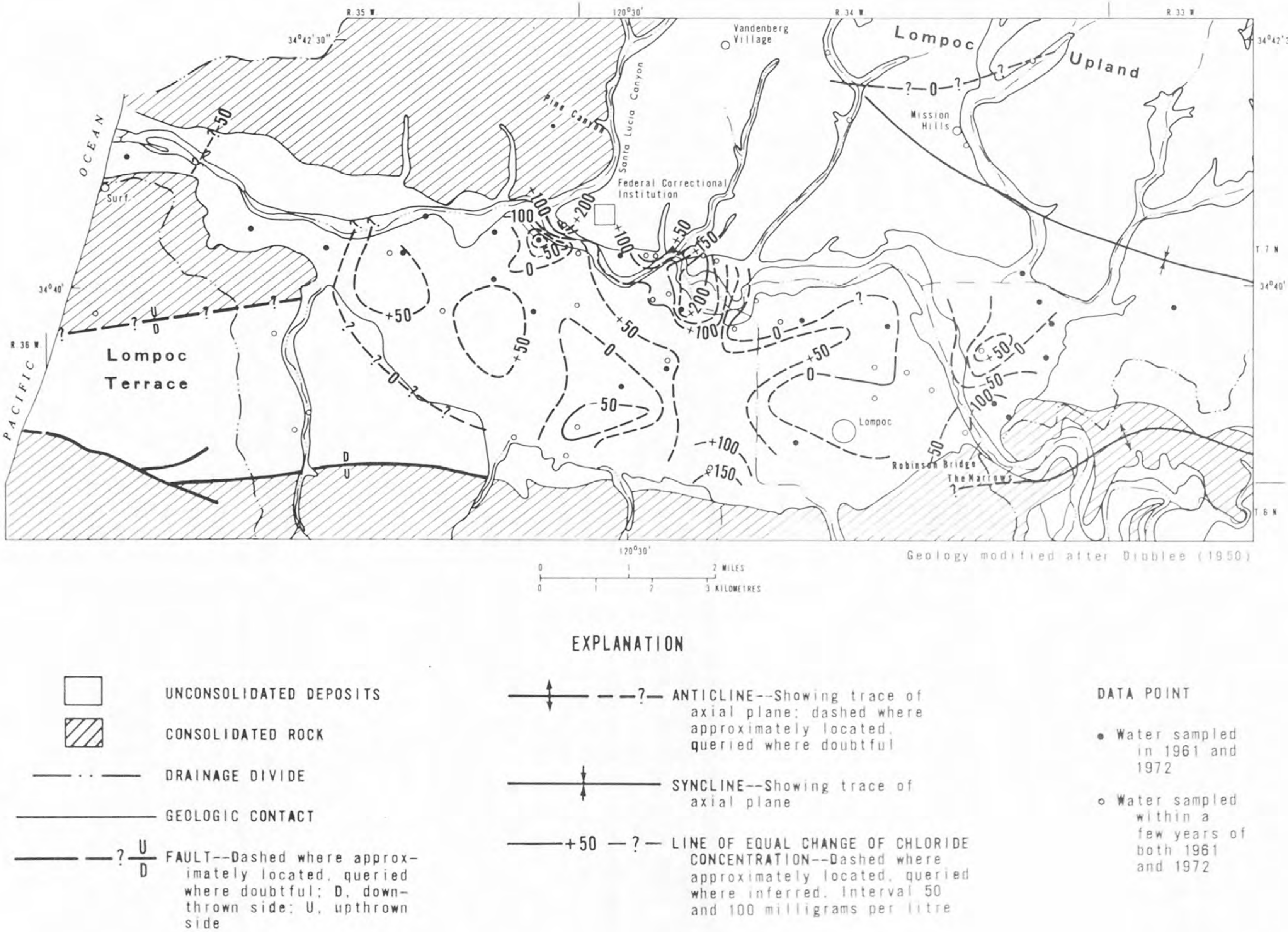


FIGURE 25.--Change in concentration of chloride in water from wells perforated in the main water-bearing zone in Lompoc plain, between 1961 and 1972.

A plausible source of sulfate in the shallow water-bearing zone is the oxidation of sulfide minerals (Krauskopf, 1967, p. 511-514; Lorenz, 1962, p. 6-9), which were deposited in the shallow water-bearing zone when the water table was at the prefarming high level. Sulfide minerals, mostly pyrite and marcasite, were found in cored samples taken below the water table in two test holes that were drilled in the shallow water-bearing zone during 1972. No sulfide was found in cores taken above the water table.

Water in the main water-bearing zone was examined by E. A. Jenne of the Geological Survey for the occurrence of sulfate using a digital computer to develop statistical data for calculations of mineral equilibria. He concluded that there was no general selective enrichment in sulfate in water from the main water-bearing zone.

The recycling of irrigation return-flow water will continue to increase the volume of poor-quality water in the shallow water-bearing zone and will eventually, by leakage, lower the quality of water in the main water-bearing zone and in turn the irrigation-return water.

Native water.--Native water of poor quality, typically high in chloride, probably has entered the main water-bearing zone along the edge of the plain in recent years, largely in response to declining water levels in the alluvium (Evenson, 1965, p. 16-17).

Some surface inflow of poor-quality water has occurred during wet years, and small quantities of subsurface inflow probably occur in an area along the southwest edge of the plain westward from about well 7N/35W-20J1 (fig. 6). However, the area in the plain that is influenced by this inflow is small and does not seem to be increasing.

The area of high-chloride concentrations at the mouth of Santa Lucia Canyon (fig. 19) attributed to connate water by Evenson (1965) is slightly larger than in 1962. Similarly, an area of high-chloride water about a mile east of Lompoc apparently extended several thousand feet farther north in 1972 than in 1961 but contained a lower peak chloride concentration. Part of the northern extension is probably in part the result of more extensive sampling during 1972.

Sewage effluent.--Sewage effluent of varying volume and chemical quality is or has been discharged at several sites in the area for many years from the city of Lompoc, Vandenberg AFB, the Federal Correctional Institution, Vandenberg Village, and Mission Hills. The effects of past discharge on ground-water quality are not known at this time except for the Lompoc area. Recharge of sewage effluent from the Lompoc sewage-treatment plant has affected ground-water quality beneath about a square mile (2.6 km^2) of the plain in an area northwest of Lompoc. A total of about 13,000 acre-ft (16 hm^3) of effluent was discharged during 1957-67 (LoBue, 1968, table 5). The effluent has been characterized by high chloride (LoBue, 1968, p. 29-34), and the area influenced by sewage effluent is probably best outlined by chloride concentration shown in figure 19. During 1957-66, dissolved solids in the effluent ranged from about 1,390 to 3,060 mg/l and averaged about 2,200 mg/l. The concentration of chloride in the effluent during this period ranged from 332 to 1,010 mg/l and averaged about 660 mg/l.

Brackish water.--High concentrations of chloride occur in water samples from several wells near the coast. The chloride probably does not represent seawater intrusion into the aquifer; more likely, it is the result of the general increase in salinity from east to west in the plain.

Other potential causes of changes

In addition to the possible continuing effects of irrigation-return flow, inflow of native water, and discharge of sewage effluent on the chemical quality of ground water in the Lompoc area, consideration should be given to the possible effects of solid waste disposal and potential recharge from the proposed Santa Ynez reservoir.

Water-softener residue.--A pile of residue (consisting largely of bicarbonates of calcium, sodium, and magnesium) about 5-10 ft (1.5-3 m) thick from the water-softener plant at Vandenberg AFB occupies about 15 acres (6 ha) in the NE¼ sec. 23, T. 7 N., R. 35 W. The material overlies alluvium near the river, where the ground-water level is within about 20 ft (6 m) of the surface.

Water-softener residues from the Lompoc municipal water-treatment plant have been incorporated in the city's solid-waste landfill in the floor of a north-trending canyon about 2 mi (3.2 km) southwest of Lompoc.

The location of both sites on alluvial sand and silt deposits would allow any leachate formed during rains to infiltrate and percolate to the shallow ground-water aquifer.

Proposed Santa Ynez reservoir.--A dam and reservoir on the Santa Ynez River near The Narrows, proposed by the U.S. Bureau of Reclamation, would impound a maximum of 425,000 acre-ft (524 hm^3) of water and would supply from approximately 17,000 to 20,000 acre-ft (20 to 24 hm^3) annually for municipal and industrial use in the Lompoc area. Under estimated 1980 conditions, about 1,500 acre-ft (1.8 hm^3) annually of this water would, after use, percolate to the ground water beneath the plain (U.S. Bureau of Reclamation, written commun., 1968; 1969).

The predicted concentration of dissolved solids in water in the proposed reservoir was estimated to range from about 400 mg/l in extremely wet years to about 1,500 mg/l during dry years and would average 725 mg/l (U.S. Federal Water Pollution Control Administration, 1967, p. 25). This is about 225 mg/l more than the estimated average concentration of the dissolved solids in present streamflow and about half the average concentration of ground water pumped from the plain. This increase in dissolved solids would be brought about in large part by the evaporation of about 10,000 acre-ft (12 hm^3) of water annually (U.S. Bureau of Reclamation, written commun., 1969) during periods of carryover storage in the reservoir.

Evaporation from a U.S. Weather Bureau pan about 3 mi (4.8 km) north of the proposed reservoir averaged about 78 in (1,980 mm) annually during 1957-61 (Blaney and others, 1963, p. 53).

The overall effect of the operation of the proposed reservoir of water quality in the plain is not readily apparent and would depend to some degree on the manner of operation of the system.

CONSIDERATION OF MANAGEMENT ALTERNATIVES TO IMPROVE WATER QUALITY

Any water-management alternatives in the Lompoc area should be made only after considering their possible effects on ground-water quality. Although water-level changes in the Lompoc area suggest that only a small percentage of the ground-water storage has been depleted, the history of ground-water-quality changes indicates that dissolved solids have doubled in water from some wells in the plain and have increased in most wells. Consequently, water quality may become a major factor limiting the utilization of ground water.

Some management alternatives to improve water quality that might be considered are discussed briefly below. They pertain only to the hydrologic aspects of the system, particularly recharge, and do not take into account the many socioeconomic, legal, and other constraints on management. The reader is referred to general discussions of principles of ground-water-quality management by Hem (1970, p. 336-338) and Water Resources Engineers (1969).

1. Water of good quality could be imported as part of the California Water Plan and applied to the main water-bearing zone by recharging directly with injection wells or by spreading ponds along the river. The imported water would contain less than 500 mg/l of dissolved solids; typical municipal sewage effluent derived from this water might contain less than 800 mg/l of dissolved solids.

Another source of water for recharge is sewage effluent generated elsewhere throughout the plain and presently lost as a source of recharge either by evapotranspiration or by disposal to the ocean.

Utilizing injection wells for recharging water directly into the main water-bearing zone would have the advantages of (1) placing the water in the aquifer from which it is to be later withdrawn, (2) locating the wells where the recharge is most needed, and (3) minimizing spreading problems associated with poor-quality water in the shallow zone.

More water could be recharged by constructing spreading facilities to salvage runoff from urbanized areas, or to induce more recharge from the Santa Ynez River, from its tributaries, or from lined channels along several of the local tributaries. Dikes, check dams, and seepage basins have been used successfully in similar hydrologic areas in southern California (Banks and others, 1954). The 2- to 3-mi (3- to 4-km) reach of the Santa Ynez River channel below Robinson Bridge is the most permeable channel area for recharge by surface spreading. Also, permeable soils and a large storage capacity exist in the Lompoc upland and Lompoc terrace.

2. The scheduling of future releases from Lake Cachuma or reservoirs to be constructed on the river could be coordinated to allow minimum losses by evaporation and by floodflows to the ocean, and thereby increase the amount of water available to recharge the ground-water reservoirs.

3. Additional storage space in the shallow water-bearing zone could be obtained by lowering the water levels by selective pumping along the most permeable reach of the Santa Ynez River below Robinson Bridge. This lack of storage space has been a major factor limiting seepage from the river during floods.

4. Some enhancement of quality could be achieved by changing the patterns of water use. The reduction on the use of ground water in some areas could prolong the availability and quality of ground water. Similarly, improvement of efficiency of irrigation practices could reduce the depletion of ground water in storage, reduce the highly mineralized irrigation-return flow, and thus reduce the downward movement of saline ground water from the shallow to the main water-bearing zone.

5. In areas where ground water currently is high in dissolved solids, such as several areas where native water enters the plain, the deleterious effect of these sources on water quality could be reduced or controlled by selective pumping and by transporting the water out of the area. Another alternative could be to use the water to grow salt-tolerant crops. Seawater intrusion, if and when it becomes a problem, could be controlled by injecting fresh water or treated sewage effluent in a line of wells across the narrow coastal end of the basin.

6. For some uses, water of better quality than that available in the main zone beneath the plain probably could be pumped from older aquifers below the main zone or from adjacent ground-water basins. This is based on a study of deep wells in the adjacent Lompoc upland.

MONITORING PROGRAM

An adequate monitoring program is the most effective method of evaluating changes of water quality which are pertinent to the prudent utilization of water resources. Such a monitoring program for the Lompoc area might include (1) adequate data on all phases of the hydrologic cycle so that any general changes that occur can be evaluated and (2) selective data that will provide additional information to better identify and determine the changes in known problem areas, which typically are areas of hydrochemical stress.

Status of Current Program

Data being collected currently provide only a general evaluation of the water resources in the Lompoc area. Streamflow on the Santa Ynez River and on some of the local tributaries has been measured for many years by the Geological Survey in cooperation with Santa Barbara County and other agencies. Water levels are measured in about 90 wells by the Geological Survey and the U.S. Bureau of Reclamation twice each year, and the water from about 10 wells is sampled yearly for chemical analysis. Drillers' logs of new wells in the area are collected by the State of California. Annual pumpage data and chemical analyses are available from most of the municipal wells and federally owned wells, and the Geological Survey has estimated unmetered pumpage in the plain for many years.

Long-term data collection by the National Weather Service, Santa Barbara County, the U.S. Forest Service, and other agencies presumably will continue to provide climatic data in the Santa Ynez River basin.

Future Monitoring Possibilities

Surface Water

A more intensive program to monitor streamflow quantity under various conditions of flow would better define seepage losses from the Santa Ynez River in the reach between the gages at The Narrows and near Pine Canyon. A few standard water analyses and several specific-conductance measurements at each gage over a period of years would allow a more quantitative estimate to be made of the quality of recharge from this source.

Additional streamflow and chemical data for the major tributaries would monitor recharge and the loss of recharge attributable to lined channels.

Ground Water

Additional data collection directed toward the shallow ground-water zone and other existing or potential problem areas would augment the water-quality data currently available and could be used to evaluate the changes in ground-water quality occurring in specific problem areas. If the results of the continuing monitoring program were periodically evaluated, the scope of sampling and analysis could be modified to keep pace with current knowledge of the hydrologic system. The frequency and type of periodic water analysis would be governed by the objectives of the monitoring program and by the analytical results. Where rapid and significant changes in water chemistry occur or where constituents of great concern to public health are involved, wells could be sampled more often than where few changes occur. Frequent and easily obtained field measurements of such characteristics as specific conductance, pH, and temperature, if properly utilized and evaluated, would appreciably reduce the need for more extensive sampling and analysis.

For consistent results all sampling and analytical procedures should be done according to recognized standard methods.

General information

Construction of 10 or more shallow observation wells would provide better general ground-water quality coverage both areally and at different depths in the shallow water-bearing zone. Standard chemical analysis could be made on water from the wells annually over a period of 3 to 5 years. Water from one or more of the shallow wells in an irrigated area could be sampled monthly for chemical analyses, and field measurements of specific conductance, pH, and temperature could be made.

Information on specific problem areas

Lompoc sewage-disposal area.--Two or more observation wells screened at different depths constructed at each area of present and past recharge would monitor any changes. Monitoring the effects of the proposed change in location, scheduling, and quality of treated sewage effluent for recharge in the Santa Ynez River east of Lompoc will require 10 to 20 shallow observation wells constructed along the reach proposed for recharge. Observation wells between the recharge reach and nearby large-capacity wells and two additional deep wells perforated in the main water-bearing zone underlying the recharge area would monitor migration of the recharged water.

A better understanding of effects of the recharge would be obtained if the monitoring net in the proposed area of recharge were planned, constructed, and background samples taken prior to any recharging of effluent. A standard analysis made initially of water from each well would include the following:

Alkalinity	Specific conductance (field)	pH (field)
Bicarbonate	Fluoride	Potassium
Boron	Hardness	Silica
Calcium	Iron	Sodium
Chloride	Magnesium	Sulfate
Dissolved solids (sum)	Nitrate	Temperature (field)

Complete analyses of the sewage effluent, including trace constituents, are important. These data and past analyses in the area will provide background data useful in evaluating future changes.

Additional background data could be obtained by sampling five or more shallow wells and one or more deep wells near the proposed recharge site, and analyzing for constituents that normally occur in trace concentrations, some of which are present in local ground water. These constituents should include, as a minimum, the following:

Aluminum	Lead	Pesticides and herbicides
Arsenic	Methylene blue active substances	Phosphate
Barium	Mercury	Selenium
Cadmium	Molybdenum	Strontium
Chromium		Zinc
Copper		

Vandenberg Village sewage-disposal area.--Sewage effluent discharged on the land surface near Vandenberg Village by spraying may have important future effects on local ground water. Test holes drilled at three or more sites in the areas of present and past discharge would monitor these effects. In addition to the shallow observation wells, well 7N/34W-20C1, downgradient from the area of discharge, could be sampled yearly. The depth and perforated interval in this well are not known; if the well is not perforated near the water table, a shallow piezometer could be installed for sampling nearby and screened about 5 ft (1.5 m) below the water table.

Water-softening residue disposal area.--Ground water in the area west and south of the pile of softening-plant residue in the NE¼ sec. 23, T. 7 N., R. 35 W., may show effects of infiltration of the soluble residue. Several shallow observation wells constructed in the area would determine local ground-water gradients and indicate if leachate from the residue has entered the ground water. Abandoned well 7N/35W-23B1 nearby and downgradient from most of the residue could be sampled. The well reportedly is perforated from 57 to 178 ft (17.4 to 54 m) in depth, and the water level is within about 25 ft (7.6 m) of land surface.

Lompoc sanitary landfill area.--Test holes drilled across the narrow canyon south of well 6N/34W-5K3 below the sanitary landfill facility operated by the city of Lompoc would delineate the bedrock surface and determine if the alluvium is saturated. If saturated conditions exist, one or more of these wells located at the low point of buried bedrock could be sampled at least yearly and after heavy rains.

The area monitored could supplement monitoring of the poor-quality native water in well 6N/34W-5K3. Existing wells in the area that would serve as sampling points for monitoring the poor-quality native water are 6N/34W-5D1, 5F1, 5H5, and 5K1-3.

Mouth of Santa Lucia Canyon.--Most of the wells formerly sampled to monitor water of poor quality near the mouth of Santa Lucia Canyon were destroyed or buried by the floods of 1969. If it is not feasible to renovate wells 7N/35W-24B1, B2, H1, and H2, new shallow observation wells could be installed in the canyon in the NE cor. sec. 24, T. 7 N., R. 35 W.

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