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WATER-RESOURCES INVESTIGATION USING ANALOG MODEL TECHNIQUES IN THE SAUGUS-NEWHALL AREA LOS ANGELES COUNTY, CALIFORNIA

By

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Prepared in cooperation with the
Newhall County Water District

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WATER-RESOURCES INVESTIGATION USING ANALOG MODEL TECHNIQUES IN THE SAUGUS-NEWHALL AREA, LOS ANGELES COUNTY, CALIFORNIA

By S. G. Robson

ABSTRACT

The Saugus-Newhall area is in the upper Santa Clara River valley in northwestern Los Angeles County, about 30 miles north of Los Angeles. The area has two main aquifers, the alluvial aquifer and the underlying Saugus aquifer. These two aquifers are the subject of this investigation.

The alluvial aquifer consists of river channel alluvium as much as 200 feet thick with a transmissibility ranging from 50,000 to 325,000 gallons per day per foot and a storage coefficient of 10 to 20 percent. In 1945 about 210,000 acre-feet of recoverable ground water was in storage in the alluvial aquifer. The alluvial aquifer is the major source of ground-water pumpage and has supplied about 600,000 acre-feet of effective pumpage during the period 1945 through 1967. Ground-water pumpage and variations in the quantities of surface-water recharge have caused large fluctuations in the water levels in the alluvial aquifer.

The Saugus aquifer has a maximum saturated thickness of about 3,500 feet and ranges in transmissibility from 2,000 to 200,000 gallons per day per foot. Based on limited available data, the Saugus aquifer may contain as much as 6 million acre-feet of ground water in storage under steady-state conditions. Meager available data indicate the water quality in some areas of the Saugus aquifer is poor so that only a fraction of the ground water in storage in the aquifer may be usable for domestic water supplies.

Floodflow in the streams in the area is the major source of recharge to the alluvial aquifer and the underlying Saugus aquifer. The chemical quality of the ground water is largely dependent on the chemical quality of the surface-water recharge. Ground-water discharge occurs along the Santa Clara River below Castaic Junction.

Water will be imported to supplement the existing water resources. An analog model of the ground-water basin indicates that it will not be possible to artificially recharge the proposed quantities of imported water into the alluvial aquifer above Saugus unless ground-water pumpage from that area is increased.

The model further indicates that the alluvial aquifer may not be able to supply enough water, even when artificially recharged with imported water, to meet the estimated maximum pumping rate to 1990 used in the model and that increased pumpage from the Saugus aquifer may cause water-level declines in both aquifers and may eliminate the natural ground-water discharge from the aquifers.

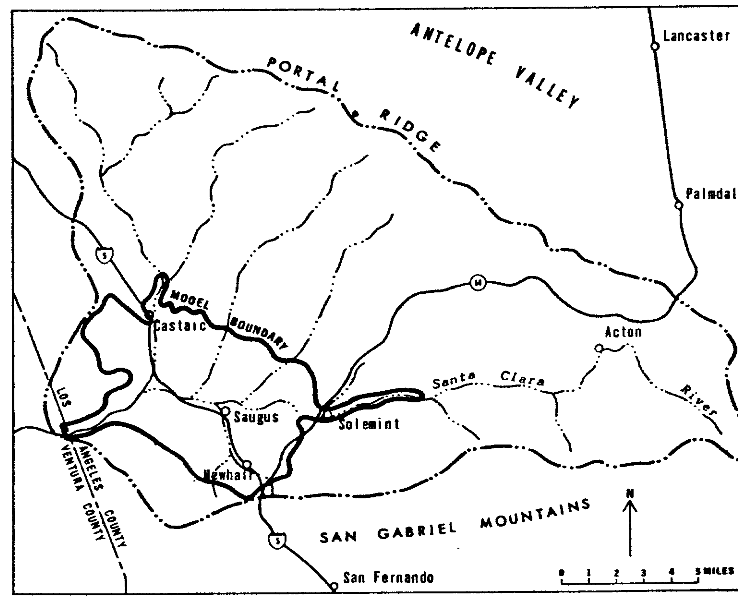
INTRODUCTION

Purpose and scope

Since 1945 ground-water users in the Saugus-Newhall area (fig. 1) have witnessed periodic declines in ground-water levels. During the most severe phases of these declines, well yield was markedly decreased or interrupted. Supplementing the water resources of the area with imported water will help alleviate this problem.

The purpose of this project was to study the water resources of the Saugus-Newhall area of the upper Santa Clara River valley. The study was primarily directed at an evaluation of the availability, quantity, and potential for development of the ground-water resources. An electrical analog model of the aquifers aided in determining the effects on the aquifers of such management practices as changes in the rates of natural recharge to the aquifers, artificial recharge of imported water, and increased pumpage to meet future water demands. A knowledge of the changes caused by increased pumpage and artificial recharge is necessitated by the rapid increase in urban water demands. Urbanization also requires water purveyors to supply larger quantities of water of better chemical quality than was necessary for agricultural users. For this reason the chemical quality of water from the various natural sources was briefly studied to determine if chemical quality could affect development.

The scope of the project included the collection of data on water levels in wells, pump tests, drillers' logs and electric logs of wells and test holes, chemical analyses of water, streamflow measurements, and precipitation records. Particular emphasis was placed on the collection of data for 1945-67, for which period maps showing aquifer transmissibilities, storage coefficients, and water-level contours were developed. In addition, the data provided a means of estimating the quantities of surface-water recharge to the aquifers, quantities of underflow into and out of the aquifers, and recharge from precipitation.



Study area

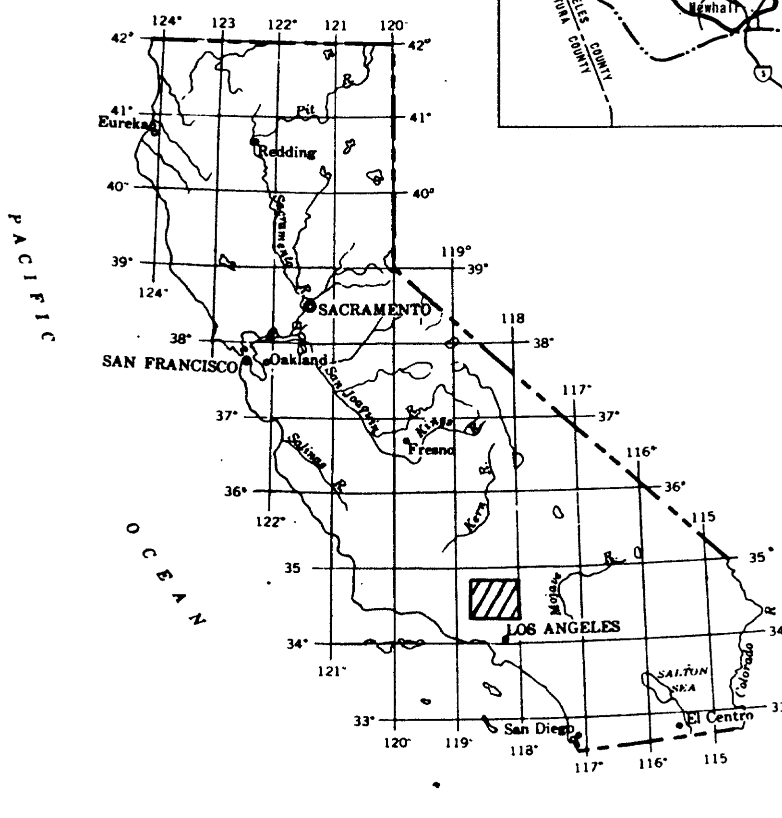


FIGURE 1.--Index map.

Once the hydrologic parameters had been evaluated, an electrical analog model of the aquifers was constructed and operated at the Analog Model Unit of the U.S. Geological Survey in Phoenix, Ariz. After the model was built, a procedure for verifying its accuracy was undertaken (see section on electrical analog modeling procedure). The verified model was then used as an aid in determining the effects on the aquifers of the various management procedures set forth in the purpose. The final phase of the project involved interrogating the analog model and preparing this report.

This report was prepared by the U.S. Geological Survey, Water Resources Division, in cooperation with the Newhall County Water District. The work was done during 1970 under the general direction of R. Stanley Lord, district chief in charge of water-resources investigations in California, the immediate direction of James L. Cook, chief of the Garden Grove subdistrict, and under the immediate supervision of W. F. Hardt, group project leader.

Electrical Analog Modeling Procedure

An electrical analog model of an aquifer is a device in which the flow of electricity through the resistor-capacitor network of the model is analogous to the flow of water through the aquifer. The ability of the aquifer to store and transmit water is simulated by the ability of the analog model to store and transmit electricity. Because of this analogy, cause and effect relations, which are easily determined in the model, can be directly related to the corresponding cause and effect relations in the aquifer.

After construction, the model is verified by testing for accuracy and making corrections and refinements in the hydrologic parameters used to construct it. The model is then modified to correspond to these refinements, again tested for accuracy, and new refinements made. This procedure is repeated until the model reproduces historic water-level fluctuations to the required degree of accuracy and, when this occurs, the model is considered to be verified. This procedure is followed while the model is operated under steady-state and non-steady-state conditions.

Steady-state conditions are the nonvarying set of hydrologic parameters that produce a dynamic equilibrium in the aquifer. As used in this report, these conditions are characterized by the absence of ground-water pumpage and constant quantities of surface-water recharge to the aquifer, underflow, infiltration of precipitation to the aquifer, and ground-water discharge. The water-level contours developed during steady-state conditions may vary in space but not with time. For modeling purposes it is advantageous to begin the study period at a time of steady-state conditions because complications encountered in subsequent work with the model will be minimized.

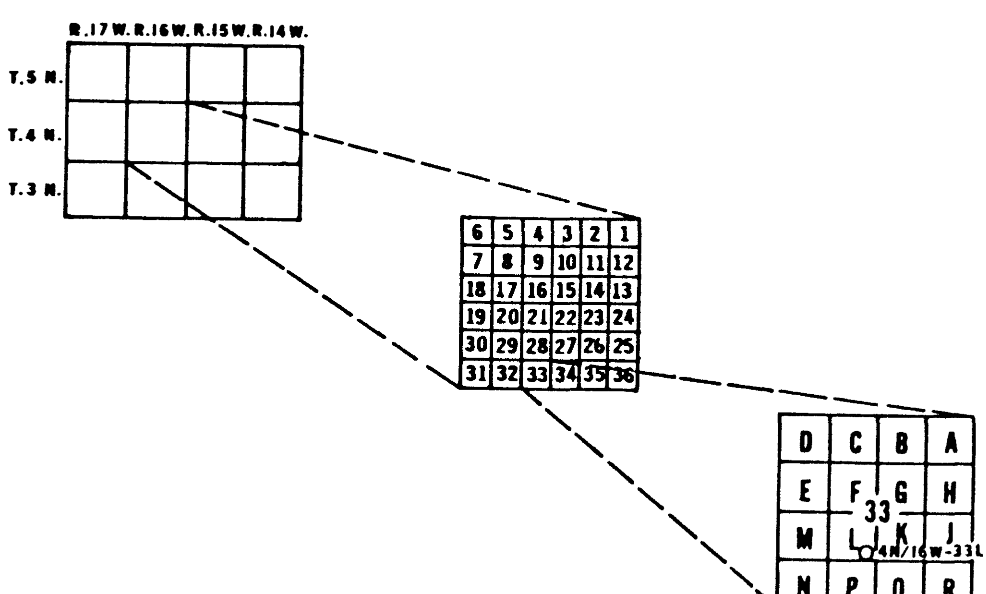
Non-steady-state conditions reflect an absence of dynamic equilibrium in the aquifer. This is due to variations in the quantities of natural recharge and discharge that have occurred since steady-state conditions. Also considered are the effects of man on the aquifer such as ground-water withdrawals from the aquifer, changes in quantities of surface-water recharge due to dams and channel modifications, and increased recharge to the aquifer from sewage effluent. The recharge and discharge used in the non-steady-state model is the change from the steady-state recharge and discharge rather than the absolute value of the recharge and discharge.

Readouts from the model, which have been verified under these two sets of conditions in conjunction with other available data, are then used as aids in solving the problems set forth in the purpose and scope.

Well-Numbering System

The well-numbering system used in this report conforms to that used by the U.S. Geological Survey in California since 1940. It has been adopted as official by the California Department of Water Resources and by the California Water Resources Control Board.

Wells are assigned numbers according to their location in the rectangular system for the subdivision of public land. As shown in the diagram below, the part of the number preceding the slash (as in 4N/16W-33L1) indicates the township (T. 4 N.); the part of the number between the slash and the hyphen indicates the range (R. 16 W.); the number following the hyphen indicates the section (sec. 33); the letter following the section number designates the 40-acre subdivision of the section. Within each 40-acre tract the wells are numbered serially as indicated by the final digit. Thus, well 4N/16W-33L1 is the first well to be listed in the NE¼ SW¼ sec. 33, T. 4 N., R. 16 W., San Bernardino base line and meridian.



Acknowledgments

This project was greatly aided by the cooperation received from members of many agencies. Employees of the Newhall Land and Farming Co., the Newhall County Water District, the County of Los Angeles, and the Bouquet, Solemint, and Valencia Water Cos. were very cooperative in allowing access to filed records and in supplying data on pumpage from wells and measurements of water levels in wells. The U.S. Soil Conservation Service, the Los Angeles City Department of Water and Power, and the California Department of Water Resources were helpful in furnishing data on land use and surface-water runoff.

Special acknowledgment is made to members of the Los Angeles County Flood Control District without whose continued efforts of hydrologic-data collection this project would not have been possible. The wealth of data compiled by the Flood Control District and the ready cooperation of individuals in making these data available greatly facilitated work on this project.

Description of the Project Area

The study encompasses a drainage area of about 630 square miles in northwestern Los Angeles County, about 30 miles north of Los Angeles (fig. 1). Newhall, the largest city in the area, has a population of about 8,500, and four other small towns have a combined population of about 5,000.

The study area is a region of high topographic relief and ranges in altitude from about 800 feet at its lowest point to about 6,500 feet in the San Gabriel Mountains. Generally, the surface water drains southward, and the intermittent tributaries empty into the westward-flowing Santa Clara River, the principal stream. The Santa Clara River, near the southern limit of the area, traverses a relatively flat valley. Much of the land in this valley has been in agricultural use since about 1820. At the present time the valley near Newhall is rapidly being urbanized.

Of the 630-square-mile drainage area only about 84 square miles have sufficient ground-water potential to be included in this hydrologic study. This 84-square-mile area (referred to as the model area in this report) consists of very permeable river channel deposits underlain by very thick but less permeable poorly consolidated marine and nonmarine sandstone and conglomerate.

Climate

The climate of the upper Santa Clara River valley is similar to that of other mountain and valley areas of southern California. The summers are hot and dry with midday high temperatures at Newhall of 100°F and nighttime lows of 70°F being common. During the winter midday high temperatures of 50°F and nighttime lows of 30°F are not uncommon.

Most of the precipitation in the area falls from November to March when the potential evapotranspiration is low (fig. 2). This produces an excess of water that is dissipated either as surface-water runoff or as direct recharge to the aquifers. From April to October the potential evapotranspiration greatly exceeds the precipitation, allowing for little runoff or ground-water recharge.

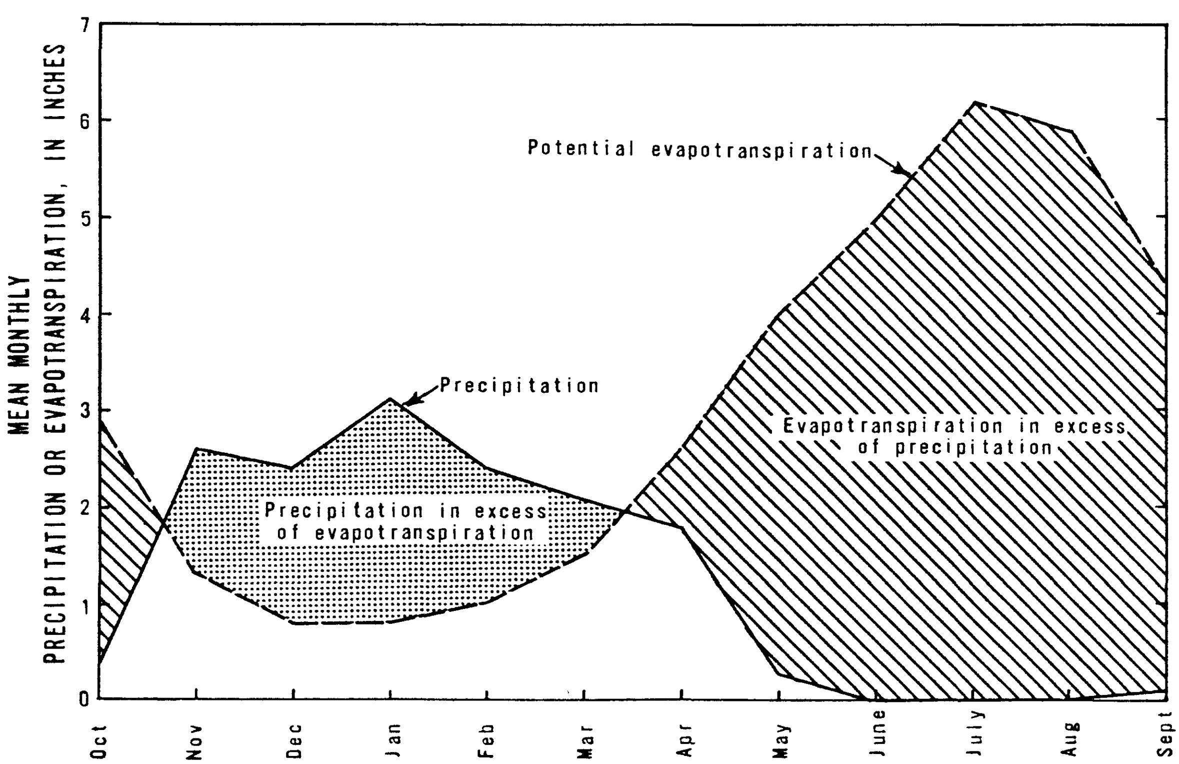


FIGURE 2.—Mean monthly precipitation and potential evapotranspiration.

Numerous rain gages are operated by the Los Angeles County Flood Control District throughout the study area. On the basis of these rain-gage records, the Los Angeles County Flood Control District has calculated the average precipitation in the area. From the data the cumulative departure from the 95-year mean annual precipitation was plotted (figs. 3 and 4). The quantity of precipitation varies producing periods of wet years and dry years. In general, the dry periods have been longer than the wet periods and may contain several individual wet years such as 1952, 1958, and 1962. The two successive wet years 1966 and 1967 may indicate the beginning of another period of wet years. This is further indicated by the larger than average quantities of precipitation in 1969.

As shown in figure 4, generally the greater quantities of precipitation fall at the higher altitudes. However, no distinct relation between quantity of precipitation and altitude can be found for the study area because of the high desert and coastal precipitation patterns. For example, 7 inches of mean annual precipitation occurs at the 3,500-foot altitude near Acton; 22 inches of mean annual precipitation occurs at the same altitude west of Newhall.

The wet period that ended in 1945 produced enough water to fill the aquifer and virtually eliminated the prior effects of ground-water pumpage in the model area. As a result, in 1945 the aquifers were functioning under conditions which approximated those of steady-state conditions. The period 1945-67 was chosen as the study period for this project and includes the latest dry period beginning with the near steady-state conditions of 1945 and ending in 1965.

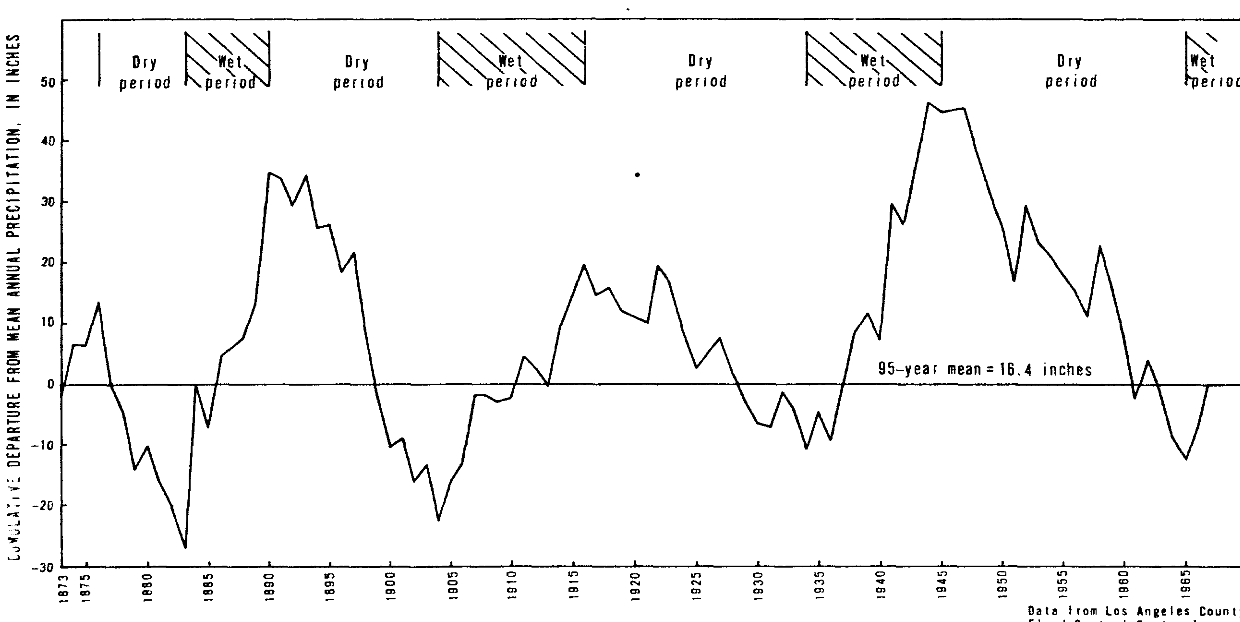


FIGURE 3.--Cumulative departure from 95-year mean annual precipitation.

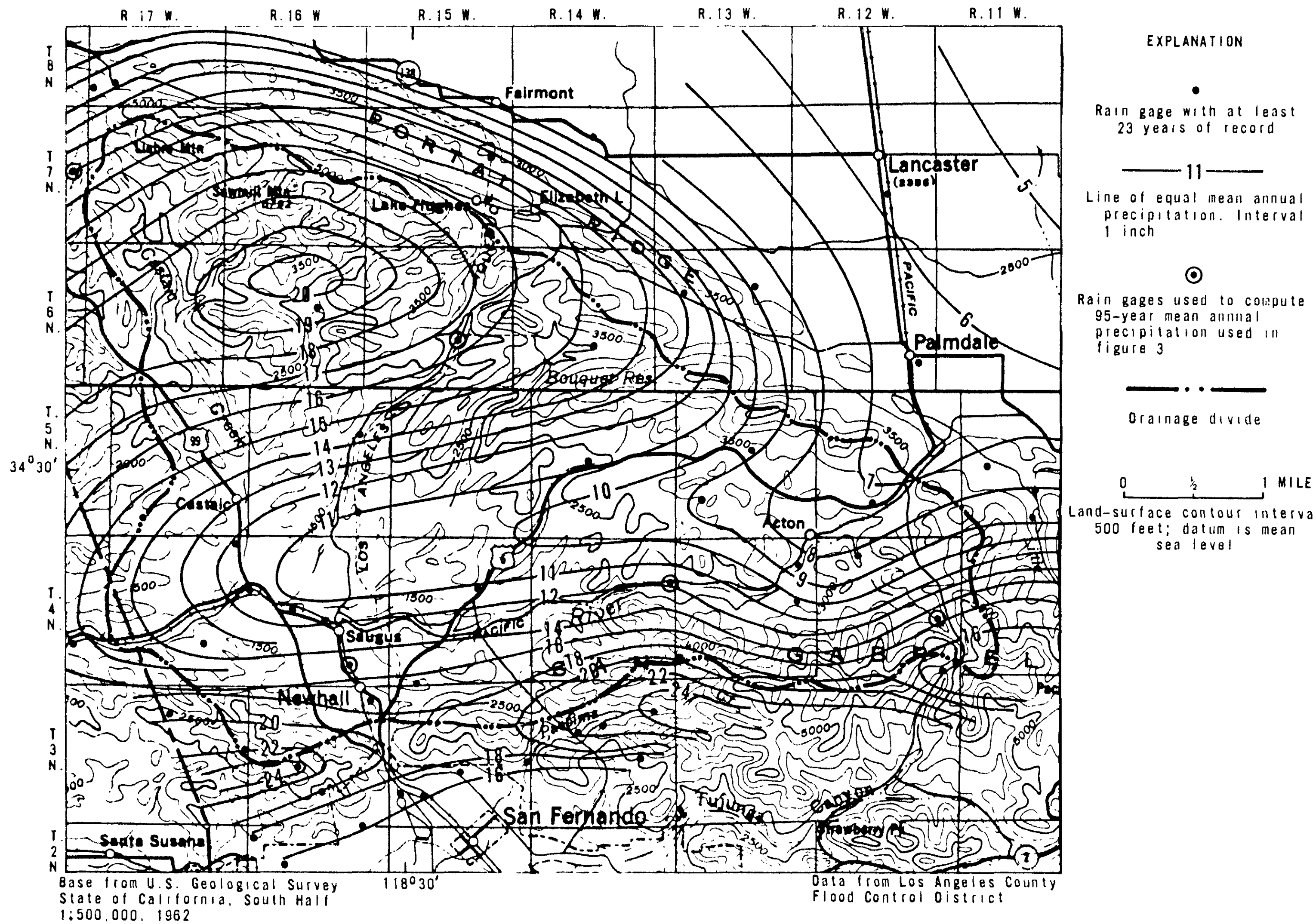


FIGURE 4.--Northwestern Los Angeles County showing mean annual precipitation for the 23-year period 1945-67.

The mean annual precipitation on the drainage area during this 23-year study period was 14.4 inches and was distributed as shown in figure 4. The 95-year mean annual precipitation in the area is 16.4 inches. Thus, the study period depicts hydrologic conditions that occurred under a 12-percent deficiency in precipitation. The subsequent descriptions of the hydrologic conditions of the area and the predicted effects of future manmade changes on the system reflect the effects of this 12-percent deficiency in precipitation. Any attempt to project quantitative cause-and-effect relations to other time periods must take into consideration this precipitation variable.

Of the approximate 13 inches of mean annual precipitation that falls on the model area, an estimated 5 to 10 percent is direct recharge to the aquifers. The 4,500 acre-feet per year of precipitation recharge used in the steady-state analog model is within this 5 to 10 percent range. This recharge was distributed over the model area in quantities proportional to the precipitation in each area. Because the yearly variations were considered to be negligible, no precipitation recharge was used in the non-steady-state model.

GEOLOGY AND AQUIFER CHARACTERISTICS

Geology of the Area

Because the geology of the area was described by Winterer and Durham (1962) and by Oakeshott (1958), it will not be discussed in this report except to summarize the geology that relates to the water-bearing characteristics of the lithologic units.

About 546 square miles of the 630-square-mile drainage area is largely non-water-bearing. The area is mountainous and generally consists of igneous and sedimentary rocks ranging in age from Jurassic to Pliocene. The igneous rock is primarily granite and yields only small quantities of water to wells from cracks and joints. The sedimentary rock is mainly well-consolidated siltstone, mudstone, sandstone, and conglomerate and yields only small quantities of water to wells from scattered intermittent moderately consolidated zones. The non-water-bearing rocks surround the water-bearing deposits in the study area to form a cup-like basin. The water-bearing deposits that fill the basin are as much as 7,000 feet thick near Castaic Junction (Winterer and Durham, 1962, p. 319).

The major aquifers in the study area are the Saugus Formation and the river channel alluvium. As described by Winterer and Durham (1962, p. 318), the Saugus Formation is a marine and nonmarine deposit of Pleistocene age consisting of "lenticular units of light-colored, loosely consolidated, poorly bedded, ill-sorted conglomerate, conglomeratic sandstone, and sandstone alternating with beds of greenish-gray siltstone, silty sandstone, and light-brown to moderate reddish-brown sandy siltstone and claystone." In the upper, nonmarine parts of the formation the loosely consolidated conglomerate, conglomeratic sandstone, and sandstone predominate, and in the lower, marine zones the tighter siltstone and claystone are more prevalent. The formation increases in thickness from its edges to as much as 7,000 feet at a point west of Castaic Junction. However, only about the upper 3,500 feet of the formation in that area probably has significant potential for ground-water development.

The river channel alluvium, of Holocene age, consists of poorly bedded, uncolsolidated gravel, sand, and silt. Occasional beds of clay are also found, mainly in the Castaic Junction area. The alluvium occurs in the valleys of the major streams and ranges in thickness from a few feet at its extremes to about 200 feet near Saugus.

The boundary of the Saugus aquifer shown on plate 1 represents the estimated limit of the water-bearing part of the Saugus Formation and generally corresponds to the geologic boundary of the Saugus Formation. Likewise, the boundary of the alluvial aquifer shown on plate 1 represents the estimated limit of the water-bearing materials of that deposit. Though small areas of saturated Saugus Formation and alluvium exist beyond the boundaries shown, those areas are either too small or too far removed from the main aquifers to be considered in this study.

In several parts of the study area, terrace deposits have been mapped overlying the Saugus Formation (Winterer and Durham, 1962). Although these deposits seem to be permeable, they are very thin, occur above the water table, and are not a source of water.

Two major faults cross the water-bearing materials in the basin, the San Gabriel fault, which trends northwestward, and the Holser fault, which trends eastward. The San Gabriel fault is a right-lateral fault and is the major structural feature in the area. There is evidence that the fault has produced about 2,300 feet of vertical displacement in the base of the Saugus Formation near Saugus, and 15 to 25 miles of right-lateral displacement along the fault after late Miocene time (Winterer and Durham, 1962, p. 334). The Holser fault is a reverse fault and is the lesser of the two faults. It seems to have a maximum vertical displacement in the base of the Saugus Formation of about 1,000 feet and is inferred to intersect the San Gabriel fault just east of Saugus.

Since its deposition, the Saugus Formation has undergone considerable deformation as evidenced by the many synclines and anticlines and by the many small faults throughout the area. The traces of the two major faults in the formation are indicated in some areas by steeply dipping beds and only minor faulting rather than by large discontinuities.

Alluvial Aquifer Characteristics

Although it is the smaller of the two major aquifers in terms of storage capacity, most water wells are drilled into the river channel alluvium. The alluvial aquifer is very permeable, and adequate quantities of water can be pumped from fairly shallow wells. However, in computing the water-bearing characteristics of the two aquifers only that part of the river channel alluvium or the Saugus Formation that has significant water-bearing potential was considered. For example, the shallow alluvium that exists to the south of Newhall was considered to have insufficient saturated thickness to yield significant quantities of water to wells. Thus, the wells in that area were considered to be pumping from the Saugus aquifer, even though they are of relatively shallow depth.

On the basis of an analysis of about 1,200 pump-efficiency tests and 200 drillers' logs of wells, estimates were made of the ability of the alluvial aquifer to transmit water. This ability to transmit water is termed transmissibility (T) and is the measure of the quantity of water in gallons per day at the existing water temperature which will pass through a vertical strip of aquifer 1-foot wide and the full saturated thickness of the aquifer under a one to one hydraulic gradient.

Pump-efficiency tests run by the Southern California Edison Co. determined the specific capacity of wells in gallons per minute per foot of drawdown. This figure was converted to an estimated transmissibility by multiplying by 1750 in accordance with the method described by Thomasson, Olmsted, and Le Roux (1960, p. 220-223). A second method of estimating T was used where no pumping tests were available. The various lithologic units described in drillers' logs were assigned permeability values (table 1). The values were multiplied by the thickness of the unit and summed over the total saturated thickness to arrive at an estimate of transmissibility. The T estimates from the two procedures were plotted and contoured to develop the transmissibility map for the alluvial aquifer shown on plate 1.

TABLE 1.—*Coefficients of permeability assigned to lithologic units in drillers' logs*

Material described by driller	Coefficient of permeability, in gallons per day per square foot
Clay	1
Silt	5
Sand, fine	10
Sand and medium sand	200
Sand, coarse	800
Gravel and fine gravel	2,500
Gravel, coarse	5,000
Clay and sand and gravel	10
Silt and sand and gravel	50
Sand and gravel	2,000
Conglomerate	1,000
Gravel and boulders	3,000
Sand and boulders	2,500
Boulders	5,000

The transmissibility of the alluvial aquifer ranges from 50,000 gpd (gallons per day) per foot of saturated thickness to 325,000 gpd per foot. The permeability of the alluvial aquifer ranges from 300 gpd per square foot to 2,700 gpd per square foot. The areas of higher transmissibility are generally in the center of the alluvial valleys where the saturated thickness is greatest and where the alluvial deposits have undergone the best grain-size sorting by the stream. The areas of higher *T* will yield greater quantities of water to wells than will the areas of lower *T*, assuming similar well construction and equal drawdown. As a result, the areas of high *T* should be given prime consideration in the location of future well fields.

An area of low *T* occurs in the alluvial aquifer from about the west edge of sec. 16, T. 4 N., R. 16 W., to Castaic Junction. In this area drillers' logs of wells show a greater prevalence of clay strata than is common in other wells in the model area. Logs of several wells along the approximate trace of the Holser fault show that about 50 percent of the material is clayey. It is not clear if this condition is due to effects of the Holser fault.

In the Santa Clara River valley measurements of water level in wells which were perforated in the alluvial aquifer on either side of the San Gabriel fault indicate a difference of as much as 30 feet. This is due to a narrow zone of low *T* in the alluvial aquifer produced by the fault. Because the width of the fault zone is unknown, the *T* cannot be calculated directly. In the model, however, a *T* of 50,000 gpd per foot for a horizontal width of 500 feet was sufficient to produce the required change in water level across the zone.

The San Gabriel fault near Castaic and the Holser fault may also have some influence on the *T* of the alluvial aquifer. However, the water-level differences across the faults in those areas were not sufficient to indicate conclusively the effects of the faults in the alluvial aquifer. As a result, in the analog model, no change in the *T* of the alluvium was made along the trace of the faults in those areas.

Pump-efficiency tests were run on about 75 wells in the alluvial aquifer on a roughly annual basis during the study period. The estimates of *T* based on these pump-efficiency tests show a marked variation corresponding to the change in saturated thickness of the aquifer. This is illustrated by figure 5 in which about 300 pump-efficiency tests for 15 selected wells are plotted and used to define two trend lines.

Because the pump-efficiency tests cover a 23-year period, the slope of the trend lines shown in figure 5 is affected by the decreasing efficiency of the well as it ages. The exact quantitative effects of aging are not known, but data indicate that the slope of both lines might be decreased by as much as 30 percent to account for this aging.

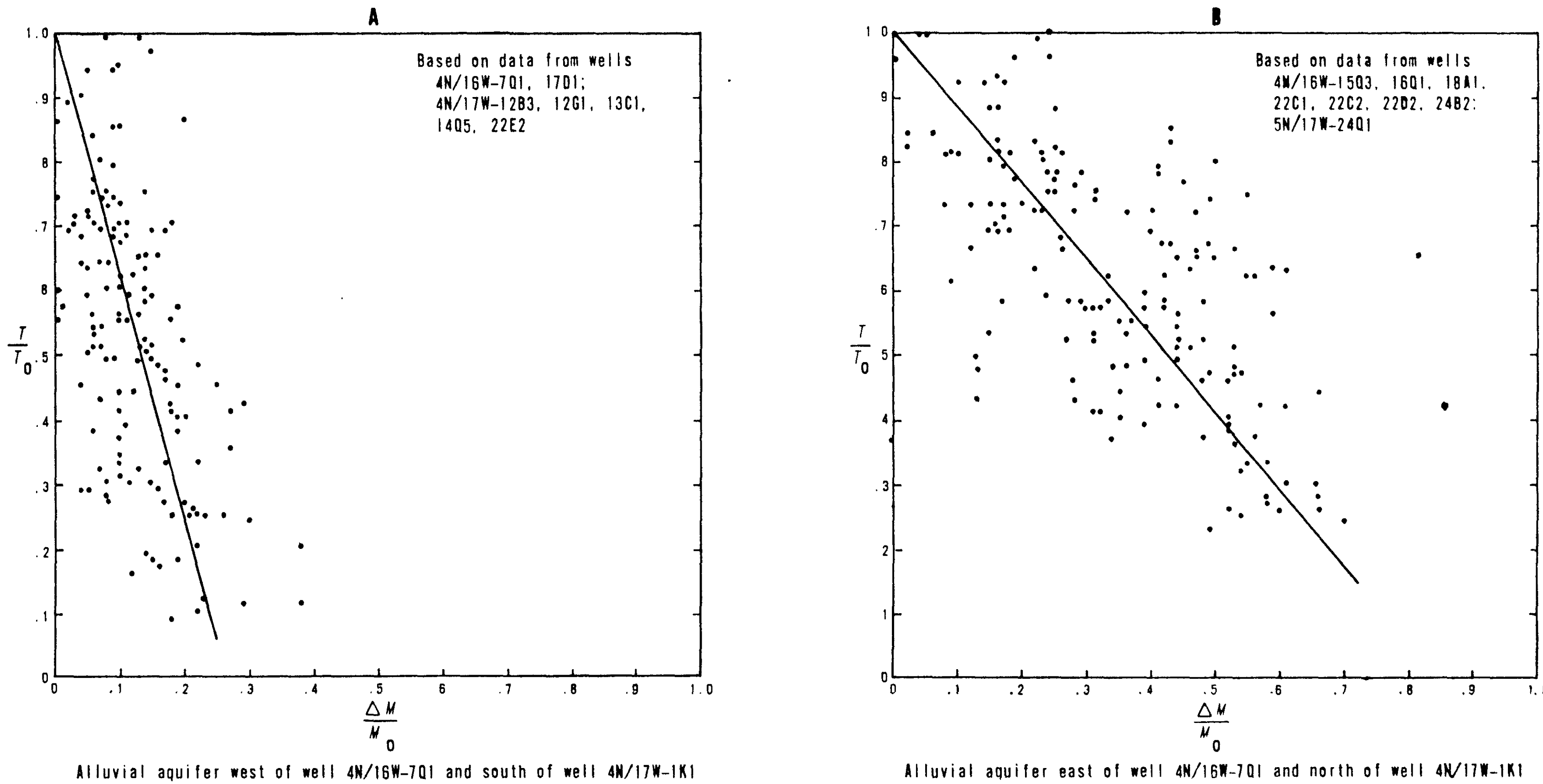


FIGURE 5.--Change in transmissibility with decrease in saturated thickness for alluvial aquifer. T_0 and M_0 are the transmissibility and saturated thickness determined from pump tests run in 1945. T and ΔM are the transmissibility and change in saturated thickness from the 1945 saturated thickness as determined from pump tests run between 1945 and 1967.

A comparison of the slope of the two lines indicates that the *T* of the alluvial aquifer in the Santa Clara River valley below Castaic Junction is more sensitive to small changes in saturated thickness than is the *T* of the aquifer above Castaic Junction. Figure 5A indicates that below Castaic Junction the lower 80 percent of the alluvial aquifer has a much lower *T* than the upper 20 percent. This was substantiated by a field test on well 4N/17W-13C2 which indicated that 60 percent of the water entering the well came from the upper 10 percent of the saturated interval. This condition indicates that some economy may be achieved in the future by not drilling wells in this area to the full 150- to 200-foot thickness of the alluvium.

Figure 5B indicates that in the alluvial aquifers above Castaic Junction the wells receive water fairly uniformly throughout the full saturated thickness of the aquifer. A 50-percent decrease in saturated thickness produces a 60-percent decrease in *T*.

This change in *T* with change in saturated thickness complicates the analog simulation of aquifer response. In the model the *T* network for the alluvial aquifer was constructed using the standard fixed-resistor network with the knowledge that a varying *T* network could be constructed if subsequent work with the model indicated that this was necessary.

In order to determine how sensitive the model is to changes in *T*, a sensitivity analysis was run. A separate *T* network was constructed for the area of the alluvium from the east edge of sec. 17, T. 4 N., R. 16 W., to the middle of sec. 18, T. 4 N., R. 16 W. The network had a *T* of one-third the *T* used in the model. Recharge was modeled at the left end of both reaches, and discharge was modeled at the right end of both reaches. Water-level declines were then measured at the discharge ends. The results showed a difference in water-level declines of about 5 feet, or about a 10-percent change in the magnitude of the declines.

In most areas of the model the changes in *T* caused by declines in water levels probably would not cause serious errors in the model readouts. Verifications of the model confirmed this assumption, with the exception of the alluvium south of Saugus. In that area, the original *T* was too high because of declining water levels that caused partial to total dewatering of the alluvial aquifer. Because of the limited area and the lack of *T* control, a varying *T* network was not considered feasible. Instead, *T* was decreased to more closely approximate that which occurred during the middle of the study period. This is the *T* shown on plate 1.

The quantity of ground water in storage in the alluvial aquifer varies considerably because of the effects of ground-water pumpage and surface-water recharge to the aquifers. In the dry period 1945-51 the ground water in storage decreased by about 55,000 acre-feet (table 2). In 1952 large quantities of surface-water recharge occurred, and by the end of that year the ground water in storage had increased by about 35,000 acre-feet. This rapid fluctuation in storage is characteristic of the area and has continued in a like manner throughout the study period. In 1961, 1963, 1964, and 1965 about 140,000 acre-feet of ground water was in storage in the alluvial aquifer. This is the smallest quantity of storage in the study period.

TABLE 2.--*Recoverable ground water in storage in the alluvial aquifer*

[acre-feet]

Area[1]	1945	1951	1952	1963	1967
Castaic Valley	25,000	18,000	24,000	21,000	25,000
San Francisquito Canyon	12,000	9,000	12,000	8,000	11,000
Bouquet Canyon	10,000	3,000	5,000	4,000	6,000
Upper Soledad Canyon	26,000	12,000	26,000	15,000	25,000
Lower Soledad Canyon	29,000	19,000	23,000	13,000	16,000
Central Santa Clara River	72,000	61,000	64,000	47,000	50,000
Lower Santa Clara River	36,000	33,000	36,000	34,000	37,000
Total for alluvial aquifer	210,000	155,000	190,000	142,000	170,000

[1]Areas shown on plate 9.

A given change in the volume of recoverable ground water in storage is associated with a water-level change of specific magnitude. The relation between the two quantities is a measure of the storage coefficient of an aquifer. The storage coefficient is defined as the quantity of water released from or taken into storage per unit surface area of aquifer per unit change in head. This quantity of water can be expressed as a percentage of the volume of the aquifer. For example, in a water-table aquifer such as the alluvial aquifer, a change in head of 1 foot might yield 0.20 cubic foot of water from each cubic foot of dewatered aquifer, thereby giving a storage coefficient of 20 percent.

For the alluvial aquifer storage coefficients were assigned to the various lithologic units described in drillers' logs of wells. The average storage coefficient for each log was calculated and used to prepare a map showing spatial storage variations. Because of inaccuracies in this type of estimation, plate 1 was drawn to show only two average storage coefficients. Thus, the storage boundaries shown on plate 1 are approximate limits of areas with storage coefficients averaging 10 percent and 20 percent. These are the values used in the analog model.

Saugus Aquifer Characteristics

The Saugus Formation, the largest aquifer in the study area, contains an estimated maximum of 6 million acre-feet of recoverable ground water. The lower zones of the formation are of marine origin and tend to be more tightly consolidated than the upper zones. Only the upper 3,500 feet of the formation in this area probably has significant water-bearing potential. In modeling the Saugus aquifer a maximum saturated thickness of 2,000 feet was used in computing the transmissibility and storage characteristics. This is considered to be the maximum effective thickness of the model aquifer because water wells are not pumping from any greater depths, and numerous beds of claystone and siltstone occur at this depth. Plate 2 shows the saturated thickness of the main water-bearing part of the Saugus Formation as determined from electric logs of oil wells. As shown on the plate, the basin has a large area of thick saturated material south of the San Gabriel fault. The area north of the fault has less saturated thickness due to the effects of the vertical displacement across the fault.

To date (1969) only 12 water wells were drilled deep enough in the Saugus aquifer to yield useful information about its water-bearing characteristics. Because all the wells are near the alluvial aquifer in the southern part of the model area, they do not adequately represent the water-bearing characteristics of the aquifer as a whole. However, electric logs and pump test data for six of the water wells were used to develop a relation between the T of the aquifer and resistivity characteristics shown on the electric logs. In general the larger the resistivity deflection from the projected clay line of the long normal curve of an electric log, the more permeable the zone which the deflection represents. When the average deflection for the zone is calculated and multiplied by the thickness of the permeable zone, a measure of the transmissibility is obtained which, when summed for all the permeable zones in the log, can be related to the T of the aquifer by use of the T-electric log relation developed for the six water wells. The T of the Saugus aquifer in areas without water wells was estimated using this relation and the electric logs of oil wells.

This procedure assumes that factors such as the resistivity of the drilling mud and the formation water and the degree of cementation of sands are uniform in all logs. Unfortunately, because of these uncertainties, the procedure provides a poor estimate of T of the aquifer.

On the basis of the procedure about 100 electric logs of oil wells and six electric logs of deep water wells were used to develop *T* data for the Saugus aquifer. The data were originally used in the analog model. Subsequent model runs indicated that the water-level gradient south of Newhall was too flat. As a result, the *T* of the Saugus aquifer in this area was reduced to 2,000 gpd per foot to more closely agree with the *T* indicated by pump tests on shallow wells. The low *T* still did not produce an exact match of the water-level gradients near Newhall. This suggests that the original *T* estimate for the Saugus aquifer may be too high. However, because of the lack of data in this aquifer no aquifer-wide *T* changes were made. Additional information on the *T* in the Saugus aquifer is needed, and a future study of this aquifer would be of great value.

As shown on plate 2, the *T* used for the Saugus layer of the model ranges from 2,000 gpd per foot to 200,000 gpd per foot. Permeability ranges from about 5 gpd per square foot to about 100 gpd per square foot. The area of highest *T* is south of the San Gabriel fault where the saturated thickness is greatest. That area has a greater potential for ground-water development than other areas of the Saugus aquifer provided the water quality in the western part can be tolerated (see section on quality of water).

The electric logs of oil wells indicate that the Saugus aquifer north of the San Gabriel fault has a much lower *T* and less saturated thickness than the area south of the fault. Because no deep water wells have been drilled north of the fault, it is not possible to determine the quantity or quality of water that might be pumped from the Saugus aquifer in the area. However, in this area the aquifer probably has only limited water-bearing potential, possibly yielding enough water to wells for domestic use but not enough for large-production municipal requirements.

In verifying the model it was necessary to decrease *T* along the San Gabriel and Holser faults. The faults were modeled as a strip one node space wide (1,000 feet) with a *T* of 2,500 gpd per foot. However, a pump test run on Saugus well 4N/16W-21D1 near the Holser fault did not indicate the presence of a low permeability barrier as was indicated by the model readouts.

A possible explanation for the apparent inequity may lie in the deformation of the Saugus Formation mentioned earlier (page 11). Because of the stratigraphic deposition of sedimentary materials, the vertical permeability of an aquifer may be several orders of magnitude less than the corresponding horizontal permeability. When stratified beds are deformed so that steep dips occur along the flanks of synclines, anticlines, or near faults, the direction of low permeability is no longer vertical but is shifted to a roughly horizontal plane normal to the strike and dip of the beds. In the Saugus Formation steeply dipping beds predominate along the two major faults and in synclines and anticlines adjacent to, and parallel with, the faults. Thus, a definite narrow zone of low horizontal permeability may not exist at the fault faces, rather zones about a mile wide along the two faults could have a markedly reduced horizontal permeability in the direction normal to the fault strike. This could account for the pump-test results and the necessity of a reduced T near the faults as indicated by the model. For simplicity of construction, the zone of low permeability was built into the model as a strip one node space (1,000 feet) wide coincident with the two faults, and no attempt was made to determine the actual effective width of the zone.

Because of the few water wells in the Saugus aquifer, no direct estimate of the storage coefficient was made. Instead, the analog model was used to determine that a storage coefficient of 0.25 percent gave the best results. This value was used for the whole Saugus aquifer, and further refinements in spatial variations were not attempted. The 0.25 percent storage coefficient is within the range of values usually associated with artesian aquifers. It also agrees with the oil well electric log data which indicate many thin zones of low permeability in the aquifer that could act as the confining strata necessary to produce an artesian condition.

In an artesian aquifer, such as the Saugus aquifer, the water released from or taken into storage is governed mainly by the compressibility of the aquifer material and of the water. In a water-table aquifer, the volume of water released from or taken into storage is due not only to the above conditions, but also to gravity drainage of the materials through which the water moves. Under water-table conditions, water obtained through compressibility is so small compared to the quantity obtained from gravity drainage that it can be ignored. Accordingly, a water-table storage coefficient of 10 percent was used in estimating the recoverable water stored in the Saugus aquifer as 6 million acre-feet.

In the analog model the alluvial and Saugus aquifers were constructed as two separate and distinct aquifers, each with its own T and storage network. In connecting the two networks a vertical resistance was used to simulate the effects of vertical permeability on water leakance from one aquifer to the other. In the model three values of vertical permeability were required to produce the proper response in the two aquifers. The three values are 10 gpd per square foot, 0.75 gpd per square foot, and 0.0075 gpd per square foot and are distributed as shown on plate 1.

The areas with higher values of vertical permeability roughly coincide with areas of steeply dipping beds in the Saugus Formation. Most of the steep dips are along the San Gabriel and Holser faults and in the triangular-shaped area between the two faults southeast of Castaic Junction. In those areas dips are predominantly in the 50° to 90° range, whereas in most of the surrounding areas dips range from 0 to 35°. It is not clear at this time whether or not the vertical permeability in the area southwest of the gaging station on Castaic Creek at State Highway 126 should be as high as shown on plate 1. In this area the beds do not dip as steeply as those near the faults, which would suggest that the vertical permeability might be lower than the 10 gpd per square foot shown.

SURFACE-WATER RUNOFF AND RECHARGE AND GROUND-WATER DISCHARGE

Most of the surface-water runoff in the Saugus-Newhall area enters the model area as floodflow from the narrow mountain canyon creeks of the Santa Clara River and its tributaries. This flow is the result of precipitation runoff that usually occurs from December to April. The runoff is extremely variable, often ranging from near zero to several thousand cubic feet per second within the span of a few hours. Perennial base runoff that occurs in most of the mountain canyons above the limits of the model area usually percolates into the streambed before reaching the model area. As a result most of the area's stream channels are dry through the summer.

As the winter surface-water runoff moves downstream through the model area, ground-water recharge occurs. The recharge was so extensive in the dry period 1945-65 that even though 60,000 acre-feet of flow was gaged on the Santa Clara River above Lang railroad station, only about 2,000 acre-feet passed the Santa Clara River at the Old Highway Bridge gaging station (fig. 6). This is primarily a dry-period occurrence however, for during a wet period, such as 1934-45, ground-water levels in the alluvial aquifer rise so near the surface that surface-water recharge to the aquifers is greatly reduced.

During the study period the quantity of surface-water recharge to the alluvial aquifer was controlled primarily by the availability of surface-water runoff and was influenced only slightly by the head in the aquifer. In wet years, when ample quantities of surface-water runoff were available, water levels recovered as much as 70 feet in parts of the alluvial aquifer. This demonstrates the sensitivity of the alluvial aquifer to surface-water recharge and the major importance streamflow plays in the functioning of the ground-water system.

Because most of the ground-water recharge comes from the deep percolation of streamflow, it is necessary in modeling the ground-water system to know the quantity of surface water flowing into the model area for each year of the 23-year study period. Streamflow gaging-station records furnish most of these data for the gaged drainage areas. In the ungaged drainage areas tributary to the model area estimated runoff was computed. Figure 6 shows the location of streamflow gaging stations and ungaged drainage areas. Because only minor quantities of surface-water runoff originate in areas underlain by the Saugus Formation, those areas were not considered as a source of runoff.

Flow for the years that gaging-station records were missing was estimated using the procedure for the graphical correlation of gaging-station records described by Searcy (1960). Rainfall-runoff relations were developed for Spunky Creek and Pacoima Creek (fig. 6) and assumed to apply to the adjacent ungaged drainage areas. The runoff from each of the ungaged areas was then calculated from the known quantities of annual precipitation that occurred in each area. Because the estimated data are less accurate than measured data, the estimated runoff was sometimes changed if warranted by subsequent readouts from the analog model. The magnitude of these changes was at all times within the limits of accuracy of the estimated runoff.

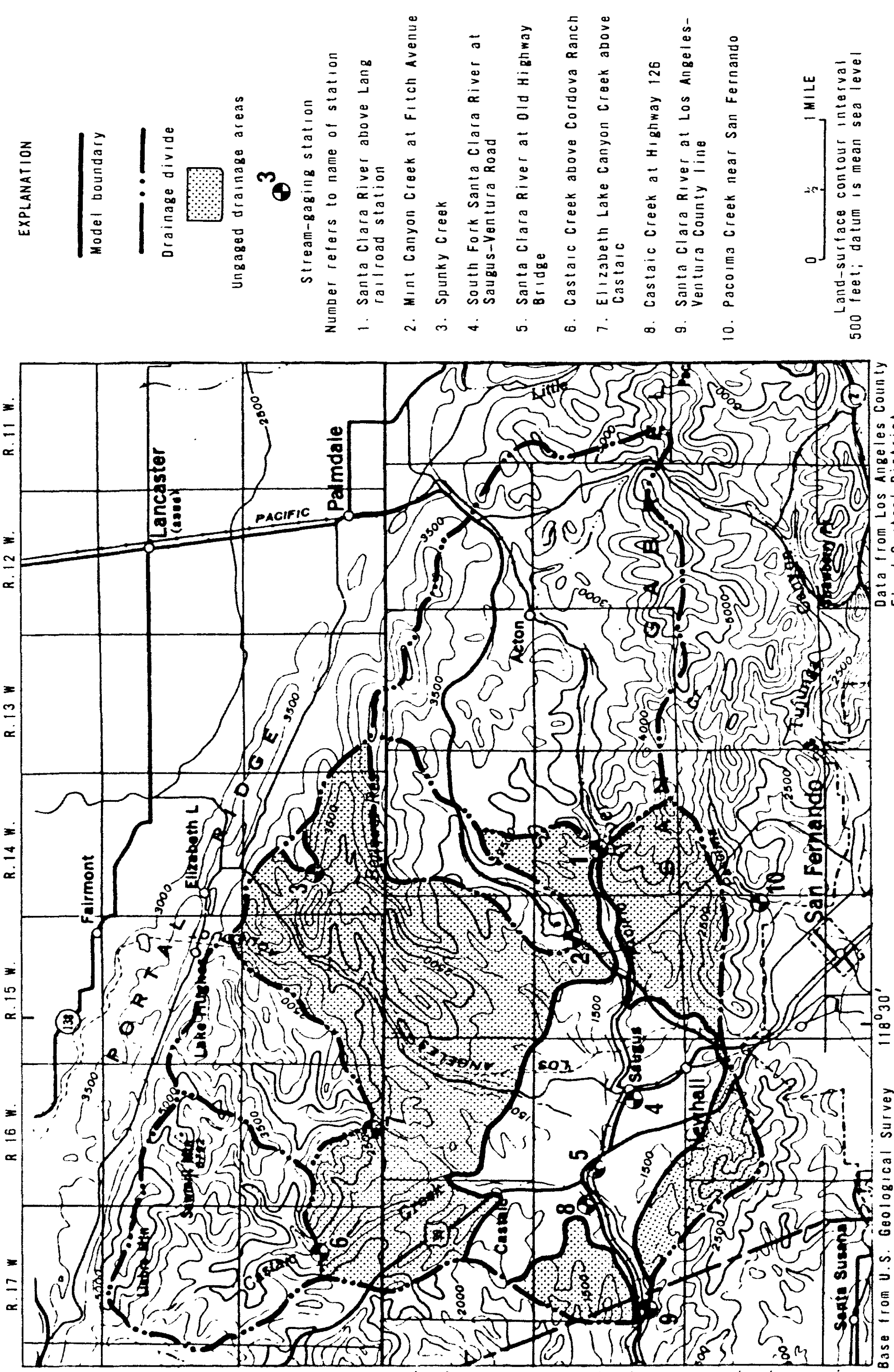


FIGURE 6.--Location of stream-gaging stations and ungaged drainage areas.

Table 3 lists the combined runoff data from the gaged and ungaged drainage areas to show the total surface-water inflow to the model area from the drainages indicated. The quantities of recharge that occurred in each recharge reach are the differences in flow at the upstream and downstream ends of each reach (pl. 3).

As shown in table 3 the recharge for every recharge area is averaged for each of the nine recharge pulses used in the model. These average quantities of recharge were then reduced by the quantity of steady-state surface-water recharge that occurred in each area. The resulting differences are the approximate quantities of surface-water recharge built into the non-steady-state model. When a negative recharge resulted from this subtraction, the negative quantity was modeled as though it were ground-water discharge along that reach.

The last three columns in table 3 show that the mathematical rules of rounding were not strictly adhered to in choosing the non-steady-state model recharge from the recharge calculation. Slight revisions in the quantities of recharge were made during the verification of the model and can easily be tolerated because of the low degree of accuracy of the rainfall-runoff data used to derive the recharge data for the ungaged streams.

In the non-steady-state model this surface-water recharge is assumed to occur at a uniform rate along each recharge reach (pl. 3). This assumption is based on two criteria. First, in the dry period distribution of recharge depends on the availability of surface water and not on depth to water in the aquifer. Second, no information is available on areal variations in the vertical permeability of the alluvium in the unsaturated zone.

In Dry Canyon, recharge resulting from surface water released from the Los Angeles Department of Water and Power aqueduct was modeled as underflow to Bouquet Canyon at the junction of Dry and Bouquet Canyons. The underflow averaged 2,000 acre-feet per year for the 3 years 1945-47 and was considered to be negligible thereafter. Other releases from the aqueduct are included with the inflow figures of the creeks in which the releases took place.

The steady-state surface-water recharge shown in table 3 is the quantity of recharge that would occur in each area of the model under steady-state conditions. This recharge was determined by the same procedure used to determine the non-steady-state recharge (upstream inflow minus downstream outflow). The steady-state recharge computation, however, was for the period from about 1940 to 1945 during which time the basin was near steady-state conditions.

TABLE 3.—*Surface-water runoff and recharge*

[Inflow at model boundary: all or part of data was estimated]

Year	Inflow at model boundary (acre-feet)	Ground-water recharge (acre-feet)	Pulse	Mean recharge for pulse (acre-feet)	Steady-state recharge (acre-feet)	Non-steady-state recharge (acre-feet)
			CASTAIC CREEK			
1945	3,500	1,400				
1946	5,100	2,000	1	1,700	1,200	0
1947	4,700	1,600				
1948	200	100				
1949	300	300	2	500	1,200	-1,000
1950	1,400	1,400				
1951	100	100				
1952	35,100	15,800	3	15,800	1,200	+15,000
1953	1,700	1,600				
1954	1,500	500				
1955	1,400	1,300	4	1,900	1,200	+1,000
1956	4,200	3,900				
1957	2,500	2,300				
1958	42,700	18,500	5	18,500	1,200	+18,000
1959	1,700	1,200				
1960	400	400	6	600	1,200	0
1961	200	200				
1962	31,500	16,700	7	16,700	1,200	+16,000
1963	1,100	1,100				
1964	900	900	8	1,400	1,200	0
1965	2,200	2,100				
1966	28,200	14,900	9	10,800	1,200	+10,000
1967	34,000	6,600				
Total:	204,600	94,900				
23-year mean:	8,900	4,100				
			SAN FRANCISQUITO CANYON CREEK			
1945	1,800	600				
1946	2,400	2,400	1	1,600	1,000	0
1947	2,900	1,700				
1948	800	800				
1949	700	700	2	800	1,000	0
1950	700	700				
1951	800	800				
1952	10,800	7,000	3	7,000	1,000	+6,000
1953	700	700				
1954	1,500	1,500				
1955	1,600	1,500	4	1,400	1,000	0
1956	2,000	2,000				
1957	1,300	1,300				
1958	12,000	9,700	5	9,700	1,000	+8,500
1959	700	700				
1960	800	800	6	700	1,000	0
1961	700	600				
1962	5,600	3,900	7	3,900	1,000	+2,500
1963	700	700				
1964	700	700	8	1,000	1,000	0
1965	1,600	1,600				
1966	6,000	2,500	9	4,800	1,000	+4,000
1967	7,800	7,200				
Total:	64,600	50,100				
23-year mean:	2,800	2,200				

TABLE 3.--*Surface-water runoff and recharge*--Continued

Year	Inflow at model boundary (acre-feet)	Ground-water recharge (acre-feet)	Pulse	Mean recharge for pulse (acre-feet)	Steady-state recharge (acre-feet)	Non-steady-state recharge (acre-feet)
			BOUQUET CANYON CREEK			
1945	1,500	500				
1946	2,300	2,300	1	1,500	1,000	0
1947	2,900	1,700				
1948	400	400				
1949	700	700				
1950	1,100	1,100	2	600	1,000	0
1951	400	400				
1952	10,300	10,000	3	10,000	1,000	+9,000
1953	500	500				
1954	1,300	1,300				
1955	1,000	900	4	1,000	1,000	0
1956	1,300	1,300				
1957	1,200	1,200				
1958	13,300	13,200	5	13,200	1,000	+12,000
1959	2,400	2,200				
1960	500	500	6	1,000	1,000	0
1961	400	300				
1962	4,400	3,100	7	3,100	1,000	+2,000
1963	600	600				
1964	800	800	8	900	1,000	0
1965	1,300	1,300				
1966	5,200	2,300	9	4,600	1,000	+4,000
1967	7,400	6,800				
Total:	61,200	53,400				
23-year mean:	2,700	2,300				
			SANTA CLARA RIVER			
1945	6,300	6,300				
1946	4,500	4,500	1	4,800	5,000	0
1947	3,700	3,700				
1948	1,700	1,700				
1949	1,300	1,300		1,200	5,000	-4,000
1950	1,100	1,100	2			
1951	800	800				
1952	27,700	25,700	3	25,700	5,000	+20,000
1953	2,200	2,200				
1954	2,000	2,000				
1955	1,300	1,300	4	1,500	5,000	-3,000
1956	1,200	1,200				
1957	1,000	1,000				
1958	10,800	10,800	5	10,800	5,000	+6,000
1959	1,800	1,800				
1960	800	800	6	1,200	5,000	-4,000
1961	1,000	1,000				
1962	6,200	6,200	7	6,200	5,000	+1,000
1963	1,200	1,200				
1964	700	700	8	900	5,000	-4,000
1965	900	900				
1966	10,700	10,200		10,200	5,000	+5,000
1967	10,300	10,100	9			
Total:	99,200	96,500				
23-year mean:	4,300	4,200				

TABLE 3.—*Surface-water runoff and recharge*—Continued

Year	Inflow at model boundary (acre-feet)	Ground-water recharge (acre-feet)	Pulse	Mean recharge for pulse (acre-feet)	Steady-state recharge (acre-feet)	Non-steady-state recharge (acre-feet)
			SOUTH FORK SANTA CLARA RIVER			
1945	2,200	1,000				
1946	2,500	1,000	1	1,200	1,400	0
1947	3,000	1,600				
1948	600	500				
1949	600	500	2	700	1,400	0
1950	1,100	1,000				
1951	500	500				
1952	17,100	5,000	3	5,000	1,400	+3,500
1953	600	200				
1954	2,000	1,000				
1955	1,200	1,000	4	900	1,400	0
1956	2,300	1,500				
1957	1,800	1,000				
1958	12,800	5,000	5	5,000	1,400	+3,500
1959	1,800	1,200				
1960	600	500	6	700	1,400	0
1961	600	500				
1962	9,800	3,000	7	3,000	1,400	+1,000
1963	2,000	1,200				
1964	2,100	1,300	8	1,200	1,400	0
1965	2,200	1,000				
1966	11,700	4,000		4,500	1,400	+2,700
1967	10,200	5,000	9			
Total:	89,300	38,500				
23-year mean:	3,900	1,700				

In steady-state conditions the water levels in the alluvial aquifer are near land surface, and ample quantities of surface water are available for recharge. Under these conditions the surface-water recharge may become head dependent, and the assumption that recharge occurs at a uniform rate along the reach is no longer correct. The Santa Clara River above the east boundary of sec. 20, T. 4 N., R. 15 W., is the only reach in the area that seemed to be significantly affected by this steady-state head dependency. This is made apparent by the variation in quantities of steady-state recharge used in the Santa Clara River (pl. 3).

The reach of the Santa Clara River between the Old Highway Bridge gaging station and the Santa Clara River at Los Angeles-Ventura County line gaging station has negligible surface-water recharge from floodflows. In this reach perennial flow occurs along most of the length of the river because of rising ground water discharging into the stream, discharge from sewage-treatment plants, and excess irrigation water flowing from nearby fields. Unlike the upstream recharge reaches where the quantity of surface-water recharge is controlled by the availability of water in the river, the recharge in this reach is controlled by the depth to water in the alluvial aquifer. As the ground-water levels are very near (and in some places slightly above) the bottom of the river channel, only limited surface-water recharge takes place.

Because ground water is at or near the surface in this area, lush vegetation grows near the river. Aerial photographs indicate that this vegetation covers about 450 acres. The phreatophyte-consumptive use (Robinson, 1958, and McDonald and Hughes, 1968) was estimated to be 4.5 feet per year, or 2,000 acre-feet per year. The annual rate of consumptive use is fairly constant and has not changed significantly during the study period. The evapotranspiration loss would be greatly reduced if the ground-water levels in the area could be rapidly lowered below the root zone of the phreatophytes. However, this may not be economically practical because of the number of wells required and the relatively small quantities of water of poor chemical quality that could be salvaged (see section on quality of water).

Under steady-state conditions the model indicated that about 23,200 acre-feet per year of ground water discharged along the river between the Old Highway Bridge gaging station and the Los Angeles-Ventura County line gaging station (pl. 3). When the estimated 2,000 acre-feet per year of phreatophyte-consumptive use is subtracted, the remaining 21,200 acre-feet per year is the model-indicated quantity of surface-water base flow which left the area. Because of the inaccuracy of the estimate of flow passing the Santa Clara River at Los Angeles-Ventura County line gaging station prior to 1945, the quantity of base flow that actually left the area was estimated to be 20,000 acre-feet per year. This figure, however, is in close agreement with the 21,200 acre-feet per year indicated by the model.

Under non-steady-state conditions ground-water extraction from wells and reduced surface-water recharge have caused a drastic reduction in the discharge of ground water to the stream in this area. The reduction in ground-water discharge means that more ground water is available for use in other areas of the aquifer and was simulated in the non-steady-state model as an induced recharge to the alluvial aquifer in the Santa Clara River between the two downstream gaging stations.

In the model the induced recharge averaged about 16,000 acre-feet per year during the 1945-67 study period. The 5,200 acre-feet per year difference between the steady-state ground-water discharge and the non-steady-state induced recharge is the average base flow which occurred between 1945 and 1967, as indicated by the model. The records of streamflow obtained at the Santa Clara River at Los Angeles-Ventura County line gage since 1949 indicate that the average base flow was 4,300 acre-feet per year. The difference between the two quantities is acceptable because the averages are for two slightly different periods. The base flow which occurred between 1945 and 1949 would have been greater than that of later years because the aquifer was still fairly near steady-state conditions. Thus, the average base flow for 1945-67 would be greater than the 4,300 acre-feet per year found for the 1949-67 period.

Ground-water underflow occurs where the model boundary intersects the major stream valleys. Estimates of the quantities of steady-state underflow are as follows:

	Acre-feet per year
Castaic Creek Canyon at model boundary	3,100
San Francisquito Canyon at model boundary	2,200
Bouquet Canyon at model boundary	2,600
Santa Clara River above Lang railroad station	Insignificant
Sand Canyon at Santa Clara River	1,000
Mint Canyon at Santa Clara River	800
South Fork Santa Clara River at alluvial aquifer boundary	1,300
Total	11,000
Santa Clara River at Los Angeles-Ventura County line gaging station	-2,000

The underflow in the Santa Clara River at Los Angeles-Ventura County line gaging station is indicated as a negative quantity to signify that it is flow out of the model area.

Under non-steady-state conditions these quantities of underflow have been decreased slightly because of pumpage and lesser quantities of surface-water recharge to the small aquifers above the model boundaries. However, the changes in underflow were not considered to be significant, and no change in underflow was considered in the non-steady-state model.

QUALITY OF WATER

Surface water is the main source of recharge to the aquifers in the study area. Thus, the chemical quality of the surface water has a direct bearing on the quality of the ground water. Unlike the gradual quality changes that occur in the ground water, the quality of surface water is extremely variable.

One factor affecting the quality variation in surface water is the quantity of flow in the stream. Figure 7 shows the relation between the discharge and the dissolved-solids concentrations in the surface water passing the Santa Clara River at Los Angeles-Ventura County line gaging station. As shown in the figure the dissolved-solids concentrations range from 500 to more than 4,000 mg/l (milligrams per liter) depending on the quantity of flow in the river. A change in concentration of 1,000 or 2,000 mg/l can occur within

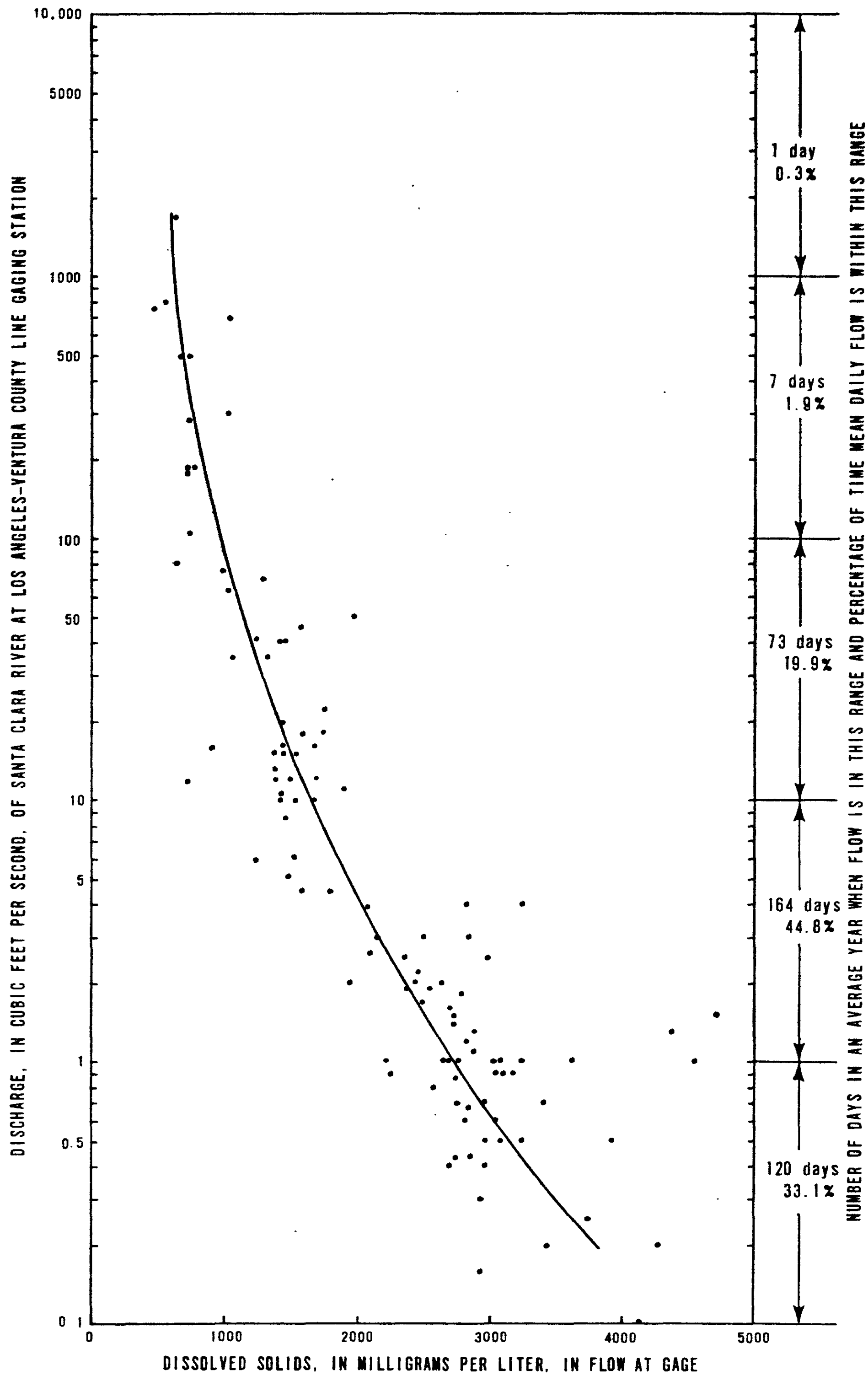


FIGURE 7.--Surface-water quality versus flow at the Los Angeles-Ventura County line gaging station.

2 to 3 hours, as floodflows cause great changes in discharge in that period of time. Though the quality of water may be in the 500 to 1,000 mg/l range during floodflows, these flows occur only about 2 percent of the time, or for about 8 days in an average year. As the volume of flow decreases, the effects of small quantities of very poor quality perennial flow in Potrero Creek and other nearby tributaries, coupled with rising ground water in the lower Santa Clara River, cause the dissolved-solids concentrations to increase. As a result the dissolved-solids concentrations are in the 1,500 to 4,000 mg/l range about 78 percent of the time or about 284 days in an average year.

Most streams in the study area exhibit this inverse relation between discharge and the quality of the water. Potrero Creek, for example, seems to range in dissolved-solids concentrations from 2,500 to 10,000 mg/l. The dissolved-solids concentrations in San Martinez Grande Creek range from 3,000 to 10,000 mg/l; in Pico Creek the range is from 1,500 to 6,000 mg/l. The larger streams tributary to the Santa Clara River also show a decrease in dissolved-solids concentration with an increase in discharge. The larger streams, however, have better quality water than those previously discussed, generally in the 100 to 1,000 mg/l dissolved-solids range.

Within these ranges of dissolved-solids concentrations, each drainage area exhibits a characteristic water type which does not change significantly with discharge. For example, the flow at the Santa Clara River at Los Angeles-Ventura County line gaging station may range in dissolved-solids concentrations from 500 to more than 4,000 mg/l; however, throughout this range the water remains predominantly sodium, calcium, sulfate in type.

The pattern diagrams on plate 3 show the general water types in streams in the study area. These diagrams show the quality of the surface water at the rate of discharge indicated and do not necessarily represent the average water quality in that drainage area. The best quality surface water is in the Santa Clara River above Saugus, and its tributaries, Bouquet Canyon Creek, San Francisquito Canyon Creek, Placerita Creek, and Castaic Creek. As shown on plate 3, the water in these streams contains calcium as the predominant cation and bicarbonate as the major anion except for Castaic Creek which contains sulfate as the major anion.

The water in the streams tributary to the Santa Clara River is of good quality; bicarbonate and dissolved-solids concentrations range from about 100 to 200 mg/l, and 200 to 500 mg/l, respectively. In the upper Santa Clara River, bicarbonate concentrations usually range from 100 to 400 mg/l; dissolved-solids concentrations range from about 200 to 800 mg/l. Downstream from the mouth of the South Fork of the Santa Clara River, the chemical character of the water changes. Below this point, sulfate is usually the predominant ion, and the water is of generally poorer quality. At the Old Highway Bridge gaging station sulfate concentrations generally range from 100 to 3,000 mg/l and dissolved-solids concentrations range from about 300 to 4,000 mg/l.

The water in many of the streams to the west of Newhall is of very poor quality (pl. 3). San Martinez Grande Canyon Creek and Potrero Creek have perhaps the poorest quality surface water of any of the streams. Sulfate concentrations range from 2,000 to 6,000 mg/l, and dissolved-solids concentrations range from 2,500 to 10,000 mg/l. Even though flow from these streams amounts to only a small percentage of the total surface-water inflow to the model area, the ion concentrations are so high that this water has a detrimental effect on the chemical quality of the other surface and ground water in the area. The winter flow coupled with poor quality irrigation return water in the summer months produces part of the degradation in water quality of the Santa Clara River below the South Fork confluence. The reason for the high sulfate concentrations in these streams has not been investigated, but gypsum-rich formations in the drainage areas above the model boundaries seem a likely source (U.S. Soil Conservation Service, 1966).

On plate 4 pattern diagrams of the same type used on plate 3 are plotted for water samples taken from wells perforated in the alluvial aquifer. A comparison of plates 3 and 4 shows that the water in the alluvium is of approximately the same chemical type as the surface water in the adjacent streams. The similarity in water types is further evidence of the surface-water recharge to the alluvial aquifer.

In the alluvial aquifer north and east of Saugus, the ground water is primarily calcium bicarbonate in type. Calcium and bicarbonate concentrations are usually about 80 and 280 mg/l, respectively, and sulfate concentrations are about 90 mg/l. Near Saugus ground water in the alluvial aquifer gains sulfate from the high-sulfate surface-water recharge from the South Fork Santa Clara River and from the sulfate ground waters southwest of Saugus. The resultant water has calcium and bicarbonate concentrations of about 170 and 360 mg/l, respectively, and sulfate concentrations of about 430 mg/l.

The chemical quality of water in the alluvial aquifer generally degrades as it moves from the areas of recharge along the streams to the area of discharge below Castaic Junction. For the last few years of the study period the dissolved-solids concentrations of the ground water in the upper Santa Clara River valley has been about 600 mg/l, ground water in Bouquet Canyon about 1,000 mg/l, and ground water in San Francisquito Canyon about 700 mg/l. Near Saugus, these waters merge with the South Fork ground water (800 mg/l dissolved solids) to give a resultant ground-water dissolved-solids concentration of about 900 mg/l. Farther downstream this water in turn merges with the ground water in Castaic Creek of about 1,000 mg/l dissolved solids and with the rising water from the Saugus Formation of about 1,000 mg/l to give a resultant dissolved-solids concentration below Castaic Junction of about 1,000 mg/l. The rising ground water that leaves the area has between 1,500 and 3,000 mg/l dissolved solids.

In addition to the change in water quality with location, the water in the alluvial aquifer has shown some deterioration in quality during the 1945-67 study period.

The ground water in the alluvial aquifer in Castaic Creek has increased in dissolved solids from about 600 mg/l in 1948 to about 1,000 mg/l in 1966. In the San Francisquito Creek area water in the alluvial aquifer has increased in dissolved solids from about 600 mg/l in 1948 to about 700 mg/l in 1967. There are not enough chemical data to determine what the dissolved-solids concentrations were during the first part of the study period in the central part of Bouquet Canyon; however, the 1967 concentrations are about 1,000 mg/l. Near the mouth of Bouquet Canyon, ground water shows a marked increase in dissolved-solids concentrations from 700 mg/l in 1947 to about 1,200 mg/l in 1967. This area also shows an increase in nitrate concentration from 5 mg/l in 1949 to 81 mg/l in 1965. The unusually large increase in dissolved-solids and nitrate concentrations is probably due to the effects of septic tanks and a feed-lot operation in the area.

The water in the alluvial aquifer in the South Fork Santa Clara River and in the Santa Clara River above Saugus has not changed significantly in quality during the study period and remains at about 700 and 600 mg/l dissolved solids respectively. Water from the alluvial aquifer immediately west of Saugus shows an increase in dissolved solids from about 500 mg/l in 1948 to about 900 mg/l in 1967. The change in quality with time diminishes to the west until at wells 4N/16W-17A1 and 4N/16W-17P1, no significant change in dissolved-solids concentration has occurred. In the Santa Clara River valley below Castaic Junction the change in the quality of water from the alluvial aquifer has ranged from about 1,000 mg/l dissolved solids in 1947 to 1,500 mg/l in 1966. This large change in quality reflects the decreased flushing action of the diminishing quantities of rising ground water in this reach of the river.

Below Castaic Junction the quality of water in the alluvial aquifer is influenced by the quality of the water in the Saugus aquifer. Comparison of the diagrams for the alluvial aquifer with the diagram for well 4N/17W-13J1 in the Saugus aquifer (pl. 4) shows that the water types in the two aquifers in this area are similar. This is as expected because of the movement of water from the Saugus aquifer into the alluvial aquifer and subsequently into the surface water base flow of the Santa Clara River.

The diagrams for the Saugus aquifer show a wide variation in both the type and quality of the water. In the three shallow wells, 4N/16W-32Q1, 3N/16W-3D2, and 3N/16W-4Q1, the effect of the high sulfate surface waters shown on plate 3 is readily apparent. However, in this same area the deep wells, 3N/16W-3D3, 4N/16W-35M2, 4N/16W-35L1, and 4N/16W-34A3, do not show the effect of this high-sulfate water. Apparently, wells perforated in the deeper zones in this area obtain water from the area to the south and east where the surface-water quality is somewhat similar to that found in the deep zones. The water in the deep wells 4N/16W-21D1, 22M1, 34A3, 35M2, and 35L1 is primarily sodium calcium bicarbonate as opposed to the sodium calcium sulfate water in the alluvium near these wells. This would indicate that there is limited exchange of water between the alluvial aquifer and the deeper zones of the Saugus aquifer in this area.

Because the high-sulfate water in the shallow zones of the Saugus aquifer does not seem to move into the deeper zones in these areas, it may move into the deeper zones to the northwest as indicated by the sulfate water in the deep well 4N/16W-33L1. Some of the shallow high-sulfate water may move into the alluvial aquifer near Saugus, in part accounting for the high-sulfate concentrations in well 4N/16W-28A1, which is not closely associated with the high-sulfate surface waters of the South Fork of the Santa Clara River.

The water quality in the deep well 4N/16W-17J1 is similar to that in the alluvium in secs. 21 and 22, T. 4 N., R. 16 W. This would suggest that some of the recharge to the Saugus aquifer in this area comes from the alluvial aquifer. However, because there is no water-quality data for the Saugus aquifer north of the San Gabriel fault, it is not possible to accurately determine from quality of water data where the major areas of recharge are for the zone between the San Gabriel and Holser faults. In the area between the two faults no deep wells are west of well 4N/16W-17J1 which could indicate the quality of the water entering the area from that direction. The two shallow wells 5N/17W-32H2 and 35M1 show markedly different water types, one sodium bicarbonate water and the other calcium sulfate water. As a result, no definite water type is indicated.

The deep wells in the Saugus aquifer show dissolved-solids concentrations ranging from about 400 near Newhall to about 1,000 mg/l near Castaic Junction. Concentrations of dissolved solids in the wells have not changed significantly from the time the wells were drilled (1958-63) to 1967. Some data indicate that water in the shallow wells in the Saugus aquifer near Newhall has not changed markedly in dissolved-solids concentration during the study period. The dissolved-solids concentrations of water from the shallow wells range from about 500 to about 3,600 mg/l depending on location. The wells with the highest dissolved-solids concentrations are west of Newhall in the area of high-sulfate surface waters.

A sewage-treatment plant near Saugus discharged a total of about 4,300 acre-feet of treated effluent into the Santa Clara River between 1963 and 1967. This effluent is of a different chemical type than the water normally found in the alluvial aquifer below Saugus (pls. 3 and 4). The concentrations of sodium and chloride in the effluent are about twice those found in the water of the alluvial aquifer, and nitrate concentrations (99 mg/l) are from three to five times those of the ground water. However, the concentrations of calcium, magnesium, bicarbonate, and sulfate are less than those normally found in the water of the alluvial aquifer below Saugus. Nitrate is the only determined constituent that is of a markedly higher concentration in the effluent than in the adjacent ground water. Because the U.S. Public Health Service (1962) recommends only relatively low concentrations (45 mg/l) of nitrate in water for public supply use, the alluvial ground water in this area should be monitored to assure that the nitrate concentrations do not exceed safe limits. As of 1967, the percolation of the water into the alluvial aquifer does not seem to have presented a serious pollution hazard to the aquifer because of the small quantities of effluent involved.

GROUND-WATER PUMPAGE AND WATER LEVELS

Ground-Water Pumpage

Because of insignificant precipitation or surface-water runoff in the summer, municipal and agricultural water demands have been met by pumping from aquifers. Agricultural demands account for most of the water pumped in the area. For example, in 1961 about 43,000 acre-feet of water was pumped, of which about 40,000 acre-feet was for agricultural use and 3,000 acre-feet was for municipal and domestic use. By 1967 urbanization caused a decrease in agricultural water use and a rapid increase in municipal and domestic water use. The lag in water demand as land is converted from agricultural to urban use is evident in the decreased pumpage in 1967. Total pumpage was 33,000 acre-feet with 23,000 acre-feet for agricultural use and 10,000 acre-feet for municipal and domestic use.

Pumpage data for about 120 wells in the model area were supplied by the cooperator. The data are based on metered discharge figures where available or on records of electrical power consumption when no metered data are available. The data contain most of the significant pumpage from wells for the period 1947-67.

For the years 1945 and 1946 pumpage data were estimated for the entire study area. For a few wells that had no data pumpage data were estimated for the entire study period. This was done by measuring the irrigated acreage shown on aerial photographs flown in 1947, 1952, 1954, 1959, 1964, and 1968. The number of acres under irrigation in each year was converted to an estimated pumpage figure by assuming a consumptive use factor of 4.0 feet per acre. The resulting pumpage was assigned to wells adjacent to the irrigated fields.

The pumpage data supplied by the cooperator are the total quantity of water pumped by each well in the course of the year. This does not represent the net extraction from the aquifers because part of the water applied to a field percolates into the ground and eventually recharges the aquifer. The net extraction is termed effective pumpage in this report and represents the quantity of pumped water not returned to the aquifers in the process of any type use, be it agricultural, municipal, or domestic.

Many studies have been conducted to determine the quantity of water consumed by various agricultural crops. Blaney and Criddle (1962) indicated that the annual consumptive use for crops in areas with a climate similar to that of the Newhall area ranges from a high of 4.5 feet for alfalfa to a low of 1.7 feet for general vegetable crops. These consumptive-use figures were applied to the acreage of each type of crop grown on the Newhall Land and Farming Co. property (pl. 5).

The data indicated that the crop consumption amounted to about 50 percent of the water supplied to fields along the Santa Clara River, and in Dry Canyon, San Francisquito Canyon, and parts of Castaic Valley. In the area between the Santa Clara River and Newhall the soil is somewhat less permeable than in areas along the Santa Clara River (U.S. Soil Conservation Service, 1966). This is also indicated by the water requirements for crops in this area. About 65 percent of the water supplied to this area is consumed by crops as opposed to 50 percent consumptive use in the more permeable areas.

Similar crop-use calculations made for the farming operations of the Wayside Honor Rancho in Castaic Valley indicate that 65 percent of the applied water is consumed. Though the soil permeabilities in this area do not seem to be significantly different from those of the Santa Clara River valley, less water is used to grow crops. This is probably due to more carefully controlled irrigation practices in the Honor Rancho.

The consumptive use of water for municipal and domestic purposes was estimated on the basis of work by Harold Conkling (written commun., 1948). An estimated 65 percent of the water supplied to a household is used in the home and returned directly to the sewer system with very little loss. The remaining 35 percent is assumed to be used outside, of which an estimated 10 percent recharges the aquifers and 25 percent is consumed.

In areas served by septic tanks nearly all the water entering the tank recharges the aquifer near the area of use. However, in areas served by a sewer system, most of the ground-water recharge occurs near the outfall from the treatment plant. Thus, for a specific well, the percentage of pumped water that is consumed or transported away from the well site varies considerably. The percentages for sewer-system service areas and for septic tank service areas widely separated from the well were about 90 to 100 percent, and for septic tank service areas near the pumped well percentages were about 25 percent.

The outfall from the sewage-treatment plant at Saugus was modeled as ground-water recharge along the Santa Clara River below Saugus. This recharge varied from zero in 1962 to 1,370 acre-feet in 1967. The recharge from the effluent was modeled by reducing the total effective pumpage from nodes DA-82, DB-94, DD-89, DE-83, and DF-87 by the amount of the recharge.

The consumptive-use figures for agricultural and municipal use were applied to the pumpage data for each well to compute effective pumpage. The procedure for applying the figures varied depending on the water use and the proximity of the well to the area of use. The effective pumpage data for closely spaced wells were combined to reduce the number of pumping nodes in the analog model. These combined effective pumpage data were assigned to nodes in the analog model (pl. 5). This resulted in 36 pumping nodes in the alluvial aquifer and nine pumping nodes in the Saugus aquifer. The effective pumpage data for each node were broken into seven time periods or pulses and the average pumpage in each period was determined. The model pumpage simulates the average pumpage for each time period. The total effective pumpage for each model node is shown in table 4.

TABLE 4.—*Effective ground-water pumpage, 1945-67*

[Figures are sum of pumpage occurring during the years shown]

Node	Pumpage (acre-feet)							
	Pulse 1 1945-47	Pulse 2 1948-51	Pulse 3 1952	Pulse 4 1953-55	Pulse 5 1956-59	Pulse 6 1960-66	Pulse 7 1967	23-Year Total
ALLUVIAL AQUIFER								
BB-50	600	1,050	350	750	530	1,410	40	4,730
BQ-52	900	2,150	720	2,480	3,780	7,060	920	18,010
CB-52	600	800	240	790	1,550	4,510	620	9,110
CC-86	610	610	210	980	1,960	1,280	0	5,650
CF-120	480	640	160	480	620	840	410	3,630
CI-49	1,100	2,560	510	2,880	3,880	6,640	880	18,450
CL-48	510	690	150	1,040	400	3,030	300	6,120
CL-84	540	800	10	1,760	1,530	1,710	240	6,590
CL-115	250	450	350	470	750	1,220	0	3,490
CQ-54	70	60	10	120	2,270	3,980	240	6,750
CR-109	1,500	1,200	300	900	800	950	180	5,830
CS-46	520	2,370	380	1,320	1,670	5,730	10	12,000
CS-60	1,690	3,590	590	3,110	2,430	3,590	170	15,170
CT-64	850	2,200	560	1,540	800	1,480	230	7,660
CU-47	1,300	2,220	400	2,690	4,220	5,060	470	16,360
CU-74	2,980	4,700	910	4,880	4,610	7,570	1,000	26,650
CW-57	260	370	40	180	240	870	0	1,960
CW-105	1,050	1,400	350	1,050	1,350	2,110	0	7,310
CX-98	1,170	2,120	450	1,700	1,640	4,970	1,070	13,120
CY-46	120	200	50	150	470	1,000	80	2,070
DA-82	3,310	6,390	970	3,180	3,810	5,890	50	23,600
DB-40	7,810	10,580	1,810	6,730	7,390	14,110	1,550	49,980
DB-94	2,160	3,200	650	2,880	3,560	3,890	280	16,620
DD-40	580	1,490	510	2,250	2,340	3,850	600	11,620
DD-89	13,600	33,340	5,840	19,780	22,230	28,620	2,210	125,620
DD-118	1,770	2,370	750	1,600	910	2,510	470	10,380
DE-83	0	290	180	960	1,210	3,500	80	6,220
DF-35	400	700	20	690	1,060	880	110	3,860
DF-87	8,600	12,800	2,320	6,640	8,920	12,440	1,120	52,840
DF-113	0	240	0	1,180	2,930	2,780	320	7,450
DF-164	450	600	150	450	140	1,340	230	3,360
DG-104	540	1,430	190	3,340	5,140	5,180	380	16,200
DH-24	4,760	11,470	2,160	10,430	10,720	20,180	1,290	61,010
DH-137	1,500	2,000	500	1,500	1,600	50	0	7,150
DJ-157	450	600	150	450	450	810	150	3,060
DL-140	1,200	1,600	400	1,100	870	4,070	1,050	10,290
Total:	64,230	119,280	23,340	92,430	108,780	175,110	16,750	599,920
SAUGUS AQUIFER								
CY-52	0	0	0	0	0	750	170	920
CY-74	0	0	0	0	0	770	90	860
DE-74	0	0	0	0	0	1,510	970	2,480
DI-88	0	0	0	0	0	5,950	1,240	7,190
DQ-94	300	400	100	300	470	7,560	720	9,850
DY-94	0	0	0	0	0	11,680	1,930	13,610
EG-78	0	0	0	0	0	3,060	520	3,580
EG-98	540	870	260	990	2,300	3,120	620	8,700
EK-96	0	0	0	0	80	110	100	290
Total:	840	1,270	360	1,290	2,850	34,510	6,360	47,480
Grand Total:	65,070	120,550	23,700	93,720	111,630	209,620	23,110	647,400

The irrigated fields between Newhall and the Santa Clara River receive most of their water by pipeline from wells near the Santa Clara River. Because the water is exported for use in an area away from the wells, the metered pumpage was considered to equal the effective pumpage (100-percent consumptive use). The exported irrigation water produced about 2,500 acre-feet per year of ground-water recharge in the area of the irrigated fields. This quantity was modeled as a constant recharge to the area of the fields in the non-steady-state model.

Water pumped from several wells in the lower Santa Clara River area is exported from the model area and lost from the system. The wells were assigned a 100-percent consumptive use when pumping for export. When the wells were pumped for agricultural use inside the model area, a different consumptive-use value was used, depending on the crop and the location of the fields.

Steady-State Water Levels

In the Saugus-Newhall area the alluvial aquifer has a limited potential for storage of ground water. Because of this the water levels in the alluvial aquifer fluctuate markedly in response to the cyclic effects of surface-water recharge. This fluctuation also occurred before man began developing the ground-water basin. As a result, a true steady-state condition has never existed in the study area. For several years prior to 1945 larger-than-average quantities of precipitation runoff occurred. The abundance of surface water filled the ground-water reservoir and held the water table at a fairly constant level during the wet years. As a result, the 1945 water-level-contour map (pl. 5) was chosen as an approximation of the steady-state water-level conditions.

The steady-state water-level contour map for the alluvial aquifer produced by the model (pl. 6) closely matches the 1945 contour map (pl. 5). The most marked differences between plates 5 and 6 are in the upper Castaic Creek Canyon and the upper Bouquet Canyon areas. Here the variations in surface-water recharge prior to 1945 seem to have raised the water levels in the alluvial aquifer above that of the steady-state conditions. With the exception of these two areas, plates 5 and 6 agree within about 10 feet. This is a sufficient degree of accuracy for the alluvial aquifer to be considered verified under steady-state conditions.

Under steady-state conditions the water-level contours in the alluvial aquifer are near land surface and show a fairly uniform gradient downstream. Depth to water ranges from about 10 to 30 feet in the areas upstream of Castaic Junction, and the water table is at land surface below Castaic Junction. The water-level gradient near Saugus is flatter than elsewhere because of the high transmissibility and greater width of the aquifer in most of this area and because of the small quantity of recharge from the South Fork Santa Clara River area. An abrupt change in water levels of 10 to 20 feet occurs in the alluvial aquifer at the San Gabriel fault. As discussed earlier this is due to the low transmissibility of the fault zone.

Because of a lack of water-level measurements in wells, a map of the 1945 potentiometric surface[1] for the Saugus aquifer was not constructed. The verification of the steady-state model was based solely on the water-level contours generated for the alluvial aquifer. Plate 6 shows the model-generated steady-state potentiometric surface for the Saugus aquifer. Because it is not possible to verify this map, care must be used in its interpretation. This is especially true for the area north of the San Gabriel fault and the area north and northwest of Castaic Junction. In these areas control on the aquifer characteristic parameters is very poor. Consequently, the contours probably more accurately depict the general flow patterns in the area than they do the actual heads to be encountered in the aquifer.

In the area south of the San Gabriel fault and south of Castaic Junction better data control is available. In most of this area the potentiometric surface is probably a reasonable representation of the actual steady-state conditions of head. The head changes across the San Gabriel and Holser faults are as much as 20 feet and are considered reasonable in the absence of other data.

Steady-state head gradients in the Saugus aquifer range from about 10 to 50 feet per mile south of the Holser and San Gabriel faults. The flatter gradients are in the broader more permeable parts of the aquifer, whereas the steep gradients lie in an area of low permeability south of Newhall. Fragmentary water-level measurement data suggest that these steady-state gradients may be too flat near Newhall. This is further indicated by the non-steady-state heads in this area.

Non-Steady-State Water Levels in the Alluvial Aquifer

The water table in the alluvial aquifer is subject to two types of fluctuations, seasonal and long term. Seasonal fluctuations are due to pumpage from wells used for agricultural purposes. Water levels decline during the May through September pumping season and recover during the winter months when agricultural pumping ceases. Figure 8 is typical of this type of seasonal water-level fluctuation in the alluvial aquifer in the central part of the model area.

Long-term fluctuations are due to variations in the quantities of surface-water recharge that occur from dry years to wet years. The water-level hydrographs on plate 7 show this type of fluctuation. Because these hydrographs are drawn to show the average annual water levels in the aquifer near the well, the seasonal water-level fluctuations shown in figure 8 are eliminated.

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[1]The potentiometric surface of an artesian aquifer (that is, the Saugus aquifer) is an imaginary surface which coincides with the hydrostatic pressure level of the water in the aquifer. The water table in an unconfined aquifer (that is, the alluvial aquifer) is a particular potentiometric surface.

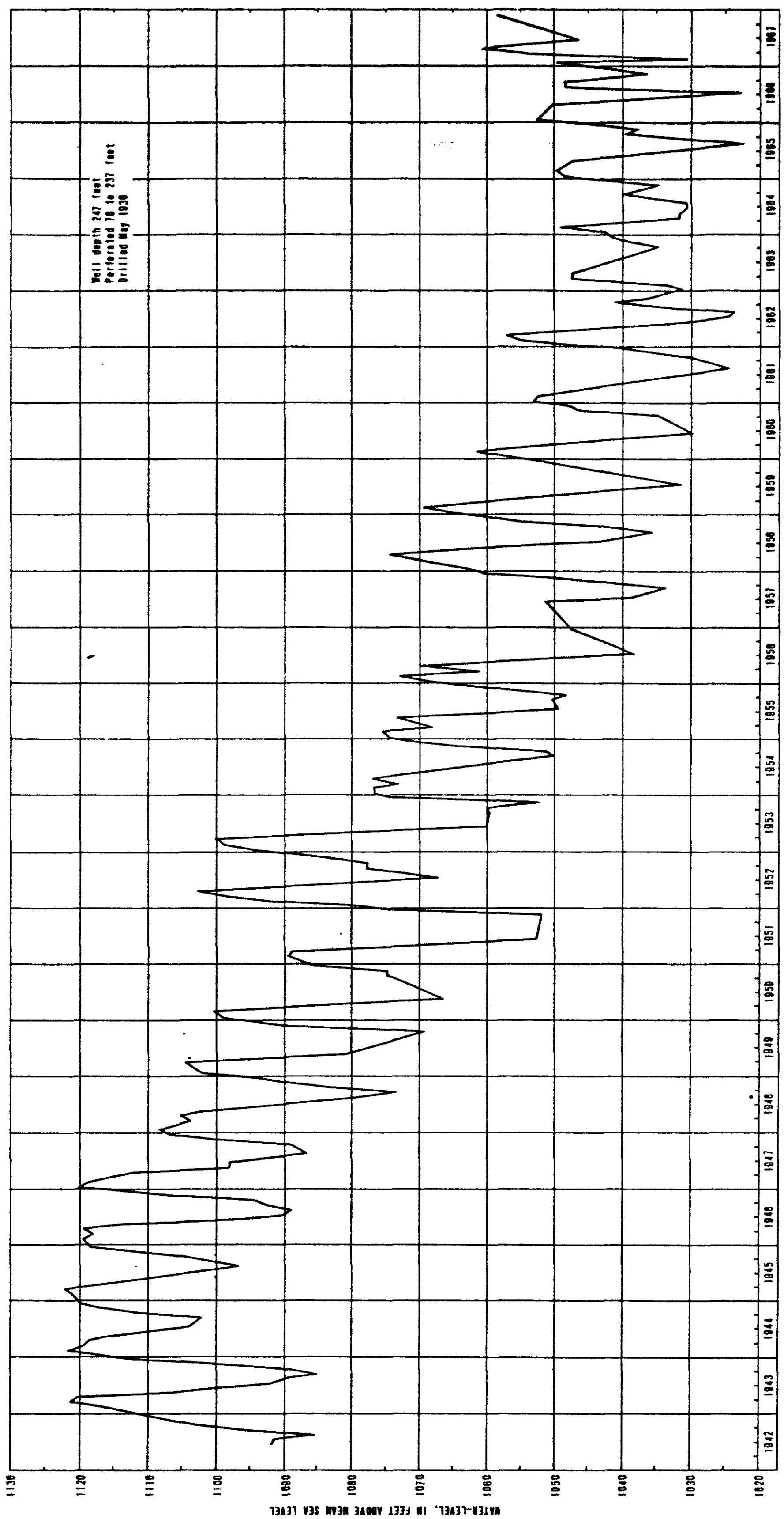

FIGURE 8.--Hydrograph of well 4N/16W-22D2 perforated in the alluvial aquifer.

The wells showing the greatest long-term water-level fluctuation are toward the upstream ends of the alluvial valleys. Those wells show the most pronounced water-level variation because they are in areas where the river channel alluvium is narrow and thus has a limited area over which ground water can be stored. Where the river channel alluvium is broader, a greater area is available for ground-water storage, and water levels in wells are not so readily influenced by variations in the quantities of surface-water recharge.

The hydrographs of wells perforated in the alluvial aquifer located in the central part of the study area show a fairly steady decline in water levels during the study period (pl. 7). The declines are as much as 85 feet in some places. Because the water levels in this area do not respond markedly to the surface-water recharge from individual wet years, steady declines can be expected to occur whenever the area has a dry period similar to those shown in figure 3. In spite of the water-level declines, this area is preferable to the upstream areas for development of future well fields because water levels will not be as strongly affected by short-term dry periods as will those in upstream areas.

The water-level contours shown on plate 7 depict the conditions in the alluvial aquifer in 1963 when the aquifer was near the point of greatest water-level decline. A comparison of the water-level contours on plates 5 and 7 shows that the water level has declined throughout the area. A comparison with contour maps for years other than 1963 shows a similar pattern of declines.

The water-level hydrographs produced by the analog model (pl. 7) are shown coincident with hydrographs based on water-level measurements in wells. The extent of agreement between the pairs of hydrographs is a measure of the non-steady-state model verification. Most of the model-generated hydrographs are within 15 feet of the hydrographs based on water-level measurements. In general the model-generated hydrographs match the water-level trend (as determined from water-level measurements) and show the correct response to the wet and dry years. When the accuracy of the data used to construct and verify the model is considered, the agreement shown by the pairs of hydrographs on plate 7 is sufficient to consider the alluvial aquifer verified in the non-steady-state condition.

Non-Steady-State Potentiometric Surface in the Saugus Aquifer

Water-level measurements for wells in the Saugus aquifer are not evenly distributed over the area of the aquifer. Most measurements are for shallow wells along the tributaries to the South Fork Santa Clara River south of Newhall. The few measurements available for deep wells in the aquifer do not define the long-term head fluctuations that occurred during the study period.

Because of the lack of data only four short-term deep-well hydrographs were available to use in the non-steady-state verification of the Saugus aquifer (pl. 7). The measurements indicate that in the area south of the San Gabriel fault and east of Castaic Junction, the potentiometric surface produced by the model is too flat (pl. 7). This was also indicated by the steady-state run. The model-based heads shown on plate 7 are correct south of Castaic Junction but are about 70 feet low at Newhall. This is shown by the discrepancy between the two hydrographs for well 4N/16W-35L1 (pl. 7). Because there are no water-level measurements for the area north of the San Gabriel fault and Castaic Junction, it is not known whether or not the potentiometric surface shown for that area is correct.

In view of the lack of definitive data for the Saugus aquifer, it is felt that this layer of the model is adequately verified for present needs. The hydrologic parameters used to model the Saugus aquifer are initial estimates. Consequently, before more detailed information about the Saugus aquifer can be obtained from the model, additional studies of the hydrologic characteristics of the aquifer should be made. With present data only general information can be deduced regarding the ground-water flow network in the Saugus aquifer.

A comparison of the assumed steady-state potentiometric surface (pl. 6) with the 1963 potentiometric surface (pl. 7) shows that in the model the Saugus aquifer has undergone a decline in head over most of the area of the aquifer. This decline is due to pumping from the Saugus aquifer and to water-level declines in the overlying alluvial aquifer. The model-generated hydrographs on plate 7 indicate that the declines in the Saugus aquifer have been similar to those that occurred at adjacent points in the alluvial aquifer. This suggests that future pumping from or artificial recharge to one of the aquifers will have an effect on the head in the other aquifer. Head changes in the Saugus aquifer, however, are generally less than the corresponding changes in the alluvial aquifer. This is due to the low vertical component of permeability between the two aquifers and lesser quantities of pumping from the Saugus aquifer than from the alluvial aquifer.

WATER BUDGET

Table 5 shows the water budgets for the steady-state and the non-steady-state model. All quantities of inflow and outflow used in the model are shown. Under steady-state conditions the quantity of inflow to the model must equal the quantity of outflow. As shown, the total inflow and total outflow are both equal to about 25,000 acre-feet per year. Surface-water recharge and underflow are the major sources of inflow, and ground-water discharge is the principal outflow.

TABLE 5.—*Water budget*

	Steady-state water budget (acre-feet per year)	Non-steady-state water budget for 1945-67 (total flow in acre-feet)
INFLOW		
Surface-water recharge		
Castaic Creek	1,200	94,900
San Francisquito Canyon Creek	1,000	50,100
Bouquet Canyon Creek	1,000	61,900
South Fork Santa Clara River	1,400	38,500
Santa Clara River	5,000	96,500
Total	9,600	341,900
Underflow at model boundaries		
Castaic Creek valley	3,100	72,100
San Francisquito Canyon	2,200	50,200
Bouquet Canyon	2,600	59,200
Mint Canyon	800	19,300
Sand Canyon	1,000	21,900
South Fork Santa Clara River	1,300	30,900
Total	11,000	253,600
Precipitation recharge	4,500	103,000
Recharge from irrigation between Newhall and the Santa Clara River	--	67,000
Total	4,500	170,000
Total inflow	25,100	765,500
Alluvial aquifer storage depletion	--	37,300
Saugus aquifer storage depletion	--	11,500
Total	--	48,800
Total inflow plus storage depletion	--	814,300
OUTFLOW		
Ground-water discharge	21,200	120,200
Phreatophyte consumption	2,000	46,000
Ground-water pumpage	--	647,400
Underflow at Los Angeles-Ventura County line	2,000	45,100
Total outflow	25,200	[1]858,700

[1]Total outflow minus total inflow plus storage depletion equals 44,400 equals 5.2 percent error.

In the water budget for the non-steady-state condition the figures shown are the total quantities of inflow or outflow which occurred in each area during the 23-year study period. When the ground-water storage depletion is added to the inflow data, the total inflow must equal the total outflow within the limits of accuracy of the model. As shown, these totals agree within 5.2 percent or about 44,000 acre-feet. Surface-water recharge and underflow are still the main sources of inflow, but ground-water pumpage is by far the greatest source of outflow from the basin.

MODEL READOUTS

The major water purveyors in the Saugus-Newhall area are presently considering the effects of various water-resources management practices in order to arrive at management techniques that will make the best use of the existing and future water resources of the areas. The analog model was used to supply information about the response of the aquifers to each of the following conditions:

1. What are the effects of loss of natural floodwater recharge to the aquifers?

2. What are the effects on the aquifers of artificial recharge of imported water?

3. What are the effects on the aquifers of increased pumpage to meet future water requirements?

Effects of Loss of Floodflow

Because water levels in the alluvial aquifer respond to variations in surface-water recharge, information about the effects of an extended drought during which no floodflow recharge occurs is of value.

To simulate an extended drought, the model was run for the 1945-67 period under the following conditions:

1. The surface-water recharge to the model did not exceed steady-state surface-water recharge.

2. Loss of floodflow recharge to the aquifers will cause large water-level declines which will decrease the quantity of ground-water discharge in the Santa Clara River below Castaic Junction. This ground-water discharge cannot be decreased by more than the original steady-state ground-water discharge. To simulate this limit in the model, the induced recharge in the area was not allowed to exceed the value of the steady-state ground-water discharge.

3. The aquifers were assumed to be in steady-state conditions at the beginning of the drought.

4. All other hydrologic parameters were maintained at the values which were normally used in the non-steady-state model during the 1945-67 study period.

Under these conditions the model produced the hydrographs shown in figure 9. Because the transmissibility in the model does not vary as a function of head, these hydrographs represent the theoretical response of the basin to the conditions set forth above. Under actual field conditions the decrease in transmissibility with decline in head would cause the alluvial aquifer to be dewatered sooner than indicated by the hydrographs in figure 9. The hydrographs do indicate, however, that without the effects of floodflow recharge most of the alluvial aquifer could not support the modeled rate of ground-water pumpage for more than 14 to 18 years after steady-state conditions. The aquifer would support this pumpage for an even shorter period of time if the basin were not at steady-state condition at the beginning of the drought. The benefit the basin receives from floodflow recharge can be seen by comparing the hydrographs produced by the model for the alluvial aquifer under 1945-67 historic conditions with the hydrographs for the no-floodflow condition.

The loss of floodflow recharge in the alluvial aquifer causes head declines in the Saugus aquifer. As shown by the hydrographs in figure 10, after 23 years the no-floodflow condition produces declines in the Saugus aquifer about 100 feet below those of the normal condition. These declines do not produce complete dewatering of the aquifer because of its large saturated thickness.

Effects of Artificial Recharge

The Upper Santa Clara Valley Water Agency has contracted with the State of California for delivery of northern California water to meet future water requirements in the study area. The quantities of imported water tentatively will range from 1,600 acre-feet per year in 1971 to 41,500 acre-feet per year in 1990 but could be increased somewhat if required (table 6). One management procedure under consideration proposes that all water imported between 1971 and 1980 be artificially recharged to defer the cost of treatment facilities. The channel of the Santa Clara River between Solemint and Saugus was chosen as a possible site for artificial recharge on the basis of the hydrology of this area and the proposed alinement of a 36-inch diameter pipeline. The analog model was used as an aid in determining the effects of the recharge on the aquifers.

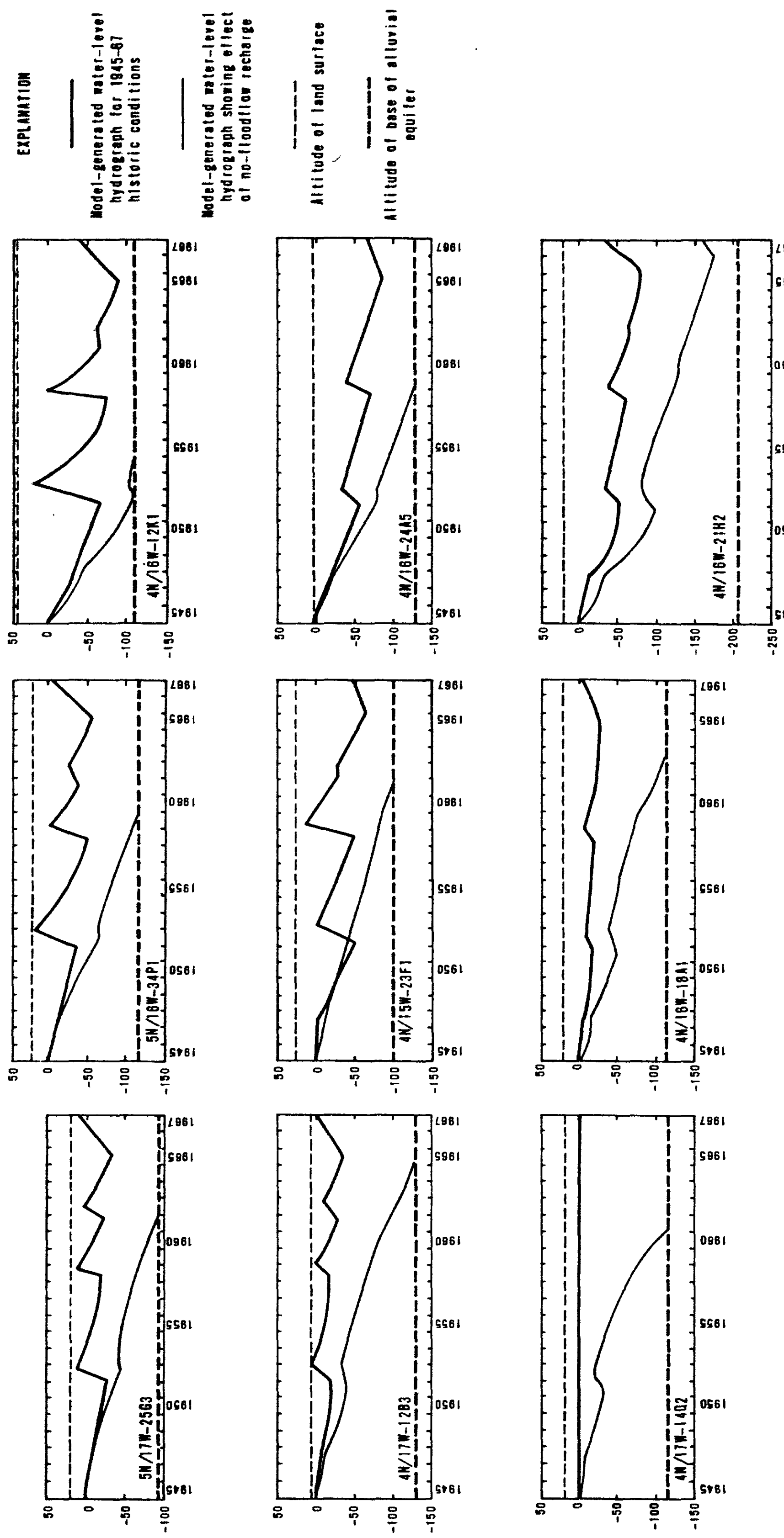

FIGURE 9.--Model-generated hydrographs showing effect of no-floodflow recharge for the alluvial aquifer.

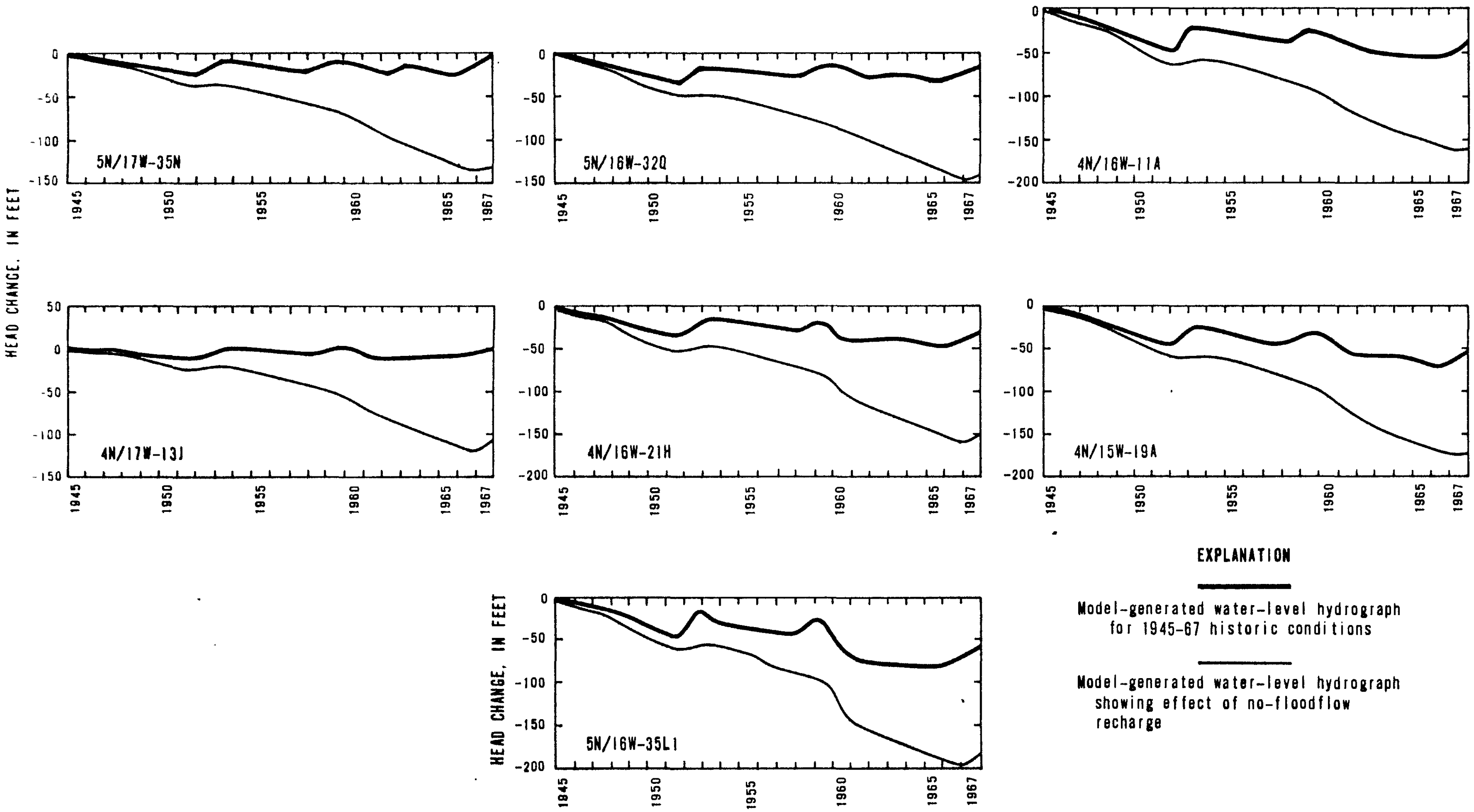

FIGURE 10.--Model-generated hydrographs showing effect of no-floodflow recharge for the Saugus aquifer.

TABLE 6.--*Imported water entitlements and artificial recharge*

Year of delivery	Annual project water entitlements (acre-feet)	Year used in model simulation	Artificial recharge (acre-feet)	Pulse	Mean for pulse (acre-feet)
1971	1,600	1956	1,600	1	2,650
1972	3,700	1957	3,700		
1973	5,700	1958	5,700	2	5,700
1974	7,500	1959	7,500		
1975	9,500	1960	9,500	3	9,500
1976	11,400	1961	11,400		
1977	13,400	1962	13,400	4	13,400
1978	15,300	1963	15,300		
1979	17,700	1964	17,700	5	17,700
1980	20,100	1965	20,100		
1981	22,100				
1982	24,600				
1983	26,900				
1984	29,100				
1985	30,900				
1986	32,900				
1987	35,300				
1988	37,400				
1989	39,300				
1990	41,500				
Total:			105,900		106,000

To simulate the artificial recharge, the model was run for the 1956-65 period under the following conditions:

1. The quantities of artificial recharge were modeled as indicated in table 6 and were distributed equally along a 0.7-mile reach of the Santa Clara River below Solemint.

2. Because surface-water recharge from 1971 to 1980 cannot be predicted, the surface-water recharge for the 1971-80 period of artificial recharge was assumed equal to the surface-water recharge that occurred from 1956-65. The total surface-water recharge in this 10-year period is among the lowest that occurred in any 10-year period from 1945-67. As a result the artificial recharge is applied to the aquifer when it is in an optimum condition to receive additional recharge. The average precipitation on the area during this 10-year period is 13.3 inches. The surface-water recharge in this 10-year period represents conditions resulting from a 19-percent deficiency in precipitation based on the 95-year average of 16.4 inches.

3. The basin was assumed to be in steady-state condition prior to 1970. This is a reasonable approximation because the surface-water recharge that occurred in the wet years 1966, 1967, and 1969 produced ground-water conditions in the basin not too dissimilar to those that occur under steady-state conditions.

4. All other hydrologic parameters are maintained at the values that normally occurred in the 1956-65 period.

Under these conditions the model produced the hydrographs for the 0.7-mile recharge reach shown on plate 8. These theoretical hydrographs indicate that under the above-described conditions the water levels will rise almost 130 feet above land surface in the vicinity of the recharge reach. Because this is clearly impossible, this indicates that without a change in pumpage the quantities of artificial recharge used must be reduced or the size of the recharge reach must be increased.

To determine the effects of a larger recharge reach, a second run was made on the model. In this run the length of the artificial recharge reach was increased to 3.5 miles extending from below Solemint to about 0.5 mile upstream of the Bouquet Canyon Creek confluence. The same quantities of recharge were supplied to the model as were used in the previous run. Conditions 2, 3, and 4 above were also maintained for this run.

As shown by the hydrographs for the 3.5-mile reach on plate 8, the model-generated water levels in the vicinity of the recharge reach still rise above land surface. The water levels near the recharge reach rise about 65 feet above land surface as opposed to the 130 feet of rise using the 0.7-mile reach. A further beneficial effect of the longer recharge reach is evidenced by the more pronounced water-level rises produced in alluvial aquifers some distance from the area of recharge. Both recharge reaches produce about 25 feet of water-level rise in the Saugus aquifer near the recharge reach and lesser rises at points more distant from the reach.

Though the longer recharge reach improved the artificial recharge conditions, the alluvial aquifer in the area of the Santa Clara River probably has inadequate storage capacity to hold the quantities of artificial recharge used in these runs. This judgment is further substantiated by the fact that the hydrographs shown on plate 8 represent the model-generated response of the alluvial aquifer under optimum recharge conditions. It would be even less likely that these quantities of water could be artificially recharged if the aquifer were receiving quantities of surface-water recharge greater than those which occurred in the 1956-65 period. On the basis of the two model runs it seems that either the quantities of imported water to be artificially recharged must be reduced or the ground-water pumping in the vicinity of the recharge reaches must be increased significantly.

Care must be used in the interpretation of the results of the two model runs because the accuracy of the verified model influences the accuracy of subsequent runs. The alluvial aquifer has been verified to an accuracy commensurate with that required for the aquifer in all the model readouts. For the southern part of the Saugus aquifer the model verification was of poorer accuracy than in other areas of the aquifer. The 25-foot rise in head produced in the Saugus aquifer in the two runs was not in this poorly verified area. However, this head change should not be considered an exact figure. Rather, the head change of 25 feet indicates that moderate rises can be expected to occur in the Saugus aquifer near the areas of artificial recharge in the alluvial aquifer.

Effects of Increased Water Demand

This model run simulates the effects on the alluvial and Saugus aquifers of an increase in water demand in the study area and artificial recharge in the alluvial aquifer. The conditions to be simulated in this run are:

1. Water demands in the study area between 1970 and 1990 will be as large as could be expected to occur during this period.

2. Artificial recharge to the alluvial aquifer will occur at the rates shown in table 6 between 1970 and 1980. The 3.5-mile reach of the Santa Clara River below Solemint will be used for the artificial recharge.

3. After artificial recharge is discontinued in 1981 the quantities of imported water shown in table 6 will be treated and supplied directly to the users. The imported water will serve as the primary source of supply for the area, and pumping from the aquifers will be used to supplement the supply as demands require.

Water demand used in the run was estimated on the basis of the smaller of the two population projections made by Philip Abrams Consulting Engineers Inc. (written commun. entitled "Water Facilities Development for Greater Newhall County Water District Service Area," 1967, 101 p.). The report indicated that the 1990 population of the area would be at least about 287,000. This population estimate is larger than the population estimates made by the Los Angeles County Planning Commission (228,000) and the 240,000 estimated by Bookman and Edmonston Consulting Civil Engineers (written commun. entitled "Feasibility of Financing and Constructing Facilities for Main Conveyance and Treatment of Water from the State Water Project," 1967, 86 p.). The 287,000 population estimate was used as the basis for estimating future water demands in the area because this would probably be the maximum demand to occur. The predicted population for each year between 1970 and 1990 given in the Abrams report was converted to a water-demand figure by applying a per-person demand which varied from 235 gpd per person in 1970 to 255 gpd per person in 1990. Using this procedure, a projected water demand was developed for each of the four major municipal water purveyors in the area (fig. 11) based on service areas delineated by Abrams. The projected water demands for the farming operations of the Wayside Honor Rancho and the Newhall Land and Farming Co. were based on estimates of available agricultural land to 1990 (fig. 11).

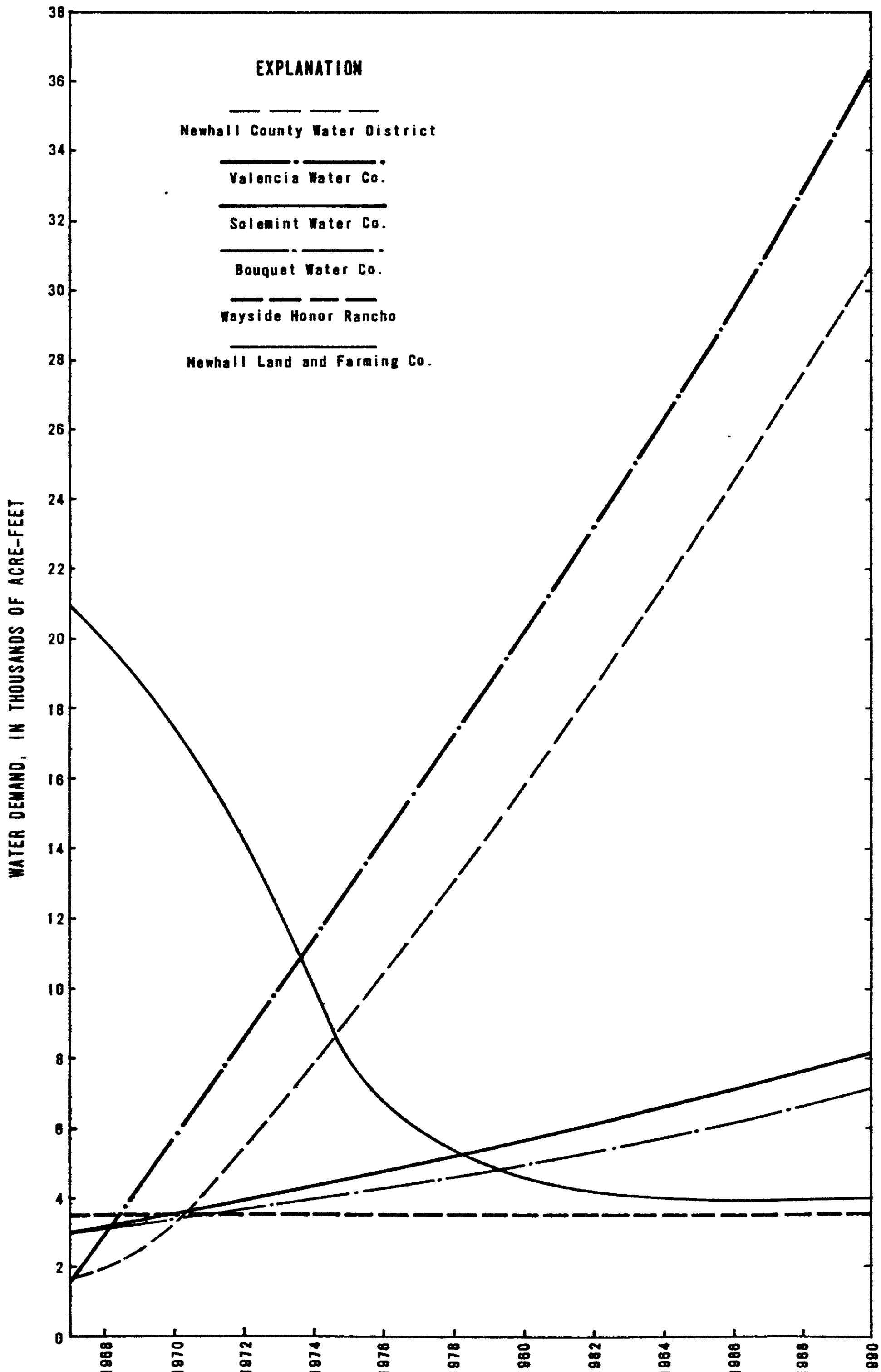

FIGURE 11.--Projected water demand, 1970-90.

Because all the water imported prior to 1980 is to be artificially recharged to the alluvial aquifer, water demands to that date must be met entirely by pumping from the aquifers. Effective pumpage was calculated for this run using a procedure similar to that described on page 34. In the model the effective pumpage required by each water purveyor between 1970 and 1980 was generally assigned to nodes near the area of use (table 7). However, in order to increase the pumpage adjacent to the artificial recharge reach, as was shown to be necessary in the two previous runs, some water demands were met by pumping from nodes near the artificial recharge reach in preference to nodes nearer to the area of use. After artificial recharge was discontinued in 1981 the model pumpage was reduced because of the direct use of the imported water. The model pumpage continued to increase after the 1981 reduction because the rate of delivery of imported water used in this run did not increase as rapidly as did the water demand (fig. 12).

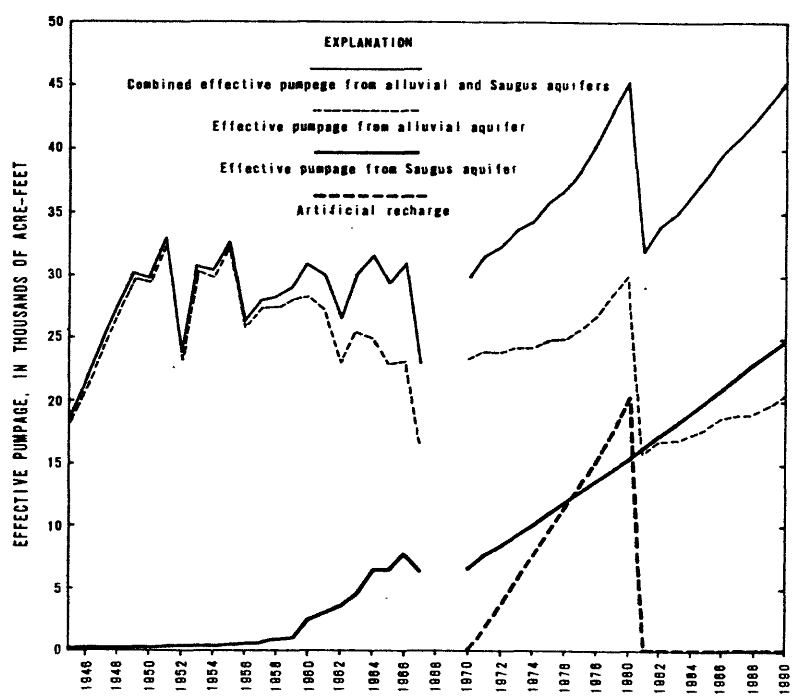

FIGURE 12.--Effective ground-water pumpage and artificial recharge.

TABLE 7.--*Effective ground-water pumpage, 1970-90*

Node	Pulse 1 1970-72	Pulse 2 1973-75	Pulse 3 1976-78	Pulse 4 1979-80	Pulse 5 1981-84	Pulse 6 1985-88	Pulse 7 1980-90	21-year Total
	Pumpage (acre-feet)							
				ALLUVIAL AQUIFER				
BB-50	800	1,500	1,500	1,000	2,000	2,000	1,000	9,800
BQ-52	2,700	2,700	2,700	1,800	3,600	3,600	1,800	18,900
BX-88	300	600	900	600	1,200	1,200	600	5,400
CB-52	2,700	2,700	2,700	1,800	3,600	3,600	1,800	18,900
CF-120	1,500	1,500	1,500	1,000	2,000	2,000	1,000	10,500
CI-49	1,500	1,500	1,500	1,000	2,000	2,000	1,000	10,500
CM-111	200	700	1,200	1,000	2,000	2,000	1,000	8,100
CN-84	300	600	900	600	1,200	1,200	600	5,400
CR-109	900	900	900	600	1,000	1,800	1,000	7,100
CX-98	1,500	1,500	1,500	1,000	1,200	2,000	1,300	10,000
CX-105	400	700	1,100	1,000	2,000	2,000	1,000	8,200
DA-82	9,900	4,200	0	0	0	0	0	14,100
DA-172	1,500	1,500	1,500	1,000	2,000	2,000	1,000	10,500
DB-40	6,000	6,000	6,000	4,000	8,000	8,000	4,000	42,000
DB-132	2,300	5,900	9,000	8,200	5,500	3,000	1,900	35,800
DD-89	13,500	7,500	1,300	0	0	0	0	22,300
DD-121	4,600	7,400	10,400	8,800	4,100	6,600	3,900	45,800
DF-113	1,300	3,200	5,300	4,900	0	0	0	14,700
DF-164	1,800	1,800	2,000	1,600	1,600	1,600	1,100	11,500
DG-104	2,600	3,000	3,800	2,700	2,500	3,700	2,000	20,300
DH-24	6,000	6,000	6,000	4,000	8,000	8,000	4,000	42,000
DH-137	1,300	3,800	6,700	5,900	2,000	2,000	1,000	22,700
DJ-157	1,400	1,500	1,500	1,000	2,000	1,800	1,000	10,200
DL-140	5,400	5,400	5,900	4,000	5,700	5,800	3,800	36,000
DM-148	300	900	1,500	1,000	2,000	2,000	1,000	8,700
DS-96	300	300	300	200	1,600	6,700	3,500	12,900
Total:	71,000	73,300	77,600	58,700	66,800	74,600	40,300	462,300
				SAUGUS AQUIFER				
CY-74	2,900	4,200	4,500	3,000	6,000	6,000	3,000	29,600
DE-74	10,500	12,500	13,500	9,000	19,500	20,000	10,000	95,000
DI-88	400	4,400	9,300	8,000	18,500	20,000	10,000	70,600
DQ-94	0	0	1,600	3,600	13,800	20,000	10,000	49,000
DY-94	2,900	3,000	3,000	2,000	4,000	10,400	10,800	36,100
EE-106	2,900	3,000	3,000	2,000	4,000	4,000	2,000	20,900
EG-98	2,900	3,000	3,000	2,000	4,000	4,000	2,000	20,900
EK-86	300	300	300	200	600	1,300	800	3,800
Total:	22,800	30,400	38,200	29,800	70,400	85,700	48,600	325,900
Grand Total:	93,800	103,700	115,800	88,500	137,200	160,300	88,900	788,200

The model run was made under the following conditions:

1. The artificial recharge was modeled in the 3.5-mile reach of the Santa Clara River using the projected water entitlements to 1980 as shown in table 6.

2. As in previous runs, the surface-water recharge for the period of the model run, 1970-90, was based on historic surface-water recharge conditions for the period 1945-65. For this period the average rainfall was 13.6 inches. The surface-water recharge therefore depicts conditions of flow resulting from a 17-percent deficiency in precipitation based on the 95-year average of 16.4 inches.

3. The effective pumpage was modeled as indicated in table 7.

4. Sewage return to the alluvial aquifer was modeled as 4,000 acre-feet per year in the reach of the Santa Clara River between the treatment plant at Saugus and the Golden State Freeway. This quantity was increased over that previously used to include the larger quantities of effluent that would result from increased urbanization in the area.

5. As in the previous runs the basin was assumed to be in steady-state condition prior to 1970 (see page 47).

6. All other hydrologic parameters were maintained at the values that normally occurred in the 1945-65 period.

Under these conditions the model produced the hydrographs for the alluvial and Saugus aquifers shown on plate 9.

In the alluvial aquifer the increased pumpage from the lower Soledad Canyon area (table 8) prevents the water levels from reaching land surface as a result of artificial recharge. The hydrographs near the lower Soledad Canyon area show sufficient decline during the 1971-80 period of artificial recharge to indicate that under the modeled conditions the full water entitlements to 1980 probably can be successfully artificially recharged in this area.

This model run represents climatic conditions that are 17 percent below the long-term average. Future surface-water recharge in excess of the values modeled could drastically affect the ability of the aquifer to accept artificial recharge. As a result it is not feasible to specify the exact quantities of artificial recharge that will occur in future years. Instead, the quantities of artificial recharge shown in table 6 should be used as objectives with the knowledge that in periods of above-average surface-water recharge these quantities may have to be modified.

TABLE 8.—*Effective ground-water pumpage, 1945-65 and 1970-90, by area*

Area	1970-90 pumpage	1945-65 pumpage	Change in pumpage
Alluvial aquifer			
Castaic Valley area	58,100	50,300	+7,800
San Francisquito Canyon area	10,800	11,600	-800
Bouquet Canyon area	43,900	29,800	+14,100
Upper Soledad Canyon area	76,900	13,900	+63,000
Lower Soledad Canyon area	139,300	37,800	+101,500
Central Santa Clara River	49,300	269,500	-220,200
Lower Santa Clara River area	84,000	147,100	-63,100
Total for alluvial aquifer	462,300	560,000	-97,700
Saugus aquifer	325,900	33,400	+292,500
Total:	788,200	593,400	+194,800

The hydrographs show an increase in the rate of water-level decline in the alluvial aquifer after 1984 in spite of only moderate rates of pumping from that aquifer (fig. 12). These declines are due to increased pumping from the Saugus aquifer. This pumping produces water-level declines in the Saugus aquifer which induce greater quantities of recharge into that aquifer from the overlying alluvial aquifer. The areas most strongly affected by this induced flow from the alluvial aquifer are the areas of high vertical permeability shown on plate 1. The 65 feet of water-level decline in 1990 shown in hydrograph 4N/17W-14Q2 (pl. 9) is largely produced by this condition. This decline would greatly reduce the use of water by phreatophytes in this area and would eliminate ground-water discharge to the Santa Clara River. This would reduce the steady-state natural ground-water discharge of the basin by 23,000 to 25,000 acre-feet per year. Although some of this water is presently (1967) being intercepted by pumping, all the water should not be intercepted, for some natural discharge is desirable to maintain the proper salt balance in the basin (Coluzzi and Richardson, 1968).

In the Bouquet Canyon and upper and lower Soledad Canyon areas the model hydrographs indicate that the alluvial aquifer will be dewatered before 1990 (pl. 9). Most of the other areas of the alluvial aquifer also show a marked reduction in saturated thickness by 1990. Under the conditions of this run the model of the alluvial aquifer is not able to supply enough water to meet the pumpage required of the aquifer to the year 1990. Increased pumping from the Saugus aquifer is not a simple panacea for the problems in the alluvial aquifer because pumping from the Saugus aquifer can cause water-level declines in the alluvial aquifer.

The accuracy of the model verification for the alluvial aquifer is such that the response is a good indication of the response that could be expected to occur in the actual alluvial aquifer under identical hydrologic conditions. However, care must be used in the interpretation of the model-generated response because the model response is valid only for the hydrologic conditions under which it was made. It was assumed that the T in the alluvial aquifer was independent of head in the aquifer and that the quantity and distribution of effective pumpage, artificial recharge, surface-water recharge, and ground-water discharge were representative of the conditions that would actually occur in the future. The validity of each of these assumptions will affect the ability of the model to predict future conditions.

In addition to affecting the water levels in the alluvial aquifer, the modeled pumping from the Saugus aquifer produced large head declines in the Saugus aquifer. The hydrographs on plate 9 show how the modeled pumping affects the Saugus aquifer. This pumpage produced as much as 250 feet of head decline in the areas of major pumping near Newhall. The declines decrease at greater distances from the areas of heavy pumping.

A comparison of the hydrograph for alluvial-well 4N/17W-14Q2 and the hydrograph for Saugus-well 4N/17W-13J1 shows that greater declines have occurred in the Saugus aquifer than have occurred in nearby points in the alluvial aquifer. In the steady-state condition the heads in the two aquifers are very similar in this area, and the Saugus aquifer discharged into the alluvial aquifer. Consequently, the greater decline in the Saugus aquifer reverses the natural gradient and induces flow into the Saugus aquifer, thereby eliminating the only area of natural discharge from the aquifer. This would be an undesirable condition because it would create a problem of maintaining a proper salt balance in the basin.

The effect of pumping from the Saugus aquifer on the ground-water discharge might be lessened by using a different distribution of pumped wells. One possibility would be to locate more wells north of the Holser fault in hope that the barrier effect of the fault would help to partially isolate the resulting water-level declines from the southern part of the aquifer. In addition, the natural discharge of the aquifer might be replaced or supplemented by pumping from wells near the area of natural discharge. This water could then be transported from the area carrying with it the salts that were normally removed by natural ground-water discharge.

The model-generated response for the Saugus aquifer is of greater accuracy in the areas where the verification produced the best correlation of heads (pl. 7) and of lesser accuracy in the area south of Newhall where the verification produced a poorer correlation of heads. However, because of the greater pumping stress placed on the aquifer in this run, the accuracy for this run at any point in the aquifer is probably somewhat less than that for the same point in the verification run (pl. 7). Interpretation of this model-generated response for the Saugus aquifer is subject to the same limitations as were discussed for the alluvial aquifer.

A second model run was made to show the effects on the basin of the conditions imposed in the previous run without artificial recharge in the Santa Clara River. The hydrographs produced under these conditions are shown on plate 9.

The model indicated that the alluvial aquifer would be dewatered in the upper and lower Soledad Canyon areas prior to 1980. This is primarily due to the heavy pumping in the lower Soledad Canyon area between 1970 and 1980 which is not compensated for by artificial recharge as it was in the previous run. After 1980 the hydrographs for this run and the previous run are almost parallel with the previous run water levels between 10 and 50 feet higher than those for this run.

In the Saugus aquifer the hydrographs for this run are between 10 and 30 feet lower than the corresponding hydrographs for the previous run. In general the removal of the artificial recharge from the alluvial aquifer does not produce a significant change in water levels in the Saugus aquifer. The same management problems are produced by this set of conditions as were produced in the previous run, the major differences being that the problems occur as much as 10 years sooner. These model-generated readouts are subject to the same limitations as are the readouts from the previous run (page 54).

CONCLUSIONS

On the basis of the study of the hydrology of the area and the readouts from the analog model the following conclusions have been reached:

1. The alluvial aquifer has been the source of most of the ground water pumped in the area. The quality of water in this aquifer is readily affected by small quantities of inflow of either better or poorer quality water because of the relatively small quantity of ground water in storage in the aquifer. The water in this aquifer can in turn affect the chemical quality of the water in the Saugus aquifer. Urbanization will place additional stress on both aquifers by increasing the quantity of poor-quality sewage effluent and good-quality imported water available for recharge into the alluvial aquifer. In addition, heavy pumping from the Saugus aquifer to meet future water demands could drastically reduce the ground-water discharge from the basin. This could result in the buildup of salts within the basin because of the lost flushing action of the ground-water discharge.

These conditions substantiate the belief that a proper water-quality management program must be established within the basin. This should include the initiation and operation of a systematic periodic water-quality sampling program. These data can then be used to evaluate the effects on the basin of the above water-quality considerations.

2. The ability of the alluvial aquifer to accept artificial recharge is dependent on the storage space available within the aquifer. In the Saugus-Newhall area the space available for recharge in the alluvial aquifer varies widely depending on the quantity of surface-water recharge that occurs each year. To determine how much artificial recharge could take place each year, a water-level measuring program should be initiated in the lower Soledad Canyon area. Using these measurements and other data, estimates of the space available for the storage of water in the aquifer in the coming year could be made. This would facilitate obtaining the proper quantities of imported water for artificial recharge each year.

3. The model indicates that under historic pumping conditions the full entitlement of imported water to the year 1980 probably could not be artificially recharged in the 3.5-mile reach of the Santa Clara River below Solemint. This is due to the lack of storage in the alluvial aquifer. When an estimated maximum pumping rate to 1990 is distributed so the pumping near the artificial recharge reach is greatly increased, it seems possible to artificially recharge all the imported water to be delivered prior to 1980.

4. On the basis of readouts from the analog model it seems that the maximum quantities of pumping that might be demanded of the alluvial aquifer to 1990 cannot be supplied by that aquifer. To meet the maximum water requirements of the area, either more water must be imported than was used in the model run or pumping from the Saugus aquifer must be increased. However, the model indicates that increased pumping from the Saugus aquifer causes large head declines in that aquifer and induces declines in the alluvial aquifer. In the model declines were large enough to greatly diminish the ground-water discharge from the alluvial aquifer and to eliminate all natural outflow from the Saugus aquifer. If this condition were allowed to continue unchecked, water-quality problems could develop in the basin because of the imbalance of salts being carried in and out of the basin.

As a result, pumping in the Saugus aquifer cannot be increased indiscriminately without producing detrimental effects in both aquifers. A proper choice of pumping patterns in the Saugus and alluvial aquifers could minimize the adverse effects of increased pumpage. However, further interrogation of the model is required to determine whether or not the Saugus aquifer can support the proposed rate of pumping without dewatering the alluvial aquifer.

5. The Saugus aquifer is a potentially large source of ground water with an estimated maximum of 6 million acre-feet of recoverable water in storage. Further study of this aquifer is required to delineate the areas of poor water quality and to determine more accurately the transmissibility and storage coefficients of the aquifer. Future studies of the Saugus aquifer should give prime consideration to the area north of Castaic Junction and the San Gabriel fault because few hydrologic data are available for this area. With greater knowledge of this aquifer the ground-water basin model could be updated to give more precise information about the response of this aquifer to various ground-water management practices and to more accurately determine the potential for future utilization of the aquifer.

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