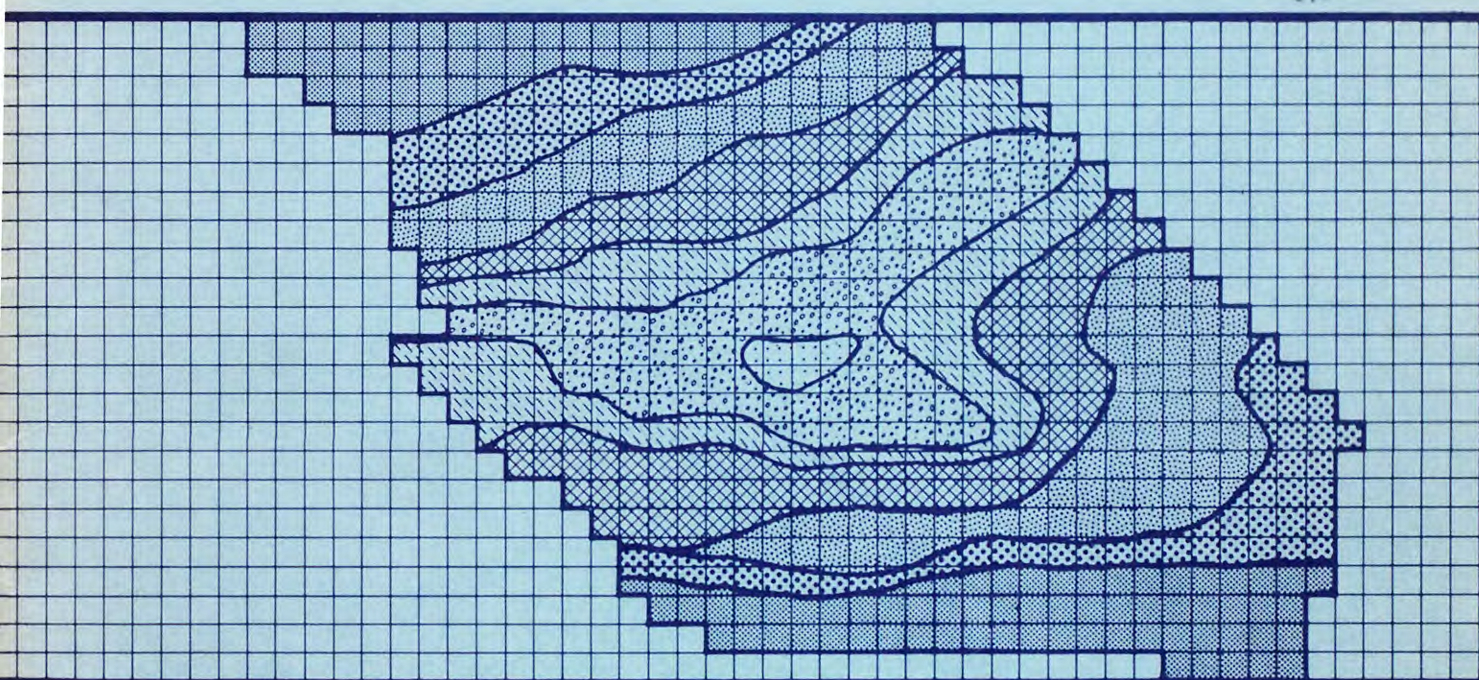
MATHEMATICAL MODEL OF THE SAN JUAN VALLEY GROUND-WATER BASIN SAN BENITO COUNTY, CALIFORNIA



U.S. GEOLOGICAL SURVEY, Water Resources Division
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Prepared in cooperation with the
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16. Abstracts

A quantitative description of past, present, and future conditions of aquifer development in the San Juan Valley ground-water basin is provided and used to verify aquifer parameters. Net perennial recharge to the basin equals 6,700 acre-ft/yr and occurs as infiltration from rain, direct runoff, and minor streams. During the period 1945-68, infiltration from the San Benito River to San Juan Valley averaged 3,100 acre-ft/yr. Net discharge from the basin during the period 1945-68 occurred mostly as pumping from irrigation wells and averaged 13,100 acre-ft/yr.

Use of the model to simulate the recharge of water imported to the basin indicates that in San Juan Valley future water levels will stabilize or recover when recharge equals or exceeds 3,000 acre-ft/yr.

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San Benito County Water Conservation

and Flood Control District

August 1974

UNITED STATES DEPARTMENT OF THE INTERIOR

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MATHEMATICAL MODEL OF THE SAN JUAN VALLEY GROUND-WATER BASIN

SAN BENITO COUNTY, CALIFORNIA

By Robert E. Faye

ABSTRACT

A mathematical model study of the San Juan Valley ground-water basin in San Benito County, Calif., has quantitatively described the ground-water hydrology of the basin under past, present, and future conditions of development. An analysis of conditions in the basin prior to large-scale ground-water development indicates that net recharge equaled 9.23 cubic feet per second and occurred as subsurface flow to the eastern part of the basin and infiltration of rain, direct runoff, and minor streamflows. Net predevelopment discharge equaled 9.23 cubic feet per second and occurred as aquifer discharge to the San Benito River. The 9.23 cubic feet per second of predevelopment recharge is considered to be perennial recharge to the basin.

Large-scale ground-water development occurred in the area during the period 1945-68 and caused water levels to decline throughout most of the basin. Progressive depletion of aquifer storage during this period changed the San Benito River from a gaining (perennial) stream to a losing stream along most of its reach in the basin area. Net discharge from the basin during the period 1945-68 averaged 18.10 cubic feet per second. Of this amount 17.82 cubic feet per second occurred as pumpage from wells, and 0.28 cubic foot per second occurred as basin discharge to the San Benito River. Net recharge to the basin during the same period averaged 13.57 cubic feet per second. Of this amount 4.34 cubic feet per second occurred as infiltration from the San Benito River and 9.23 cubic feet per second occurred as perennial recharge.

Use of the calibrated mathematical model to simulate quantities of imported water entering the basin from the San Benito River indicates that water levels in San Juan Valley will stabilize or recover when additional recharge equals or exceeds 3,000 acre-feet per year.

INTRODUCTION

Purpose and Scope

This study by the U.S. Geological Survey was done in cooperation with the San Benito County Water Conservation and Flood Control District. The purpose of the study was two-fold. First, the ground-water hydrology of the San Juan Valley ground-water basin was to be evaluated qualitatively and quantitatively. Second, a working hydrologic model of the ground-water basin was to be developed and made available to the cooperator as a management tool. The scope of the study consisted of:

1. Organizing and evaluating hydrologic data for the San Juan Valley ground-water basin;

2. Developing a transient-state, digital computer model of the ground-water basin; and

3. Using the computer model to evaluate various ground-water management alternatives for San Juan Valley.

Location and Extent of the Study Area

The San Juan Valley ground-water basin is in the northwestern part of San Benito County about 40 miles southeast of San Jose (fig. 1). The basin consists of the flat, alluvial San Juan Valley and those parts of the Lomerias Muertas, Flint Hills, and Bird Creek Hills that border the valley on the north and east (fig. 2). These bordering hills together with the Pajaro River to the northwest and the San Andreas rift zone to the south form the topographic and geologic boundaries of the ground-water basin.

The main drainageway of the basin is the west-flowing San Benito River which traverses the northern periphery of San Juan Valley and empties into the Pajaro River just west of the Lomerias Muertas (fig. 2).

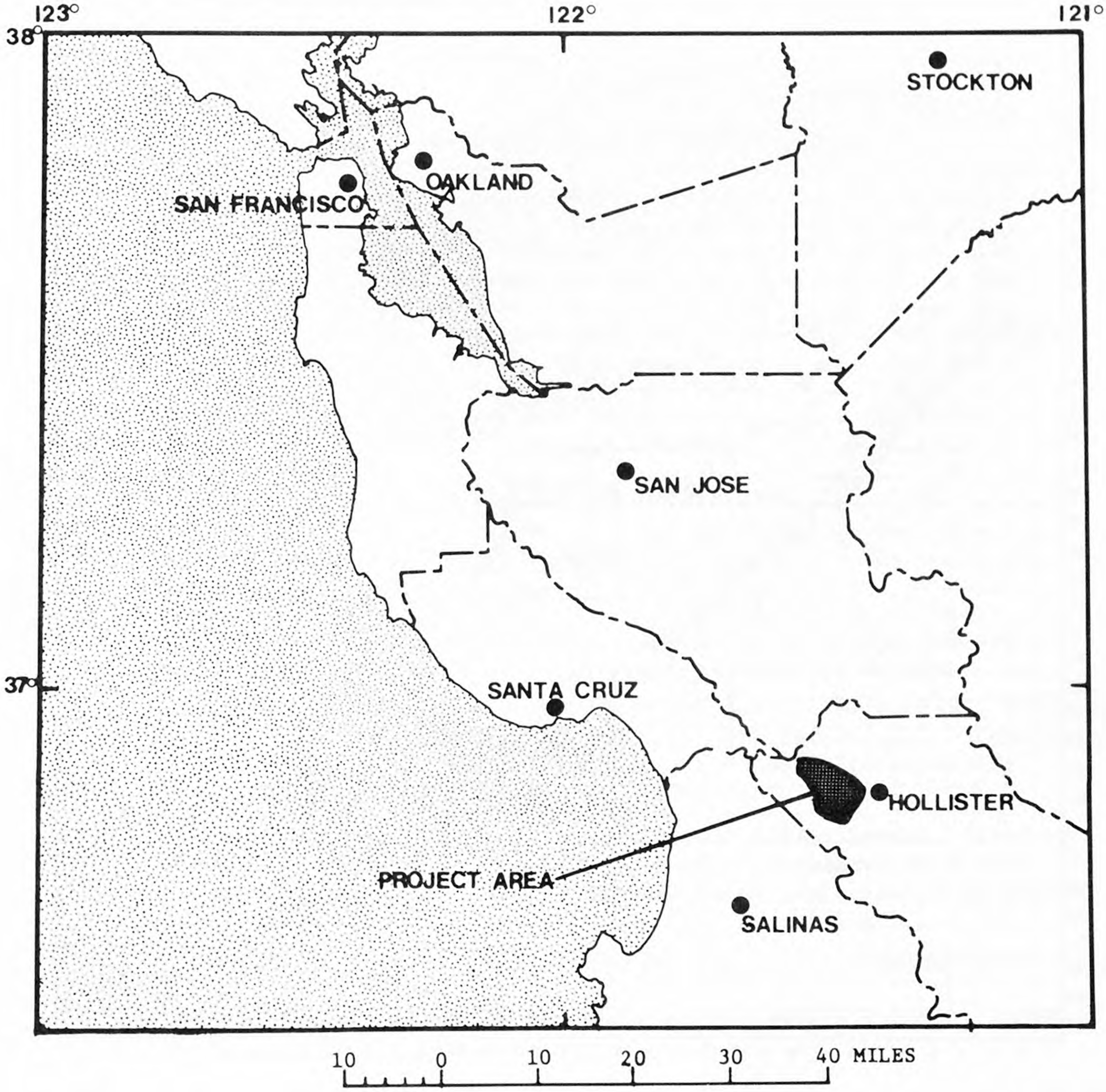


FIGURE 1.--Location of project area.

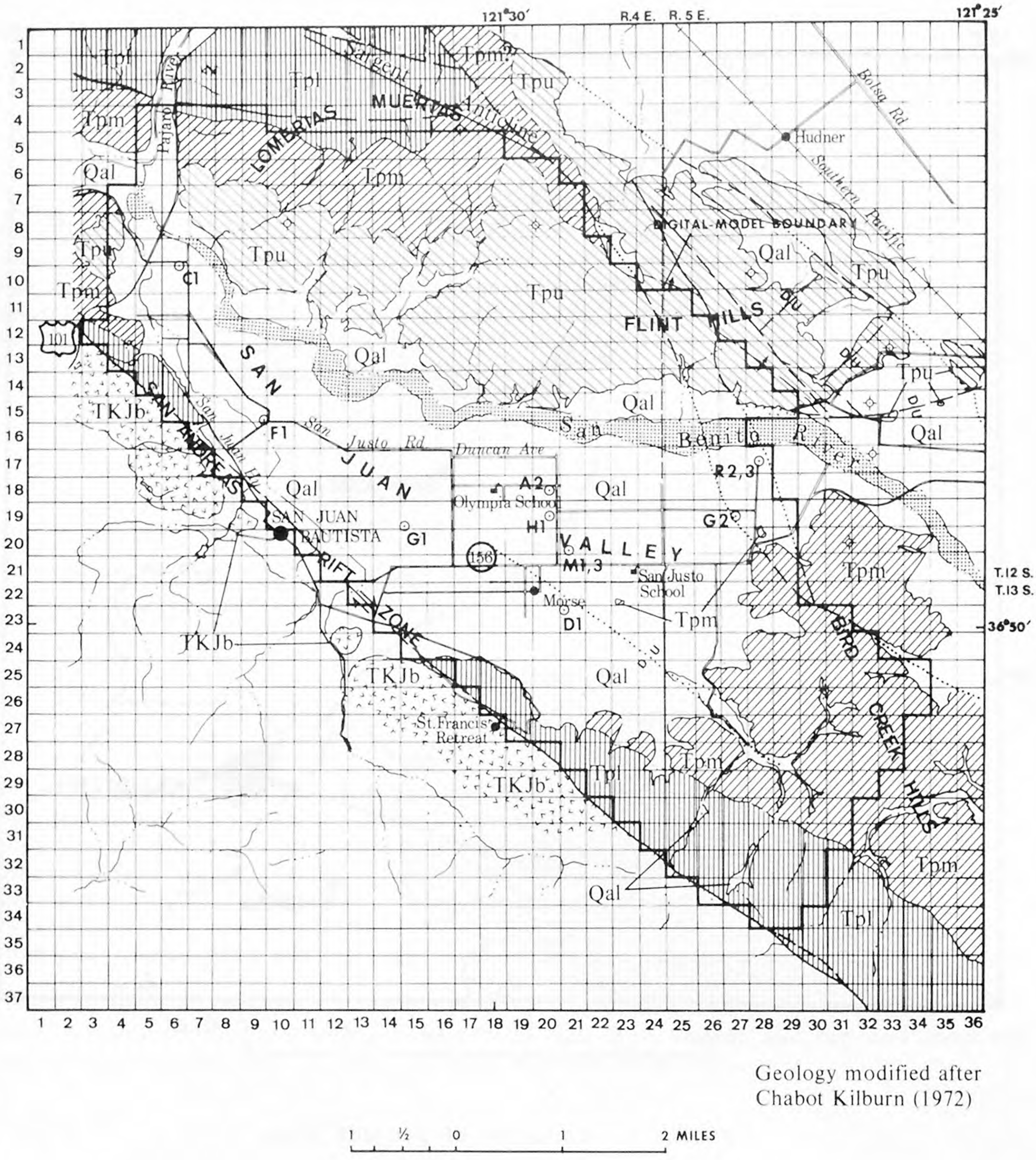


FIGURE 2.--Generalized geologic map showing location of observation wells, digital-model grid network, and model boundary.

CORRELATION OF MAP UNITS

Qal	Holocene	QUATERNARY
Tpu, Tpm, Tpl	Pliocene	TERTIARY
TKJb		TERTIARY, CRETACEOUS, AND JURASSIC

DESCRIPTION OF MAP UNITS

Qal — ALLUVIUM - Clay, silt, sand, and gravel

PURISIMA FORMATION

Tpu — Upper member - Predominantly friable pebble gravel and sand. Locally contains siltstone all of terrestrial origin

Tpm — Middle member - Poorly consolidated, mostly terrestrial, friable, massive sandstone interbedded with gypsiferous clay. Locally contains friable pebbly sandstone and pebble conglomerate. Contact with underlying unit gradational

Tpl — Lower member - Mainly friable to semifriable, bedded, fine- to medium-grained arkosic sandstone and interbedded micaceous siltstone, fossiliferous, of shallow marine to brackish marine origin

TKJb — CONSOLIDATED BEDROCK - Sedimentary, igneous, and metamorphic rocks

Lithologic contact - Dashed where approximately located; short dashed where inferred

U / D — Fault - Dashed where approximately located; dotted where concealed. U, upthrown side, D, downthrown side. Arrows show direction of relative horizontal movement

Anticline - Showing trace of crestal plane. Dashed where approximately located

Digital-model boundary

G2 — Water well - Number and letter indicates well referred to in text

Oil or gas well

Well-Numbering System

The well-numbering system used by the Geological Survey in California shows the locations of wells and springs according to the rectangular system for the subdivision of public land. For example, in the number 12S/4E-35H1, which was assigned to a well in San Juan Valley, the part of the number preceding the slash indicates the township (T. 12 S.); the number between the slash and the hyphen indicates the range (R. 4 E.); the digits between the hyphen and the letter indicate the section (sec. 35); and the letter following the section number indicates the 40-acre subdivision of the section, as shown in the following diagram. Within each 40-acre tract the wells are numbered serially, as indicated by the final digit of the number. Thus, well 12S/4E-35H1 is the first well to be listed in the SE¼NE¼ sec. 35.

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

Definitions of Hydrologic Terms

Aquifer: An aquifer is a formation, group of formations, or a part of a formation that contains sufficient permeable material to yield significant quantities of water to wells and springs.

Acre-foot (acre-ft): A unit volume of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or 325,851 gallons.

Confined water: Ground water that is under sufficient hydraulic head to rise above the level at which it is encountered by a well, but which does not necessarily rise to or above the surface of the ground.

Cubic foot per second (cfs): The rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to 7.48 gallons per second, 448.8 gallons per minute, 646,317 gallons per day, or 1.98 acre-feet per day.

Evapotranspiration: The water removed from an area by transpiration by plants and evaporation from soil, snow, and water surfaces.

Gaining stream: A gaining stream is a stream, or reach of a stream, whose flow is being increased by inflow of ground water.

Hydraulic conductivity: A measure of an aquifer's capacity to transmit water, expressed in feet per day (fpd) or feet per second (fps).

Losing stream: A losing stream is a stream, or reach of a stream, that is losing water to the ground-water reservoir.

Permeability: Synonymous with *hydraulic conductivity*.

Specific capacity: The rate of discharge of water from a well divided by the drawdown of water level within the well.

Specific yield: As applied to a rock or soil, it is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume.

Transmissivity: The rate of flow in gallons per day per foot (gpd/ft), at a 1-foot-wide vertical strip of aquifer extending the full saturated height of the aquifer under a unit hydraulic gradient.

Water table: That surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. In wells which penetrate to greater depths, the level will stand above or below the water table if an upward or downward component of ground-water flow exists.

Discussion of the Mathematical Model

The linear mathematical model used in this study is an idealized representation of the San Juan Valley ground-water basin. It describes in concise quantitative terms the response of the ground-water system to various conditions of stress or development. Once such a quantitative response has been obtained, the model can be used to facilitate an understanding of the hydrologic system and aid in determining how climate, geology, and man influence the ground-water basin. A detailed discussion of model theory and the analytical approach to model development is given in Pinder and Bredehoeft (1968).

Hydrologic relations are seldom simple and thus cannot be exactly described by a practical model. Model development, therefore, requires assumptions and approximations designed to simplify the so-called real world. A model is only as accurate as the assumptions used in its development, and these assumptions should be kept in mind when evaluating model output. The simplifying assumptions used in constructing the model for this study are:

1. The San Juan Valley ground-water basin consists of one unconfined aquifer with areally distributed values of transmissivity and specific yield.

2. The areally distributed values of specific yield remain constant with time.

3. Vertical flow components within the aquifer are negligible with respect to horizontal flow components.

4. Quantities of aquifer discharge and recharge occur at constant rates over a designated period of simulation.

5. The hydrologic boundaries of the ground-water basin can be simulated by the model as flow, no-flow, or constant-head boundaries.

In order to use the mathematical model as a predictive tool it must first be calibrated. Model calibration is accomplished by combining, in the model, hypothetical distributions of transmissivity and specific yield values with sets of known or estimated ground-water flow conditions. The correct, or calibrated, combination of aquifer parameters and flow conditions is said to be determined when model-generated water levels approximate historical water levels within some predetermined limit of accuracy. Model calibration frequently requires that historical ground-water flow regimes be adequately simulated. Quantitative data or parameters generated as a result of such simulations are referred to in this report as model-verified information. The validity and accuracy of this information must be considered with respect to the limitations and assumptions of aquifer modeling and should not be construed as having been determined by actual measurements.

Nodal Array and Inputs to the Mathematical Model

For this study, a uniform grid network of 37 rows and 36 columns was superposed on a plan view of the San Juan Valley ground-water basin. A model boundary was then placed on the grid by tracing along the individual rectangular areas, or nodes, where they approximate the basin boundaries (fig. 2). Each node, when drawn to scale, encompasses a one-sixteenth square mile area or 40 acres. Model-control points were designated at the center of each node. All parameters communicated to, or computed by, the model were referred to the various nodes in units of feet and seconds. An individual node is designated by the number of the row and column. For example, the tenth node of the fifth row is designated (5-10).

At each nodal center, the following information is required by the model:

1. Nodal dimensions, in feet (ft);
2. Initial water-table head in the aquifer, in feet above mean sea level;
3. Bottom altitude of the aquifer, in feet above mean sea level;
4. Hydraulic conductivity of the aquifer, in feet per second;
5. Specific yield of the aquifer; and
6. Recharge or discharge rates, in cubic feet per second (cfs), are required at nodes designated as points of net recharge or net discharge.

HYDROLOGY OF THE SAN JUAN VALLEY GROUND-WATER BASIN

The geology, aquifer characteristics, and movement of water within the San Juan Valley ground-water basin have been described and documented by Kilburn (1972).

Geology and Aquifer Characteristics

Underlying most of the San Juan Valley ground-water basin are non-water-bearing bedrock formations of Jurassic, Cretaceous, and Tertiary age. These formations consist mostly of sedimentary and igneous rocks and their metamorphic equivalents. The major aquifers in the ground-water basin are alluvium of Holocene age and the Purisima Formation of Pliocene age (fig. 2). Most of San Juan Valley is formed by the alluvium which consists of lenticular beds of unconsolidated gravel, sand, silt, and clay. The alluvium is generally very permeable and is the principal source of ground water in the basin. The Purisima Formation has been divided by Kilburn (1972) into a lower, middle, and upper member. The upper member is exposed in the Lomerias Muertas and Flint Hills and underlies the alluvium in most of San Juan Valley. Exposed beds consist of friable pebble gravel and sand. The upper member is generally less permeable than the alluvium but has been moderately developed as a source of water for irrigation. The middle member of the Purisima underlies the upper member in the northern and central parts of the basin. In the southeastern part of San Juan Valley, it is overlain by a relatively thin section of alluvium. The middle member consists mostly of bedded to massive friable sand and is considerably less permeable than the upper member or the alluvium. The lower member of the Purisima underlies the middle member and consists mainly of interbedded friable sand and weakly consolidated sandstone and siltstone. Both the middle and lower members of the Purisima Formation are considered to be poorly water-bearing.

Cross sections from Kilburn (1972) indicate that the combined thickness of the alluvium and upper Purisima ranges from at least several hundred to more than two thousand feet. The combined thickness of the middle and lower members of the Purisma ranges from about 3,000 feet to more than 6,000 feet.

Faults in the San Juan Valley ground-water basin that offset the bedrock or the Purisima are considered to be poorly permeable and act as barriers to the movement of ground water.

Hydrologic Boundaries

The hydrologic boundaries of the San Juan Valley ground-water basin are determined by the geology and topography of the area (fig. 2). The northern boundary of the basin is an east-trending fault that crosses the Lomerias Muertas and offsets the lower and middle members of the Purisima Formation. The Sargent anticline and westward and northwestward-trending faults comprise the northeastern and eastern boundaries and offset the Purisima Formation in the Lomerias Muertas, Flint Hills, and part of the Bird Creek Hills.

The southeast boundary of the basin is a ground-water and topographic divide that crosses the Bird Creek Hills. The northwest-trending San Andreas rift zone and fault constitutes a barrier to ground-water movement and forms the hydrologic boundary along most of the southern and western periphery of the basin. The western hydrologic boundary approximates the contact between alluvium and older rocks in the northwestern corner of San Juan Valley. A short reach of the San Benito River in this area receives continuous discharge from the ground-water basin and forms a constant-head boundary near the confluence with the Pajaro River.

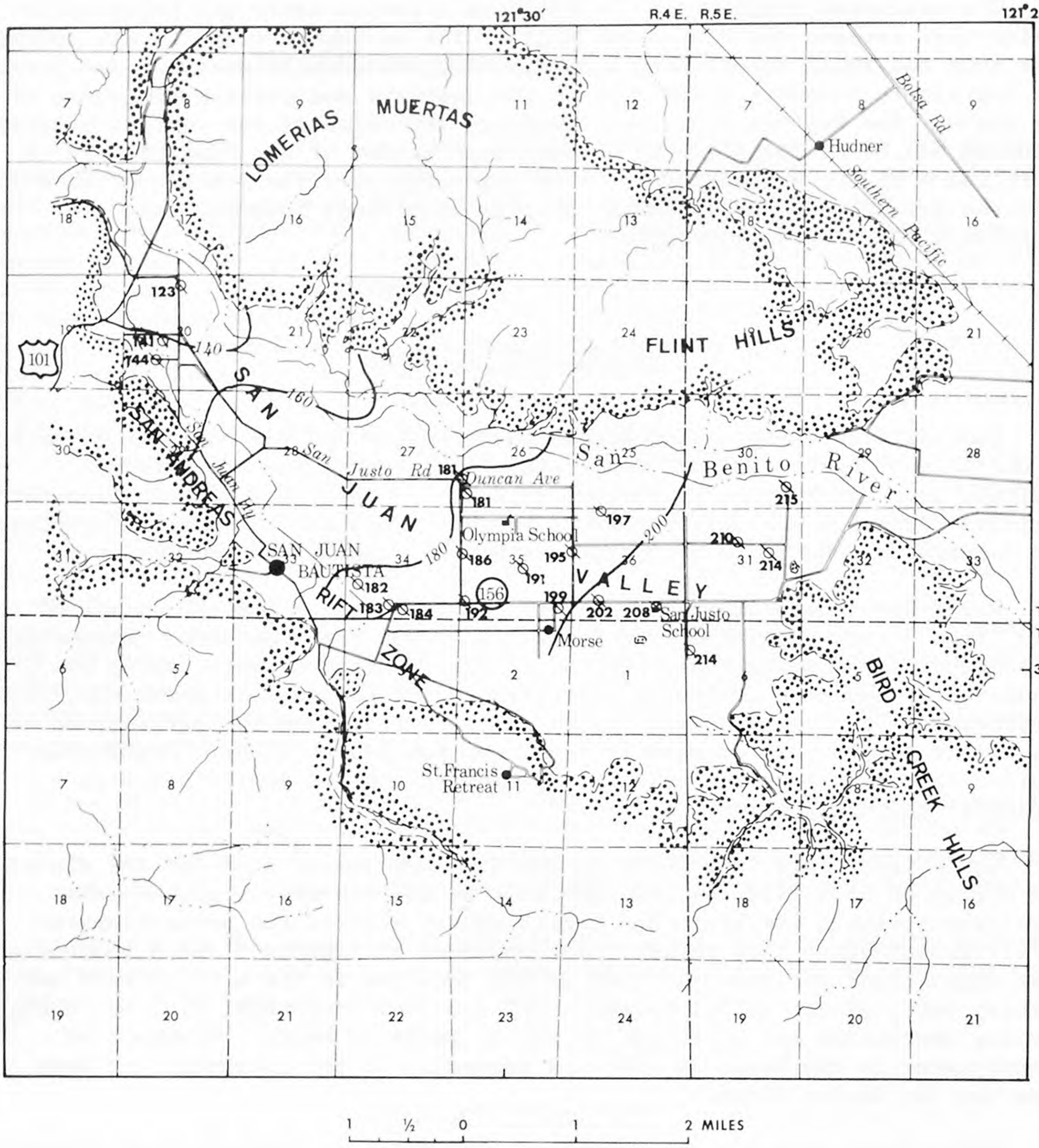
Ground-Water Movement

Generally speaking, water within the alluvium and the Purisima Formation is unconfined; however, local confinement does occur, and well records indicate that confinement is greater in deeper wells. The alluvium and the Purisima Formation are well connected hydraulically and for modeling purposes are assumed to constitute a single, basin-wide, unconfined aquifer.

Water-level data from wells in the San Juan Valley for the summer of 1913 (fig. 3) are available from Clark (1924) and are considered representative of predevelopment conditions. Kilburn (1972) indicates that, during 1913, ground-water movement generally conformed to the topographic gradients, moving northwestward through San Juan Valley and laterally from the peripheries of the valley toward, and eventually into, the San Benito River. Continuous aquifer discharge from the alluvium maintained the San Benito River as a perennial (gaining) stream in 1913.

Water-level data from wells in the San Juan Valley area for the winter and spring of 1945 (fig. 4) indicate that by the mid-1940's ground-water development within the basin had significantly altered the predevelopment (1913) ground-water flow regime. A comparison of figures 3 and 4 indicates that significant declines in water levels occurred in the southeastern and western parts of the valley between 1913 and 1945 and that, by 1945, a major pumping depression had developed in the vicinity of Morse. Movement of ground water in the basin in 1945 was generally to the southwest and away from the San Benito River.

Water-level data for the autumn of 1968 (fig. 5) indicate that ground-water levels continued to decline during the period 1945-68. In 1968, ground-water levels throughout most of San Juan Valley had declined from 20 to more than 100 feet below the 1913 levels. Since 1945, ground-water movement has generally been toward a major pumping depression in the south-central part of San Juan Valley. The periphery of this depression extends into the Lomerias Muertas and into the Flint and Bird Creek Hills and indicates that a reduction in aquifer storage has occurred in these areas.



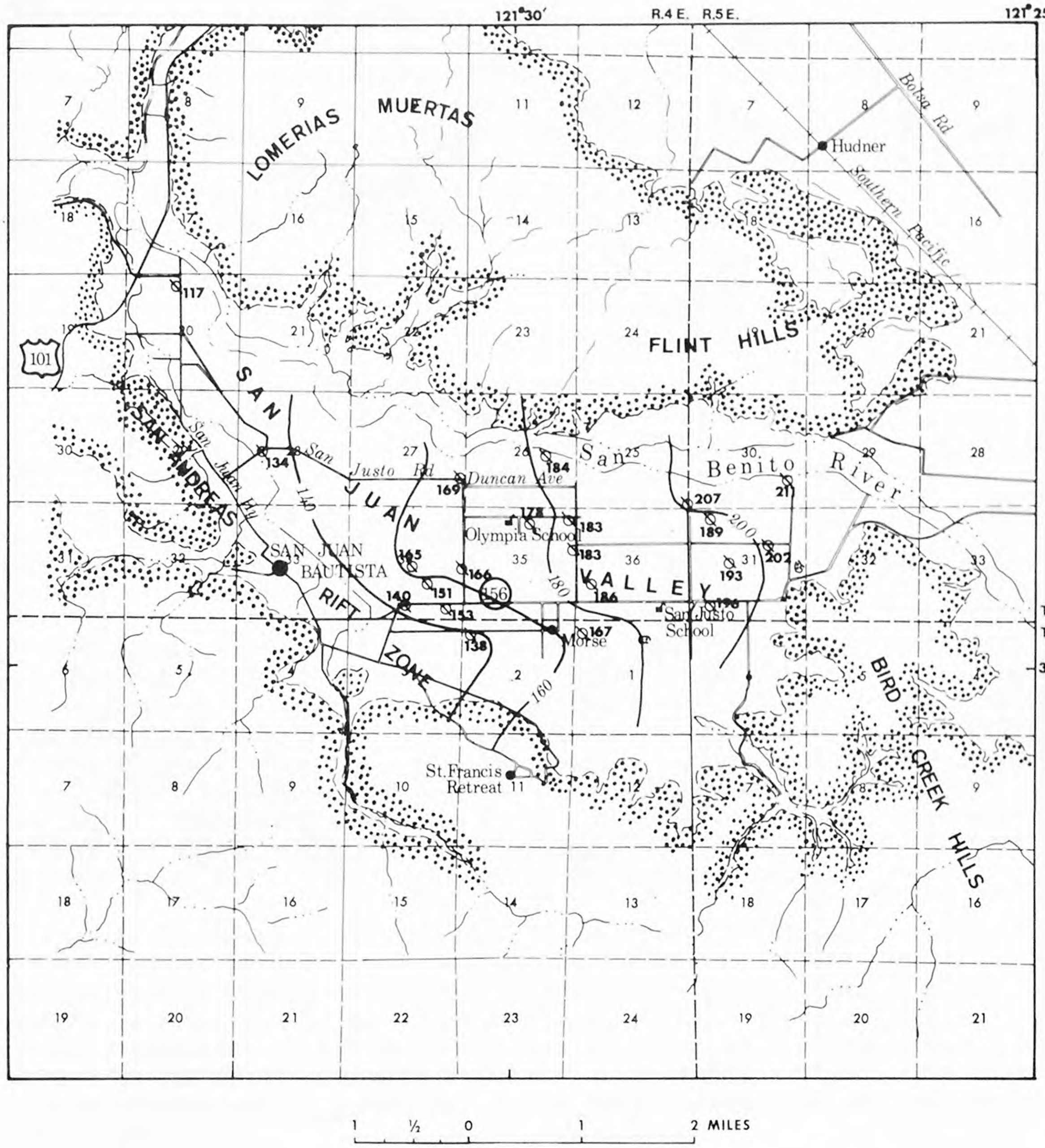
EXPLANATION

Boundary between alluvium and older rocks

140 Water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

144 Observation well - Number is altitude of ground-water level, in feet

FIGURE 3.--Water-level contours for assumed predevelopment conditions.



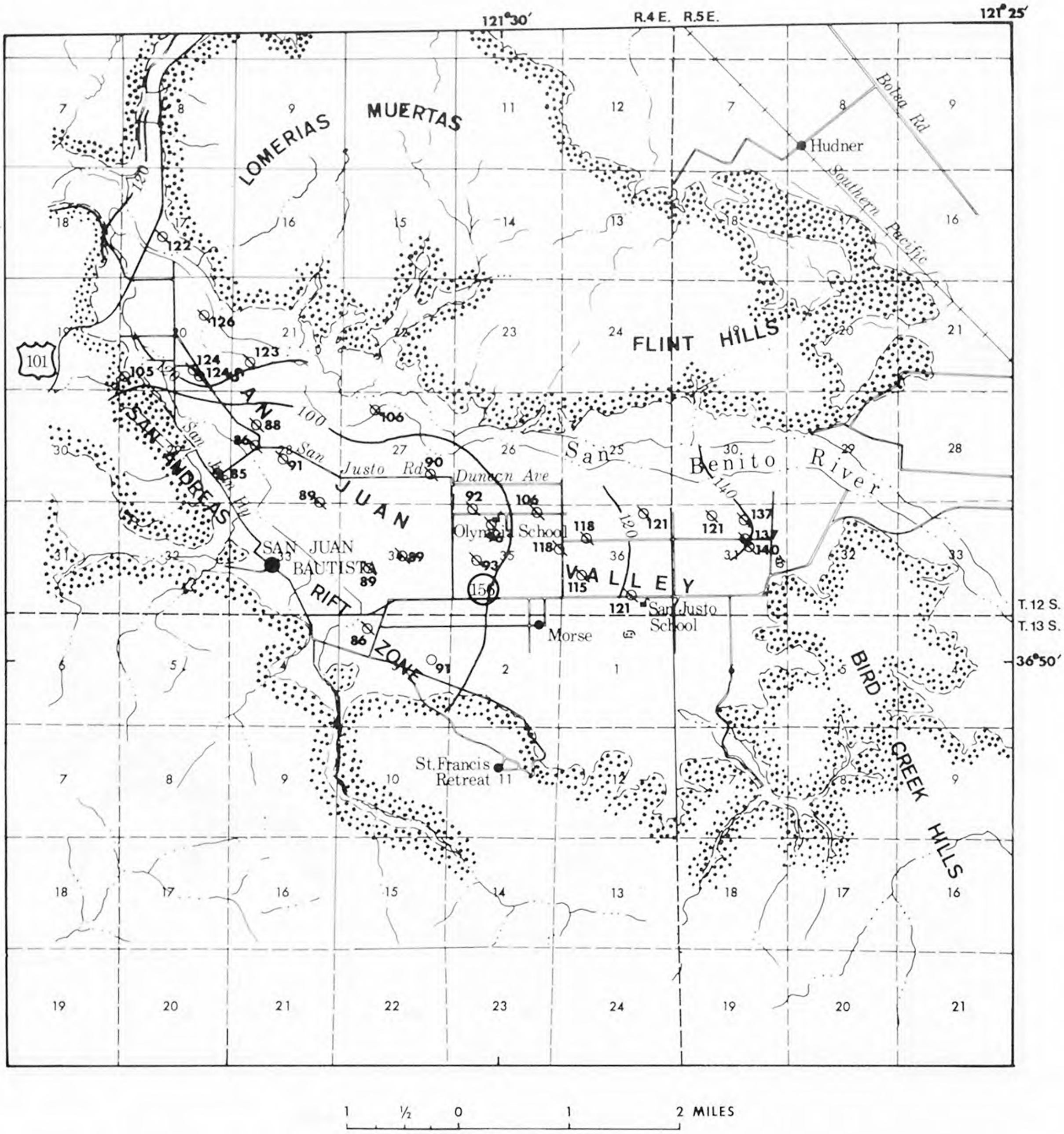
EXPLANATION

Boundary between alluvium and older rocks

Water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

Observation well - Number is altitude of ground-water level, in feet

FIGURE 4.--Water-level contours for the winter and spring, 1945.



EXPLANATION

Boundary between alluvium and older rocks

Water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

Observation well - Number is altitude of ground-water level, in feet

FIGURE 5.--Water-level contours for autumn, 1968.

The hydrographs in figure 6 show water-level fluctuations in selected observation wells in San Juan Valley. Except for well 12S/4E-20C1, the graphs show a general decline in water levels in all observation wells during the period 1945-68. A comparison of the hydrographs indicates that water levels have declined most rapidly in the central part of the valley, especially in the area north of Morse. Smaller and less rapid water-level declines occurred in wells to the east and west of this area. During the period 1945-68, the total decline in water levels in these observation wells ranged from less than 1 (12S/4E-20C1) to about 80 feet (12S/4E-34G1).

Aquifer Parameters

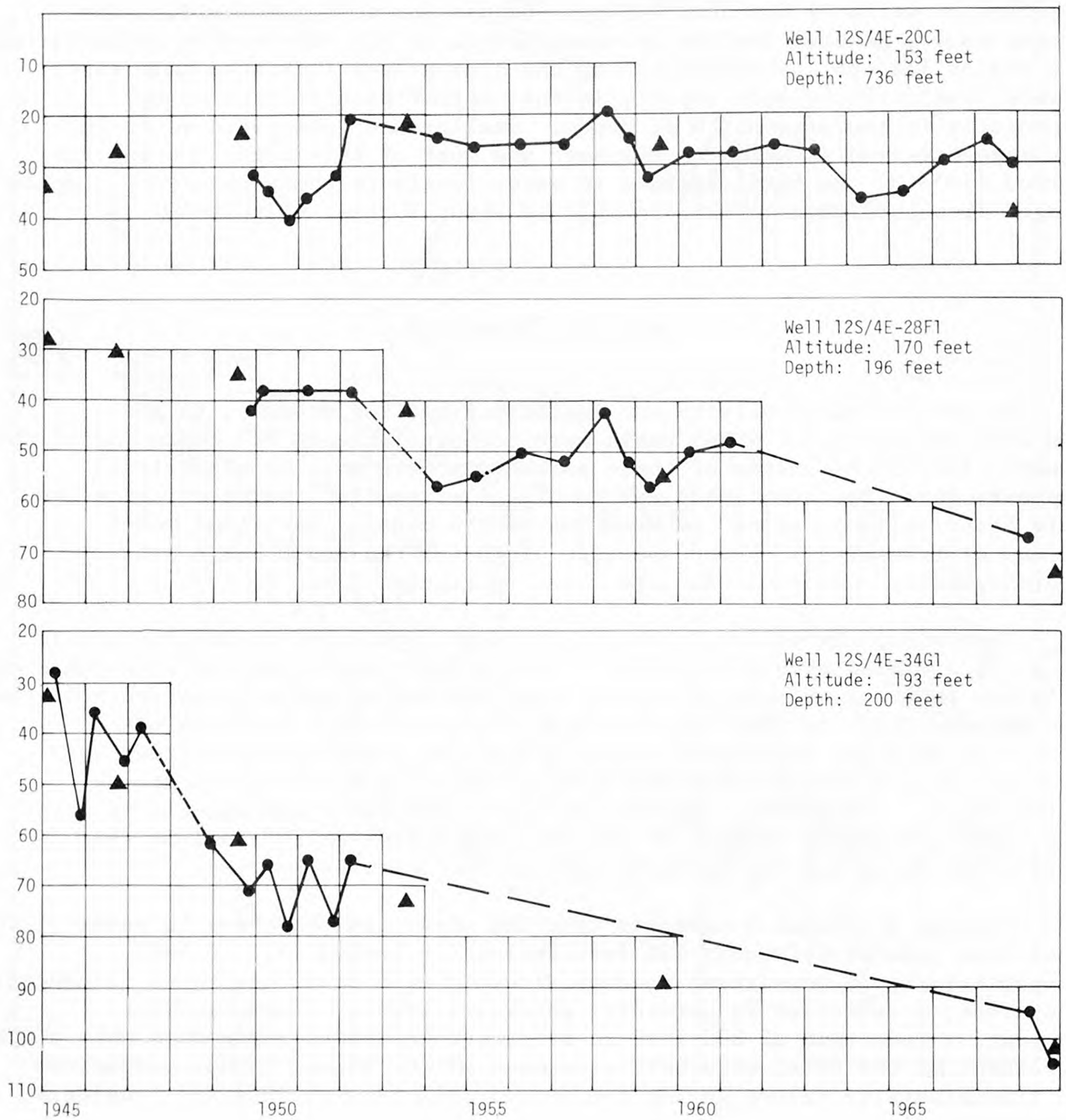
Values of transmissivity and specific yield for aquifers in the San Juan Valley ground-water basin were not available at the beginning of this study. Initial estimates of these parameters were made from specific-capacity data (Bentall, 1963) and knowledge of aquifer characteristics and were later refined during calibration of the model. The final model values of transmissivity and specific yield for the model basin are hydrologically reasonable and are shown in figures 7 and 8.

Transmissivity values in the basin range from 2,500 to 100,000 gpd/ft (fig. 7). A zone of high transmissivity is associated with the occurrence of alluvium in the east-central part of San Juan Valley and extends south to the San Andreas fault between San Juan Bautista and Morse. Lower values of transmissivity are associated with the Purisima Formation and extend away from the highly transmissive zone toward the peripheries of the ground-water basin. The lowest transmissivities in the basin are associated with the lower and middle members of the Purisima Formation and include the Bird Creek Hills and the northern part of the Lomerias Muertas.

Figures 3 through 5 indicate that the saturated thickness in parts of the basin was reduced by nearly 200 feet during the period 1913 to 1968. Transmissivity is considered to vary directly with total saturated thickness; therefore, a reduction in saturated thickness reduces transmissivity. However, a reduction of 200 feet in saturated thickness represents only about 5 percent of the total saturated thickness of the basin. Thus, variations in transmissivity values during the period 1913 through 1968 are considered insignificant.

During calibration of the model, transmissivity values at the individual nodes were also allowed to vary directly with saturated thickness. However, variations between initial transmissivity values and the values computed at a later simulation period were insignificant.

Specific yield values (fig. 7) are typical of unconfined aquifers and include a value of 0.10 throughout most of the basin and a value of 0.18 in the east-central part of San Juan Valley.



EXPLANATION

▲ Model-generated water level

● Measured water level

FIGURE 6.--Water levels in selected observation wells.

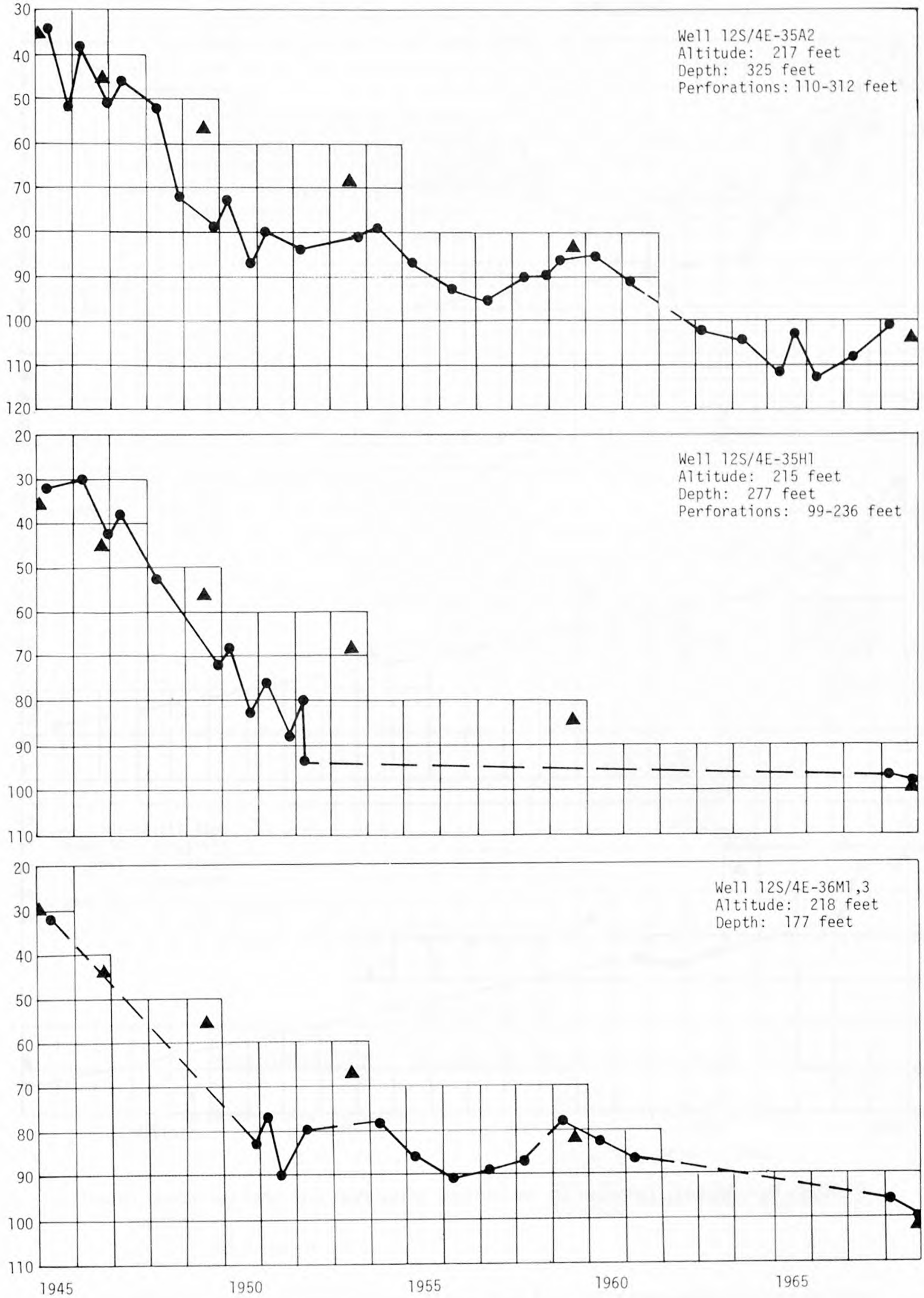


FIGURE 6.--Water levels in selected observation wells--Continued.

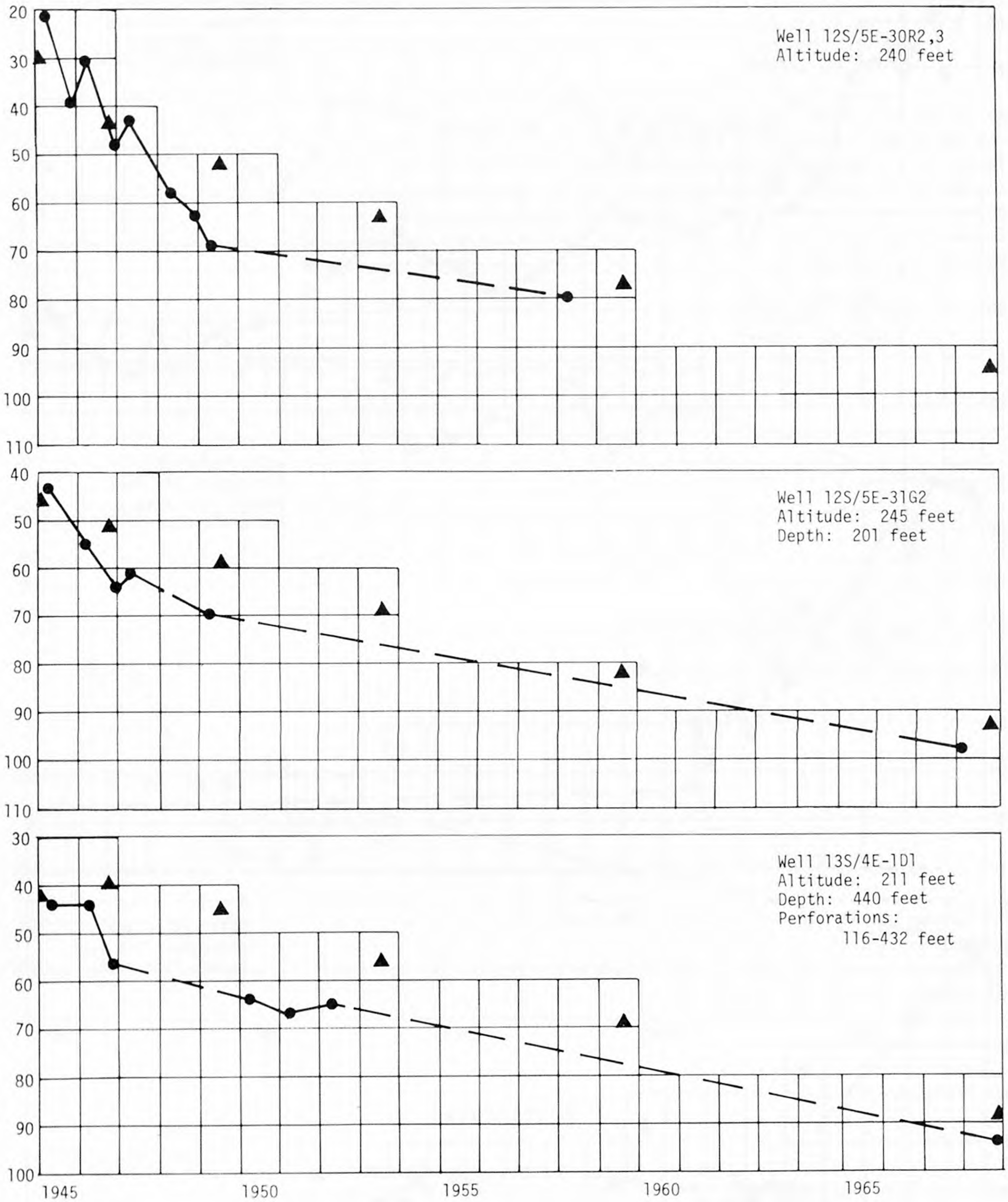
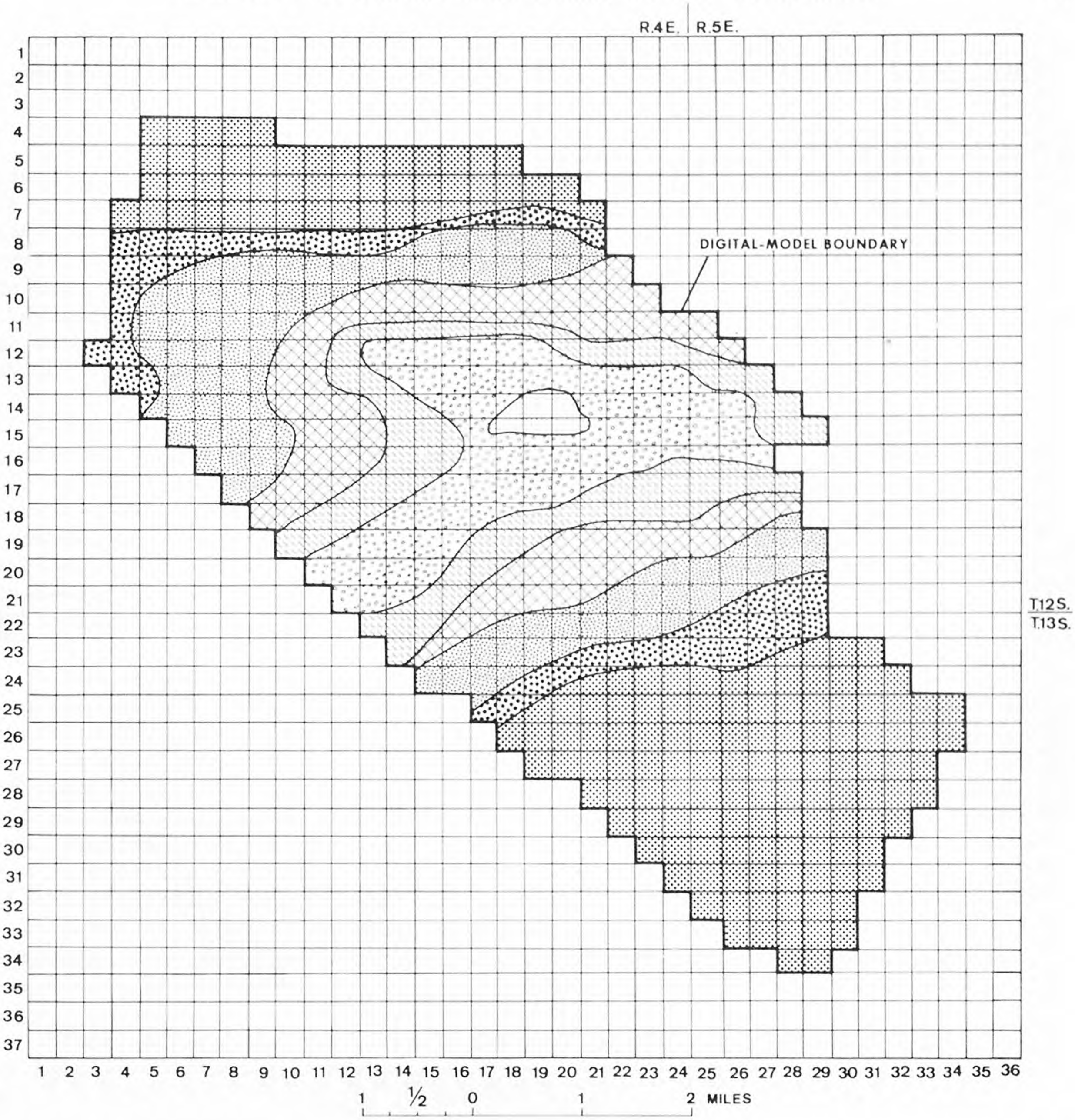


FIGURE 6.--Water levels in selected observation wells--Continued.

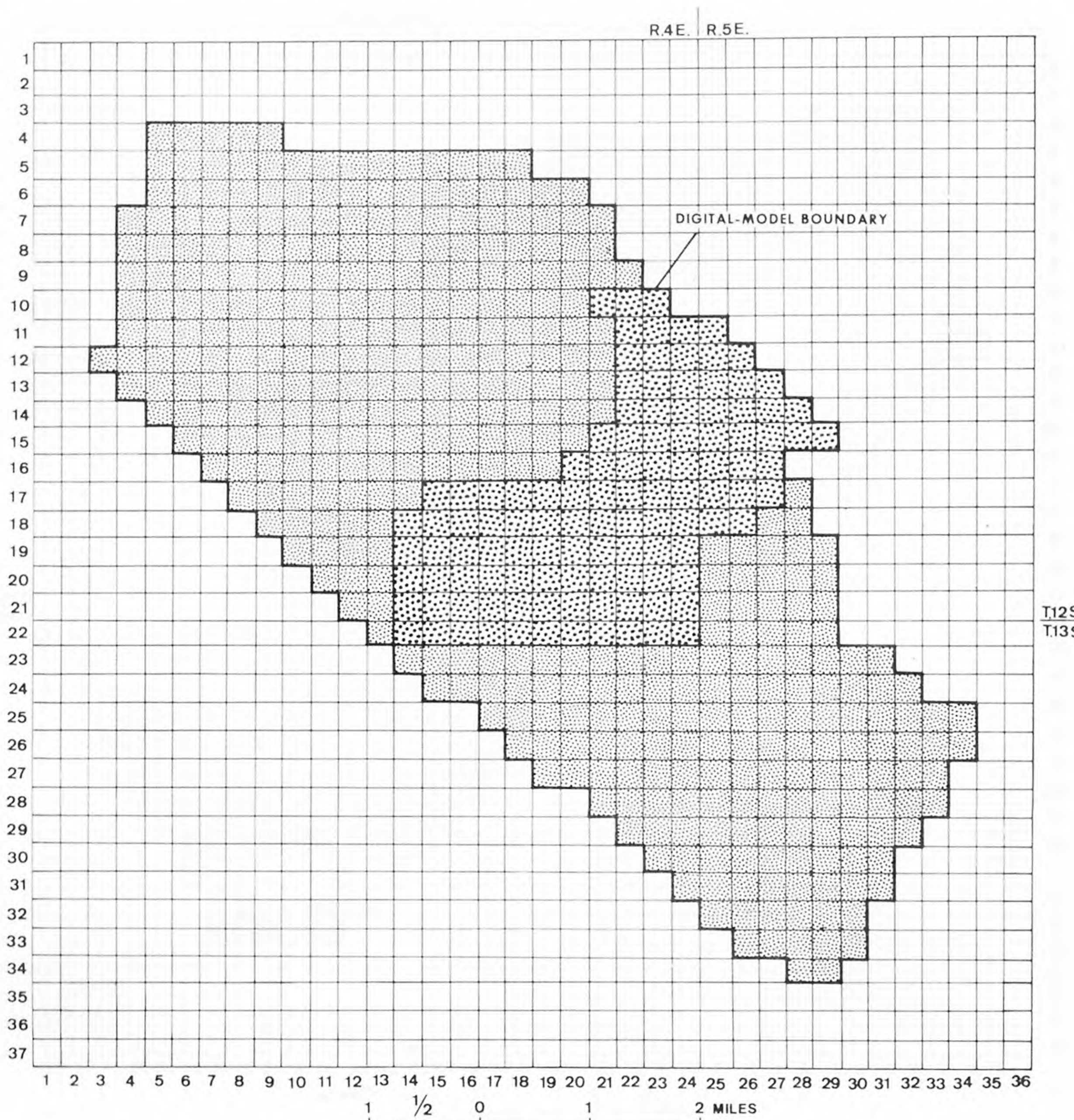


EXPLANATION

TRANSMISSIVITY, IN GALLONS PER DAY PER FOOT

- More than 100,000
- 75,000-100,000
- 50,000-75,000
- 25,000-50,000
- 5,000-25,000
- 2,500-5,000
- Less than 2,500

FIGURE 7.--Model-verified distribution of transmissivity in the San Juan Valley ground-water basin.



EXPLANATION

SPECIFIC YIELD, IN PERCENT

0.10

0.18

FIGURE 8.--Model-verified distribution of specific yield in the San Juan Valley ground-water basin.

Recharge to and Discharge from the Basin under Predevelopment Conditions

During predevelopment times, recharge to the San Juan Valley ground-water basin occurred as infiltration of rain, infiltration from streams tributary to the San Benito River, infiltration of direct runoff from surrounding hills, and subsurface flow into the eastern part of San Juan Valley. Most of the subsurface flow occurred as underflow along the San Benito River and as flow through the alluvial deposits between the Flint and Bird Creek Hills. Discharge from the ground-water basin under predevelopment conditions occurred as evapotranspiration, discharge to the San Benito River, and underflow out of the basin near the confluence of the San Benito and the Pajaro Rivers.

During calibration of the model a steady-state ground-water budget, combining equal quantities of net recharge and net discharge, was developed to represent predevelopment conditions in the San Juan Valley ground-water basin.[1] Determination of individual nodal quantities of net predevelopment recharge and discharge was a trial-and-error process during which estimated values were checked for hydrologic consistency, and computed predevelopment head configurations were checked for agreement with historical (1913) water-level data.

Figure 9 shows the model-verified quantities of net predevelopment recharge and discharge and their nodal distribution in the ground-water basin. Under predevelopment conditions net recharge to the basin was 9.23 cfs. Most of this recharge (5.77 cfs) occurred as subsurface inflow, infiltration of minor streamflows, and infiltration of direct runoff from surrounding hills. For use in the model, this volume of water was added to nodes that approximated the general location of minor streams along the periphery of San Juan Valley. Direct infiltration of rain to the water table was 3.46 cfs of net predevelopment recharge and is equivalent to the infiltration of 1.5 inches of rainfall per year throughout the basin. Net predevelopment discharge from the basin equaled 9.23 cfs and occurred as discharge to the San Benito River.

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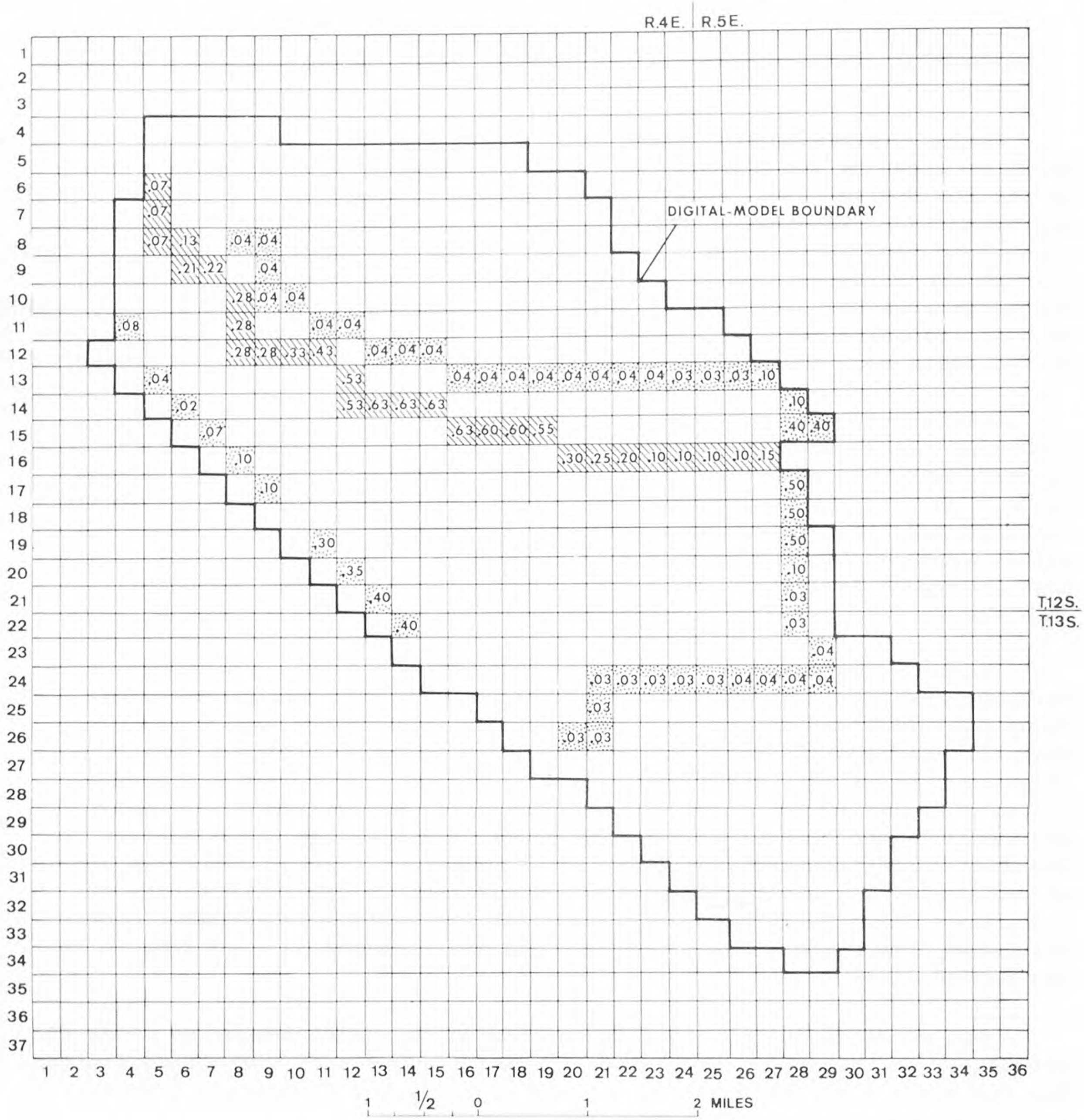
[1]Net recharge to the basin is defined as the total amount of water that percolates to the water table minus losses attributed to evapotranspiration. Net discharge from the basin is defined as all water discharged from the saturated zone except evapotranspiration.



EXPLANATION

.30 Ground-water discharge to San Benito River - Number indicates discharge per nodal area in cfs. Total discharge, 9.23 cfs

.40 Recharge along the periphery of San Juan Valley - Number indicates recharge per nodal area in cfs. Total peripheral recharge, 5.77 cfs. Within model area, infiltration from precipitation totaled 3.46 cfs

FIGURE 9.--Model-verified quantities of net predevelopment recharge to and discharge from the San Juan Valley ground-water basin.

Transient-State Ground-Water Recharge and Discharge

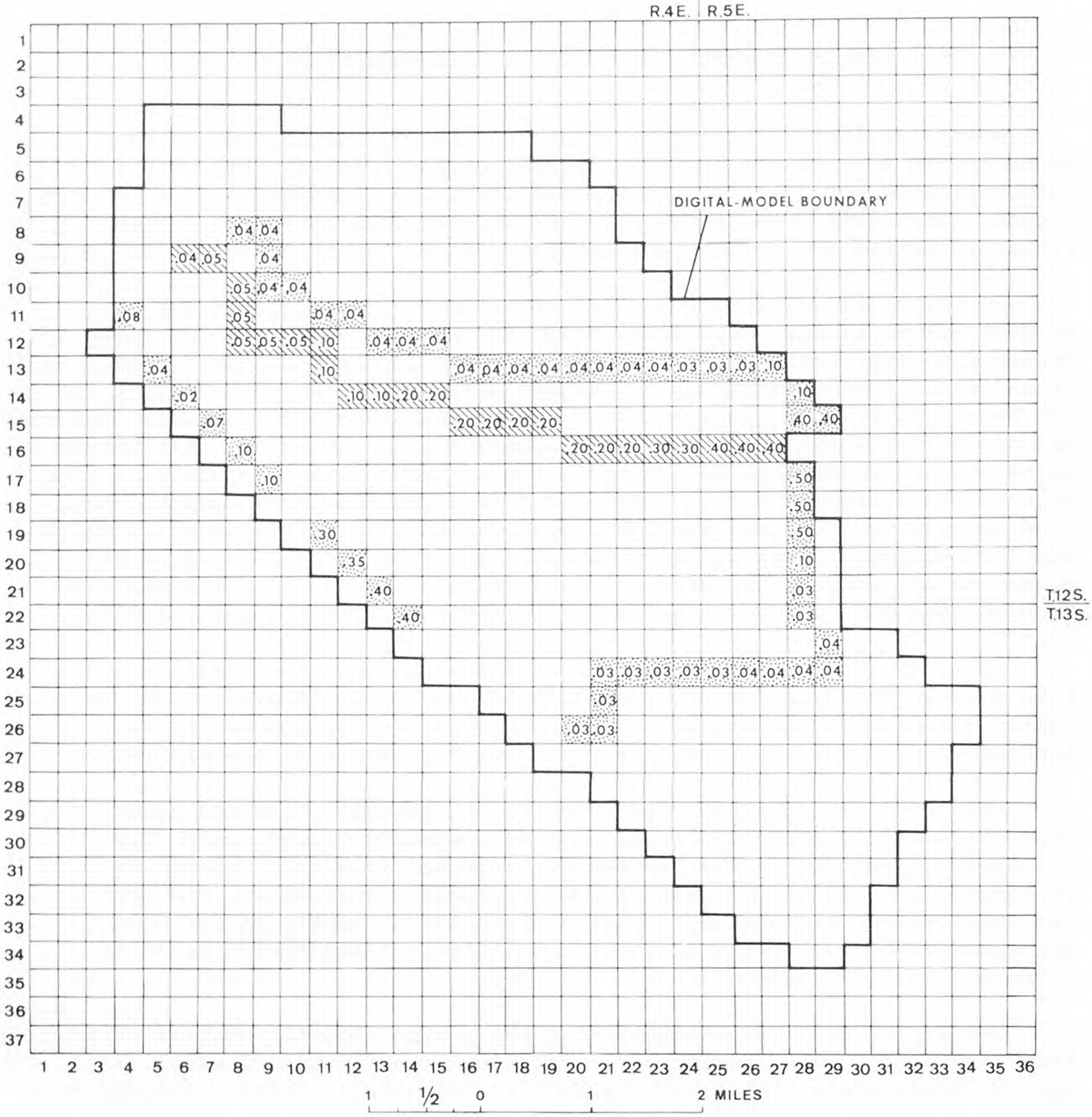
Nonsteady-state or transient-state conditions are assumed to have prevailed in most of the basin during the period 1945-68. For modeling purposes, this period (1945-68) is designated the transient period in this report. The initial and final water-table head configurations for the transient period are defined for the San Juan Valley by figures 4 and 5.

Figure 4 indicates that by 1945 significant alteration of the predevelopment ground-water flow regime had caused the San Benito River to become a losing stream along most of its reach in the San Juan Valley. As ground-water levels continued to decline after 1945, the potential of the San Benito River as a ground-water recharge mechanism progressively increased, and direct infiltration of available streamflow to the water table became a major source of recharge to the ground-water basin. Unfortunately, during most of the transient period, upstream diversions and infiltration losses from the San Benito River greatly depleted natural streamflows entering the San Juan Valley. Thus, while the potential of the river as a recharge mechanism was increasing, streamflows decreased, and most of the recharge from the San Benito River was limited to the eastern part of the valley.

Other ground-water recharge mechanisms such as direct infiltration of rain and the infiltration of streamflows along the periphery of San Juan Valley are directly dependent on precipitation and are assumed to have maintained predevelopment rates of recharge during the transient period.

The nodal distribution of model-verified quantities of net transient-state recharge is shown in figure 10. Net recharge to the basin from available streamflow in the San Benito River was 4.34 cfs of total net recharge (Chabot Kilburn, written commun., 1972), whereas net recharge from the infiltration of rain and recharge along the periphery of San Juan Valley are shown to have occurred at their respective predevelopment rates of 3.46 cfs and 5.77 cfs.

Net ground-water discharge during the period 1945-68 occurred as pumping from irrigation wells, pumping from municipal and industrial wells, and aquifer discharge to the lower reach of the San Benito River. Pumpage data for the entire transient period are not available. However, data compiled by the U.S. Bureau of Reclamation (1952, 1973) indicates that ground-water pumpage averaged 13,600 acre-feet per year (18.78 cfs) during the period 1946-50 and 14,600 acre-feet per year (20.17 cfs) during the period 1958-69. Irrigated crops in the project area are well established, and irrigation schedules are closely balanced between consumptive-use and soil-moisture requirements. Such well-regulated irrigation practices generally reduce the quantity of water available for irrigation return flow to the water table. Consequently, return flow from irrigation in the San Juan Valley ground-water basin is estimated to be 10 percent of total annual withdrawals.



EXPLANATION

.04 Infiltration from San Benito River - Number indicates infiltration rate per nodal area in cfs. Total rate of infiltration, 4.34 cfs

.04 Recharge along the periphery of San Juan Valley - Number indicates recharge per nodal area in cfs. Total peripheral recharge, 5.77 cfs. Within modeled area, infiltration from precipitation totaled 3.46 cfs

FIGURE 10.--Net transient-state recharge to the San Juan Valley ground-water basin.

Land-use practices and the use of irrigation water in the San Juan Valley ground-water basin changed little during the transient period (Chabot Kilburn, oral commun., 1972). Thus, the weighted average annual pumpage for the years 1946-50 and 1958-69 is considered representative of the entire transient period and amounts to 14,300 acre-feet per year. Distribution of this pumpage was based on the known location of irrigation wells and the percentage distribution of total pump horsepower in the ground-water basin in 1968. Modification of initial pumpage estimates during calibration of the model was minimal and based on the known time distribution of development or abandonment of large-capacity wells in a particular area during the transient period.

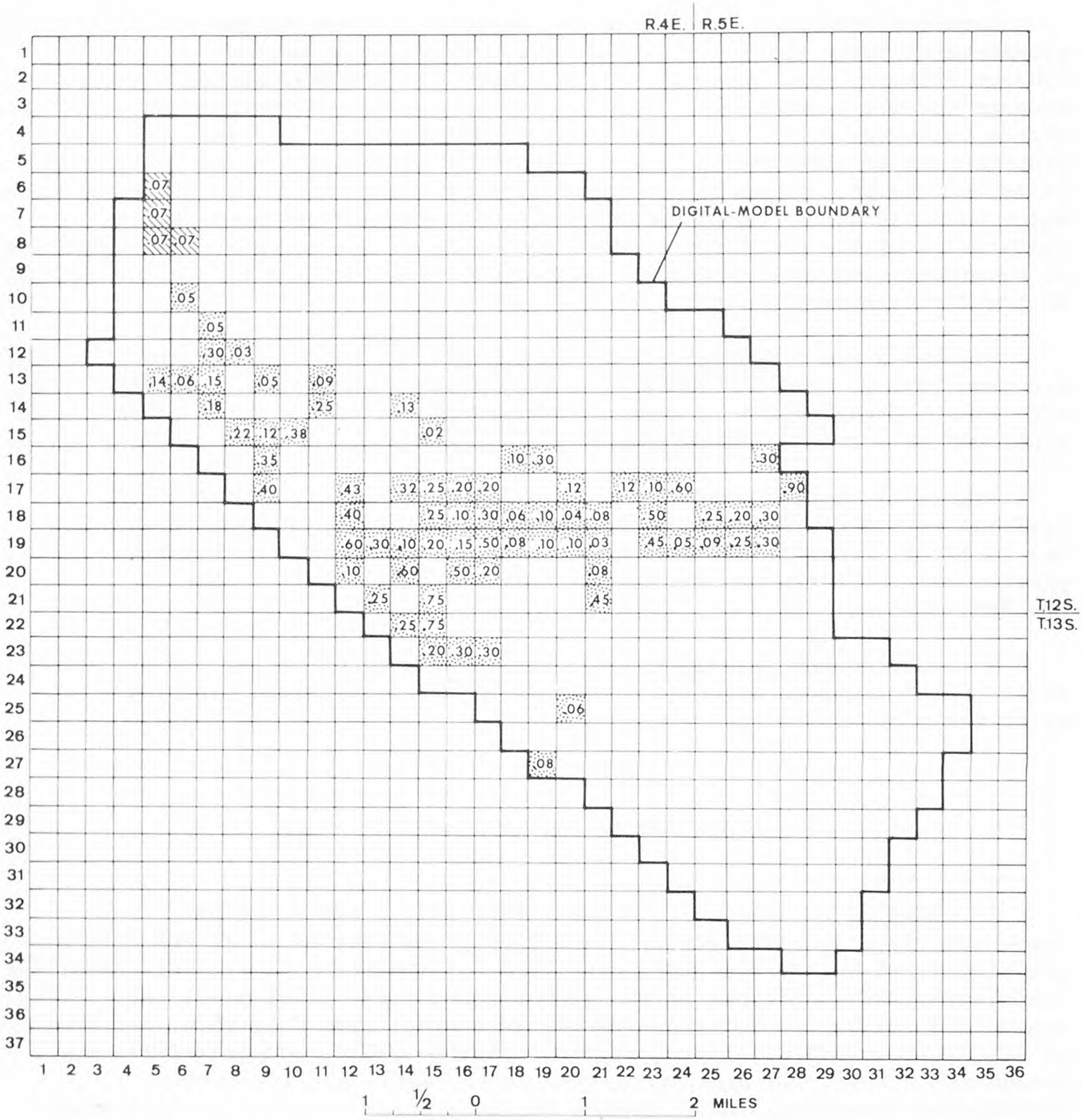
Figures 3 and 5 indicate that water levels in the northwestern part of San Juan Valley, near the San Benito and Pajaro Rivers, have changed little with time. Consequently, a short reach of the San Benito River in this area continued to receive predevelopment discharge throughout the transient period.

Figure 11 shows the model-verified distribution and quantities of net transient-state discharge from the ground-water basin. Pumpage from wells was 17.82 cfs of total net ground-water discharge during the transient period, whereas only 0.28 cfs was discharged from San Juan Valley to the San Benito River.

A comparison of figures 10 and 11 indicates that, during the transient period, net discharge exceeded net recharge in the San Juan Valley ground-water basin by an average rate of 4.53 cfs.

CALIBRATION OF THE MATHEMATICAL MODEL

In order to calibrate the mathematical model, estimates of transmissivity, specific yield, quantities of aquifer recharge and discharge, and historical water-level data were used to simulate both predevelopment and transient-state conditions in the ground-water basin. The model was considered calibrated and ready to use as a predictive tool when, for known or estimated values of transmissivity, specific yield, and quantities of ground-water flow, the model-generated water levels satisfactorily approximated historical water levels for both predevelopment and transient-state conditions.



EXPLANATION

.04 Ground-water pumpage - Number indicates net water withdrawal per nodal area in cfs. Total net pumpage, 17.82 cfs

.07 Ground-water discharge to San Benito River - Number indicates net discharge per nodal area in cfs. Total net discharge, 0.28 cfs

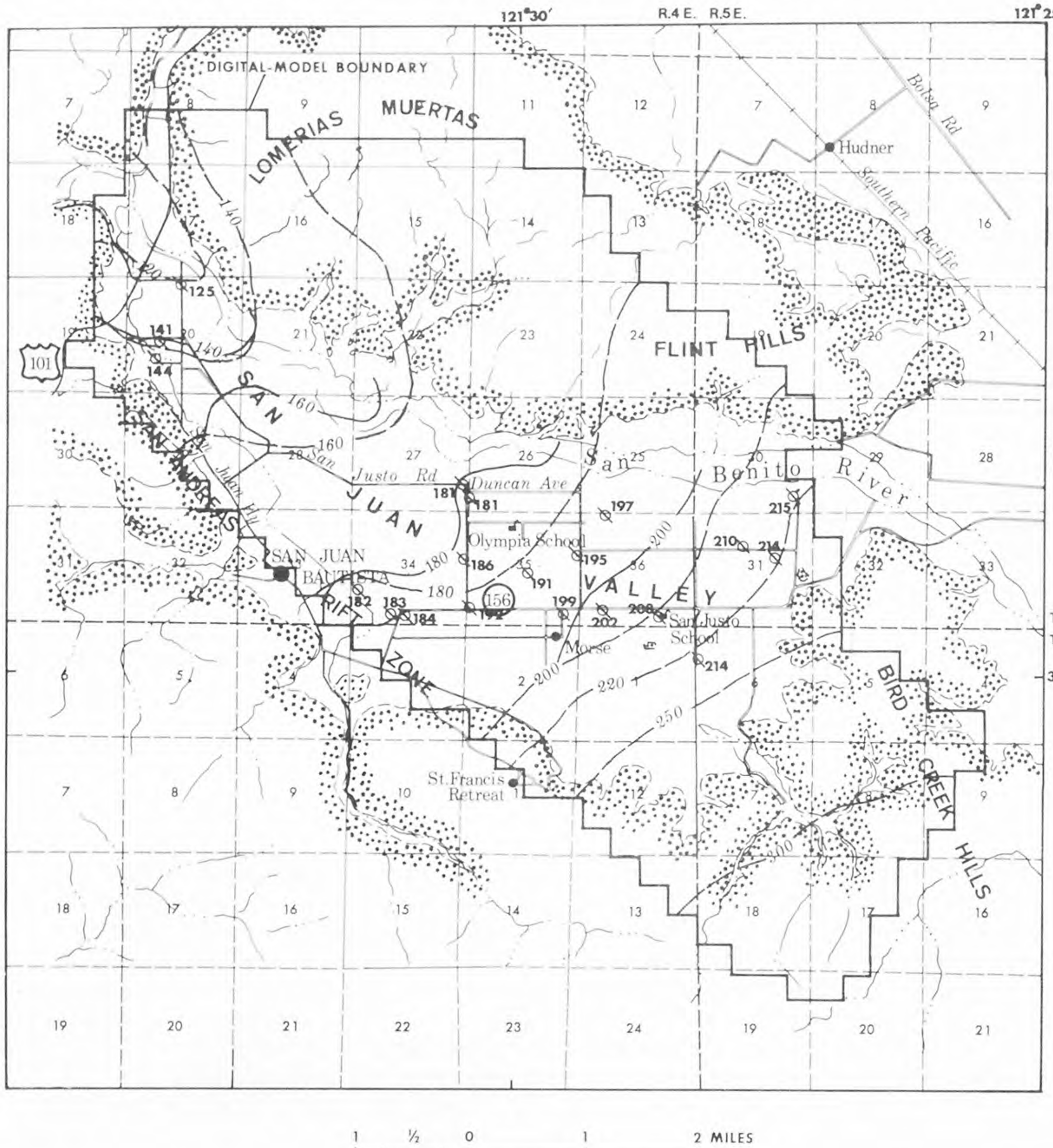
FIGURE 11.--Net transient-state discharge from the San Juan Valley ground-water basin.

Predevelopment Conditions

Predevelopment conditions in the ground-water basin were simulated using the aquifer parameters and net quantities of basin recharge and discharge described above (figs. 3, 7, 8, and 9). Initial heads in the aquifer were derived from figure 3 and from Clark (1924). After a reasonable simulation period, the model-generated head values were used to construct a water-level contour map. The model-generated contours (fig. 12) compare favorably with contours drawn from measured 1913 water-level data except for the 180-foot contour in the central part of San Juan Valley. Water-level data for 1913 (fig. 3) indicate a generally flat water table in this area, and thus the areal disparity between the simulated 180-foot contour and the contour drawn from historical data probably represents less than a 10-foot difference between measured and simulated heads. The simulated water-level contours for the Lomerias Muertas, Flint Hills, and Bird Creek Hills cannot be directly compared with historical data for 1913 because such information is not available. However, the model-generated contours are certainly compatible with the known hydrology of the area and present an internally consistent picture of the predevelopment ground-water flow regime in the basin. In the areas where historical water-level data are available, the model-generated heads are within 5 to 10 feet of the measured heads.

Transient-State Conditions

Simulation of transient-state conditions was accomplished using the values and distribution of aquifer parameters and the transient-state quantities of ground-water flow described above (figs. 7, 8, 10, and 11). Initial heads in the aquifer were derived from figure 4 for the San Juan Valley and from model-generated water-level data for parts of the Lomerias Muertas, Flint Hills, and Bird Creek Hills (fig. 12). Following a simulation period of about 24 years (1945-68), the model-generated water-level contours were compared (fig. 13) with contours drawn from historical data for autumn 1968 (fig. 5). This map (fig. 13) shows that simulated water-level contours closely approximate those contours drawn from measured data except for the 120-foot contour in the northwestern part of San Juan Valley. Figure 5 shows that the water table gradient in this area is about 1 foot per mile. Thus, the areal displacement shown on figure 13 between the simulated 120-foot contour and the 120-foot contour drawn from historical data is misleading because it represents less than a 3-foot difference between actual and simulated water levels. In other parts of the basin, where historical water-level data are available for the autumn of 1968, the model-generated heads are within 5 to 10 feet of the measured heads.



EXPLANATION

Boundary between alluvium and older rocks

—160— Water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

– – 100 – – Model-generated water-level contour - Shows altitude of water level. Contour interval 20 and 50 feet. Datum is mean sea level

186 Observation well - Number is altitude of ground-water level, in feet

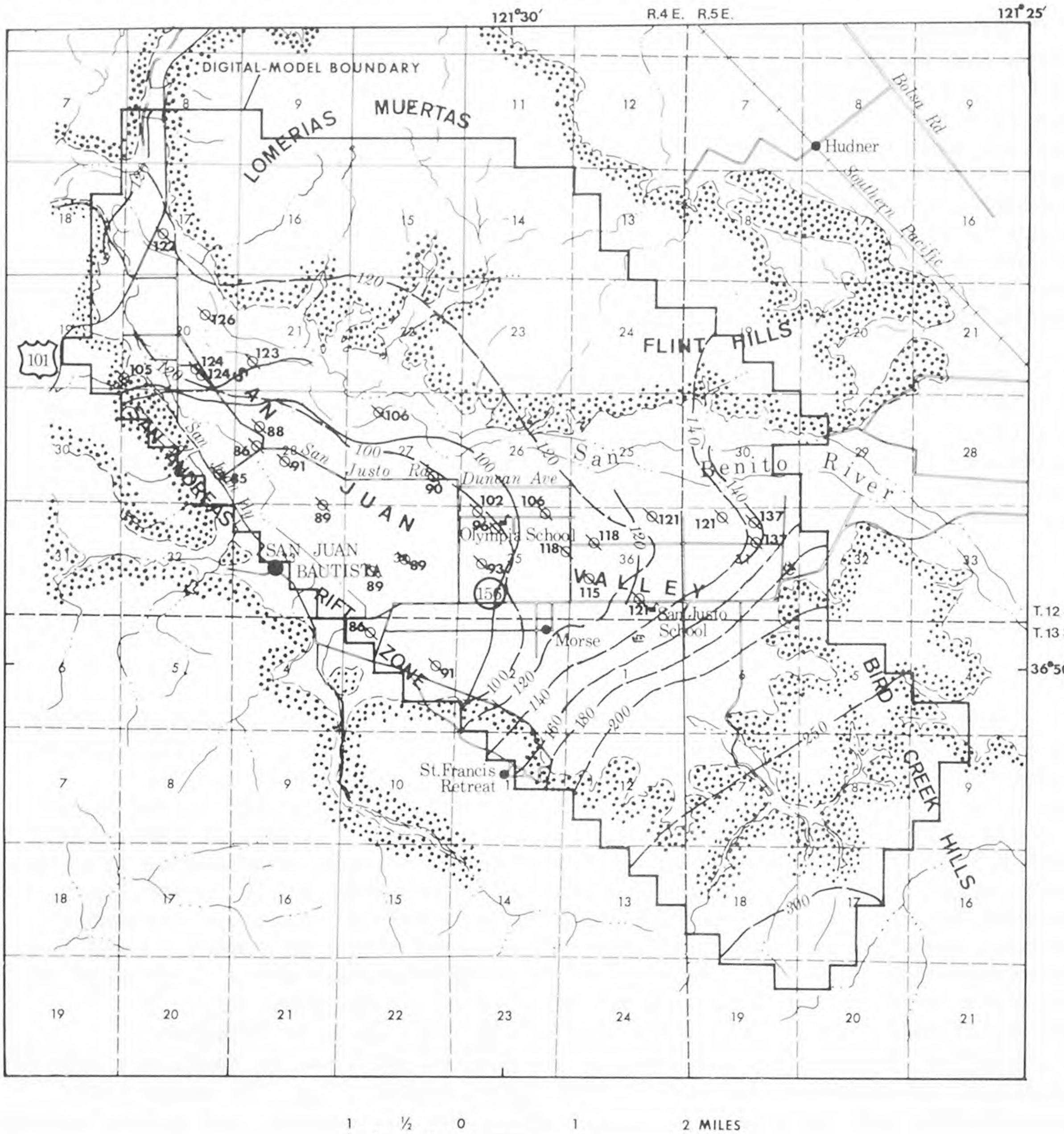
FIGURE 12.--Model-generated water-level contours and water-level contours based on observation-well records for assumed predevelopment conditions.

Hydrographs of water-level data from selected observation wells in the basin are shown in figure 6. The figure also shows model-generated water levels for the same period and indicates a generally close agreement between measured and simulated data. Agreement is especially good during the initial and final parts of the transient period. Large differences (greater than 10 ft) between measured and simulated water levels are shown on several hydrographs, especially during the 1948-52 period. Such differences are probably the result of highly variable pumping rates occurring during the period of measurement. On the other hand, the actual and simulated water levels for wells 12S/4E-20C1, 12S/4E-28F1, and 12S/4E-34G1 are practically coincident for most of the transient period.

As in the simulation of predevelopment conditions, historical water-level data for the Lomerias Muertas, Flint Hills, and Bird Creek Hills were not available for the 1945-68 period. However, model-generated water-level contours for these areas are entirely consistent with known hydrologic conditions and indicate that significant amounts of aquifer storage have been depleted from these areas since 1913 and especially since 1945.

Comment on Model Calibration

The general, close agreement between the actual and simulated hydrographs in figure 6, when considered in conjunction with the areal distribution of observation wells and the relatively accurate pumpage data for the San Juan Valley, indicates that the total transient response of the model closely approximates the long-term response of water levels in the basin. Such a response indicates good calibration of the model especially for those nodes which correspond to the location of observation wells in the basin. Further evidence of model calibration is provided by the close agreement between measured and simulated water-level data shown in figure 13 and the knowledge that both the distribution of transmissivity and a large part of the transient-state water budget were developed from the simulation of predevelopment conditions. The possibility that such an integrated combination of data and information could be significantly incorrect and yet simulate, so closely, the autumn 1968 water levels (fig. 12) seems both unreasonable and improbable. Thus, within the assumptions and approximations discussed in this report, the model is considered calibrated and ready for use as a predictive tool.



EXPLANATION

Boundary between alluvium and older rocks

Water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

Model-generated water-level contour - Shows altitude of water level. Contour interval 20 and 50 feet. Datum is mean sea level

Observation well - Number is altitude of ground-water level, in feet

FIGURE 13.--Model-generated water-level contours and water-level contours based on observation-well records for autumn, 1968.

PREDICTIONS BY THE MODEL

The mathematical model will be used primarily to simulate ground-water conditions resulting from various schemes of aquifer recharge and pumping in the San Juan Valley.

It should be kept in mind that model-generated water levels may not coincide exactly with future levels in the basin. However, the model should adequately portray general future water-level configurations and approximate depths to water in the basin. Much of the model is based on incomplete data and should be continuously refined as more and better data become available.

San Benito County is presently considering the importation of large quantities of water from the proposed San Felipe Project (U.S. Bureau of Reclamation, 1967). Possibly some of this imported water will enter the San Benito River upstream from San Juan Valley and will be recharged to the valley as underflow and infiltration from the river to the water table. Estimated quantities of imported water available for such recharge range from 1,000 to 5,000 acre-ft/yr (acre-feet per year). At the present time, Federal restrictions prohibit the use of San Felipe Project water for irrigating land in large tracts under single ownership. Thus, county officials need to determine how the recharge of imported water will affect future water levels in the San Juan Valley.

In order to simulate future ground-water levels resulting from different recharge rates, 1,000, 3,000, and 5,000 acre-ft/yr were distributed, in turn, to the eastern part of the basin as underflow, infiltrated streamflow, and subsurface flow. Estimates of streamflow infiltration rates were based on data from Kilburn (1972). The nodal distribution of the various assumed rates of recharge, in cfs, is given in table 1. Simulation of future water levels was accomplished by superimposing the values from table 1 on the net transient-state quantities of ground-water flow shown in figures 10 and 11. The model was subsequently operated for simulation periods of 5 and 9 years. The results are shown in figures 14 through 19 and indicate the following:

1. Recharge of 1,000 acre-ft/yr of imported water (figs. 14 and 15) had very little influence on the continuous decline of water levels noted for the period 1945-68. Water levels in the eastern and southeastern parts of the San Juan Valley continued to decline, and a pumping depression developed about a mile north of San Justo School. In general, water levels in the rest of the basin stabilized at 1968 levels.

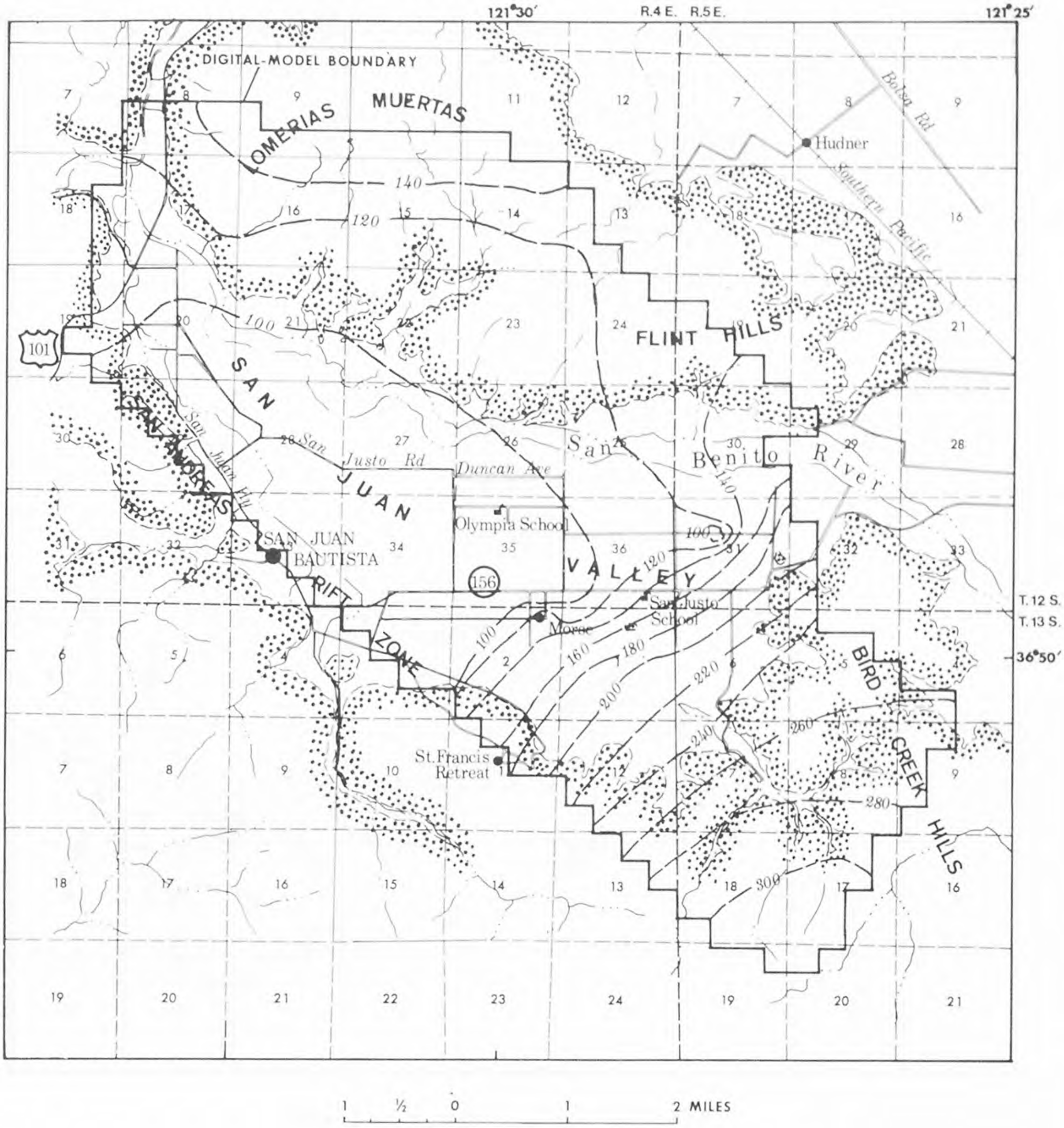
2. Recharge of 3,000 acre-ft/yr of imported water (figs. 16 and 17) generally halted the decline of water levels in the eastern part of San Juan Valley and, after 9 years, caused substantial recovery of water levels in this area. Water levels in the remaining parts of the basin showed very little change from 1968 conditions.

3. Recharge of 5,000 acre-ft/yr of imported water (figs. 18 and 19) significantly reversed the trend of declining water levels in the eastern and southeastern part of the San Juan Valley and, after 9 years, caused a substantial recovery of water levels in this area. Water levels in other parts of the basin generally remained stabilized at 1968 levels.

It should be emphasized that these model predictions simulate only a limited number of recharge conditions, using the San Benito River as a recharge mechanism. Detailed information relating streamflow and wetted area to streamflow infiltration in the San Benito River would expedite planning for the recharge of controlled releases along any designated reach of the river.

TABLE 1.--*Nodal recharge of San Felipe water to the eastern part of San Juan Valley, in cubic feet per second*

Node	1,000 acre-ft/yr	3,000 acre-ft/yr	5,000 acre-ft/yr
16-27	1.0		
17-27	.2		
17-28	.2		
15-27		0.4	
15-28		.5	
16-27		2.4	
17-27		.4	
17-28		.5	
15-27			0.38
15-28			.50
16-23			.37
16-24			.50
16-25			.75
16-26			1.10
16-27			2.50
17-27			.40
17-28			.50

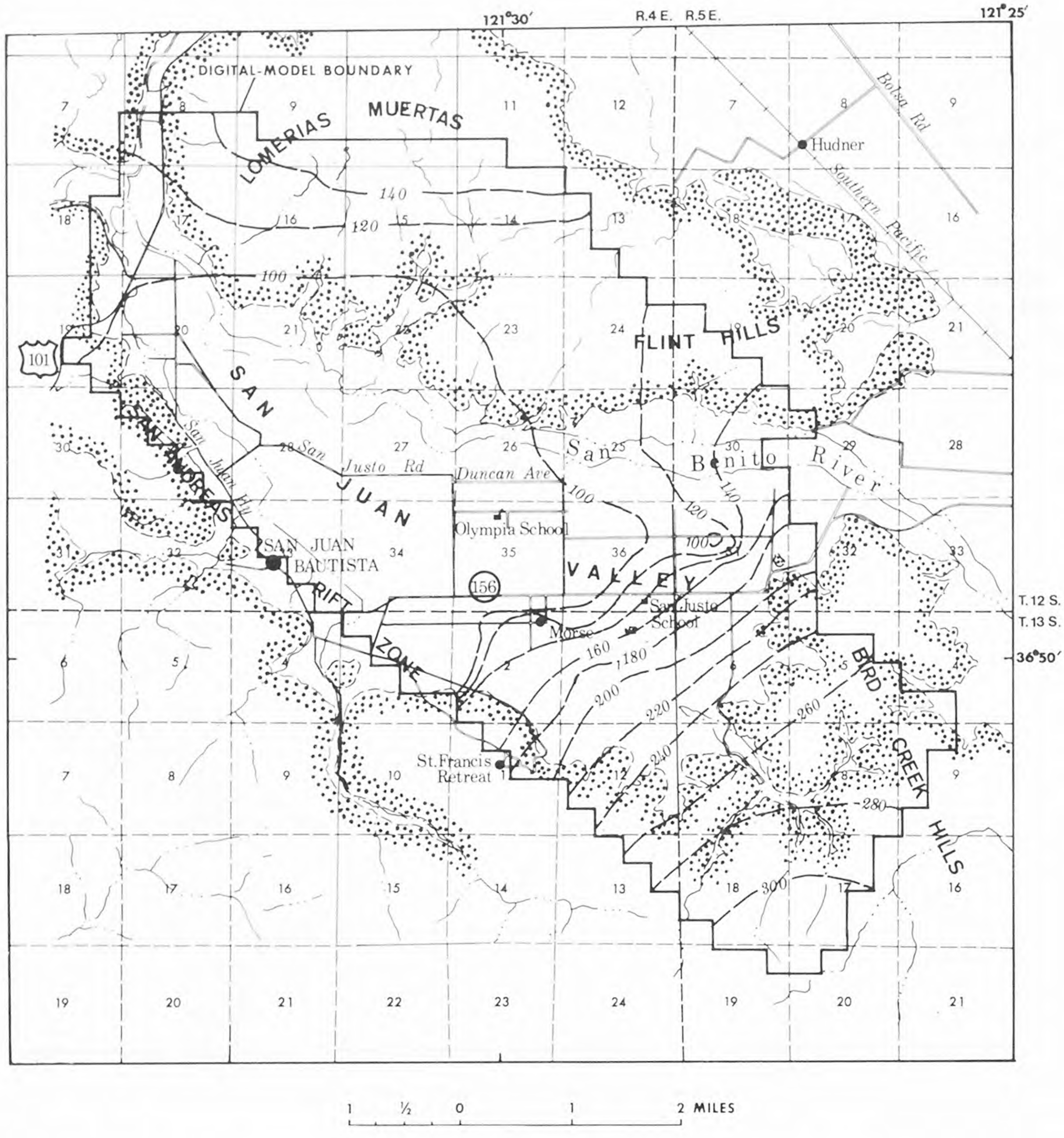


EXPLANATION

Boundary between alluvium and older rocks

120 Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 14.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 1,000 acre-feet per year for 5 years.

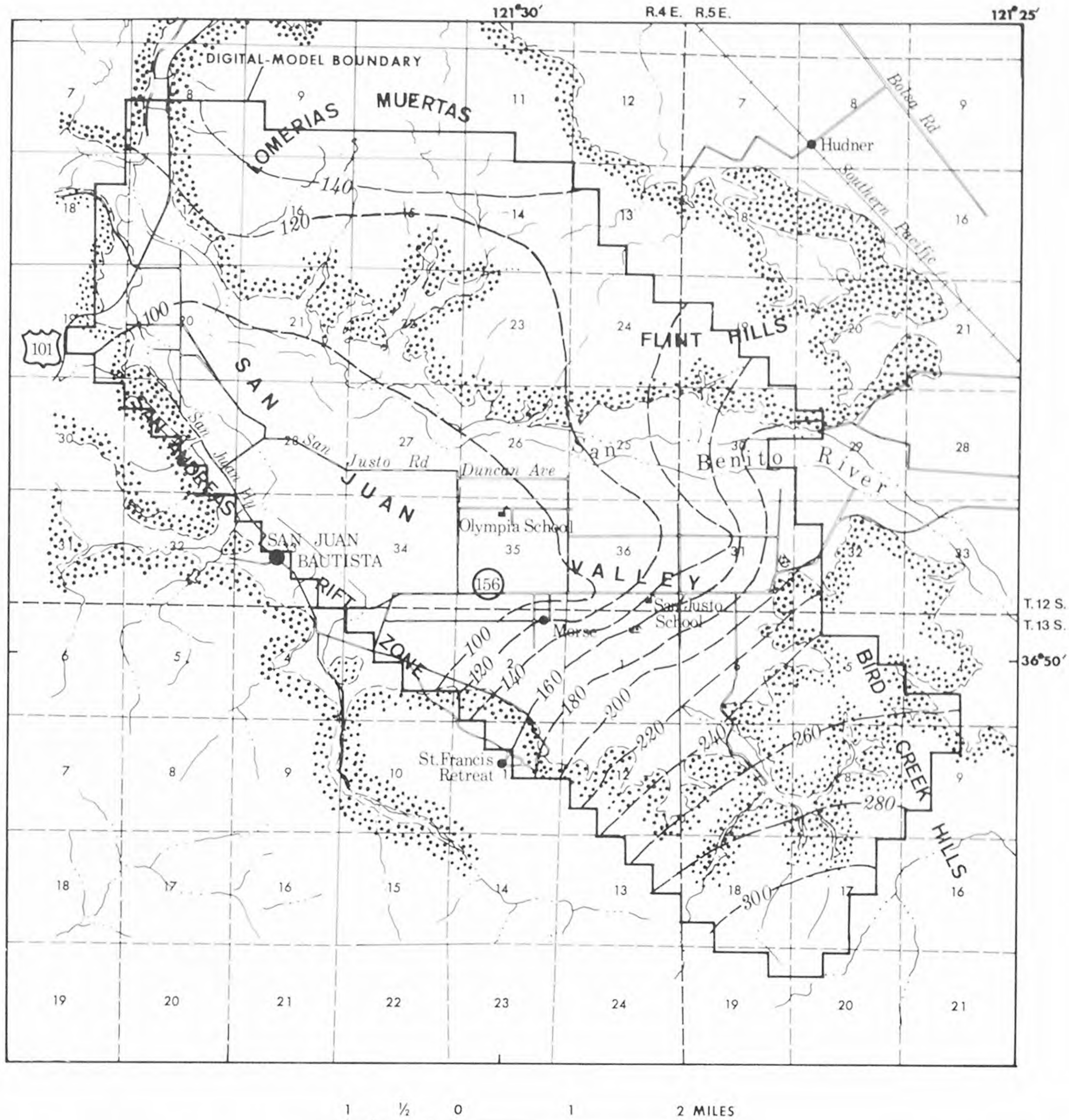


EXPLANATION

Boundary between alluvium and older rocks

180 — Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 15.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 1,000 acre-feet per year for 9 years.

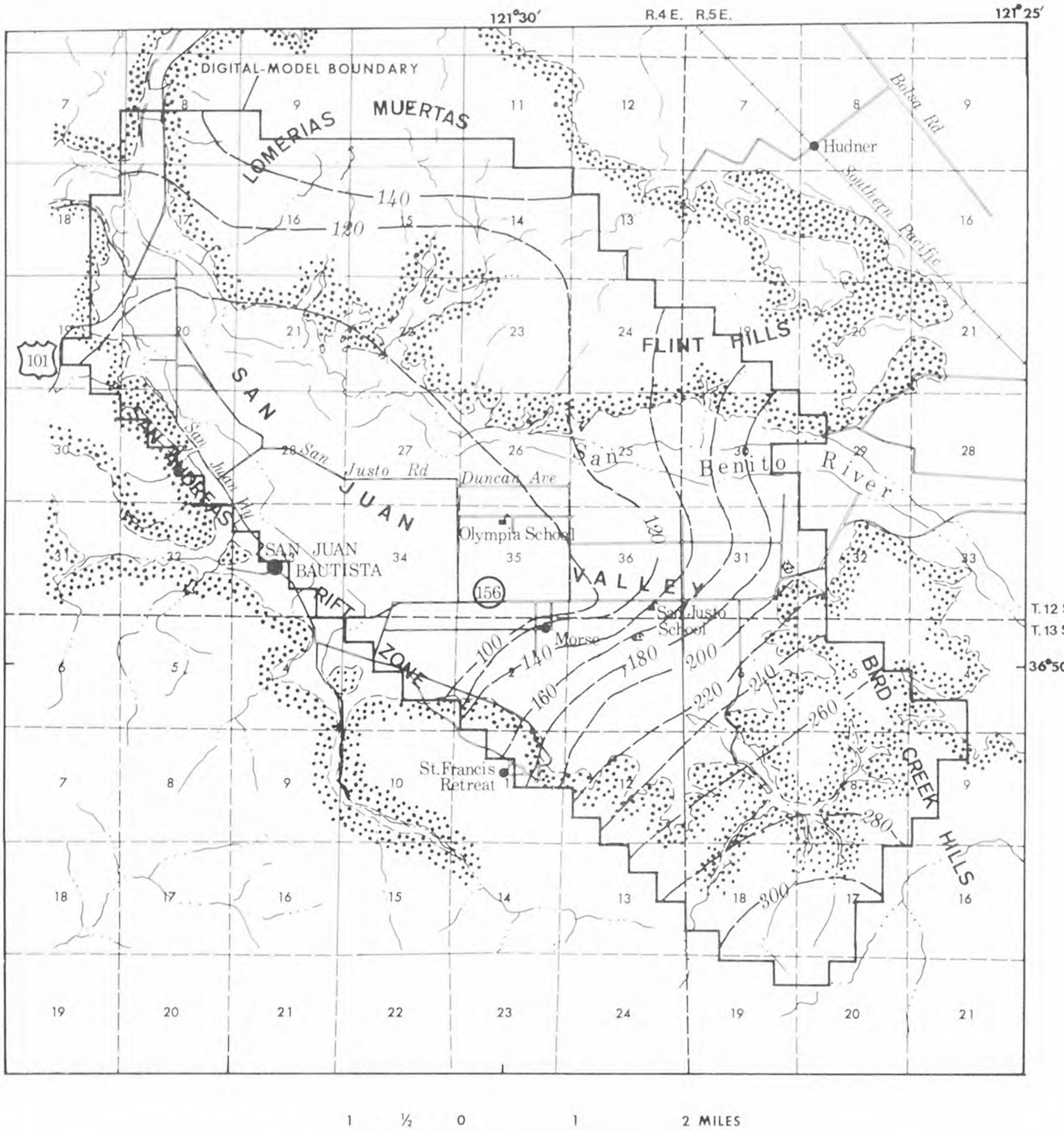


EXPLANATION

Boundary between alluvium and older rocks

180 — Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 16.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 3,000 acre-feet per year for 5 years.

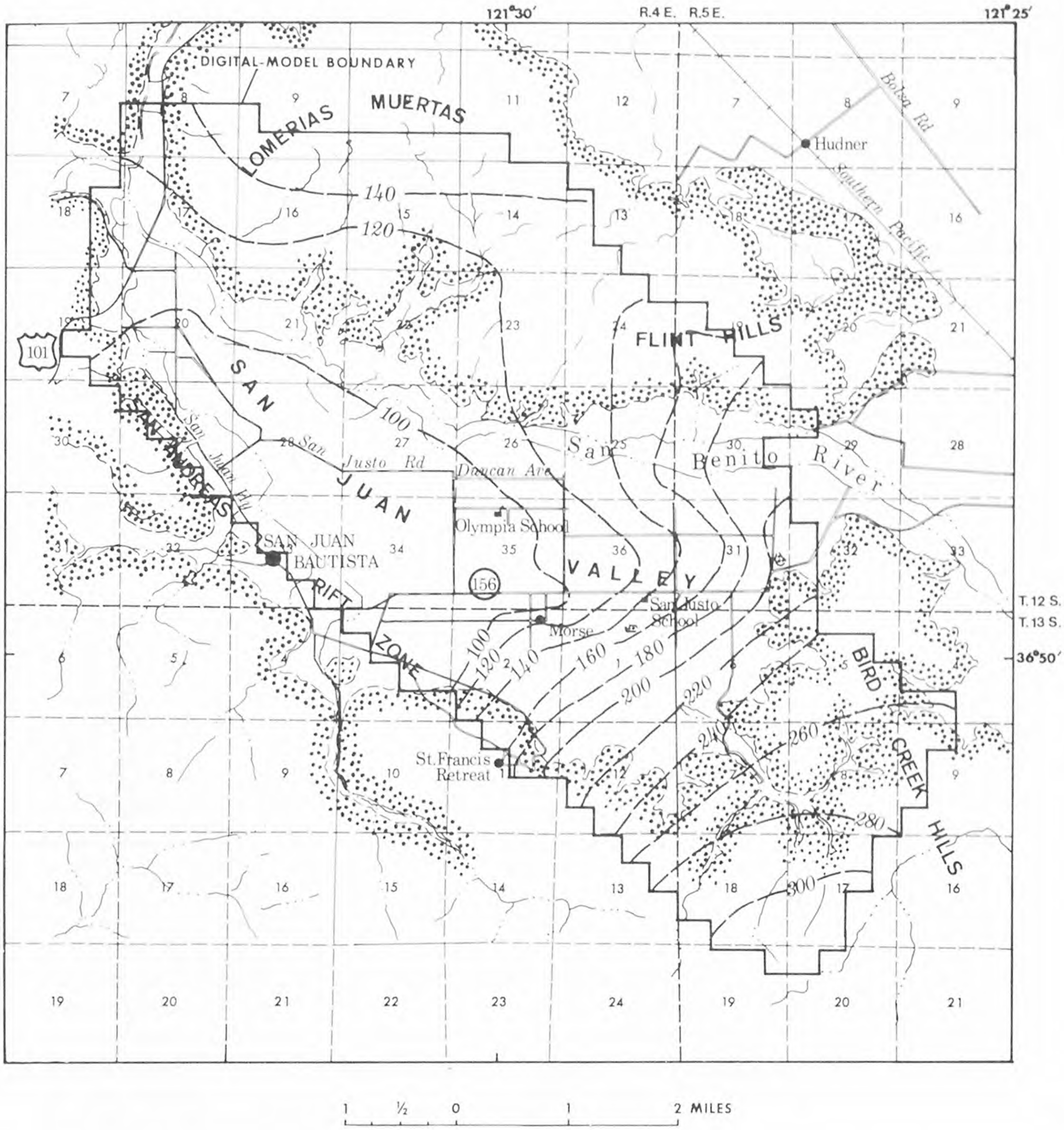


EXPLANATION

Boundary between alluvium and older rocks

—— 180 — Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 17.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 3,000 acre-feet per year for 9 years.

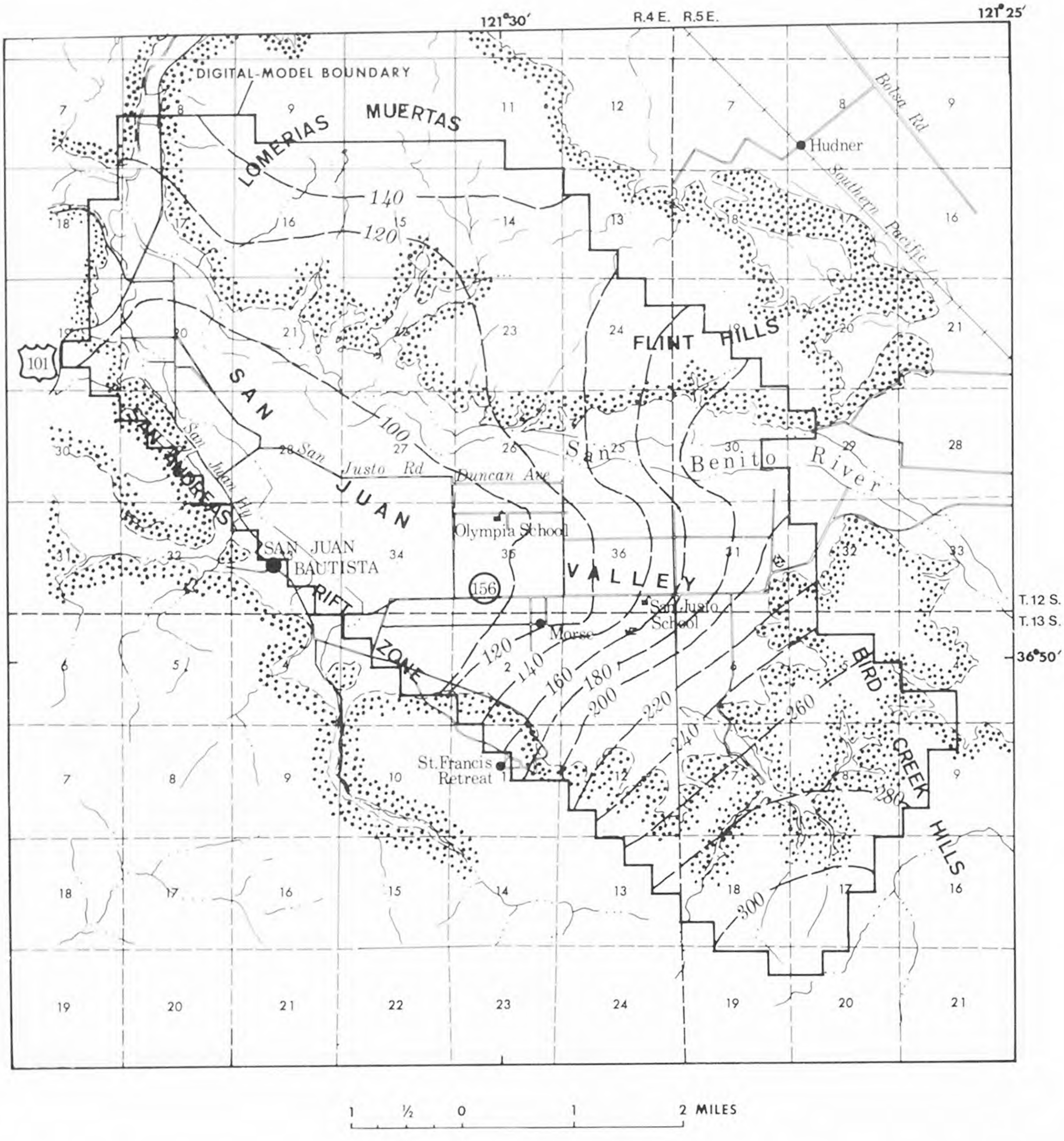


EXPLANATION

Boundary between alluvium and older rocks

—140— Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 18.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 5,000 acre-feet per year for 5 years.



EXPLANATION

Boundary between alluvium and older rocks

160 — Model-generated water-level contour - Shows altitude of water level. Contour interval 20 feet. Datum is mean sea level

FIGURE 19.--Model-generated water-level contours in the San Juan Valley ground-water basin after simulating the recharge of imported water from the San Benito River at a rate of 5,000 acre-feet per year for 9 years.

ADDITIONAL DATA REQUIREMENTS

Data relating streamflow, wetted area, and streamflow infiltration rates for the San Benito River are very critical to the proper management of the San Juan Valley ground-water basin. Detailed information of streamflow infiltration over an extended period of time is critical to model refinement. Such information may indicate that, with respect to some management practices, partial capture and infiltration of 5- and 10-year natural floodflows in the San Benito River could stabilize or reverse much of the present-day decline in water levels in the basin.

Pumpage data and comprehensive water-level data are also critical to model refinement and basin management. Pumpage from all wells should be computed annually. The need for additional comprehensive water-level data is not yet critical. However, as drawdowns become greater, additional data may be required to better define the configuration of pumping depressions.

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