Scotts Valley Water District
Scotts Valley, California

Computer Modeling for Groundwater Management

Scotts Valley Groundwater Basin

June 1997

Todd Engineers
Emeryville, California

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Executive Summary

Scotts Valley Water District (SVWD) manages water resources in the Scotts Valley area as part of its AB 3030 management plan. SVWD recognizes that a groundwater basin computer model is a useful management tool that allows simulation of the effects of management alternatives on groundwater levels and flow and subsequent evaluation of those alternatives. Accordingly, SVWD participated in development in the early 1990s of the Santa Margarita groundwater basin model, a modified version of the widely used MODFLOW code. Subsequently, SVWD authorized a modeling project in April 1996 to update and revise the Santa Margarita groundwater basin model and to apply it to management issues facing SVWD. This report summarizes the revision of the computer model and its application to selected water supply issues.

Hydrogeologic Setting

As a part of this study, a fresh look was taken at the hydrologic and particularly the geologic information that is the foundation for a groundwater model. The Scotts Valley area has a complex geologic history, including the deposition in a marine environment millions of years ago of a thick sequence of sandstones, siltstones, and mudstones. These geologic units, which have been subject to consolidation, folding, faulting, and erosion, include the major hydrogeologic units in Scotts Valley. These units include two aquifers, the deep Lompico Sandstone and Santa Margarita Sandstone, and an intervening zone, the Monterey Formation. Each of these three zones is represented by a layer in the model.

Recent exploratory drilling in the Scotts Valley area has yielded significant information on the areal extent, thickness, and depth of the hydrogeologic units. This information was used to revise the layers in the model. In addition, geologic information was used to reevaluate the effect of folding and faulting on the geologic units. This reevaluation resulted in an improved and simplified understanding of local geologic structure, indicating the presence of only one significant fault in the area.

Model Revision

The Santa Margarita groundwater basin model was developed in the early 1990s for numerical simulation of groundwater flow in the Santa Margarita Groundwater Basin, which includes the Scotts Valley area. As part of this study, modifications were made to the model to incorporate recently collected and/or reinterpreted information. As noted above, the model layers were revised according to the reinterpreted geology. Information on aquifer characteristics also was reviewed, including hydraulic conductivity, indicating the ease with which aquifer materials transmit water, and storativity, indicating the amount of water stored in an aquifer. An important part of revising the model involved updating well pumpage and water level conditions in the vicinity of SVWD. Subsequently, the revised model was calibrated. This involves adjustment of aquifer conditions and groundwater recharge values to achieve a reasonable match between simulated and observed groundwater levels. The revision and calibration process allows for increased accuracy and expanded use of the model by SVWD in addressing groundwater management issues.

Model Application

Six scenarios were defined to address issues that concern SVWD. These issues are expressed below in terms of questions, followed by a brief description of the scenario and scenario results. The results of the simulations are also summarized in Table ES-1, which shows the results of the simulations in terms of water level changes from current conditions in selected wells. It should be noted that the best use of the model is relative comparison of the magnitude of groundwater impacts among scenarios.

Scenario 0. Current Pumping into the Future. What is the effect on groundwater levels of continuing current pumping amounts at current locations with no additional groundwater development or management? This baseline scenario presumes no change in the current pumping pattern and predicts the future water levels resulting from no new action. Results of this no-action scenario indicate that additional declines in groundwater levels can be expected, at some wells exceeding 30 feet, such as in the newer North Scotts Valley Wells 7A and 3B where pumping has been initiated most recently.

Scenario 1. Redistribution of Pumping among Existing SVWD Wells. What is the effect on groundwater levels, particularly in Camp Evers, of redistributing SVWD pumpage to north Scotts Valley? This scenario is based on current pumping demand, and involves reduction of pumping of Wells 9 and 10, compensated by an increase in pumping of Well 3B. The results show that reduction of pumping in wells 9 and 10 by ceasing summer pumpage results in recoveries of about 10 to 20 feet. However, increased pumping in Well 3B causes water level declines in that well exceeding 75 feet.

Scenario 2. Development of New Wells to Meet 2006 Water Demand. What will be the effect on groundwater levels of developing two new wells to meet increasing demand? In this scenario, water demand increases to allow for 700 new connections and a new high school. Two new wells (9A and 10A) are installed, yielding a combined 450 acre-feet per year (AFY), and located in several combinations at the sites of Test Hole 16 and Test Wells 17 and 18. This scenario involved comparison of three strategies for the two planned wells at Sites 16 and 17, 16 and 18, and 17 and 18. All three strategies provide a sustainable water supply with minimal impacts on Bean Creek. Drawdowns from pumping the Lompico Sandstone at Sites 16 and 17

Table ES-1

Summary of Simulation Results, Water Level Change, Feet

(Compared to current water levels, unless otherwise noted. Negative values indicate decline.)

	Scenario										
	0	1	2A	2B	2C	3*	4A	4B	4C	5	6**
Key Well	No Action	Redis-tribution	Development of New Wells			Replen-ishment	Implementation of Water Recycling			Drought	Perennial Yield
9 City Hall	-20	12	-27	-36	-27	0	2	1	4	-27	-29
10 Businessmens	-32	22	-36	-40	-36	0	9	8	15	-40	-38
11 Lompico	-33	-43	-41	-7	-38	0	-31	-28	-30	-62	-7
3B SVWD	-38	-78	-49	-46	-46	1	-40	-41	-40	-72	-8
7A SVWD	-51	-73	-58	-59	-54	1	-54	-54	-53	-80	-8
Other Wells/Sites											
Manana Woods	-20	-17	-	-	-	-	-	-	-	-	-
7 El Pueblo	-19	-	-	-	-	2	2	-1	2	-	-6
Site 17	-	-	-13	-17	-	-	-	-	-	-	-18
Site 16	-	-	-17	-	-14	-	-	-	-	-	-
Pasatiempo 7	-	-	-5	-27	-2	0	4	-2	4	-34	-7
Site 18	-	-	-	-68	-67	-	-	-	-	-	-48
6 SVWD	-	-	-	-	-	1	-	-	-	-	-
X	-	-	-	-	-	-	-	-	-	-	-23
Y	-	-	-	-	-	-	-	-	-	-	-32
Z	--	-	-	-	-	-	-	-	-	-	-30

*Changes relative to water levels in Scenario 2B.
**Changes relative to Scenario 0.

amount to about 15 feet, while drawdowns at Site 18, extracting water from the Santa Margarita Sandstone, amount to about 68 feet.

Scenario 3. Implementation of Surface Water Replenishment. What will be the effect on groundwater levels of artificial recharge in Carbonera Creek, given future well development? This scenario builds upon the increased water demand and well development of Scenario 2, and includes a program of artificial surface water replenishment in the Carbonera Creek channel. The small amount of water replenishment envisioned in this scenario (100 AFY) provided negligible benefits. However, results of this scenario were affected by limitations of the model itself, suggesting that reevaluation may be warranted following future improvement of the model.

Scenario 4. Implementation of Water Recycling. What will be the effect of water recycling/reduction of pumping on groundwater levels, given future growth in water demand and future well development? What is the effect on groundwater levels of Kaiser Sand & Gravel Company's participation in the recycling project? This scenario also builds on Scenario 2, with increased water demand and new wells. Then the Phase 1 wastewater recycling project is implemented, resulting in a reduction in pumping of 460 acre-feet/year. The effects on groundwater of the recycling project also are simulated without Kaiser participation, in other words, anticipating loss of the single largest customer. Then Phase 2 of the recycling project is implemented to further reduce pumping. Overall, Scenario 4 shows that the reduction of pumping achieved with water recycling results in significant beneficial impacts on water levels. In this scenario, pumping was reduced particularly in Wells 9 and 10, resulting in recoveries amounting to as much as 15 feet in Well 10. Participation by Kaiser in the water recycling project is beneficial, especially for San Lorenzo Valley Water District's Pasatiempo wells.

Scenario 5. Evaluation of Drought Impacts. What will be the impact of a future drought if recycling and recharge are not implemented? This scenario simulates a severe 5-year drought like 1986-1991 with a Scenario 2 water demand and SVWD water system, but no wastewater recycling, no artificial replenishment, and no concerted conservation effort. This scenario indicates that, without active management, the impacts on production wells and Bean Creek are severe. Groundwater level declines in selected Camp Evers wells range from 27 to 40 feet, and in North Scotts Valley wells exceed 70 feet. Furthermore, Bean Creek flow is halved.

Scenario 6. Exploring Perennial Yield. What might be the potential impacts of total pumpage reaching the estimated perennial yield of 4,200 acre-feet/year? This scenario builds upon Scenario 2, then increases pumpage to 4,200 acre-feet/year using hypothetical wells, but allows no wastewater recycling and no artificial replenishment. This exploration of the concept of perennial yield illustrates that pumping of groundwater near the perennial yield limit may be sustainable, but entails undesirable impacts on wells and Bean Creek.

Conclusions and Recommendations

This modeling project demonstrates that the Santa Margarita groundwater basin model is a useful tool for evaluating groundwater development and management alternatives. Further exploration of scenarios involving distribution of pumping, water recycling, and drought impacts is warranted. The model should be updated regularly to incorporate new data on aquifer geometry, hydraulic conductivity, storativity, and water levels. In particular, available data should be improved with regard to groundwater levels and storativity values (especially for the Lompico and Monterey formations), and aquifer/stream interactions. Specific recommendations include the following.

1. The model should be applied to additional issues and scenarios, including additional scenarios for pumping distribution, well installation, water recycling and recharge.

2. The model should be regularly updated as hydrogeologic information becomes available on aquifer geometry, hydraulic conductivity, storativity, pumpage, and water levels.

3. The relative lack of water level information in the Monterey and Lompico Formations should be remedied by maintaining existing wells screened in those formations as monitoring sites and by adding new wells to the groundwater level monitoring program.

4. Data on storativity should be obtained through performance of pumping tests on wells with monitoring of an observation well.

5. Analysis of groundwater/surface water interactions along local streams should be considered for the future.

6. Consideration should be given to development of a data management system such as a geographic information system (GIS) for use in conjunction with the groundwater flow model.

Introduction

Scotts Valley Water District participated in development of the Santa Margarita groundwater basin model developed in the early 1990s. Although this model is a version of the widely accepted and applied USGS MODFLOW code, its use as a groundwater management tool did not materialize in the years following its development. In April 1996, the Scotts Valley Water District approved the revision and updating of the Santa Margarita model and its application to water issues facing SVWD. This report summarizes the development of the computer model as a water resources management tool for SVWD, and application of that tool to selected water supply issues.

Background

HISTORY

The Scotts Valley groundwater model documented in this report is based on the Santa Margarita groundwater basin model developed for the Association of Monterey Bay Area Governments (AMBAG) in 1992 (Watkins-Johnson Environmental, 1993). This Santa Margarita model was intended for use by agencies involved in management of water resources in the Santa Margarita groundwater basin, including the Scotts Valley Water District. The Scotts Valley Water District, among other agencies, served on the Technical Advisory Committee for the modeling effort and provided technical and financial support. Although considerable effort went into development of this model, its use as a groundwater management tool did not materialize in the years following its development.

The Santa Margarita model is a modified version of the widely accepted and applied USGS MODFLOW code (McDonald and Harbaugh, 1988). Review of the model for Scotts Valley Water District's AB 3030 Groundwater Management Plan (Todd Engineers, 1994) indicated that it could serve as a useful tool for groundwater management. Accordingly, the AB3030 report recommended that the Santa Margarita model be updated, revised, and applied as part of the Scotts Valley Water District's groundwater management plan.

SCOPE

This report summarizes the development of the Scotts Valley Groundwater Basin computer model as a water resources management tool for SVWD, and application of that tool to selected water supply issues facing SVWD. Revision of the model focuses on SVWD and hydrologically linked adjacent areas, while application of the model is defined by SVWD water management issues.

STUDY AREA

Revision of the model focused on the study area, shown in Figure 1, which consists of the Bean Creek and Carbonera Creek watersheds, plus a small area near Mount Hermon. As indicated, the SVWD service area includes portions of the Bean Creek, Carbonera Creek, and Branciforte Creek watersheds. SVWD currently monitors surface water and groundwater resources in the Bean and Carbonera watersheds, and has developed groundwater in both.

The small Mount Hermon area lies southwest of SVWD boundaries. The area's surface water drainage is to the San Lorenzo River to the southwest and it generally would be presumed that groundwater flow also would be toward the river. However, groundwater pumping along Graham Hill Road and Lockewood Lane has altered groundwater flow patterns, resulting in groundwater flow into the Camp Evers portion of the Bean Creek drainage. Accordingly, the study area has been expanded southwestward to the limit of the Lompico Sandstone in order to account for possible inflow from this small area.

Consideration also was given to inclusion of the Branciforte Creek watershed, which is situated immediately east of Carbonera Creek watershed. A portion of the SVWD service area extends into Branciforte watershed, and it has been suggested previously that groundwater inflow could occur to north Scotts Valley from the Lompico Sandstone outcrop in the upper Branciforte watershed. However, the limited available data are insufficient to contradict the fundamental assumption that groundwater flow parallels surface water flow. Accordingly, it is assumed that groundwater flow in Branciforte watershed is southward, paralleling the creek, and is independent of groundwater flow in the Bean and Carbonera basins.

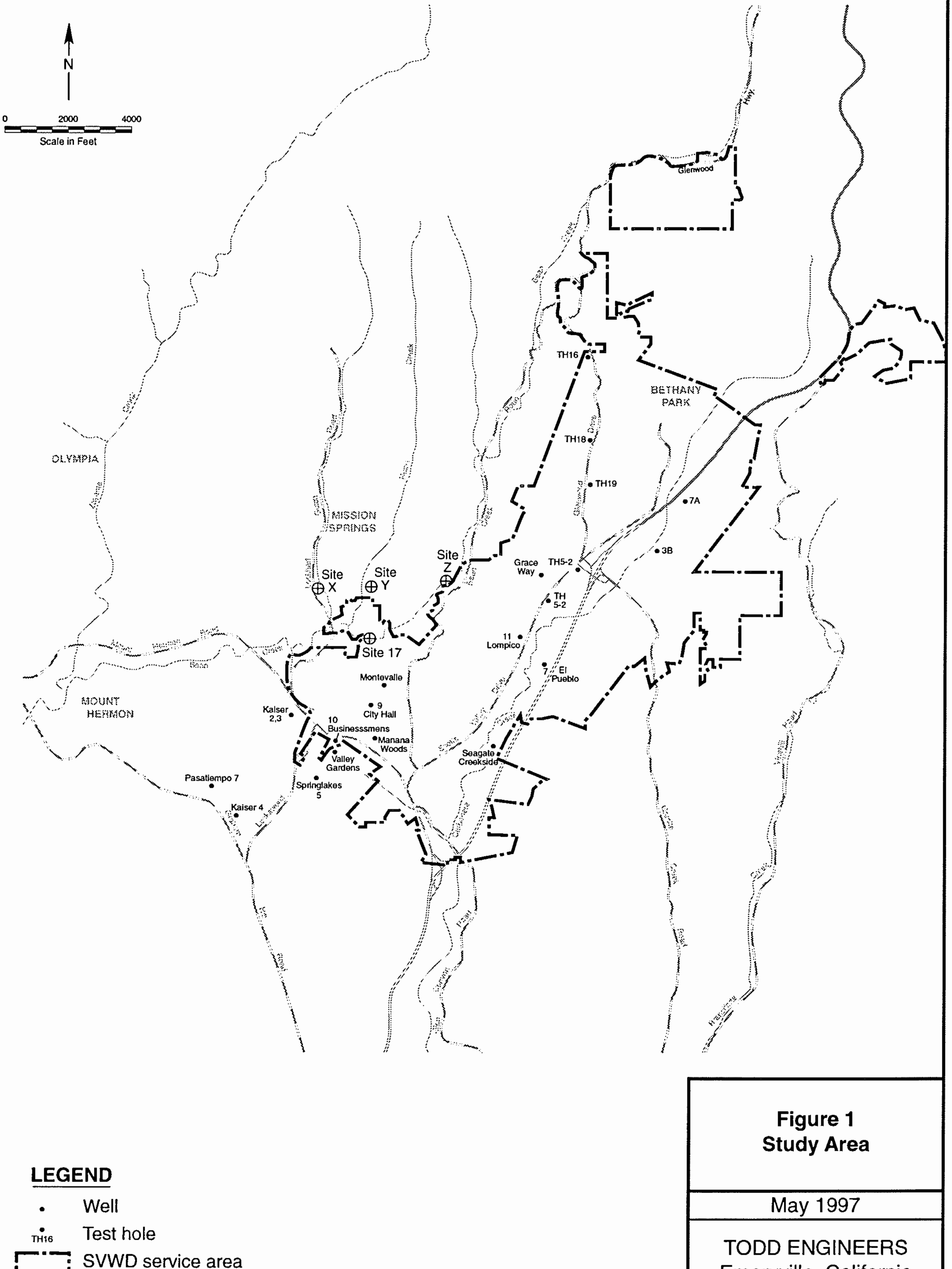

Figure 1
Study Area

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Hydrologic and Hydrogeologic Setting

A fresh look was taken at the hydrologic and particularly the geologic information that is the foundation for a groundwater model. This review was undertaken in order to develop an updated model that is consistent with the current knowledge of the groundwater basin and is capable of accurately simulating local groundwater levels and flow.

Hydrologic Setting

The study area encompasses approximately sixteen square miles in the Santa Cruz Mountains. The Scotts Valley area is rugged, exhibiting topographic relief of 1600 feet. The mountainous portions of the study area are densely forested with coast redwoods and conifers, grasslands and less dense stands of oak, madrone, and alder along ridges. Much of the topography consists of elongated, steep-sided ridges alternating with v-shaped valleys. With the exception of scattered residential developments along ridges off Glenwood Highway, most of the development in the mountainous areas consists of semi-rural and vacation homes strung out along the narrow valleys.

The major exceptions are Scotts Valley and the Camp Evers area along Mount Hermon Road. Scotts Valley is a two and one-half mile long valley along Carbonera Creek. Scotts Valley is contiguous with Camp Evers, a broad bench that straddles the divide between the Carbonera and Bean creek watersheds. These two areas, which historically supported grasslands as well as wetlands near Camp Evers, encompass most of the City of Scotts Valley, including commercial and industrial areas and the denser residential neighborhoods. Local industry is dominated by computer-related businesses. In addition, a major sand quarry, operated by Kaiser Sand & Gravel Company, is located in the southwestern portion of the study area. The area also is home to several conference centers, retreats and camps, (such as Mount Hermon and Mission Springs conference centers) as well as Bethany Bible College.

CLIMATIC CONDITIONS

The study area has a mild Mediterranean climate with most of the rainfall occurring in the winter months from November to March. Average annual rainfall in Scotts Valley is about 40 inches. An isohyetal map (Todd Engineers, May 1984) indicates that average annual rainfall is greatest in the northern, mountainous portion of the study area and generally decreases toward the southeast. Rainfall has varied from about 20 inches in dry years (e.g., 1976, 1977, 1988, and 1990) to more than 80 inches in 1983.

STREAMFLOW

The two major streams in the study area are Bean Creek and Carbonera Creek, while the southwestern portion of the study area drains to the San Lorenzo River.

Bean Creek, a tributary of Zayante Creek and the San Lorenzo River, drains the major portion of the study area. It is gaged about one mile upstream of its confluence with Zayante Creek at the western edge of the study area. Although gage records are limited, Bean Creek yields an average of 5,160 acre-feet per year (AFY). The creek is the natural drain for groundwater in the Scotts Valley area, and is perennial in its lower reach, maintaining a summer base flow of 2 to 4 cubic feet per second (cfs).

Carbonera Creek is a tributary of San Lorenzo River near its mouth at the Pacific Ocean. Carbonera Creek drains the eastern third of the study area and is gaged about one mile above the southern edge of the study area. Carbonera Creek yields an average of 2,600 AFY, but unlike Bean Creek, typically becomes dry during the summer months.

Geology

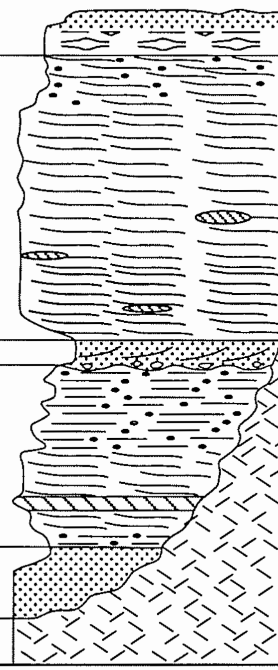
The geology of the Scotts Valley area has been described by numerous previous workers, including the U.S. Geological Survey (USGS) (Clark, 1981). A brief summary of the local geology is included here to provide the framework for the conceptual model on which the computer groundwater flow model was based. This section also presents geologic maps constructed for this study that focus on geologic information required to model groundwater flow. The next section (Hydrogeology) more fully relates the geology to regional and local groundwater flow patterns in the area.

GEOLOGIC HISTORY OF THE SCOTTS VALLEY AREA

The Scotts Valley area has a complex geologic history controlled by extensive tectonic activity and sea-level fluctuations. The area lies within the central Santa Cruz Mountains where thick sequences of sediments were deposited on and around basement granitic rocks during the Tertiary age, 65 to 1.8 million years ago. These crystalline basement rocks comprise a major tectonic block, the Salinian block, bounded by the San Andreas fault to the east and the San Gregorio fault to the west. Regional compression and tectonic activity along these faults resulted in the formation of broad marine basins or bays where thick sequences of marine sandstones and mudstones were deposited.

The lower Tertiary sediments overlying the basement rocks consist of a thick sequence (up to 10,000 feet) of sandstones, siltstones, and mudstones. Most of this sequence is either absent or too deep in the subsurface to be defined by well data in the Scotts Valley area. Therefore, these sediments are not discussed further in this report.

Geologists have subdivided the upper Tertiary sediments (deposited beginning 24 million years ago) into two transgressive sequences. Transgressive sequences represent periods of deepening ocean water with deposition of increasingly fine grain sediments. The first sequence of deepening water includes the Lompico and Monterey formations, while the second sequence includes the Santa Margarita and overlying sediments. These geologic units are described in Figure 2, which shows the relative position of the geologic units, their geologic age (middle Miocene through Pliocene age), and basic character. It should be noted that the reported

		FORMATION	LITHOLOGY	THICK NESS FEET	DESCRIPTION
UPPER TERTIARY	PLIOCENE	Purisima Formation		490	Poorly consolidated fine-grained sandstone and siltstone. Moderately permeable. Yields small quantities of water to wells. Sufficient only for domestic supply.
	MIOCENE	Santa Cruz Mudstone		0-8,800	Consolidated, fractured mudstone. Poorly permeable. Yields small quantities of water to wells. Sufficient only for domestic supply.
		Santa Margarita Sandstone		0-430	Unconsolidated medium to coarse grained sandstone with interbeds of pebbles and a gravelly zone at the base. Permeable. Yields large to small quantities of water to wells.
		Unconformity			
		Monterey Formation		40-2,660	Consolidated mudstone and sandy siltstone with a few thick interbeds of dolomite. Poorly permeable. Yields small quantities of water to wells.
		Lompico Sandstone *Unconformable on underlying rocks*		190-830+	Consolidated medium to fine grained sandstone. Moderately permeable. Yields large to small quantities of water to wells.
		Lower Tertiary and Granitic rocks			

Modified From Clark, 1981 and Muir, 1981.

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Figure 2
Partial Stratigraphic Column for the Scotts Valley Area

thicknesses of these regional units may be greater than the thicknesses that occur in Scotts Valley.

The lower transgressive sequence begins with the Lompico Sandstone, which was deposited in a shallow marinef environment. Deepening waters resulted in the deposition of an overlying mudstone, the Monterey Formation, during middle Miocene time. During this time, regional tectonic activity resulted in local folding and faulting of these sediments. The upper sections of the Monterey were eroded where uplifted and exposed. This erosional surface (or unconformity) on top of the Monterey resulted in varying thicknesses of mudstone upon which the next transgressive sequence, the Santa Margarita Sandstone, was deposited.

The second or upper transgressive sequence begins with the Santa Margarita Sandstone. Phillips (1981) conducted an extensive investigation of the depositional environment of the Santa Margarita and documented its shallow marine origin in the Scotts Valley area. The local Santa Margarita Sandstone was deposited in a tidal-dominated marine environment on an undulating Monterey surface. Tidal channels were eroded into the Monterey where clean basal Santa Margarita sands were deposited. Phillips (1981) documented tidal current directions based on outcrops of Santa Margarita in nearby quarries and concluded that the channels were controlled by ancient high areas of granitic basement rock. Although significant tectonic activity occurred prior to the deposition of the Santa Margarita, additional downwarping and movement along faults occurred during and after the deposition and continues today (Clark, 1981; Phillips, 1981).

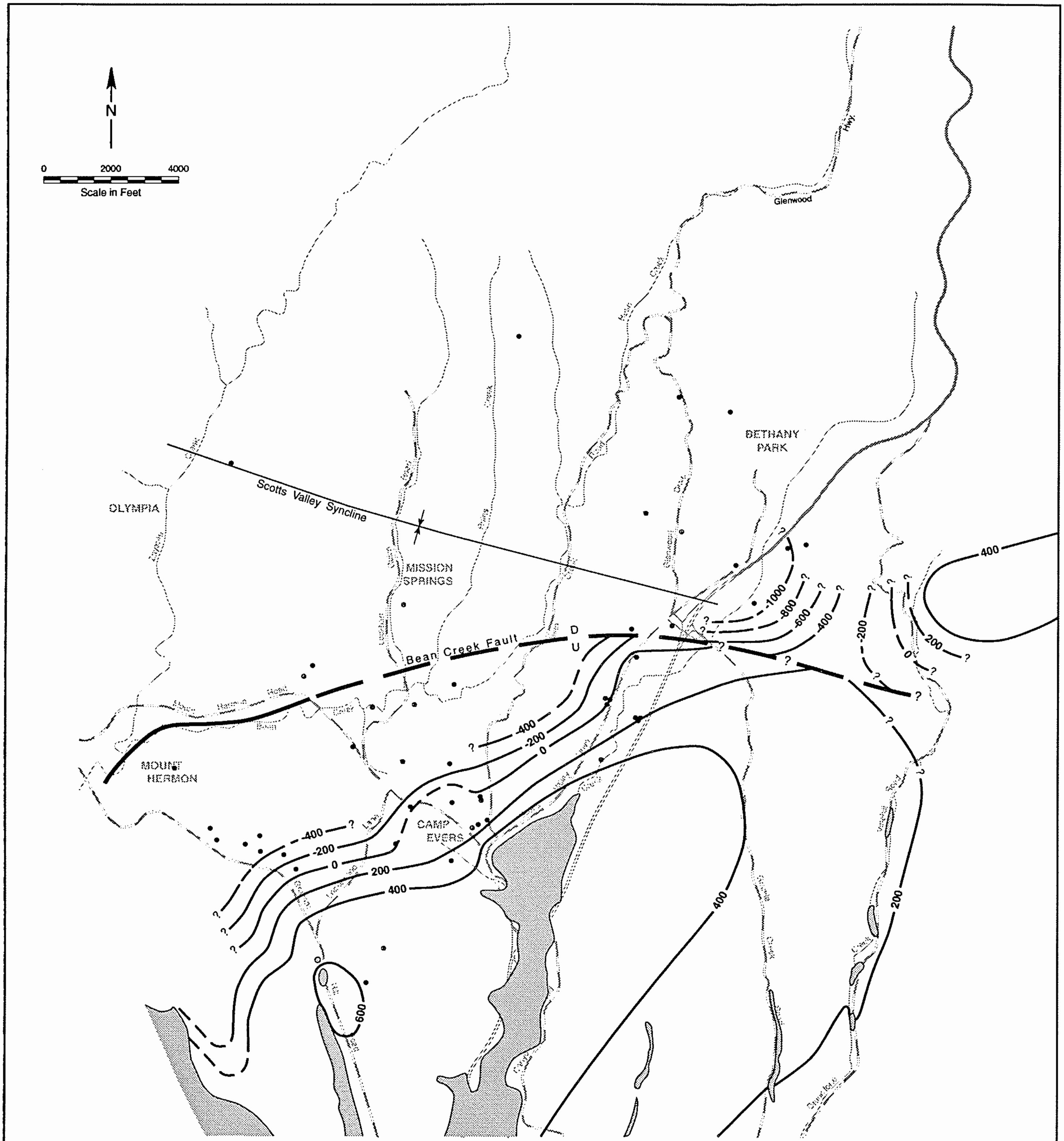
As in previous cycles, deepening water resulted in deposition of fine grain sediments on top of the Santa Margarita Sandstone. These fine-grain units include the Santa Cruz Mudstone and the siltstones of the Purisima Formation. Although present in the Scotts Valley area both in outcrop and in the subsurface, these units are above the regional water table and therefore are not included in the groundwater model.

Additional information about the main geologic units that impact the groundwater system in the study area is provided below.

GEOLOGIC UNITS

Four main geologic units appear in the subsurface throughout the study area and affect the movement of groundwater. From the oldest to the youngest these are the Pre-Tertiary Granite bedrock, the Lompico Sandstone, the Monterey Formation, and the Santa Margarita Sandstone. The geometry and extent of these units were re-evaluated for the modeling effort and regional contour maps were prepared on the top and/or base of each unit as needed for model input. These maps represent simplified surfaces of the geologic units based on surface and subsurface data. They were constructed with an emphasis on some 45 wells with geophysical log data as well as selected drillers' lithologic logs. These data provided more accurate formation identification and depths necessary for structural mapping than drillers' lithologic logs alone. A comparison between lithologic logs (drillers' logs) and geophysical logs indicated that lithologic logs alone may result in inconsistent and inexact interpretations of the actual elevations of geologic units. Outcrop patterns and measured strikes and dips were also incorporated into the subsurface interpretation. In addition, Kaiser Sand & Gravel Company (KSG) provided a contour map representing elevations of the top of the Monterey across the KSG property in the southwestern portion of the study area. This map was generated using soil borings and wells on the KSG property and was incorporated into the geologic map of the top of the Monterey.

These maps, showing the areal extent and geometry of the main geologic units within the model domain, are depicted on Figures 3, 4, and 5. A more detailed description of these geologic units and the accompanying geologic maps are provided below.



LEGEND

Surface outcrop of Granite

—400— Structural contours of top of Granite, in feet MSL
Negative numbers denote elevations below sea level

Geologic fault, dashed where inferred

D/U denotes downthrown and upthrown sides

• Well data used in mapping

Figure 3
Estimated Top of Granite

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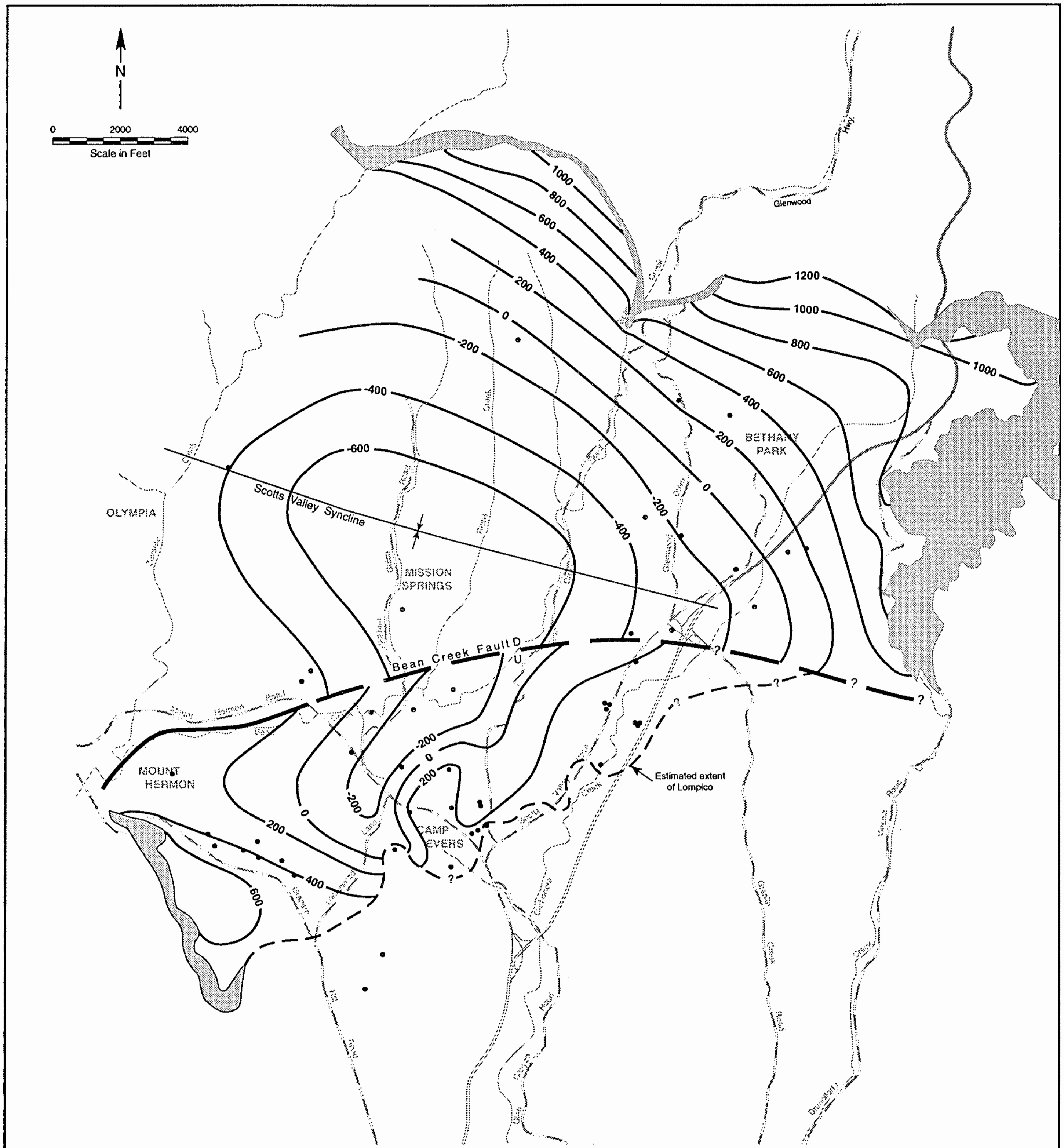

LEGEND

- Surface outcrop of Lompico
- —400— Structural contours of the top of the Lompico Sandstone, in feet MSL
- Negative numbers denote elevations below sea level
- Geologic fault, dashed where inferred
- D/U denotes downthrown and upthrown sides
- • Well data used in mapping

Figure 4
Estimated Top of Lompico Sandstone

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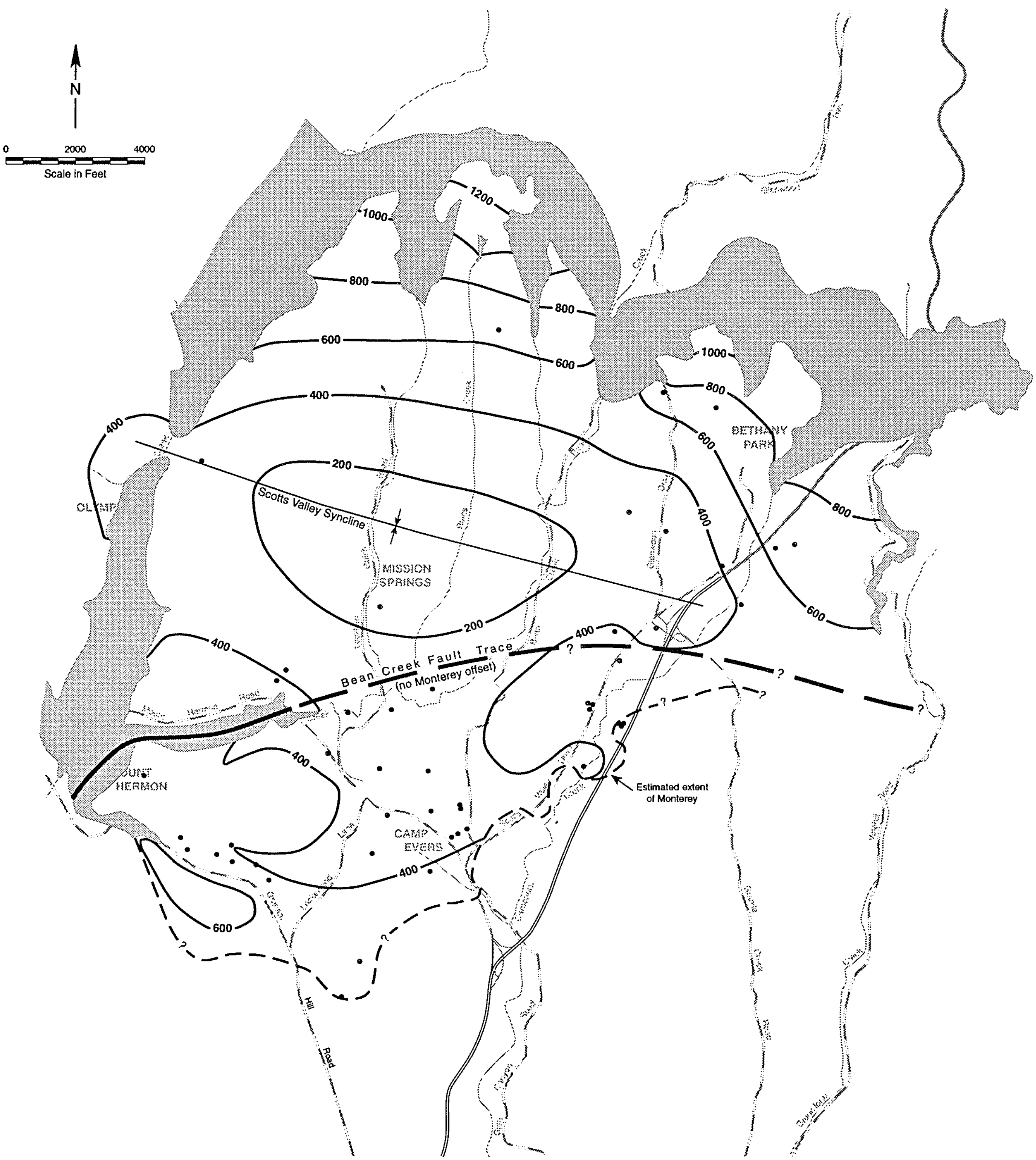

LEGEND

- Surface outcrop of Monterey
- —400— Structural contours of the erosional surface of the Monterey Formation, in feet MSL
- Geologic fault, dashed where inferred
- • Well data used in mapping

Figure 5
Estimated Top of Monterey Formation

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Pre-Tertiary Granite. Granitic rocks have intruded into overlying sedimentary units and form the basement rocks of the study area. A contour map of the top of the granite is shown on Figure 3 based on outcrop elevations and geophysical/lithologic logs from approximately ten wells penetrating the granite in the Scotts Valley area. Much of the Tertiary section was either eroded or not deposited where the higher elevations of granite exist. At various places, the Lompico Sandstone, the Monterey Formation, and the Santa Margarita Sandstone all lap onto and pinch out over the higher elevations of the granite (see Figure 2). For this analysis the predominant use of the granite surface is to estimate general pinch-out locations of the sediments and provide a base to the Santa Margarita Sandstone in the southern portion of the study area, where the Santa Margarita was deposited directly on top of the granite. Because of lack of data and the limited use of the granitic surface in the model, the granite is not contoured throughout the study area.

The granite surface can be characterized as a relatively smooth, northeast-southwest trending ridge in the south that deepens dramatically to the northwest. The granite reaches its highest elevation in the southern portion of the area (600 feet above mean sea level) and outcrops along the southern reaches of Carbonera and Branciforte creeks as well as other smaller tributaries in the south. The contour map shows significant downwarping along the Scotts Valley Syncline and offset along the Bean Creek fault (both discussed in the following sections). Along the syncline and on the northern (downthrown) side of the Bean Creek fault, the granite is extremely deep, lying at elevations of 1,100 feet below sea level.

Lompico Sandstone. The Lompico Sandstone is a relatively thick-bedded to massive sandstone and is Middle Miocene in age. A structure contour map on the top of the Lompico illustrates its geometry and extent (Figure 4). Lompico outcrops border the study area to the north, northeast, and southwest. The unit is penetrated in the subsurface by numerous wells in the Scotts Valley area and comprises one of the two main aquifers in the groundwater basin. As evidenced by geophysical logs, the sandstone exceeds 800 feet in thickness in wells near the axis of the Scotts Valley Syncline, but thins abruptly to the south and southeast as it laps onto the intruded granite. The Lompico is missing south and southeast of the intersection of the Lompico and granite.

Monterey Formation. The Miocene Monterey Formation overlies the Lompico Sandstone conformably (indicating no intervening erosion) and consists of a thick sequence of thinly-bedded mudstones with some interbeds of siltstone and dolomite. Geologic mapping indicates that the true thickness of the formation may reach 900 feet in the axis of the Scotts Valley Syncline. However, the top of the Monterey is substantially eroded, and thicknesses vary dramatically throughout the model domain. More typical formation thicknesses, as observed in area wells, are from about 200 feet to about 500 feet. A structure contour map on the eroded, unconformable top of the Monterey Formation is shown on Figure 5. The Monterey is characterized by a lower permeability than the overlying Santa Margarita Formation and the underlying Lompico Sandstone. A few wells are screened in Monterey siltstone interbeds with limited production.

Santa Margarita Sandstone. The Santa Margarita Sandstone is a clean, permeable sandstone deposited on the erosional surface of the Monterey Formation and outcrops over much of the study area. The unit comprises one of the major aquifers in Scotts Valley and is penetrated by most of the wells drilled in the study area. Similar to the Lompico and Monterey, the Santa Margarita is missing in the eastern portion of the study area where it pinches out over the granitic high. However, the sandstone is present and outcrops over much of the southern area where it was deposited directly on the granite as seen in exposures along Carbonera Creek south of the Camp Evers area.

Overlying Units. Additional Tertiary sedimentary units and Quaternary alluvium overlie the main geologic units throughout a large portion of the study area. These units include the

Santa Cruz Mudstone, the Purisima Formation and thin alluvial deposits in the major drainage valleys. Because these units are generally higher than the regional water table, they have not been incorporated into the groundwater model.

GEOLOGIC FOLDING AND FAULTING

Scotts Valley Syncline. Regional folding has produced a major syncline, the Scotts Valley Syncline, which crosses the central portion of the study area. The axis trends northwest-southeast (approximate azimuth 106 degrees) as mapped by the USGS and indicated on previously-described structure maps (Figures 3 through 5). Subsurface geologic mapping indicates that the deepest portion of the syncline is located in the Bean Creek watershed north of Mission Springs. The Lompico Sandstone dips relatively steeply into the syncline from outcropping areas in the north and relatively high subsurface elevations in the south (Figure 4). The erosional surface that comprises the top of the Monterey Formation mimics this general pattern, although dips into the syncline are not as steep (Figure 5). This relationship suggests that most of the compression that formed the Scotts Valley Syncline occurred after the deposition of the Lompico and Monterey but before the top of the Monterey was subject to erosion. However, some downwarping along the syncline continued after the erosion.

Bean Creek Fault Extension. The entire study area is located between two regional faults, the Zayante fault and the Ben Lomond fault, as mapped by the USGS. These faults trend northwest-southeast and appear to be related to the tectonic activity that formed the Scotts Valley Syncline. An additional fault appears to cross-cut the study area and significantly offsets the beds of the Lompico Sandstone and Monterey Formation. This is evidenced by geophysical log data from wells in the vicinity of Highway 17 at Glenwood Drive, including SVWD test holes 5-1, 5-2, and the Grace Way well (see Figure 1). This fault may represent the subsurface extension of the Bean Creek fault as identified by the USGS in the outcropping Monterey Formation in the southern reach of Bean Creek. Although the USGS considers the Bean Creek Fault to be a "minor fault" within the Monterey, several hundred feet of offset could occur in the thick Monterey Formation and still allow Monterey to appear on both sides of the fault as observed in Bean Creek. Geologic mapping suggests a downthrown northern side with approximately 450 feet of offset on the top of the Lompico (Figure 4). For purposes of the model, a simplifying assumption is made that the majority of the offset occurred prior to the erosion of the top of the Monterey (consistent with observations on folding) and therefore, no significant offset is shown on the top of the Monterey unconformity (Figure 5).

Additional Faults. Additional faults associated with the tectonic activity in the area probably exist in the subsurface but exact trace locations are unknown. Subsurface well data are too sparse to accurately locate continuous fault traces, especially if offset along the fault is limited. In addition, given the large thicknesses of the units, the Lompico Sandstone and Monterey Formation would remain somewhat continuous across faults with relatively small offset, although individual beds may be discontinuous. The inclusion of postulated faults may over-complicate the modeling and add to the uncertainty. Therefore, for the purposes of groundwater modeling, no additional faults are included in the conceptual model at this time.

Hydrogeologic Conceptual Model

The revised geologic evaluation was incorporated into previous hydrogeologic evaluations in the area to develop a consistent integrated conceptual model for representation in the computer model. This section summarizes that conceptual model.

AQUIFER PACKAGES AND PRODUCTION

As mentioned previously, the regional groundwater system is comprised of two major aquifers, the Santa Margarita Sandstone and the Lompico Sandstone, with an intervening zone of lower permeability, the Monterey Formation. Wells in the Scotts Valley area produce water predominantly from these two aquifers, although a few wells produce locally from permeable units of the Monterey Formation, which are limited in extent and thickness.

Since 1975 more than 30 major wells have been used in the study area for irrigation, municipal drinking water supply, industrial supply, and groundwater contamination remediation. Estimated current pumping rates indicate that approximately 3,200 acre-feet per year (AFY) are being produced from major wells within the model domain. Of this production, approximately 30% is from the Santa Margarita Sandstone, 60% from the Lompico Sandstone, and 10% from Monterey and other units.

OCCURRENCE AND MOVEMENT OF GROUNDWATER

Where present, the aquifers form a bowl-like basin centered on the Scotts Valley Syncline. The main source of groundwater recharge is direct infiltration of precipitation. This process is widespread in the Santa Margarita Sandstone which is exposed at the surface throughout a large portion of the study area. Limited direct infiltration also occurs in the Lompico Sandstone on the northern and eastern portions of the study area where the Lompico crops out at the surface. However, throughout most of the study area, the Lompico exists in the deep subsurface, separated from surface recharge by the thick and low permeability Monterey Formation.

This configuration results in two hydraulically continuous groundwater systems in the Scotts Valley area, a shallow groundwater system (Santa Margarita Sandstone), and a deep groundwater system (Lompico Sandstone). The shallow groundwater system is characterized by unconfined, water table conditions in the Santa Margarita Sandstone. In some areas, the base of the Santa Margarita is relatively high in elevation and lies above the regional water table, resulting in unsaturated conditions. In these areas, the water table exists in the underlying Monterey Formation, resulting in unconfined groundwater conditions in the Monterey; elsewhere in the Monterey Formation, groundwater is confined.

The deep groundwater system is illustrated by the confined nature of the Lompico Sandstone where water levels are often hundreds of feet above the top of the unit. Groundwater interaction between the three hydrogeologic units occurs through leakage from one formation to another.

Groundwater movement is highly influenced by the two low permeability units, the Monterey Formation and the granitic basement, each of which underlies the Santa Margarita Sandstone in different portions of the study area. Where Santa Margarita laps onto the granite in the southern and southeastern part of the study area, the movement of groundwater is controlled by the granite's subsurface topography. In the Carbonera Creek/Camp Evers area, it is well documented that groundwater flows southward following the creek until encountering the uplifted granite. There groundwater flow is re-directed westward through the Camp Evers area toward Bean Creek. The change in flow direction is the result of the lower permeability granite which impedes the shallow groundwater flow to the south.

Data suggest that the Monterey Formation also influences shallow groundwater flow as a result of low permeability and variable subsurface topography. These data indicate that groundwater in the Santa Margarita Sandstone generally moves toward the Scotts Valley Syncline where the Monterey Formation is at its lowest elevation, and discharges into Bean Creek. This flow path is complicated by the erosional irregularity of the top of the Monterey (or the granite where directly beneath the Santa Margarita Sandstone). For example, where the top of the Monterey is high, the saturated thickness in the Santa Margarita Sandstone is lessened and where the Monterey or granite rise above the regional water table, the Santa Margarita Sandstone is unsaturated. The Bean Creek fault does not appear to directly influence the shallow groundwater system directly, as most of the offset on the Bean Creek fault likely occurred prior to the deposition of the Santa Margarita Sandstone. However, fault movement likely influenced the erosion of the Monterey and the subsurface elevations of the granite, which appear to impact groundwater flow.

Although data are limited, the movement of groundwater in the confined groundwater system appears similar to the shallow groundwater system. Groundwater in the Lompico Sandstone is thought to flow toward the center of the basin and then leak upward into the overlying Monterey Formation. Unlike the shallow system, the confined groundwater is influenced by the Bean Creek fault. Geologic mapping suggests some 450 feet of offset, placing Lompico Sandstone on the southern (upthrown) side of the fault partially against Monterey Formation on the northern (downthrown) side of the fault. This condition may hinder groundwater movement in the Lompico across the fault due to a lesser saturated thickness and the lower permeability of the Monterey Formation.

Revision of the Groundwater Flow Model

The AMBAG model was developed in the early 1990s for numerical simulation of groundwater flow in the Santa Margarita Groundwater Basin. Although the AMBAG model was a result of considerable effort, its use as a groundwater management tool has been limited. As part of this study, modifications were made to the AMBAG groundwater flow model to incorporate recently collected and/or reinterpreted data characterizing aquifer geometry, hydraulic characteristics, and well pumpage in the vicinity of SVWD. This allows for increased accuracy and expanded use of the model by SVWD in addressing groundwater management issues.

MODEL DOMAIN AND BOUNDARY CONDITIONS

The original model domain as used by the AMBAG model was retained, with a block centered finite-difference grid comprised of 55 rows and 61 columns (Figure 6). Previous dimensions of all model cells within the grid were also retained without change. Original delineation of boundary conditions was based on the assumption that hydrologic boundaries systematically coincide with geologic boundaries. Boundary conditions were, in general, kept consistent with those used in the AMBAG model. An exception is in the southern portion of the model domain; here the geologic mapping performed for this study shows that the Monterey and Lompico formations do not extend as far south as previously indicated and are limited by shallow granite. The boundary conditions for these two units were revised accordingly.

AQUIFER GEOMETRY AND CHARACTERISTICS

As in the original AMBAG model, three layers were used to represent the Santa Margarita, Monterey, and Lompico formations. Layer 1 represents the Santa Margarita Formation as an unconfined aquifer.

Layer 2 represents the Monterey Formation as an unconfined aquifer in areas where the base of the Santa Margarita Formation is above the water table, and as a confined aquifer in other areas where the water table occurs in the Santa Margarita Sandstone. Consistent with the AMBAG model, Layer 3 was used to represent the Lompico Formation as a confined unit.

Elevations along the base of the Santa Margarita Formation were revised in the model. This revision was based on reevaluation of the top of the Monterey Formation (see Figure 5) and granitic rocks (see Figure 3) where these surfaces coincide with the base of the Santa Margarita. Accordingly, elevations of the top of the Monterey Formation also were revised in the model based on Figure 5. The saturated thickness of the Monterey Formation was estimated based on

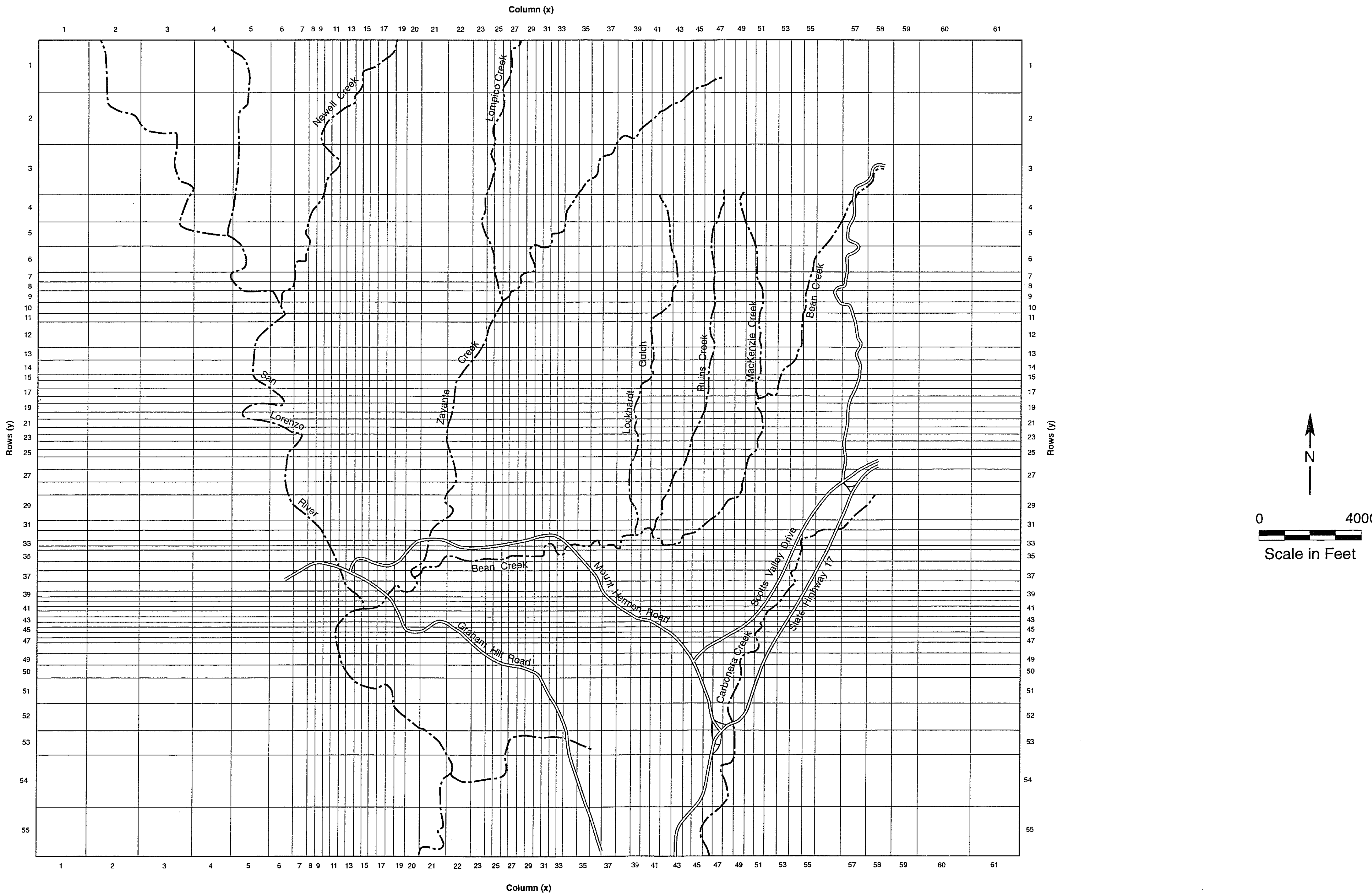

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Figure 6
Model Grid

the structure contour map of the top of the Lompico Formation (Figure 4) and that of the top of the Monterey Formation (Figure 5), plus groundwater level information.

For this study, aquifer characteristics including hydraulic conductivity also were reviewed. The recent Glenwood drilling and testing program yielded information on hydraulic conductivity for the newly installed Test Well 19. This information was combined with existing well data from sixteen additional wells with sufficiently-detailed pumping test data to derive hydraulic conductivity values for either the Santa Margarita Sandstone or Lompico Sandstone. Analysis of this information for the Santa Margarita Sandstone indicated a revised average hydraulic conductivity of 40 gallons per day per square foot.

For the Lompico Formation, an average hydraulic conductivity of 7 gallons per day per square foot was estimated. No reliable data on Monterey Formation characteristics are available; accordingly, a hydraulic conductivity of 0.5 gallons per day per square foot was estimated based on existing values in the AMBAG model and the calibration process.

Vertical conductance or leakance between Layers 1 and 2, and Layers 2 and 3 were estimated based on the previously defined hydraulic conductivities and saturated thicknesses derived from the newly generated structure contour maps. It should be noted that the influence of faults on groundwater flow (because of offsets of the Lompico and Monterey Formations) were accounted for within the model domain through the resulting disruption in the saturated thickness of the formations.

Review of available aquifer test data indicated that information on storativity is scarce; accordingly, storativity values were kept consistent with the original AMBAG model.

AQUIFER STRESSES

Representation of well pumpage (aquifer stresses) in the AMBAG model was revised based on updated records for the SVWD and SLVWD Pasatiempo wells, in addition to improved estimates for other major pumpers. The major pumping wells and their respective pumping rates are summarized in Table 1 along with the well locations in terms of the model grid rows and columns. Future well pumpage rates were estimated based on future water demand, plans for redistribution of pumpage and new well development, and plans for reduction in pumpage in response to planned wastewater recycling projects. Details of these pumping rates are discussed in detail in the Model Application section of this report.

AQUIFER-STREAM INTERACTION

This study included review of the AMBAG model's capability to simulate the interaction of local streams with the aquifers. Accordingly, alternative methods of simulating streams in the model were reviewed in light of available information on streams. In addition, the major streams in the area, Carbonera and Bean creeks, were inspected in the field. The field inspection revealed considerable variability in creek geometry. This along with a lack of field information on creek channel conductance did not allow proper representation using sophisticated modeling packages. Accordingly, simulation of Bean Creek and Carbonera Creek was maintained as in the AMBAG model, with minor changes in conductance and elevation of creek beds during the model calibration process in order to achieve field measured groundwater levels. All other creeks and streams that occur in the Santa Margarita groundwater basin were simulated as in the AMBAG model.

Table 1

Major Pumping Wells

Well Names	Row	Column	Current Pumping Rate acre-feet/year
Scotts Valley Water District			
No. 9 City Hall	37	42	200
No. 10 Businessmmen's	39	43	300
No. 11 Lompico	33	53	375
No. 7A	23	60	700
No. 3B	27	59	1
San Lorenzo Valley Water District			
Olympia 1	22	27	0
Olympia 2	21	29	200
Olympia 3	21	32	0
Pasatiempo 5 (New Probation)	49	28	5
Pasatiempo 6	48	27	45
Pasatiempo 7	49	30	200
Watkins Johnson			
Supply	38	41	30
RA 1,2	37	41	80
RA 3	36	40	80
RA 4	36	41	45
Mount Hermon Conference Center			
Mt. Hermon 1	47	23	55
Mt. Hermon 2	47	23	125
Kaiser Sand & Gravel			
Kaiser 2	39	37	30
Kaiser 3	39	37	150
Kaiser 4	51	32	205
Other Major Wells			
Spring Lakes 5	48	38	100
Vista del Lago	50	40	30
Manana Woods	42	41	70
Mission Springs	26	39	15
Fern Grove Club	49	35	10
Montevalle 3	36	43	10
Silverking	34	36	65
Interdesign	41	55	10
Valley Gardens	45	39	55
TOTAL:			**3,200**

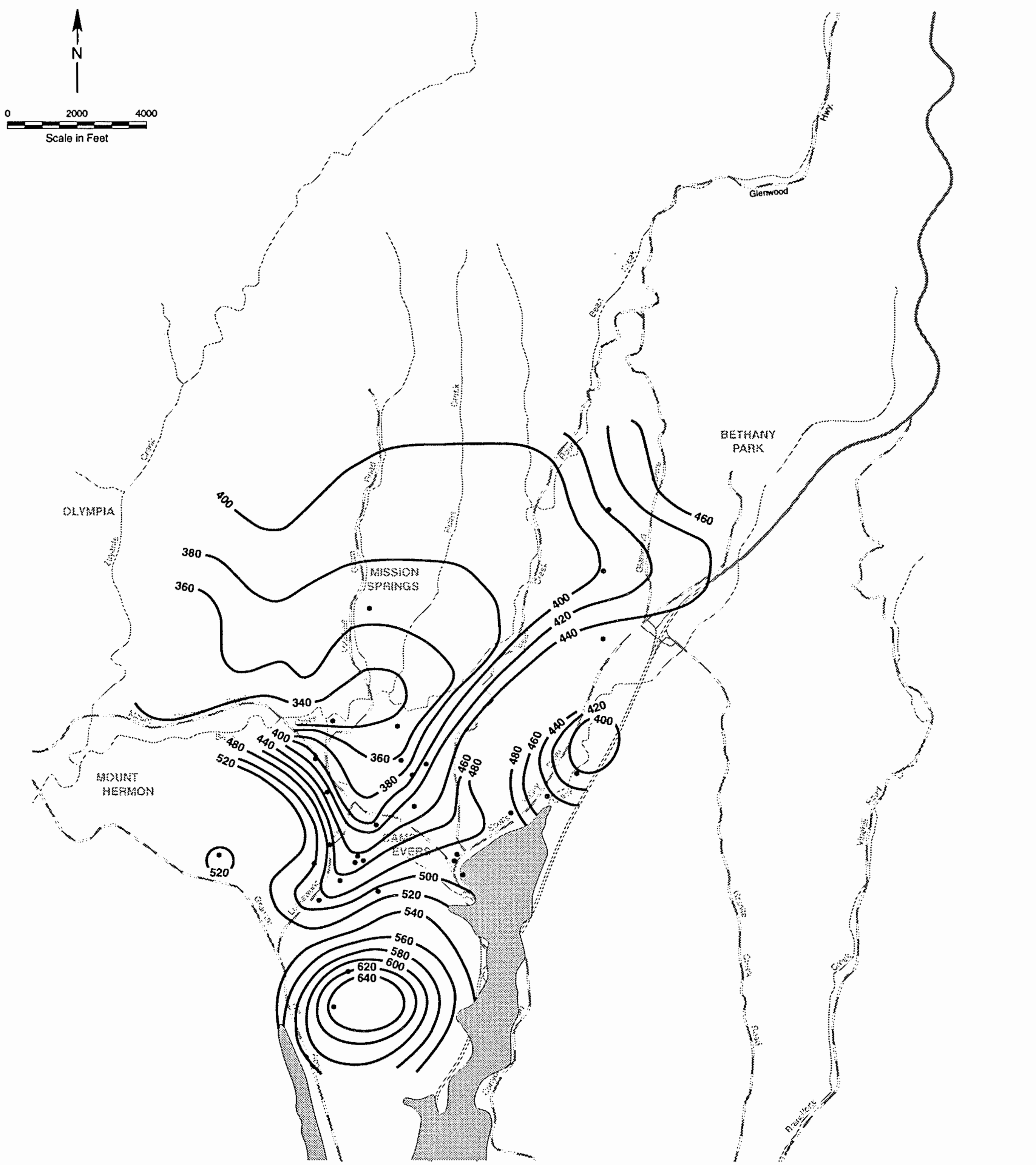
MODEL CALIBRATION

The AMBAG model was revised to improve its capability to simulate future conditions given selected scenarios. However, before such simulations could be performed, a reasonable match between simulated and observed groundwater levels needed to be achieved. The calibration process involved adjusting aquifer characteristics and recharge conditions, yielding minimal difference between simulated and observed water levels.

Figures 7 and 8 depict water level contour maps for the Santa Margarita and Lompico formations reflecting average conditions over the period 1985-1995. These water levels served as targets for steady-state calibration of the model. During the calibration process, recharge from Carbonera Creek and aquifer hydraulic transmissivity values were adjusted to reduce the difference between simulated water levels and those selected as calibration targets.

Although the calibration effort encompassed the entire model domain, calibration was focused on areas managed and potentially affected by Scotts Valley Water District. Based on previous model calibration and verification efforts associated with the original AMBAG model, the model is capable of predicting regional groundwater flow patterns within the basin with relative accuracy. In addition, model capabilities to simulate local conditions in Scotts Valley Water District were enhanced, owing to this study's focused revision and recalibration of the model.

Table 2 summarizes the comparison of average field measured water levels and those simulated by the model for selected wells. Table 2 shows the accuracy of the model with respect to the *magnitude* of impacts. As indicated, the mean difference between simulated and observed water levels for the selected wells is 0.8 feet. An additional issue concerns the *timing* of when estimated drawdowns occur. Such time-related or transient model results are sensitive



LEGEND

- Well
- Granite outcrop

Figure 7
Water Table Contour Map Santa Margarita Formation

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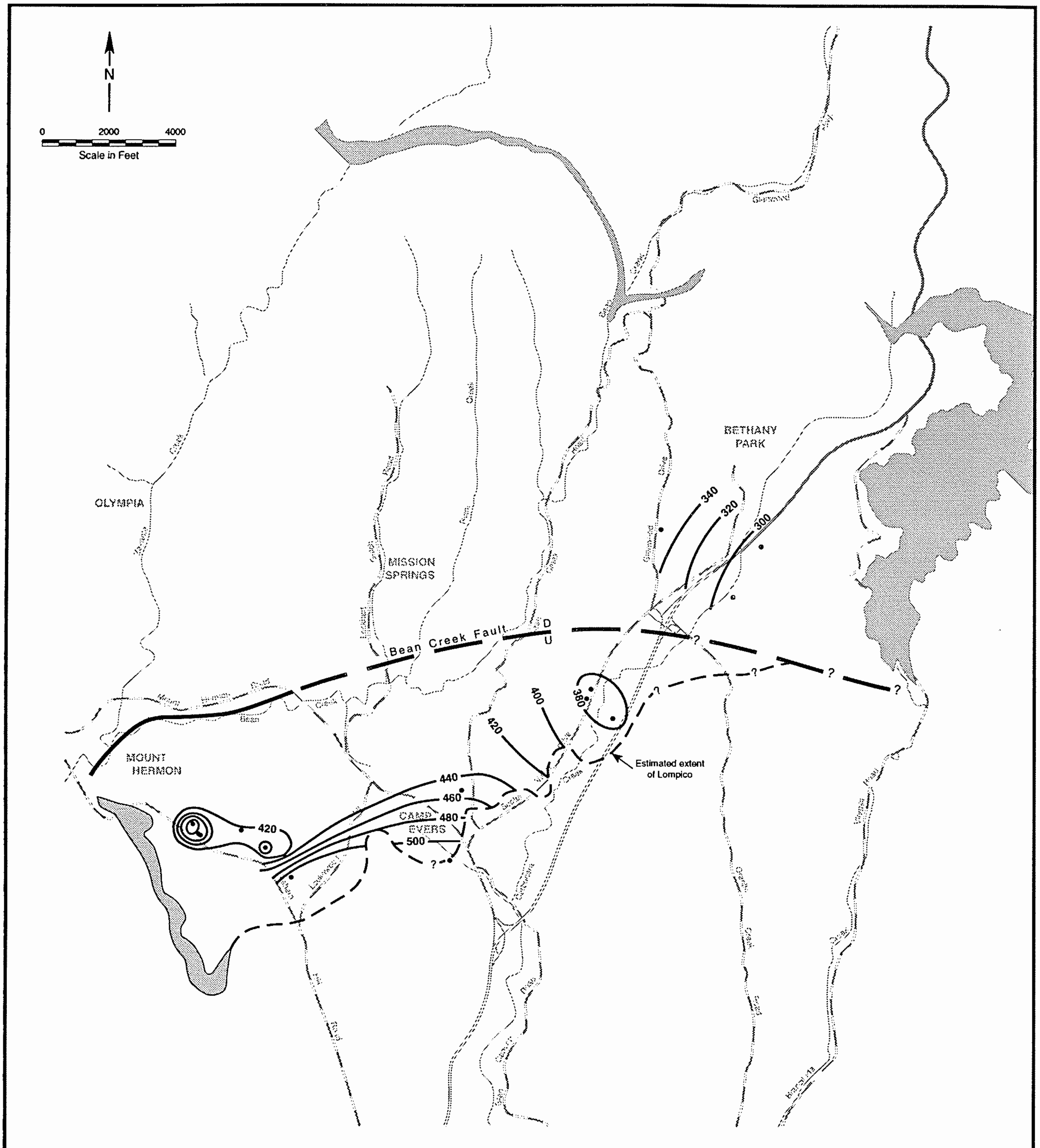

LEGEND

- • Well
- Surface outcrop of Lompico

Figure 8
Water Table Contour Map Lompico Sandstone

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Table 2

Model Calibration Results, Feet

Well Name	Average Measured Water Level	Simulated Water Level	Difference
Pasatiempo 7	398	398	0.0
Manana Woods	420	419.1	0.9
9 City Hall	420	421.4	1.4
10 Businessmens	400	401.0	1.0
7 El Pueblo	374	373.1	0.9
11 Lompico	361	360.2	0.8
7A SVWD	284	283.1	0.9
3B SVWD	289	288.4	0.6
		mean difference =	0.8

to aquifer storage values, which can be fine-tuned if an adequate database were available documenting changes over time in water levels and pumping together with field measured values of aquifer storage. Review of available water level data and field-measured storativity values indicated that such information is not sufficient to improve the model in its ability to simulate time-related events and to perform a new transient calibration and validation. As noted previously, storativity values remained unchanged from the original model. The revised model is comparable to the original model in its ability to simulate time-related events.

Model Application

A major objective of the original AMBAG modeling effort was to place the model into the hands of the parties most directly responsible for management of the Santa Margarita groundwater basin resources. The model application summarized in this section represents the hands-on use of the model by SVWD to address a variety of water management issues facing SVWD.

DESCRIPTION OF SCENARIOS

Six scenarios were defined to address a variety of issues that concern SVWD. These issues are expressed below in terms of broad questions, followed by the relevant scenario(s).

Issue: What is the effect on groundwater levels of continuing current pumping amounts at current locations with no additional groundwater development or management?

Scenario 0. Current Pumping into the Future. This baseline scenario presumes no change in the current pumping pattern and predicts the future steady-state water levels resulting from no new action.

Issue: What is the effect on groundwater levels, particularly in Camp Evers, of redistributing SVWD pumpage to north Scotts Valley?

Scenario1. Redistribution of Pumping among Existing SVWD Wells. This scenario is based on current pumping demand, and involves reduction of pumping of Wells 9 and 10, compensated by an increase in pumping of Well 3B.

Issue: What will be the effect on groundwater levels of developing new wells to meet increasing demand? Will two new wells at recent test drilling sites be able to capture sufficient recharge for sustained use? What are the effects on Bean Creek?

Scenario 2. Development of New Wells to Meet 2006 Water Demand. In this scenario, water demand increases to allow for 700 new connections and a new high school. Two new wells (9A and 10A) are installed, yielding a combined 450 AFY, with locations at test sites 16 and 17, 16 and 18, and 17 and 18, respectively.

Issue: What will be the effect on groundwater levels of artificial recharge in Carbonera Creek, given future growth in water demand and future well development?

Scenario 3. Implementation of Surface Water Replenishment. This scenario builds upon the increased water demand and well development of Scenario 2, and includes a program of artificial surface water replenishment in the Carbonera Creek channel.

Issue: What will be the effect of the planned water recycling project on groundwater levels, given future growth in water demand and future well development? Will the recycling project result in water level recovery in the Camp Evers area? What is the effect on groundwater levels of Kaiser's participation in the recycling project?

Scenario 4. Implementation of Water Recycling. This scenario also builds on Scenario 2, with increase water demand and new wells. The focus is on implementation of the wastewater recycling project, which involves provision of wastewater instead of groundwater for irrigation and industrial purposes (EOA, May 1996). Phase 1 of the wastewater recycling project, involving reduction in pumping of 460 AFY, is simulated. The effects on groundwater of the recycling project also are simulated without participation by Kaiser Sand & Gravel Company, in other words, anticipating loss of the single largest customer. Phase 2 of the recycling project also is simulated, involving additional wastewater irrigation and reduction of pumping by an additional 200 AFY.

Issue: What will be the impact of a future drought if recycling and recharge are not implemented?

Scenario 5. Evaluation of Drought Impacts. This scenario simulates a 5-year drought like 1986-1991 with a Scenario 2 water demand and SVWD water system, but no wastewater recycling and no artificial replenishment.

Issue: What does safe or perennial yield mean in Scotts Valley? What might be the potential impacts of total pumpage reaching the estimated safe yield of 4,200 AFY?

Scenario 6. Exploring Perennial Yield. This scenario simulates impacts of a hypothetical pumping pattern amounting to 4, 200 AFY. This scenario builds upon Scenario 2, then increases pumpage to 4,200 AFY, with no wastewater recycling and no artificial replenishment.

SIMULATION RESULTS

Specific descriptions and results of the six scenarios are described in the paragraphs below. Results of each scenario are expressed in terms of groundwater level changes relative to current groundwater levels, unless specified otherwise. Several of the future scenarios are defined assuming future installation and use of Wells 9A and 10A. In these cases, comparison is made to this future baseline situation in order to isolate the effect of the specific scenario. Positive scenario results indicate a relative rise in groundwater levels, while negative values indicate a decline. To allow comparison of results among scenarios, five key wells were selected to show results (see Figure 1). These key wells include:

9 City Hall	3B SVWD
10 Businessmens	7A SVWD
11 Lompico	

It should be noted that although the model's capability to simulate conditions in the vicinity of the Scotts Valley Water District wells has been improved, the best use of the model is relative comparison of the magnitude of groundwater impacts among scenarios. Only secondary emphasis should be placed on the timing of impacts. Results of scenarios are reported for steady-state conditions. Steady-state groundwater conditions describe when groundwater levels and flow are constant over time, indicating a balance between recharge and discharge, for example, between well pumpage and groundwater recharge to that well.

Scenario 0. Continuation of Current Pumping into the Future. Scenario 0 is a no-action scenario that involves continuation of current pumping rates and distribution into the future. This scenario includes no new wells, no increase in pumping, and no artificial recharge or wastewater recycling.

Table 3 summarizes the impacts of the no-action scenario for the key wells plus Manana Woods well. For wells in the Camp Evers area (Wells 9, 10, and Manana Woods) the simulation indicates that continuation of current pumping will result in additional groundwater level declines amounting to 20 to 32 feet before a steady-state equilibrium is achieved and water levels stabilize. Such declines will result in partial exposure of the uppermost screens in the Manana Woods and 10 Businessmens Wells; the uppermost screens in Well 9 City Hall already are exposed. Exposure of screens results in decline in well efficiency. Additional groundwater level declines exceeding 30 feet also are indicated in the El Pueblo/Scotts Valley Drive area (Wells 7 and 11) and in north Scotts Valley (Wells 3B and 7A). However, with the exception of the non-producing Well 7El Pueblo, screens are deep in these wells and would not be exposed.

Table 3

Scenario 0 - Continuation of Current Pumpage Into Future
(compared to current water levels)

Well Names	Water Level Change (ft)
Manana Woods	-20
9 City Hall	-20
10 Businessmens	-32
7 El Pueblo	-19
11 Lompico	-33
3B SVWD	-38
7A SVWD	-51

Scenario 1. Redistribution of Pumping among Existing SVWD Wells. This scenario assumes current pumping demand, but redistributes SVWD pumping out of Camp Evers, where significant water level declines have occurred. Pumping is reduced through cessation of summer pumping in Wells 9 and 10. Pumping of Well 3B is increased to compensate. Well 7A is pumped as the foremost well, consistent with current practice.

Table 4 reveals the results of Scenario 1 in terms of changes in water levels observed at key wells relative to current water levels. As indicated, redistribution of pumpage from the 9 City Hall and 10 Businessmens wells results in water level recoveries in these wells of 12 and 22 feet, respectively, relative to current levels. It is also instructive to compare the results of Scenario 1 with those of Scenario 0, which simulates future conditions with no change in pumping. As noted above in Table 3, Wells 9 and 10 are forecasted to decline in Scenario 0 by 20 and 32 feet, respectively. If the pumping is redistributed as in Scenario 1, the total benefit or increase in water levels in these two wells would be 32 (12 + 20) and 54 (22 + 32) feet higher, respectively, than the levels given the pumping pattern in Scenario 0. With respect to the Scenario 0 future levels, a minimal recovery of 3 feet would be observed in the Manana Woods well.

Table 4

Scenario 1 - Redistribution of Pumping
(compared to current water levels)

Well Names	Water Level Change (ft)
Manana Woods	-17
9 City Hall	12
10 Businessmens	22
11 Lompico	-43
3B SVWD	-78
7A SVWD	-73

While the Scenario 1 change in pumping patterns increases water levels in Camp Evers, the increased pumpage of Well 3B decreases water levels by 78 feet relative to current levels, or by 40 feet relative to future levels if no action is taken. This increased pumpage results in interference with the Well 7A, eventually declining its water level by 73 feet relative to current levels, or an additional 22 feet relative to the no-action Scenario 0.

Scenario 2. Development of New Wells to Meet 2006 Water Demand. In Scenario 2, water demand is increased as tabulated below, including 700 new connections and a new high school. Two new wells (9A and 10A) are simulated, yielding a combined 450 AFY, with three well site options. **Scenario 2A** involves locating the wells at test sites 16 and 17 pumping from the Lompico Sandstone. Site 16 corresponds to the location of Test Hole 16 (see Figure 1), while Site 17 refers to the planned location of a test hole near lower Bean Creek (see Figures 1 and 6, model grid row 31, column 42). **Scenario 2B** involves wells at Site 17 and near Test Hole 18 (see Figure 1). **Scenario 2C** has wells at Sites 16 and 18, pumping from the Lompico Sandstone and Santa Margarita Sandstone, respectively. Well 9A comes online in 1999-2000 and Well 10A is online in 2002-2003.

Year	Connections	Water Demand, AFY	
	Added	Added	Total
1996	87	56	1656
1997	50	32	1688
1998	226	144	1832
1999	168	108	1940
2000	85	54	1994
2001	43	28	2022
2002	10	6	2028
2003	10	6	2034
2004	10	6	2040
2005	10	6	2046
Total	699	446	

Scenario 2A. Table 5 shows the results of Scenario 2A relative to current water levels. As indicated, development of new wells at Sites 16 and 17 (combined pumping rate of 450 AFY from the Lompico) results in drawdowns of 17 and 13 feet in each of the new wells, respectively. The impact on the SLVWD Pasatiempo 7 well, amounting to five feet, is noted because site 17 is located in the lower Bean Creek area near Camp Evers. The SVWD wells in Camp Evers, Wells No. 9 and No. 10, show declines of 27 and 36 feet, respectively. However, Scenario 0 indicates that most of this decline would occur with no action. For example, with no action groundwater level declines of 20 feet are predicted to occur in Well 9; with the additional pumping in this scenario an additional decline of 7 feet is predicted to occur. Similarly, water level declines in wells 3B, 7A, and 11 would exceed 40 feet; however, comparison with Scenario 0 indicates that declines exceeding 30 feet occur even with the no-action scenario.

Table 5

Scenario 2A - New Wells at Sites 16 and 17 to Meet 2006 Water Demand
(compared to current water levels)

Well Names	Water Level Change (ft)
Site 17	-13
Site 16	-17
Pasatiempo 7	-5
9 City Hall	-27
10 Businessmens	-36
11 Lompico	-41
3B SVWD	-49
7A SVWD	-58

Scenario 2B. Table 6 summarizes changes that would occur with pumpage of 450 AFY from new wells at sites 17 and 18, extracting groundwater from the Lompico and Santa Margarita aquifer, respectively. As indicated, development of new wells at sites 17 and 18 results in a 7-foot decline in water levels at the Pasatiempo 7 well. In this scenario, Wells 9 and 10 experience declines of 25 and 34 feet, respectively. However, comparison with Scenario 0 indicates that all but a few feet of this decline would occur with no action. As in Scenario 2A, water level declines of 40 feet or more occur in SVWD Wells 3B, 7A, and 11; but most of this decline also would have occurred under the no-action Scenario 0.

Table 6

Scenario 2B - New Wells at Sites 17 and 18 to Meet 2006 Water Demand
(compared to current water levels)

Well Names	Water Level Change (ft)
Site 17	-17
Site 18	-68
11 Lompico	-7
Pasatiempo 7	-27
9 City Hall	-36
10 Businessmens	-40
3B SVWD	-46
7A SVWD	-59

Scenario 2B originally was simulated with a hypothetical well at the Test Hole 18 site (see Figure 1). However, drawdowns in the Santa Margarita Formation were excessive, so the hypothetical well was moved south to the axis of the Scotts Valley Syncline, where a greater saturated thickness is expected. Pumping at a rate of about 115 gpm of a well at this modified Site 18 was successful and resulted in a water level decline of 38 feet in that well.

Scenario 2C. Table 7 summarizes results of Scenario 2C relative to current water levels. With regard to changes in the Lompico Formation, water level impacts on the Pasatiempo 7 well are negligible. Water level declines in the new well at Site 16 amount to 14 feet, while declines from today are in the range of 38 to 54 feet in SVWD Wells 3B, 7A, and 11. However, as noted before, all but 3 to 5 feet of this decline is predicted to occur even with the no-action Scenario 0. Declines in Wells 9 and 10 are also similar to those in Scenario 2B. Pumpage from the modified site 18 well (at approximately 115 gpm) in the Santa Margarita Formation reveals a decline in well water levels of 37 feet, essentially identical to Scenario 2B.

Table 7

Scenario 2C - New Wells at Sites 16 and 18 to Meet 2006 Water Demand
(compared to current water levels)

Well Names	Water Level Change (ft)
Site 16	-14
Site 18	-67
Pasatiempo 7	-2
9 City Hall	-27
10 Businessmens	-36
11 Lompico	-38
3B SVWD	-46
7A SVWD	-54

Table 8 compares the results of Scenarios 2A, 2B, and 2C, in addition to Scenario 0. All three scenarios reach equilibrium, indicating a sustainable supply, with minimal impacts (less than five percent decline) on Bean Creek. The water level effects on the Lompico Formation are generally comparable among all three scenarios, although impacts are greatest for Scenario 2A, which relies solely on the Lompico Formation. Between Scenarios 2B and 2C, the latter appears to have slightly less impact on existing wells Lompico 11, 3B, and 7A; however, this difference probably is too small to be significant. For purposes of consideration of other future scenarios, Scenario 2B was selected to serve as the presumed development scenario for the future. Scenario 2B was selected over Scenario 2A because it utilizes both the Santa Margarita and Lompico formations for supply, consistent with the SVWD practice of distributing pumpage. Site 17 was selected over Site 16 (Scenario 2C) because of its relative proximity to existing SVWD facilities.

Table 8
Comparison of Scenario 2 Results, Change in Water Levels, Feet

Well Names	Scenario 0	Scenario 2A	Scenario 2B	Scenario 2C
Site 16	n.a.	-17	n.a.	-14
Site 17	n.a.	-13	-17	n.a.
Modified Site 18	n.a.	n.a.	-68	-67
Lompico 11	-33	-41	-40	-38
SVWD 3B	-38	-49	-46	-46
SVWD 7A	-51	-58	-59	-54

Scenario 3. Implementation of Surface Water Replenishment. In Scenario 3, water demand is increased and well development occurs as in Scenario 2B. Surface water replenishment is initiated in 1999, with an additional 100 AFY of recharge from the Carbonera Creek channel between El Pueblo and Disc Drive.

Table 9 shows the results of Scenario 3. In this scenario, water level changes are relative to the levels resulting from development of new wells to meet 2006 demand as simulated in Scenario 2B. This allows discrimination of the specific impacts of the recharge program. As indicated, implementation of surface water replenishment combined with the well development in Scenario 2B results in negligible recoveries of two feet or less. It should be noted that results of this scenario are affected by the size of model cells and leakage estimates used in the model. Reevaluation of this scenario may be warranted with future improvement of the model.

Table 9

Scenario 3 - Surface Water Replenishment
(compared to Scenario 2B water levels)

Well Names	Water Level Change (ft)
Pasatiempo 7	0
9 City Hall	0
10 Businessmens	0
6 SVWD	1
7 El Pueblo	2
11 Lompico	0
3B SVWD	1
7A SVWD	1

Scenario 4. Implementation of Water Recycling. Scenario 4 was subdivided into three scenario runs in order to address the specific issues involving Phase 1 effects, significance of Kaiser participation, and Phase 2 effects. **Scenario 4A** involves the increase in water demand and well development as in Scenario 2B and implementation of the Phase 1 water recycling project with startup of wastewater irrigation in June 1998. As a result of water recycling, pumping is reduced by 460 AFY by turning off the wells listed below.

Well	Pumping Rate, AFY
Kaiser No. 2	29
Kaiser No. 3	153
Kaiser No. 4	206
Valley Gardens	54
Seagate	5
SVWD Wells 9, 10, 11	249

Scenario 4B describes the Phase I recycling project anticipating loss of the single largest customer, Kaiser Sand & Gravel. In this scenario, water demand, well development, and Phase I water recycling occurs as in Scenario 4A without reduction of pumping by Kaiser. **Scenario 4C** builds on the Phase 1 water recycling in Scenario 4A and implements Phase 2 to further reduce pumping. Phase 2 starts in the year 2000 and entails cessation of pumping from two wells, Springlakes No. 5 (125 acre-feet/year) and Montevalle No. 3 (8 acre-feet/year). In addition, SVWD pumping is reduced by 75 AFY, with reduction distributed among existing SVWD wells.

Scenario 4A. Results of Scenario 4A are shown in Table 10. As noted previously, this scenario is built on Scenario 2B and and thereby presumes development of pumpage to meet 2006 demand. As shown, reduction of pumpage by 460 AFY as part of the Phase 1 Water

Recycling results in water level recoveries from current water levels, most notably in the Pasatiempo 7 well and 10 Businessmens well. Small water level changes of two feet in wells 7 El Pueblo and 9 City Hall well also are indicated. Declines in the Lompico 11, 3B, and 7A wells are similar to those predicted in Scenario 0 (current pumping rates into the future) and are five to nine feet less than those predicted to occur in Scenario 2B. Accordingly, implementation of water recycling lessens the water level impacts that would occur with the increase in pumping predicted for the year 2006.

Table 10
Scenario 4A - Phase 1 Water Recycling
(compared to current water levels)

Well Names	Water Level Change (ft)
Pasatiempo 7	4
9 City Hall	2
10 Businessmens	9
7 El Pueblo	2
11 Lompico	-31
3B SVWD	-40
7A SVWD	-54

Scenario 4B. Table 11 contains the results of Scenario 4B, which considers the Phase I recycling program without participation by Kaiser Sand & Gravel. A small water level increase still occurs in 10 Businessmens well, but is essentially the same change as shown in Scenario 4A. However, without participation by Kaiser, a small water level decline occurs in Pasatiempo 7 instead of recovery. Changes in the remaining wells are similar to the changes simulated in Scenario 4A.

Table 11
Scenario 4B - Phase 1 Water Recycling without Kaiser
(compared to current water levels)

Well Name	Water Level Change (ft)
Pasatiempo 7	-2
9 City Hall	1
10 Businessmens	8
7 El Pueblo	-1
11 Lompico	-28
3B SVWD	-41
7A SVWD	-54

Scenario 4C. Table 12 summarizes the water level results of Scenario 4C, which includes the Phase 1 and Phase 2 recycling projects. The benefits of recycling are most apparent in Well 10, where a significant reduction in pumping would be possible if wastewater were available for irrigation and industrial purposes. Small increases in water levels are also indicated for the Pasatiempo 7, 9 City Hall, and 7 El Pueblo wells. Declines are predicted to occur in the 11 Lompico and north Scotts Valley 7A and 3B wells. However, these declines are several feet less than would occur in the no-action Scenario 0 and six to ten feet less than would occur if water demand and pumping continued to increase without recycling as in Scenario 2B (see Table 6). It should be noted that the scenario was defined with significant decreases in pumping of Wells 10, 9, and 11 in order to provide water level recovery in Camp Evers. A different pumping pattern could be defined to focus the water level recovery elsewhere or to distribute the benefit evenly among SVWD wells.

Table 12

Scenario 4C - Phases 1 and 2 Recycling
(compared to current water levels)

Well Names	Water Level Change (ft)
Pasatiempo 7	4
9 City Hall	4
10 Businessmens	15
7 El Pueblo	2
11 Lompico	-30
3B SVWD	-40
7A SVWD	-53

Scenario 5. Evaluation of Drought Impacts. This scenario involves simulating a 5-year drought (1986-1991 conditions) with 2006 water demand and a SVWD water system with Wells 7A, 3B, 11A, 9A and 10A, with backup Wells 10 and 11 (in order of preference), but no recycling and no recharge.

The 1986-1991 drought was characterized by a 45 percent decline in average annual rainfall. Scenario 5 simulates the effect of such a severe, prolonged drought occurring after the year 2006 with increased water demand, but no water recycling and no recharge. In addition, no decrease in pumping because of water conservation efforts is included. Table 13 summarizes the results of Scenario 5. As shown, a drought with such conditions results in water level declines ranging from 27 to 80 feet in the key wells. The water level in Well 10 Businessmens declines below the perforated interval in the Santa Margarita Formation. In addition, flow in Bean Creek is reduced by approximately 50 percent.

Table 13

Scenario 5 - Five Year Drought After 2006
(compared to current water levels)

Well Names	Water Level Change (ft)
Pasatiempo 7	-34
9 City Hall	-27
10 Businessmens	-40
11 Lompico	-62
3B SVWD	-72
7A SVWD	-80

Scenario 6. Exploring Perennial Yield. Groundwater development is simulated as in Scenario 2B, then pumpage is increased to 4,200 AFY, with no wastewater recycling and no artificial replenishment. In this hypothetical case, three new wells (X, Y, and Z) are installed in an east-west alignment just north of lower Bean Creek (see Figures 1 and 6, model grid, row 28, columns 38, 43, and 49). These wells are screened in the Santa Margarita Sandstone and are intended to intercept groundwater that is recharged in the northern portion of the Santa Margarita groundwater basin.

Table 14 summarizes the results of this hypothetical future case relative to water levels that would occur in the future if current pumping were continued into the future with no recycling or recharge (Scenario 0). It should be noted that this scenario is intended to simulate pumping near the perennial yield limit of the basin and to explore the impacts that would occur as pumping approaches the perennial yield. The impacts simulated by the model include drawdowns in wells and effects on Bean Creek flow. No attempt was made to determine an optimal groundwater development system with extraction at these rates; in other words, modifying well locations or pumping rates to minimize impacts on Bean Creek or to derive acceptable drawdowns in key wells.

Table 14

Scenario 6 - Exploring Perennial Yield
(compared to Scenario 0 water levels)

Well Names	Water Level Change
X	-23
Y	-32
Z	-30
Site 17	-18
Site 18	-48
Pasatiempo 7	-7
9 City Hall	-29
10 Businessmens	-38
7 El Pueblo	-6
11 Lompico	-7
3B SVWD	-8
7A SVWD	-8

Simulation of Scenario 6 indicates that the three hypothetical wells (X, Y, and Z) are capable of sustained production with drawdowns of 23 to 32 feet. The well screened in the Lompico Formation at Site 17 shows a similar drawdown to the drawdown predicted in Scenario 2B, while the well screened in the Santa Margarita Formation at Site 18 shows a drawdown that is ten feet greater than that predicted in Scenario 2B. This reflects the effect on the Site 18 well of the pumping at the three hypothetical wells X, Y, and Z.

Table 14 shows that the effect of this scenario on the remaining wells ranges from 6 to 38 fee, with the most significant drawdowns occurring in Wells 9 and 10. It should be noted that these water levels are relative to the no-action Scenario 0, which predicts drawdowns in the key wells continuing into the future. Accordingly, Table 14 shows the additional drawdown that would occur with this scenario. For example, the Scenario 0 drawdown in Well 10 Businessmens is 32 feet; the effect of this scenario is to increase that drawdown to 70 feet (38 + 32). This amount of drawdown is not practical from an operation standpoint. However, it should be noted that this scenario was not intended to design a practical groundwater development system, but instead was intended to illustrate impacts of pumping at rates near the safe yield limit without water recycling or recharge. Given the operational system simulated in Scenario 6 with hypothetical wells X, Y, and Z, an adverse impact is excessive drawdown in Wells 9 and 10. In addition, this scenario resulted in a reduction of Bean Creek flow by 38 percent, which would entail significant impacts on downstream habitats, surface water quality, and water rights.

SUMMARY

Table 15 summarizes all six scenarios in terms of the impacts on water levels in selected wells. As noted before, the best use of the model is relative comparison among the results of the simulations. Given data limitations, particularly with regard to storativity, simulation results are expressed in terms of water levels when a steady-state condition is achieved and not in terms of specific timing of water level changes.

Results of the no-action Scenario 0 indicate that additional declines in groundwater levels can be expected from current pumping before stabilization occurs. This is particularly apparent in the newer north Scotts Valley wells (3B and 7A) where pumping has been initiated most recently. Not surprisingly, additional pumping will result in further declines, as simulated in Scenario 2 (2006 water demands and pumping). Results of Scenario 1 (pumping distribution) and Scenario 4 (water recycling) show that alleviation of groundwater level declines in any particular well is best achieved through reduction of pumping in that well. Reduction of pumping in one or more nearby wells may yield only small benefits to the subject well. Nonetheless, Scenario 4 shows that regional reduction of pumping, as can be achieved with water recycling, can result in significant beneficial impacts on water levels. The small amount of water replenishment envisioned in Carbonera Creek (Scenario 3) provided negligible benefits. Scenario 5 imagines a severe and prolonged drought with increased water demands and without

Table 15

Summary of Simulation Results, Water Level Change, Feet
(Compared to current water levels, unless otherwise noted. Negative values indicate decline.)

	Scenario										
	0	1	2A	2B	2C	3*	4A	4B	4C	5	6**
Key Well	No Action	Redis-tribution	Development of New Wells			Replen-ishment	Implementation of Water Recycling			Drought	Perennial Yield
9 City Hall	-20	12	-27	-36	-27	0	2	1	4	-27	-29
10 Businessmens	-32	22	-36	-40	-36	0	9	8	15	-40	-38
11 Lompico	-33	-43	-41	-7	-38	0	-31	-28	-30	-62	-7
3B SVWD	-38	-78	-49	-46	-46	1	-40	-41	-40	-72	-8
7A SVWD	-51	-73	-58	-59	-54	1	-54	-54	-53	-80	-8
Other Wells/Sites											
Manana Woods	-20	-17	-	-	-	-	-	-	-	-	-
7 El Pueblo	-19	-	-	-	-	2	2	-1	2	-	-6
Site 17	-	-	-13	-17	-	-	-	-	-	-	-18
Site 16	-	-	-17	-	-14	-	-	-	-	-	-
Pasatiempo 7	-	-	-5	-27	-2	0	4	-2	4	-34	-7
Site 18	-	-	-	-68	-67	-	-	-	-	-	-48
6 SVWD	-	-	-	-	-	1	-	-	-	-	-
X	-	-	-	-	-	-	-	-	-	-	-23
Y	-	-	-	-	-	-	-	-	-	-	-32
Z	--	-	-	-	-	-	-	-	-	-	-30

*Changes relative to water levels in Scenario 2B.
**Changes relative to Scenario 0.

water recycling, recharge or replenishment. This scenario indicates that, without active management, the impacts on production wells and Bean Creek are severe. Scenario 6, exploration of the concept of perennial yield, illustrates that, while pumping of groundwater near the perennial yield limit may be sustainable, it entails undesirable impacts on wells and Bean Creek.

Results of the simulations, as expected, raise many more questions regarding the best distribution of pumping, the role of recharge and water recycling, the impacts of drought, and the balance between satisfaction of water demands and potential impacts on water resources. The simulations also demonstrate that the groundwater basin model is a useful tool to further explore such issues.

Future Work

FUTURE APPLICATIONS

The application in this project of the Santa Margarita groundwater basin model to selected issues has been revealing with regard to the effects of groundwater development and management scenarios on groundwater levels in key wells and on Bean Creek flows. Only a limited number of scenarios were simulated, reflecting issues currently facing SVWD and providing a variety of applications. Innumerable variations on the selected scenarios exist; further exploration of the scenarios involving distribution of current pumping and development of future wells is warranted. In addition, as the recycling project is defined in greater detail, additional scenarios involving its implementation would be useful in the distribution of its beneficial impacts. Furthermore, potential alternatives for recharge of recycled water may be simulated.

FUTURE RESOLUTION OF DATA GAPS

It is suggested that the model be regularly updated as refinements are made to the conceptual hydrogeologic model of the basin. Specifically, as new wells are installed and tested, data on aquifer geometry, hydraulic conductivity, storativity, and water levels should be incorporated to further refine the model. Furthermore, it is suggested that groundwater pumpage and water level data be continuously collected from available wells throughout the basin, providing a more complete and consistent database for model calibration.

Available data are deficient in three main areas: groundwater levels, storativity values, and aquifer/stream interactions. However, these data gaps can be filled through SVWD's data gathering and groundwater exploration programs and similar activities of other local organizations.

With regard to groundwater levels, data are scarce and localized for the Monterey and Lompico Formations. The absence of such data limits model representation of hydraulic interaction (e.g., leakance) between the three layers and proper calibration with respect to water levels in the Monterey and Lompico formations. This data gap can be remedied by maintaining existing wells screened in those formations as monitoring sites and by adding new wells to the groundwater level monitoring program.

As previously noted in the Model Calibration section of this report, information on storage values is scarce. Storage values describe the usable amount of stored groundwater that can drained or be pumped for a unit volume of aquifer material. Storage values are key to transient calibration of the model and to accurate simulation of groundwater levels over time. Storage values can be obtained through performance of pumping tests on wells with monitoring of an observation well.

As noted in the section Aquifer-Stream Interaction, data on stream geometry and stream channel conductance are lacking. The conductance value is used to represent the hydraulic relationship between a surface water body (for example, a stream) and adjoining groundwater. The model is sensitive to conductance, and field estimation of this value would be necessary to apply sophisticated modeling software to better simulate the interactions of groundwater and surface water. Acquisition of such information likely would involve relatively detailed analysis of streamflow and groundwater levels in streamside wells.

FUTURE ENHANCEMENT OF THE MODEL

Despite the data gaps noted above, a large quantity of pertinent data has been collected to date. Additional information will be collected in the future. Given the quantity of data and precise requirements of computer modeling, a data management system such as a geographic information system (GIS) would be useful in conjunction with the groundwater flow model. Such a system allows for efficient data collection, interpretation, management, and presentation, in addition to aiding in preparation of model input and output.

The existing Santa Margarita groundwater model is limited to simulating groundwater levels and flow. Nonetheless, such a MODFLOW model may be used in conjunction with solute transport models such as MT3D (Zheng, 1990), allowing for simulation of contaminant transport throughout the basin. Output from the groundwater flow model may also be used as input into particle tracking code such as MODPATH (USGS, 1989), in order to evaluate groundwater extraction remediation efforts. Groundwater quality data were not reviewed as part of this study to assess if information on contaminant source areas, releases, and distribution are sufficient for solute transport modeling. Nonetheless, it is likely that transport of known chemical concentrations can be simulated to evaluate potential impacts on wells. In addition to the above, evaluation of management options related to economics (such as optimum placement of wells and problems of policy and water allocation) may be incorporated through joint use of the MODFLOW model with the MODMAN code (GeoTrans, 1991).

Conclusions

1. Reexamination of the geologic framework of the Santa Margarita groundwater basin demonstrates the fundamental importance of the Scotts Valley Syncline in the areal extent and geometry of the main geologic units within the model domain.

2. The geologic analysis suggests that an extension of the Bean Creek fault offsets the granitic basement rock, the Lompico Formation, and the lower Monterey Formation, and may affect groundwater flow through its offset of these units. No other faults are known to be significant.

3. The regional groundwater system is comprised of three major water-bearing zones. Two of these, the Santa Margarita Sandstone and Lompico Sandstone are major aquifers. The third, the Monterey Formation, is an intervening zone of lower permeability.

4. Two hydraulically continuous groundwater systems exist, a shallow unconfined groundwater system occurring primarily in the Santa Margarita Sandstone and a deeper confined system, which is developed for groundwater supply by wells tapping the deep Lompico Sandstone. Groundwater in these two aquifers and the Monterey Shale interact through leakage from one formation to another. Horizontal groundwater flow in all these zones generally is toward pumping wells or lower Bean Creek.

5. Groundwater flow is highly influenced by the surface configuration of the granitic basement rock and Monterey Formation. The Bean Creek fault does not directly influence shallow groundwater flow, but appears to affect groundwater flow in the deeper zones.

6. Revision of the model included revision of boundary conditions and aquifer geometry consistent with the geologic analysis, revision of aquifer characteristics (primarily hydraulic conductivity and transmissivity), and updating of groundwater levels and pumping.

7. The best use of the model is relative comparison among the results of the simulations, expressed in terms of water levels when a steady-state condition is achieved and not in terms of specific timing of water level changes.

8. Results of the no-action Scenario 0 indicate that additional declines in groundwater levels can be expected from current pumping before stabilization occurs. Additional pumping will result in further declines, as simulated in Scenario 2 (2006 water demands and pumping).

9. Results of Scenario 1 (pumping distribution) and Scenario 4 (water recycling) show that alleviation of groundwater level declines in any particular well is best achieved through reduction of pumping in that well. Regional reduction of pumping, as can be achieved with water recycling, can result in significant beneficial impacts on water levels.

10. Scenario 3, involving limited water replenishment in Carbonera Creek, indicated negligible benefits.

11. Scenario 5 (drought) indicates that occurrence of drought with increased pumping but without active management results in adverse impacts on production wells and Bean Creek.

12. Scenario 6, exploration of the concept of perennial yield, illustrates that, while pumping of groundwater near the perennial yield limit may be sustainable, it entails undesirable impacts on wells and Bean Creek.

13. Application of the model to the selected simulations demonstrates that the Santa Margarita groundwater basin model is a useful tool for SVWD to further explore groundwater management issues.

14. Available data are deficient in three main areas: groundwater levels (particularly in the Monterey and Lompico Formations), storativity values, and aquifer/stream interactions. However, these data gaps can be filled through the data gathering and groundwater exploration programs associated with the SVWD groundwater management plan and similar activities of other local organizations.

Recommendations

1. The model should be applied to additional issues and scenarios, including additional scenarios for pumping distribution, well installation, water recycling and recharge.

2. The model should be regularly updated as hydrogeologic information becomes available on aquifer geometry, hydraulic conductivity, storativity, pumpage, and water levels.

3. The relative lack of water level information in the Monterey and Lompico Formations should be remedied by maintaining existing wells screened in those formations as monitoring sites and by adding new wells to the groundwater level monitoring program.

4. Data on storativity should be obtained through performance of pumping tests on wells with monitoring of an observation well.

5. Analysis of groundwater/surface water interactions along local streams should be considered for the future.

6. Consideration should be given to development of a data management system such as a geographic information system (GIS) for use in conjunction with the groundwater flow model.

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