Chapter 3

Groundwater Basin Characteristics

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3.1 Introduction

This chapter provides an overview of the hydrogeological characteristics of the Livermore-Amador Valley groundwater basin. Multiple studies of this important groundwater resource have been conducted over the last 100 years, as cited below (Section 3.2). A good overview and summary of fundamental basin characteristics was published in the 1974 DWR Bulletin 118-2 and summarized in the May 1992 Livermore-Amador Valley Water Recycling Study, appendices A and B. This chapter only briefly recounts that information (Section 3.3) and instead focuses on those aspects directly influencing salt loading impacts such as basin connectivity (Section 3.4) and Main Basin mixing and movement (Section 3.5). The approach taken to address vadose attenuation is presented in Section 3.6. Historic and on-going hydrogeological information collection is summarized in Section 3.7.

The groundwater flow and solute transport numerical model used in this SMP to evaluate the impacts of alternative salt management strategies (see Chapter 10) is described in Section 3.8. Section 3.8 also provides a detailed discussion of model calibration work conducted and a comparison of model results to actual measured groundwater elevations and TDS trends. The groundwater model provides the best current documentation of general basin characteristics.

3.2 Previous Groundwater Basin Studies

The earliest studies relating to the groundwater supply of the Livermore Valley were conducted in the early 1900s and mainly focused on the use of Livermore Valley groundwater for a drinking water supply to the City of San Francisco, California (Tibbetts, 1907; Lawson, 1912; Williams, Jr., 1912; Vickery, 1925; Smith, 1934). These early studies developed the conceptual model of a large artesian basin. The basin was recharged in the east where gravels were exposed at the surface. In the west the gravel aquifers were semi-confined under an extensive clay cap. The California Department of Water Resources (CDWR) began studying the basin in the late 1940's and published an initial study of water resources in all of Alameda County starting in July 1955. This report was revised and updated with the cooperation of Zone 7 and finally published in 1963 as Bulletin 13. Information in this report included surface water and groundwater supplies, alternate plans for surface water development, and projected water demands. DWR continued their work in conjunction with Zone 7 and focused on groundwater recharge from streams, surface and groundwater quality, groundwater inventory and groundwater movement as it related to geological features (CDWR, 1960, 1964a, 1964b, 1966, and 1974).

In January 1964, CDWR published a report on the Alameda Creek watershed that discussed the effects of wastewater discharges on surface water and groundwater in Livermore and Sunol valleys (CDWR, 1964a). In June of that same year, a report was published discussing the need for standard well construction to prevent the commingling of waters of various qualities (CDWR, 1964b). An initial report on the geology as it relates to groundwater movement in Livermore and Sunol valleys was published in August of 1966 by CDWR as Appendix A to Bulletin 118-2. Bulletin 118-2 was published in 1974 again with the cooperation of Zone 7 and included comprehensive discussions of groundwater quality, movement, local geology, and inventory of each groundwater sub-basin (CDWR, 1966, 1974). The hydrology conceptual model was modified from Appendix A following the development and calibration of a computer flow model. Two very significant developments resulted from this modeling study. One was the realization that a detailed hydrologic inventory of all supply and demand components was absolutely essential to the quantitative analysis of the groundwater basin. Zone 7's hydrologic inventory was developed out of this early modeling effort and continues to be used as an essential element of all subsequent studies and modeling analysis. The second lesson learned was the importance of good hydrologic data records and the need to actively measure and collect hydrologic data. Bulletin 118-2 specifically recommended the construction of special monitoring wells to monitor shallow aquifer areas near recharge areas and near wastewater disposal areas.

In 1972, Brown and Caldwell Consulting Engineers completed a water quality management plan for the watershed of Alameda Creek above Niles Canyon for Zone 7 Alameda County Flood Control and Water Conservation District, City of Livermore, City of Pleasanton, and Valley Community Services District (now Dublin San Ramon Services District). The report discussed various plans for the management of surface water, groundwater, and wastewater treatment and disposal. Numerous other wastewater management studies were subsequently conducted in the 1970's leading to construction of the LAVWMA export pipeline in 1980. These studies and later ones were summarized in the report "Wastewater Disposal and Reuse Alternatives for the Livermore-Amador Valley 1960-1995" (EOA, July 1995).

In 1982, a wastewater management plan was prepared for Zone 7 that included wastewater and recycled water management policies for the unsewered, unincorporated area of the Alameda Creek watershed above Niles. It also addressed salt and nitrate loading impacts from septic tanks in these rural areas (Camp Dresser & McKee, 1982). The U.S. Geological Survey, working cooperatively with Zone 7, conducted three investigations of surface and groundwater quality and the impacts thereon of wastewater discharges in the late 1970's and early 1980's (USGS Water Resources Investigations Reports 81-46, 82-4100, 84-4352). During this decade, following 118-2, the USGS supervised the construction of new monitoring wells and the establishment of a groundwater and surface water monitoring network. Zone 7 staff working with the USGS staff developed techniques for the collection of good monitoring data on the quality and quantity of surface and groundwater within the watershed and groundwater basin.

As noted above, the May 1992 Livermore-Amador Valley Water Recycling Study contains a comprehensive summary of the local hydrogeology based on many of the above reports, particularly USGS Bulletin 118-2.

The concept of a central basin or a Main Basin was developed in the 1980's by Zone 7 and others to signify the area of the groundwater basin that contained the majority of usable groundwater storage.

Groundwater flow from the fringe basins was calculated as subsurface inflow to the Main Basin utilizing aquifer properties and groundwater gradients developed from the cooperative studies by DWR and the USGS. The Zone 7 Water Resources section calculates the annual quantity of subsurface inflow to the main groundwater basin for each water year. In 1995, Zone 7 produced an internal memorandum detailing this calculation process for the water years 1974 through 1994. Because it was determined that the majority of the subsurface inflow comes from the Dublin and western Camp sub-basins, the memo focuses on these areas. It was found that the average subsurface inflow in this region of the basin is approximately 1,000 acre/feet per year.

Zone 7 has been monitoring the salt balance of the basin since the mid-1970s and the impacts of recycled water irrigation since the early 1980s. In the early 1980's Zone 7 expanded the hydrologic inventory to include a water quality inventory of the Main Basin. This quantitative inventory of water quality is called the salt balance. The latest annual Zone 7 salt balance report (August 1999) includes salt balance calculations for the basin from 1974-1998 (see Chapter 5).

In 1998, Zone 7 and CH2MHill developed a calibrated groundwater flow and solute transport model for the Livermore Valley Groundwater Basin. A summary report documented the calibration parameters and demonstrated the model's usefulness in evaluating basin-wide trends in TDS through time (CH2MHill, 1998). This model utilized the entire historic hydrologic inventory and salt balance inventory records 1974-98 for calibration. In January 1999, CH2MHill and Zone 7 produced an additional memorandum documenting results from using the model to examine 14 salt management strategies for the groundwater basin (see Section 3.8 and Chapter 10).

In 2004, Norfleet Consultants prepared the "Preliminary Stratigraphic Evaluation, West Side of the Main Basin." This study developed updated cross sections in a portion of the Main Basin using sequence stratigraphy, a method of relating the depositional environment of sediments to the stratigraphic framework in which they were deposited. The evaluation included:

- A data quality review of selected Zone 7 existing data,
- A standard presentation format for graphic logs representing lithologic and geophysical data,
- Two cross sections through the study area,
- Sequence stratigraphic analyses to correlate the cross sections, and
- A detailed stratigraphic description to assess the geologic controls on groundwater movement in the Chain of Lakes basin recharge area.

On the cross sections, four stratigraphic sequences were identified: cyan, gray, purple and red (youngest to oldest). Each sequence was marked by a sequence boundary at the base and series of fining upward braided fluvial channels containing sand and gravel with interstratified flood plain and lacustrine clays and silts. The results of the study showed that in the study area, the base of the youngest stratigraphic sequence appears to provide a pathway for groundwater to flow between the recharge basins and the underlying shallow aquifers (<250 feet below ground surface). However, no direct pathway was observed between the recharge basins and the deeper aquifer units in the study area.

3.3 Groundwater Basin Overview

The Livermore-Amador Valley Groundwater Basin is contained in the Livermore/Amador/Dublin Valley area (herein called the Livermore Valley, but also sometimes known as the Tri-Valley).

3.3.1 Physiographic Description

The Livermore Valley, an inland structural basin, is located in northeastern Alameda County (Figure 3.1). It is surrounded primarily by north-south trending faults and hills of the Diablo Range. The valley extends approximately 14 miles in an east-west direction and varies from three to six miles in width. It is separated from San Francisco Bay by several northwesterly trending ridges of the California Coast Ranges including the Pleasanton Ridge. The valley floor slopes gently west and southwest from an elevation of approximately 700 feet above sea level in the east to approximately 320 feet above sea level in the southwest.

Six principal streams flow into and/or through the valley, and join in the southeast where the Arroyo de la Laguna flows out of the valley. The other five arroyos are essentially tributaries to the Arroyo de la Laguna:

- Arroyo Valle,
- Arroyo Mocho,
- Arroyo Las Positas,
- South San Ramon Creek?
- Tassajara Creek, and
- Alamo Creek.

Average precipitation rates range from 16 inches per year at the valley floor to over 20 inches per year in the southeast and northwest portions of the valley.

3.3.2 Geologic Description

Structural uplift of the entire Coast Ranges occurred during the late middle Pliocene & Pleistocene causing extensive folding and faulting of the region. The Livermore Valley, a structural valley formed by a faulted, asymmetric syncline, was created as a result of downwarping of the Miocene-Pliocene sandstones and conglomerates between the western bordering Calaveras Fault and the eastern bordering Greenville Fault. Continued deposition, uplift, and faulting have led to the current Livermore Valley stratigraphy (DWR, 1964b, 1974; Crane, 1988; Hall, 1958). The majority of the valley consists of the following three types of geologic units (presented from youngest to oldest).

Valley Fill/Quaternary Alluvium - The valley is partially filled with Pleistocene-Holocene age (recent alluvium) alluvial fan, stream and lake deposits, which range in thickness from a few feet along the margins to nearly 400 (and possibly 800) feet in the west-central portion. The alluvium consists of unconsolidated gravel, sand, silt, and clay. This alluvium, most likely consisting of reworked Livermore Formation, was deposited and heavily influenced by the alluvial deposition of ancestral and recent streams, including Alamo Creek, Arroyo del Valle, Arroyo Las Positas, Arroyo Mocho, South San Ramon Creek, and Tassajara Creek.

The southern region of the Livermore Valley is the most important groundwater recharge area and consists of mainly sand and gravel that was deposited by the ancestral and present Arroyo del Valle and Arroyo Mocho. The eastern and northern regions of the valley contain thinner deposits and consist of alternating layers of gravel, sand, silt, and clay that are laterally discontinuous and resulted from the deposition of smaller streams. The western region of the valley has extensive gravel layers alternating with thick clay beds totaling approximately 400 feet in thickness. The alternation of sand/gravel layers and silt/clay layers form the basic aquifers for the area (CDWR, 1966, 1974).

Livermore Formation - The Livermore Formation consists of beds of clayey gravels and sands, silt, and clay that are unconsolidated to semi-consolidated and estimated to be 4,000 feet thick in the southern and western portion of the basin (DWR, 1964b). These sediments are exposed along the south flanks of the valley in the uplands, and exhibit bed dips 5 to 25 degrees toward the northeast in the Livermore Uplands. In between, the geologic contact between the recent alluvium and the underlying Livermore Formation is not discernable from drill cuttings in the central part of the valley because the formation materials are similar. Groundwater from this formation is sodium bicarbonate in nature and of moderately good quality.

Tassajara and Green Valley Formations - The Tassajara and Green Valley Formations, located uplands north of the valley, are roughly Pliocene in age and were deposited under both brackish and freshwater conditions. They basically consist of sandstone, tuffaceous sandstone/siltstone, conglomerate, shale, and limestone. Beds typically dip 60 to 80 degrees toward the south or north in the Tassajara Uplands. These formations are bordered on the northeast by Marine sediments and are overlain to the south by the Livermore Formation. Because of low groundwater yields, the use of these formations is limited to residential or basic agricultural uses.

3.3.3 Hydrologic Inventory

It is a common misconception that the Livermore Valley Groundwater Basin is a "closed" basin. In the late 1800s, the pre-development groundwater levels in the basin created a gradient causing groundwater to flow from east to west and naturally exit the basin as surface flow in the Arroyo de la Laguna. In the early to mid-1900s, groundwater began to be extracted in appreciable amounts causing groundwater levels to drop throughout the basin. At that time, groundwater levels dropped below the point where groundwater would naturally rise into the Arroyo de la Laguna and exit the basin through stream flow. This was the closest the Main Basin came to being, by definition, totally enclosed. Surface application of extracted groundwater through irrigation and septic systems reintroduced the groundwater to the system with minimal outflow at the Arroyo de la Laguna.

Since that time, additional development has required increased import of surface water and use of groundwater. The groundwater basin cannot be considered "totally enclosed" since water is exported from and recharged into the basin through various means. These include:

- Dewatering and export of mining water from the gravel pits,
- Export of irrigation runoff by streams to the Arroyo de la Laguna, and
- Municipal pumpage plus export of resultant treated wastewater to the bay through the LAVMA pipeline.

The total outflow of water from the basin is on average 20,000 acre-feet per year (this is about 8% of the total groundwater storage: 240,000 acre-feet). Approximately 20,000 acre-feet per year recharges (i.e., inflow) the groundwater basin through percolation of irrigation and stream flow.

The ratio of inflow to outflow will vary depending on precipitation. During drought years outflow increases due to increased pumping. During wet years more imported water is available and used to artificially recharge the basin. Land use also plays an important role total inflow and outflow from the groundwater basin.

As evidenced by the increase in "gaining stream" reaches during seasonal highs, observed groundwater levels have appeared to rise in various parts of the basin. Primarily, these gaining reaches are in the northeastern and western portions of the groundwater basin (Figure 3.3). Reasons for these increases may in part be attributed to urban development, which uses more imported water than groundwater from localized wells. Urban development also increases applied water recharge due to landscape irrigation.

3.4 Occurrence and Movement of Groundwater

3.4.1 Definitions

For the purposes of this report, geologic formations will be grouped into one of three categories:

Water Bearing Formations - Water bearing strata represent geologic deposition of quaternary alluvium and portions of the Livermore Formation that are believed to extend beneath the alluvium.

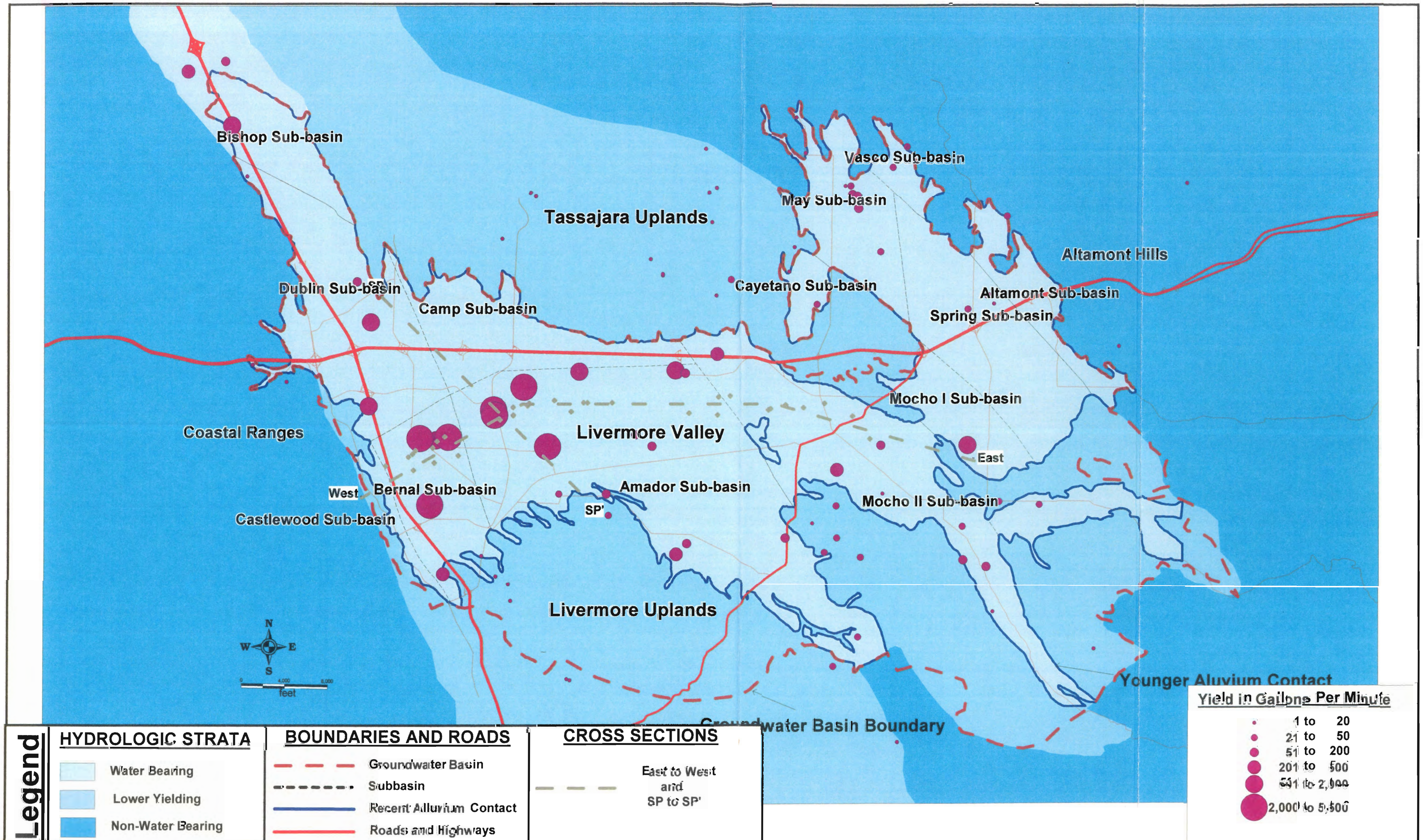
Low Yielding Formations - The Tassajara Formation, Green Valley Formation, and upland areas of the Livermore Formation display lower yields. Groundwater from these formations is sodium bicarbonate in nature and of moderately good quality.

Non-water Bearing Formations - Totally non-water bearing strata consist of Cretaceous to mid-Tertiary marine sediments that do not readily absorb, transmit, or yield water to wells in appreciable amounts. Often, the groundwater that is extracted is of a poor quality sodium bicarbonate-chloride or sodium chloride nature with dissolved solids ranging from 700 to 2150 parts per million (CDWR, 1964b).

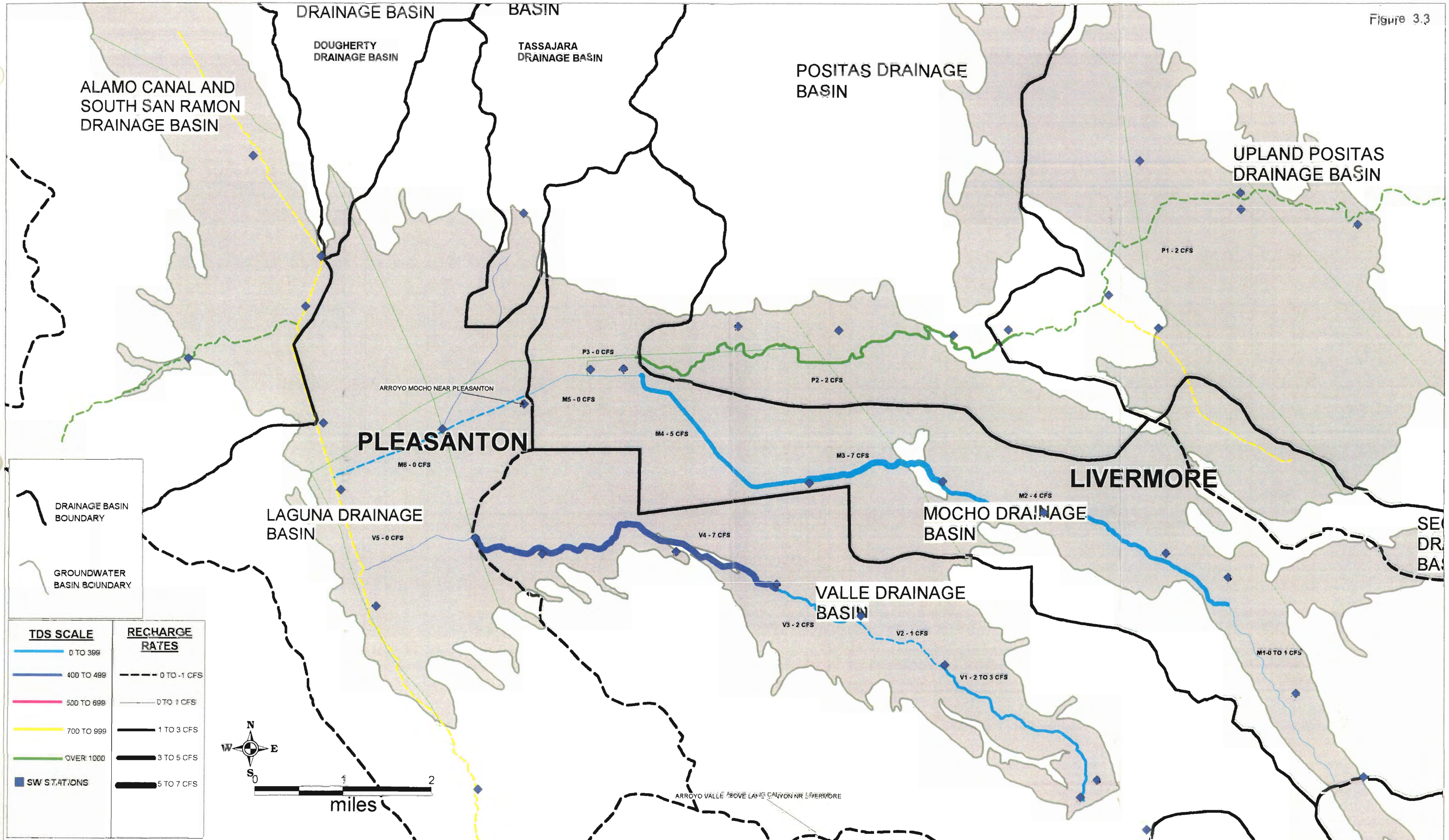
Several types of groundwater boundaries are present either along the edges of the basin or within the basin. These boundaries can be categorized into four types:

Barrier - A boundary where there is no hydraulic connectivity between the adjacent aquifer unit. Examples of this boundary may represent movement along a

	Zone 7 Water Agency 5997 Parkside Drive Pleasanton, CA. 94588	Water Resources Engineering Salt Management Plan **Figure 3.1: Vicinity Map**



ZONE 7 WATER AGENCY 5997 PARKSIDE DRIVE PLEASANTON, CA. 94588	DRAWN BY: C Mahoney	SCALE: 1" = 8,000'	WATER RESOURCES ENGINEERING SALT MANAGEMENT PLAN **FIGURE 3.2:** **BASIN OVERVIEW**
	DESIGNED BY: C MAHONEY	DATE: 3 JULY 2000	
	CHECKED BY: D LUNN	REVISED BY:	
	APPROVED:	FILE: \zone7-file\mapinfo\SMP\Fig3-2.WOR	



ZONE 7 WATER AGENCY 5997 PARKSIDE DRIVE PLEASANTON CA 94588	DRAWN BY: GERALD GATES	SCALE: 1" = 1 MILE	WATER RESOURCES ENGINEERING SALT MANAGEMENT PLAN
	DESIGNED BY: GERALD GATES	DATE: 3 JULY 2000	
	CHECKED BY: DAVID LUNN	REVISED BY: C MAHONEY	**FIGURE 3.3:**
	APPROVED:	FILE: h:\SMP\Fig3-3.WOR	**STREAM RECHARGE RATES AND TDS**

fault where a permeable unit has been displaced against a non-permeable unit or where the unit "pinches out" and abuts an impermeable unit.

Cascade - A boundary where movement along a fault has partially displaced an aquifer unit causing stepped flow across the boundary. This may exist along the upper aquifer of the Livermore fault boundary.

Leaky - A boundary where horizontal fault movement produces fault gouge that slows the movement of water across the boundary.

Unrestricted - A boundary where aquifer characteristics may change slightly, but do not impede the flow of water across the boundary. Examples of this can be observed by a slight change in head, but not in specific capacity between two wells on opposing sides of the boundary.

In a layered aquifer system, combinations of boundary types may exist along boundaries. The level of information varies as to which specific boundary conditions apply to many of the sub-basin boundaries. However, definite evidence for the existence of these boundaries is found in the differences in water level and/or water quality characteristics of the wells on either side of the given feature.

3.4.2 Basin Boundaries

The Livermore Valley Groundwater Basin is located in the heart of the Livermore Valley watershed and extends south into the hills south of Pleasanton and Livermore. It includes the areas occupied by both the flat portions of the Livermore Valley and the Livermore uplands (Figure 3.2). The basin is bounded on the:

- West by northwesterly trending ridges of the California Coast Ranges (including Pleasanton Ridge) and the Calaveras fault,
- North by the Tassajara Uplands and the steeply dipping east west trending Tassajara Formation.
- East by the Greenville fault and by the marine formations exposed in the Altamont Hills.
- South by the Verona faults and Livermore Uplands and the steeper Livermore Highlands.

While the Arroyo de la Laguna has little recharge, the other streams in the basin have "losing stream" stretches where at least a portion of their flow percolates through the stream bed and recharges the groundwater basin aquifers. In addition, three tributaries to the Arroyo Las Positas (i.e., Cayetano Creek, Altamont Creek, and Arroyo Seco) and one tributary to the Arroyo Mocho (i.e., Dry Creek) can also impact the basin. The stream locations and the known "losing stream" stretches are shown on Figure 3.3 along with their approximate recharge rates.

Several subsurface barriers form impediments to lateral movement of groundwater in the Livermore Valley basin (DWR, 1964b, 1974). Based on these apparent linear groundwater barriers, the basin has been divided into sub-basins. Some of these sub-basins have a much larger capacity to store and transmit groundwater and are very significant for the local groundwater supply. These had been called the central basin, but since 1985, they have been called the **Main Basin**. These consist of the following sub-basins (shown on Figure 3.2):

- Bernal (usually includes the smaller Castle Sub-Basin)
- Amador
- Mocho I

The other basins are called **Fringe Basins**. These consist of the following sub-basins:

- Altamont
- Bishop
- Camp
- Cayetano
- Dublin
- May
- Spring
- Vasco
- Mocho II

Vertically, the majority of the groundwater basin can be split into two hydraulic zones:

Upper Aquifer Zone - The upper aquifer zone consists of alluvial materials including primarily sandy gravel and sandy clayey gravels. These gravels are usually encountered underneath the surficial clays (typically 20 to 40 feet bgs) to about 80-150 feet bgs. This aquifer extends throughout the majority of the groundwater basin. Groundwater in this zone is unconfined. The 2004 Stratigraphic Evaluation called this zone the 'Clay Sequence'. In the Main Basin, the upper aquifer is underlain by a relatively-continuous, silty clay aquiclude up to 50 feet thick.

Lower Aquifer Zone – Due to a lack of accurate geologic information, the water bearing units below the upper aquifer zone have been collectively known as the Lower Aquifer Zone. The aquifer materials consist of semi-confined to confined, leaky, coarse-grained, water-bearing units interbedded with relatively impermeable, fine-grained units. As additional geologic information becomes available it is possible that this zone can be further subdivided into distinct aquifers. For example, Norfleet (2004) split the lower aquifer zone in the Amador Sub-basin into the "Gray," "Purple," and "Red" sequences. In future geologic and modeling studies, Zone 7 will likely extend the Norfleet sequence boundaries beyond the Norfleet study area.

In general, multiple aquifers are recognized in the alluvium of the Livermore Valley. As shown in Figure 3.4, a cross section of the basin from west to east, the water bearing alluvium increases in thickness from east to west across the basin and thins both north and south at its boundaries. Cross section SP to SP' (Figure 3.5) also shows a thickening of sediments from north to south to the central portion of the groundwater basin and then a thinning from the center towards the south. Although the upper aquifer zone appears to be very thick and continuous through the Central Amador Sub-basin, the water bearing units within the lower aquifer zone are often discontinuous and inter connected. The more recent geologic logging and monitoring of multilevel monitoring wells are allowing better understanding of the hydrostratigraphic units within the recent alluvium.

3.4.3 Subsurface Inflow into the Main Basin

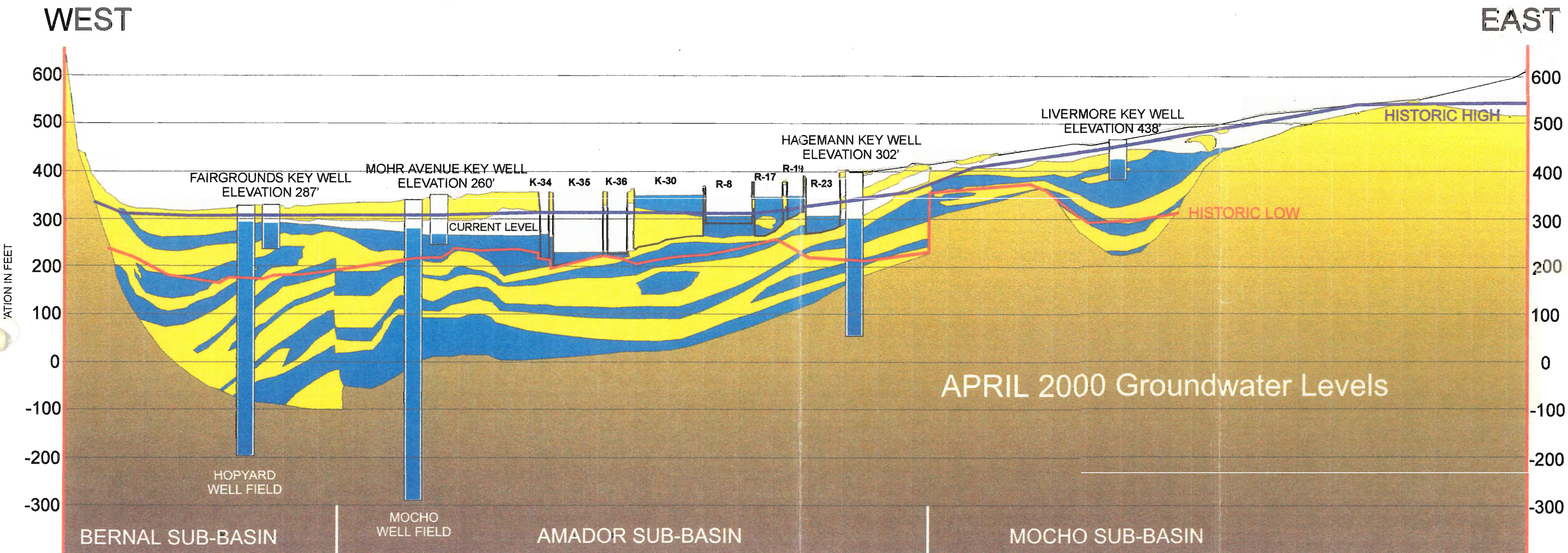
The existence of groundwater barriers along the edges and within the basin continues to be confirmed by the groundwater level measurements, investigations by Zone 7, and other investigations. In 1974 these groundwater barriers were generally interpreted as fault related. However, some may be the result of hydrostratigraphic boundaries and not fault related.

South of the basin, groundwater from the Livermore Formation is believed to move along the strike of the beds to the northwest and enter the Main Basin at the southern portions of the Bernal and Amador sub-basins. North of the basin, the near-vertical structural dip of the Tassajara and Green Valley formations is believed to prevent the commingling of waters among these formations and the alluvium, essentially cutting this water off from the groundwater basin (DWR, 1966, 1974, Zone 7 files).

The outer boundaries of the Main Basin have been divided into 10 regions of interest with respect to groundwater connectivity (Figure 3.6). Region 1, followed by regions 2 and 7, contribute the greatest amounts of subsurface inflow to the Main Basin through the shallow aquifers (Upper Zone). Subsurface inflow from the deeper aquifers (Lower Zone) is considered negligible as shown in Table 3.1.

Estimates of future inflow are based on currently planned development and assume that the potentiometric surface of the Main Basin will be drawn down to accommodate the added demand. Future TDS was taken from the technical memorandum, *Phase 4 Groundwater Modeling: Salt Management Plan Simulations* (CH2MHill, 1999). Scenario 1A, which examined the base case

LIVERMORE-AMADOR VALLEY GROUNDWATER BASIN
EAST-WEST CROSS-SECTION



	Zone 7 Water Agency 5997 Parkside Drive Pleasanton, CA. 94588	Water Resources Engineering Salt Management Plan **Figure 3.4: East-West Cross Section**

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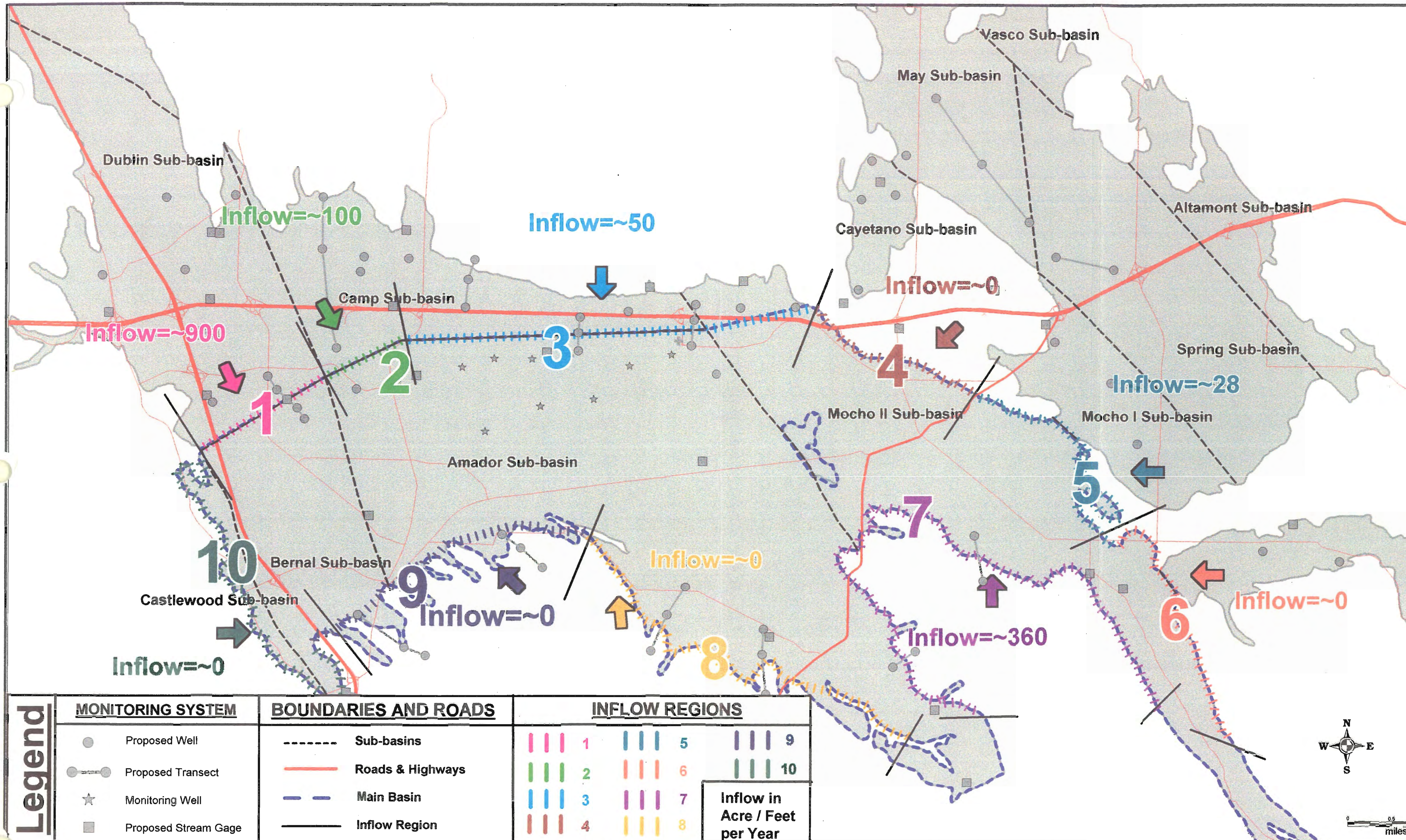

ZONE 7 WATER AGENCY
5997 PARKSIDE DRIVE
PLEASANTON, CA. 94588

DRAWN BY: C MAHONEY	SCALE: 1" = 1 mile
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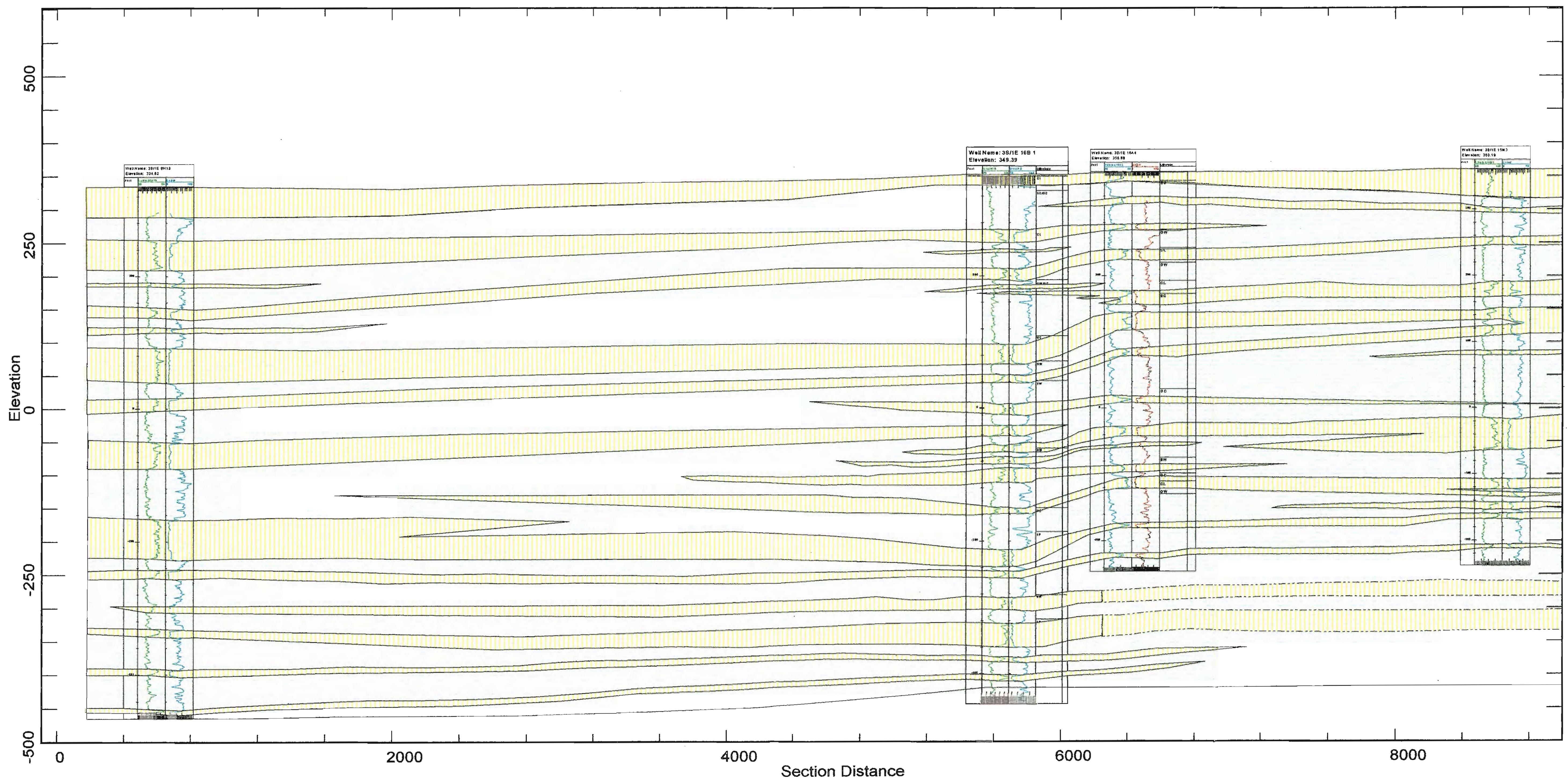
WATER RESOURCES ENGINEERING
SALT MANAGEMENT PLAN
Figure 3.6:
Hydrologic Regions of Inflow



Sand/Gravel Unit

Clay Unit

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Pleasanton, CA 94588

Salt Management Plan
Figure 3.5: SP - SP' Cross Section

Vertical Exaggeration: 5

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Nov. 1, 2000

scenario with no recycled water injection, was used to represent future impact conditions. This scenario examined TDS at 50 years from the initial condition of October 1995.

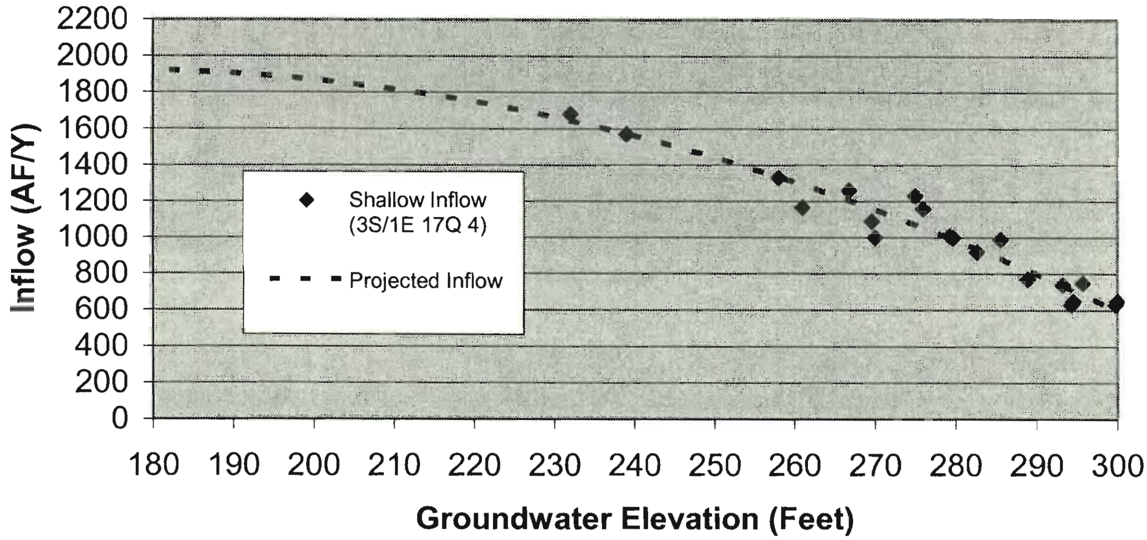
Table 3-1
Subsurface Inflow and TDS with Respect to Urban Development
Inflow (Acre Feet per Year) and TDS (mg/L)

Inflow Region	Upper Zone afy		Lower Zone afy		Upper Zone Mg/L		Lower Zone mg/L	
	Current Inflow	Future Inflow	Current Inflow	Future Inflow	Current TDS	Future TDS	Current TDS	Future TDS
1	900	950	<50	<50	900	1000	400	850
2	100	200	<10	<20	1000	1000	400	950
3	50	100	<5	<10	850	1000	450	850
4	N	N	N	N	750	800	450	800
5	28	U	N	U	650	700	500	700
6	N	N	N	N	700	750	450	700
7	360	360	N	N	450	450	450	450
8	N	N	N	N	450	400	450	350
9	N	N	N	N	500	700	450	650
10	N	N	N	N	600	900	500	800
Total Inflow	1438	1610	<65	<65				

Notes:
TDS = Total dissolved solids
N = Negligible inflow
U = Unknown at this time
AFY = acre-feet per year

In Figure 3.7, inflow from the "Fairgrounds Key" Well, currently designated as 3S/1E 17Q 4, is shown at observed groundwater elevations. These data represent calculated inflows from 1974 through 1994 into the northwestern boundary of the Main Basin as associated with the observed groundwater elevation. The projected linear curve represents the average inflow that may be expected at any given groundwater elevation. As the basin approaches the historic low elevation of 180 feet below ground surface (e.g., following a seven-year drought), the relative rate of subsurface inflow decreases. At some elevation below 180 feet, inflow is projected to stabilize at about 1,900 AF/year.

Figure 3-7:
Trends in Shallow Aquifer Inflow



Region 1 is the boundary between the Dublin Sub-basin and the Main Basin. The boundary is the Parks Fault, which creates a vertical zone of very low permeability at about a 100-foot depth. Subsurface groundwater inflow is precluded below this depth, therefore, subsurface inflow occurs mainly in the shallower portion over this boundary. Subsurface flow across this Region 1 boundary accounts for the majority of groundwater flow into the Main Basin. Subsurface flow from the Dublin Sub-basin into the Main Basin is calculated from groundwater gradients every year. The average calculated flow is approximately 900 acre-feet per year with a TDS of about 900 mg/L and it moves from northwest to southeast.

Region 2 is the western boundary between the Camp Sub-basin and the Main Basin. This boundary is made up of the eastern extension of the Parks Fault and a low permeability boundary of alluvial deposits interfingering with the less permeable alluvial deposits eroded from the Tassajara Formation. North of the boundary, all subsurface flow is in the upper aquifer. The Tassajara Formation precludes deep formation subsurface inflow from entering into the Main Basin. This inflow is computed each year from groundwater gradients and averages about 100 acre-feet. The100 AF/year of subsurface inflow moves in the upper aquifer alluvial materials that overlie the Livermore and Tassajara formations and crosses the Amador Sub-basin boundary flowing south. Again, inflow from the deeper aquifers in considered to be minor.

Region 3 represents the eastern boundary between the Camp Sub-basin and the Main Basin and the western portion of the Cayetano Sub-basin and the Main

Basin. Again the lower aquifer groundwater from the northern portion of this sub-basin is precluded from flow into the Main Basin. Shallow subsurface inflow in this region is moving south to southwest and is estimated to be approximately 50 AF/year or less.

Region 4 is the boundary between the eastern portion of the Cayetano Sub-basin and the Main Basin. The Cayetano Sub-basin is underlain by the Tassajara Formation, which has little to no hydraulic connectivity with the overlying alluvial deposits and the Main Basin, and contains water of a sodium bicarbonate character. The volume of subsurface flow is assumed to be insignificant and travels southwest. Minor flows rise into the creek and are counted in the Arroyo Las Positas stream recharge calculations.

Region 5 is the northern boundary between the Mocho I Sub-basin and the Main Basin, or more specifically the Mocho II Sub-basin. Subsurface flow is limited to the upper aquifer. Gradients in this area are very flat and often flow to the East. Zone 7 estimates no flow across this gap and others have estimated 28 AF/Y.

Region 6 represents the contribution of Dry Creek to the Main Basin. Only small quantities of surface water flow through this creek due to agricultural applications. It is unknown how much of the surface flow recharges the groundwater and moves as subsurface flow. Subsurface flow moves in a western direction across this boundary and is assumed to be insignificant.

Region 7 is the boundary between the Main Basin and the less permeable Livermore Formation uplands located between the upper reaches of Arroyo Mocho and Arroyo del Valle. Groundwater quality in this area ranges from a sodium chloride to a sodium bicarbonate water type. Subsurface flow exits in this region through a storm drain on the northeastern side of the boundary and moves in a north to northwest direction to the Arroyo Mocho. Discharge from this drain is estimated to be approximately 360 AF/year but with a fairly low TDS of 450 mg/L. It recharges the groundwater via the Arroyo Mocho and is included in Arroyo Mocho recharge calculations.

Region 8 is the boundary between the Main Basin and the less permeable Livermore Formation uplands located west of the Arroyo del Valle. Water here is considered to be of a sodium bicarbonate character. Subsurface flow in this region is moving northwest and is assumed to be insignificant. This is based on well yields and observations of dry summer creek beds.

Region 9 is the boundary between the Main Basin and southwestern most area of less permeable Livermore Formation uplands. Water in this region is of sodium bicarbonate character. The Livermore Formation in this area is striking northwest/southeast and is dipping northeast toward the Main Basin. Subsurface flow in this region is moving northwest along strike and is assumed to be insignificant. This is based on field observations at dry creeks and from limited well observation within the uplands.

Region 10 is the boundary between the Castle Sub-basin and the Main Basin. The boundary is the west branch of Calaveras Fault. Formations west of the fault are water bearing.

Table 3.1 shows that future development is not anticipated to result in any significant changes to the quantity or quality of subsurface inflow to the Main Basin. Region 1, the largest contributing area, is only expected to increase in flow from 900 to 950 AF/year and the TDS is only projected to increase from 900 to 1000 mg/L. Total inflow would increase from 1438 to 1610 AF/year (+215 AF/year). Areas in the lower zone showing moderate TDS increases are also areas with negligible inflow.

3.4.4 Main Basin Groundwater Mixing and Movement

Groundwater always moves from areas of high groundwater level potential (high groundwater level elevation) towards area of low potential. Recharge in an area raises the groundwater level elevation and discharge from an area lowers the groundwater level elevation. The difference in groundwater level potential per unit distance between two points is called groundwater level gradient. Therefore, groundwater always moves from areas of artificial and natural recharge towards areas of artificial and natural discharge or withdrawal. In general, recharge and discharge areas in the same aquifer create intra-aquifer (horizontal) movement and in different aquifers create inter-aquifer (vertical) movement.

The main groundwater basin is a multi-layered system having an upper unconfined aquifer overlaying a sequence of semi-confined aquifers. In general groundwater in both the upper and lower aquifer zones generally follows a westerly flow pattern, along the structural central axis of the valley, towards municipal or gravel mining company groundwater pumping wells in the western portion of the basin.

The groundwater movement and mixing in the Main Basin is very dependent on the location and magnitude of recharges into and discharge from the basin. Stream recharge, ASR injection, rainfall recharge, applied water recharge and subsurface inflow are the main sources of recharge. The main demand components (pumpage or discharge components) are municipal pumpage, agricultural pumpage, gravel mining water use and groundwater basin outflow. The average annual Main Basin recharge and pumpage is about 20,000 AF.

Groundwater monitoring data, and results from the Zone 7 numerical groundwater model for the Main Basin, indicate that the extent of mixing in the Main Basin varies considerably from location to location. The groundwater model animations help visualize the groundwater movement in the basin. Bernal, Amador and

Mocho II are the three main sub-basins of the Main Basin. The groundwater exchange between these sub-basins also varies with the extent of groundwater elevation gradient changes.

The Main Basin is made up of the Castle, Amador, Bernal, and the Mocho II sub-basins overlain by recent alluvium. The Mocho Sub-basin has been divided into two distinct areas, Mocho I and Mocho II distinguished by a change in aquifer characteristics from a sodium bicarbonate (Mocho I) to a magnesium bicarbonate water type (Mocho II) and by the presence of the less permeable Livermore Formation extending from both north and south into the middle of the sub-basin. The Main Basin is bounded:

- On the north primarily by the Parks Boundary and by a lack of hydraulic continuity with the Livermore and Tassajara formations,
- On the west by the Calaveras Fault,
- On the south primarily by thinning of the recent alluvium and contact with the Livermore Formation, and
- On the east by the divide between the Mocho I and II sub-basins.

Amador Sub-basin - The Amador Sub-basin is located in the west central portion of the groundwater basin and is bounded to the:

- West by the Pleasanton Fault,
- East by the Livermore Fault,
- North by a permeability barrier of inter-fingering of alluvial deposits. Historically this boundary was thought to also include a fault called the Parks Fault, however there has not been any direct evidence of this fault. It is possible that this barrier is caused by permeability change between younger and older alluvium. Herein this boundary is called the Parks Boundary, and
- South by the drainage divide and partly by contact with non-water bearing formations.

This sub-basin is host to the majority of high production wells and has both unconfined and confined aquifers. Well production in this sub-basin ranges from 42 to 2,820 gallons per minute (gpm) and specific capacities of 1.1 to 217 gpm per foot of drawdown (CDWR, 1974). Waters from this sub-basin are of good to excellent quality, characterized by sodium bicarbonate, magnesium bicarbonate, and calcium bicarbonate with few instances of elevated levels of boron and nitrate.

In this sub-basin the maximum thickness of the Quaternary alluvium was previously thought to be approximately 500 feet. However, Norfleet (2004) did not find any evidence for the bottom of the alluvium at over 800 feet below ground surface. The alluvium is believed to lie unconformably over the Livermore Formation.

Bernal Sub-basin - The Bernal Sub-basin is located in the southwestern portion of the groundwater basin and is bounded to the west by branches of the Calaveras Fault, to the east by the Pleasanton Fault, to the north by the Parks Fault, and to the south by contact with non-water bearing formations and partly by contact with the Verona Fault. Both unconfined and confined aquifers exist in the water bearing sediments. Waters from this sub-basin are of fair to excellent quality. However, much of the upper aquifer water has high TDS exceeding 600 mg/l. The water from the northern and southern portions of the sub-basin are of a sodium bicarbonate nature, while the central portion is of the magnesium bicarbonate type and the western and south-central portion is of a calcium bicarbonate character.

The Bernal Sub-basin is the point of convergence for all of the major streams that drain the Livermore Valley. The Arroyo de la Laguna subsequently drains the sub-basin. Like the surface water, the groundwater also historically converges in this sub-basin, which allows for the mixing of the dominant cations of sodium, magnesium, and calcium. The Quaternary alluvium is estimated to have a thickness of at least 400 feet in this sub-basin and conformably overlies the Livermore Formation. Well production in this sub-basin ranges up to 3,500 gpm and specific capacities range from 3 to 260 gpm per foot of drawdown.

Mocho I/II Sub-basin - The Mocho Sub-basin is located in the east central portion of the groundwater basin and is bounded to the west by the Livermore Fault, to the east by the Tesla Fault, to the north by the Tassajara Formation that is not hydraulically connected to the sub-basin, and to the south by the Livermore Uplands and contact with non-water bearing marine formations. Both unconfined and confined aquifers exist in the water bearing sediments. Waters from this sub-basin are of fair to excellent quality sodium bicarbonate (Mocho I) and magnesium bicarbonate character (Mocho II) with some instances of elevated boron and sodium ions.

The recent alluvium ranges in thickness from approximately 10-50 feet thick in Mocho I and up to 150 feet thick in Mocho II. This alluvium overlies, both conformably and unconformably, the Livermore Formation. Mocho I and Mocho II appear to be hydraulically connected only in the shallow alluvial deposits. Well production in this sub-basin ranges up to 950 gpm with specific capacities of 2 to 50 gpm per foot of drawdown.

3.4.5 Horizontal Mixing and Movement (Intra-Aquifer Movement)

Groundwater level gradient and hydraulic conductivity are two essential parameters for characterizing groundwater movement in an aquifer. Hydraulic conductivity is an aquifer property and groundwater gradient is dependent on recharge/discharge locations.

Upper Aquifer - The upper aquifer in the Main Basin has generally good hydraulic conductivity. The presence of geologic faults in the Main Basin does not impede flow at shallow depths as compared to the higher impedance at deeper depths.

The main components of recharge for the upper aquifer are the areal recharge (rainfall and irrigation), stream recharge, fringe basin subsurface inflow and groundwater inflow from deep aquifers at some locations. The discharge components are dewatering by gravel mining, rising groundwater in Arroyo de la Laguna, and leakage to the deeper aquifer. Figure 3.8 presents the groundwater level contours for the upper and deep aquifers.

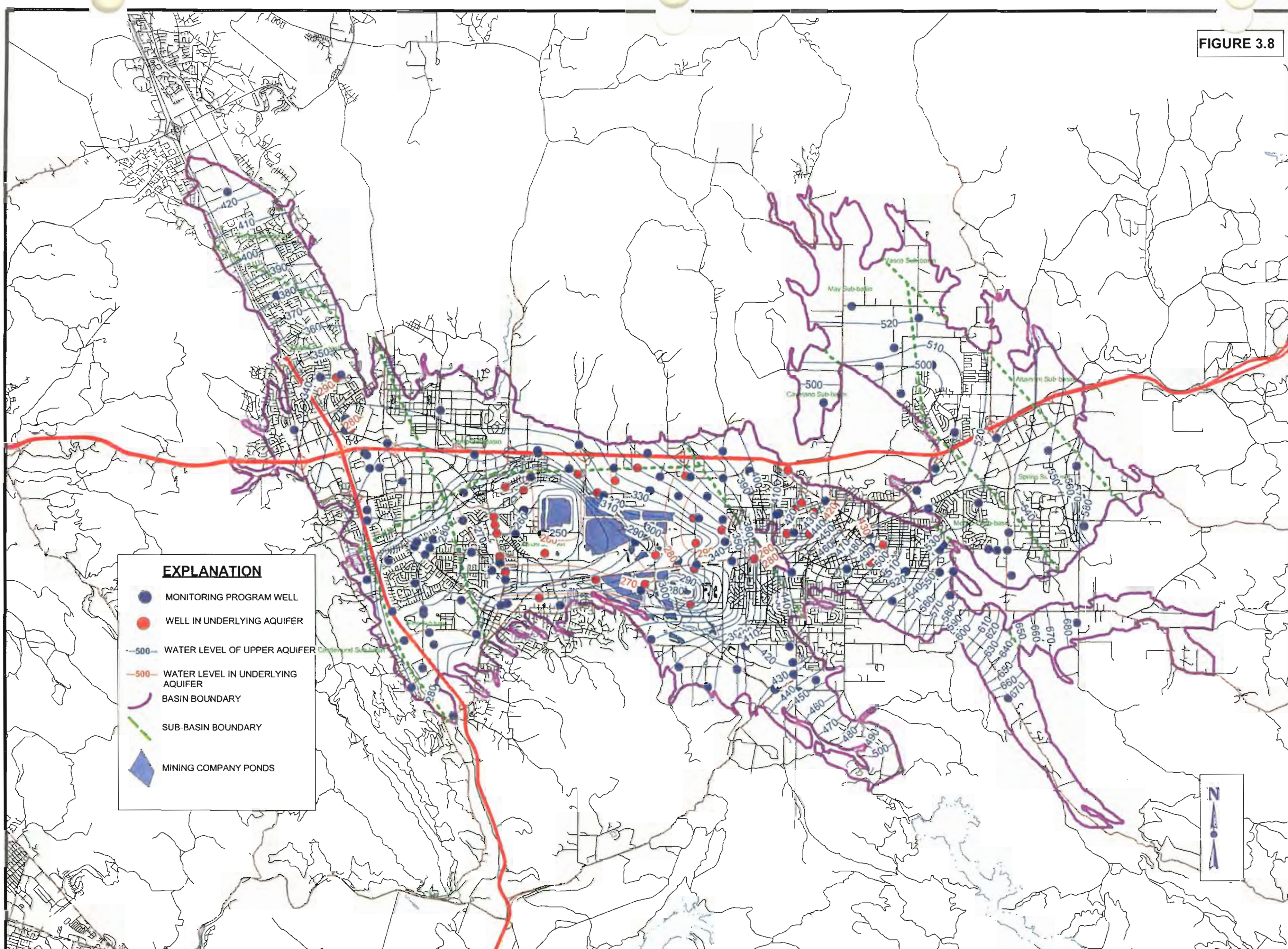
Areal recharge occurs over most of the Main Basin and in and of itself does not create any significant groundwater gradients in the upper aquifer. This is primarily why Main Basin areas in the upper aquifer that do not have any other major source of recharge or discharge other than areal recharge have very poor groundwater mixing and movement. For the Bernal Sub-basin upper aquifer, the recharge sources are areal recharge and subsurface inflow from the Dublin Sub-basin. The discharge components are the small amount of rising groundwater to Arroyo de la Laguna and leakage to the deeper aquifer.

Groundwater exchange between the Amador and Bernal sub-basins also occurs. There is a significant groundwater gradient from north to south in the northern portion of the Main Basin due to subsurface inflow from the Dublin Sub-basin recharging this area. The gradient can also be affected due to groundwater leakage to the deep aquifer occurring in the central portion of this sub-basin during drought years. There is also a mild groundwater gradient from the western and southern portions towards the center.

The stream recharge that occurs along the arroyos creates a higher groundwater potential along the arroyos. For the most part the groundwater flows away from the stream recharge areas. Groundwater de-watering by gravel mining companies in the Amador sub-basin creates groundwater gradients towards the central portion of the Main Basin. The groundwater level contours in Figure 3.8 indicate flow from the eastern part of the Main Basin towards the central part of the Main Basin. A part of the areal recharge and stream recharge that occurs in the Amador and Mocho II sub-basins moves towards the gravel mining areas and the remaining portion moves down to the deep aquifer.

Groundwater TDS in the upper aquifer at most locations is dependent upon the TDS of the locally recharged water. The groundwater TDS along the northern boundary of the Main Basin is high because of the high TDS subsurface inflow from the Dublin Sub-basin and high TDS recharge from Arroyo Las Positas. The groundwater TDS along Arroyo Mocho and Arroyo Valle is lower because of the lower TDS water recharged in those areas. The groundwater TDS in the shallow aquifer at locations where the recharge source is only areal recharge, and at

FIGURE 3.8



ZONE 7 WATER AGENCY
5997 PARKSIDE DRIVE PLEASANTON CA 94588

DRAWN BY: STEVEN J. ELLIS
DESIGNED BY: STEVEN J. ELLIS
CHECKED BY:
APPROVED BY:

WATER RESOURCES ENGINEERING
GROUNDWATER LEVEL CONTOURS
FALL 1996

SCALE: 1" = 6000' (ON ORIGINAL)
DATE: 10 JANUARY 1997
FILE NO.: B-342

locations not receiving any low TDS stream recharge, is high because of the high TDS of the areal recharge.

Although the TDS of rainfall recharge is insignificant, the TDS of recharge from irrigation is generally quite high. For example, if the irrigation water TDS is 300 mg/l, the irrigation water recharge (percolate) TDS could range from 1,200 mg/l to 3,000 mg/l depending upon the soil type. Typically 75-90% of the applied irrigation water evaporates and 10-25% recharges into the aquifer, along with 100% of the applied salts. This concentration process increases the TDS of recharge from irrigation by 4-10 times the TDS of irrigation water.

Deep Aquifer - The deep aquifer in the Main Basin is a sequence of semi-confined aquifers with good hydraulic conductivity. The presence of some geologic faults in the Main Basin impedes flow across the sub-basin boundaries at deeper depths.

The recharge components for the deep aquifer include groundwater leakage from the upper aquifer and treated surface water injection from the Hopyard well #6 (ASR well). As discussed in Section 3.3, subsurface inflow from the fringe basins through the deep aquifer is insignificant. Since the groundwater leakage from the upper aquifer is spread over the Main Basin, it does not create any significant potential gradient between two geographically separated points. The Hopyard #6 injection raises the groundwater potential in the Hopyard well field depending upon the injection amounts.

The discharge components from the deep aquifer include groundwater pumpage and leakage into the upper aquifer in the Amador Sub-basin due to upper aquifer dewatering near the gravel mining operations. The groundwater pumpage is the major reason for gradients between two geographically separated points in the deep aquifer in the Bernal and Mocho II sub-basins. Groundwater pumpage and leakage to the upper aquifer are the main reasons for gradients in the Amador Sub-basin.

The mixing in the deep aquifer appears to be primarily dependent upon the distribution and amount of groundwater pumpage from the aquifer. The groundwater model animations show how some of the stream recharge on Arroyo Valle leaks to the deeper aquifer and moves towards Pleasanton's municipal wells (Pleasanton #5, 6 & 8).

3.4.6 Vertical Mixing and Movement (Inter-Aquifer Movement)

The relatively low hydraulic conductivity of the aquitard layers impedes the vertical movement of groundwater between the upper and lower aquifers. The low conductivity of the aquitard is the major reason for the slower movement and reduced mixing that occurs between the upper and deep aquifers.

The location of the water sources and water sinks also controls the movement and mixing of groundwater in the Main Basin aquifers. Most of the vertical movement and mixing occurs by leakage through the aquitard separating the upper and lower aquifers. Some exchange also occurs by leakage due to geologic faults and wells screened in different aquifers.

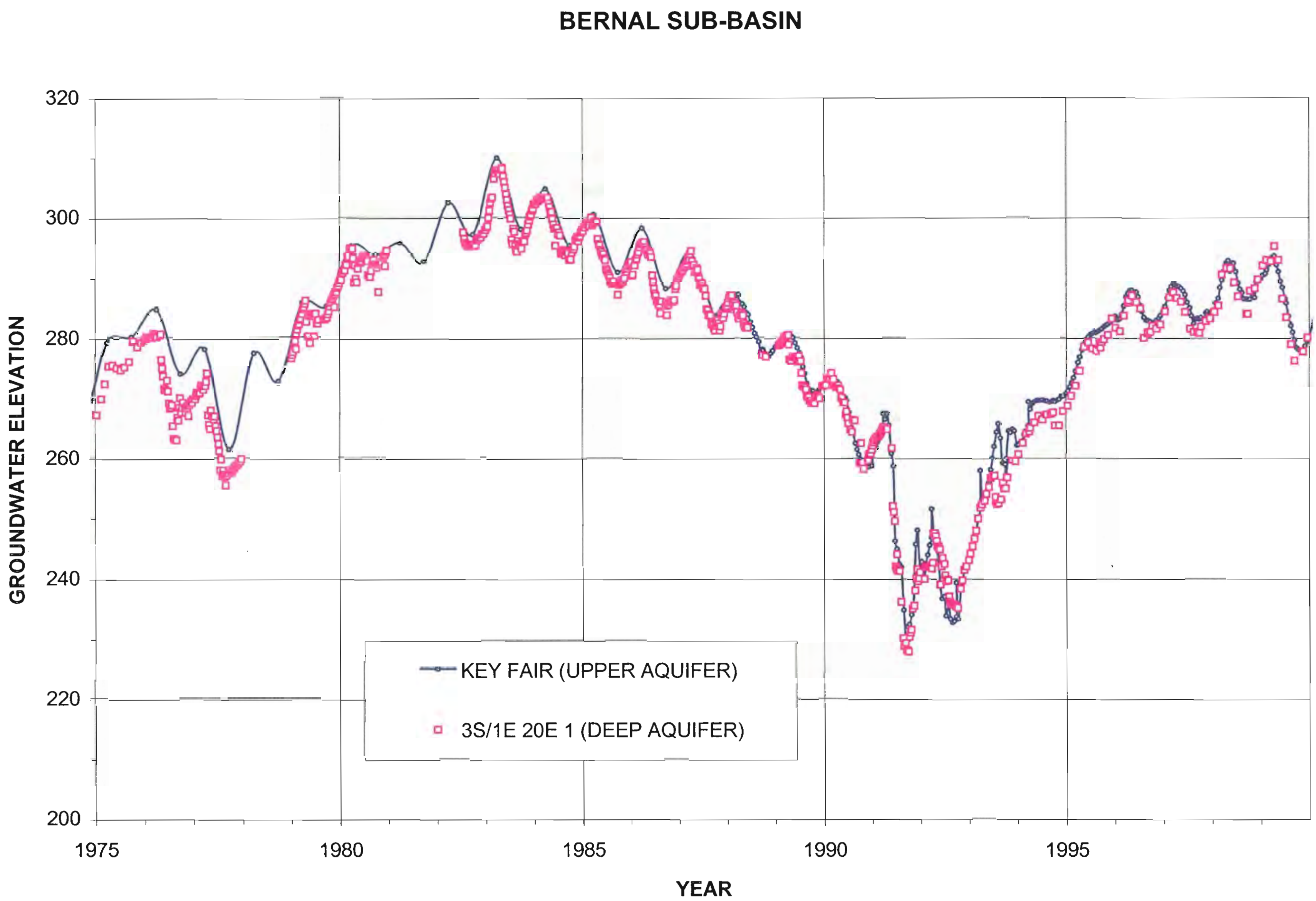
The exchange between the two aquifers, as indicated by the groundwater monitoring data, varies depending upon the thickness and permeability of the separating aquitard and the potential gradient. Even though the movement of water and salts from the upper aquifer to the lower aquifer is slow, it is still the major source of recharge to the lower aquifer. In the past, prior to injection (ASR) to the lower aquifer, the leakage from the upper aquifer was the only source of water and salts.

Water quality monitoring data and the groundwater model simulations indicate that the movement of salts from the upper aquifer to the lower aquifer is even slower due to the other transport mechanisms. This section describes the mixing processes occurring between the upper and deep aquifers within the Bernal, Amador and Mocho II sub-basins.

Bernal Sub-basin upper and deep aquifer mixing - Figure 3.9 presents the actual groundwater level data for two wells in the Bernal Sub-basin for the period 1975-99. The Fairgrounds Key well levels are representative of the upper aquifer and well 3S/1E 20E1 levels are representative of the deep aquifer. During drought conditions in 1976-77 and 1987-92, the deep aquifer groundwater levels declined due to increased municipal pumpage. The groundwater levels in the upper aquifer also declined with the decline in the upper aquifer tracking the decline in the deep aquifer. Since there was no significant increase in pumpage from the upper aquifer, this indicates that significant amounts of groundwater moved from the upper to the deep aquifer. Similarly, when the upper aquifer groundwater level recovered during wet years, the deep aquifer groundwater levels followed. From this figure and other groundwater level data, it can be concluded that there is significant linkage between the two aquifers. The increase in potential gradient due to wet or dry conditions increases the amount of groundwater mixing between the upper and deep aquifers in the Bernal Sub-basin.

Amador Sub-basin upper and deep aquifer mixing - Figure 3.10 presents groundwater level data for two wells in the Amador Sub-basin. The Mohr Avenue key well represents groundwater levels in the upper aquifer and the Mocho-II represents groundwater levels in the deep aquifer. During drought conditions in 1976-77, the groundwater level in both aquifers declined due to increased groundwater pumpage from the deep aquifer. The groundwater levels in the upper aquifer recovered during 1978-83 due to wet years, and the groundwater levels in the deep aquifer returned to even higher elevations than before the drought. Then, the gravel mining companies increased their pumpage from the upper aquifer,

Figure 3.9



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municipal pumpage increased from the deep due to drought conditions, and both aquifers declined from 1984 through 1992.

The upper aquifer levels declined to lower elevations than in the deep aquifer. This happened because of deeper mining (but still within the upper aquifer) and hence increased pumpage from the upper aquifer at this location. The groundwater flow around these wells seemed to be from the deep to the upper aquifer during that period. It can be concluded that there is linkage between the two aquifers and that whenever there is sufficient gradient, groundwater flows and there is mixing between the upper and deep aquifer.

Mocho-II Sub-basin upper and deep aquifer mixing - Figure 3.11 presents groundwater level data for two wells in the Mocho II Sub-basin for the period 1975-99. The figure shows the groundwater levels in the Livermore Key well as representative of the upper aquifer and well 3S/2E 8p1 as representative of the deep aquifer. The major groundwater pumpage from this sub-basin is the municipal pumpage by CWS. It does not change significantly for the most part with either dry or wet conditions. During 1991-92, CWS pumped more than their GPQ. This increased pumpage lowered the deep groundwater levels during that period. As the upper aquifer levels recovered during the subsequent wet years, the deep aquifer levels followed higher. This indicates groundwater movement from the upper to the deep aquifer.

In summary, it can be concluded from the water level monitoring data and groundwater model simulations that there is inter and intra aquifer mixing, the extent of which varies with location and time. During prolonged droughts when the deep aquifer is pumped heavily, the upper aquifer water and salts move to the deep aquifer. The increased pumpage during these dry years increases the vertical hydraulic gradient and the horizontal gradient towards the pumping centers. The increased groundwater level potential gradient during drought years thereby increases the mixing in the main groundwater basin.

3.5 Vadose Zone Attenuation

Attenuation is a natural process whereby a material is reduced in amount, force, or severity. Attenuation may occur by various methods including dilution, dispersion, absorption, biodegradation, volatilization, and/or chemical reactions with soil particles. The vadose zone of soil is that area where the soil is mainly void of water. This region is also called the unsaturated zone or zone of aeration and generally represents the soil layers which lie above a water table or saturated zone, where present.

Evaluation of vadose zone attenuation within a groundwater basin poses various problems with respect to modeling. Example sites must be chosen carefully to insure that they represent the overall groundwater basin vadose zone. The general thickness of the vadose zone at these sites must be established for both wet and dry

Figure 3.10

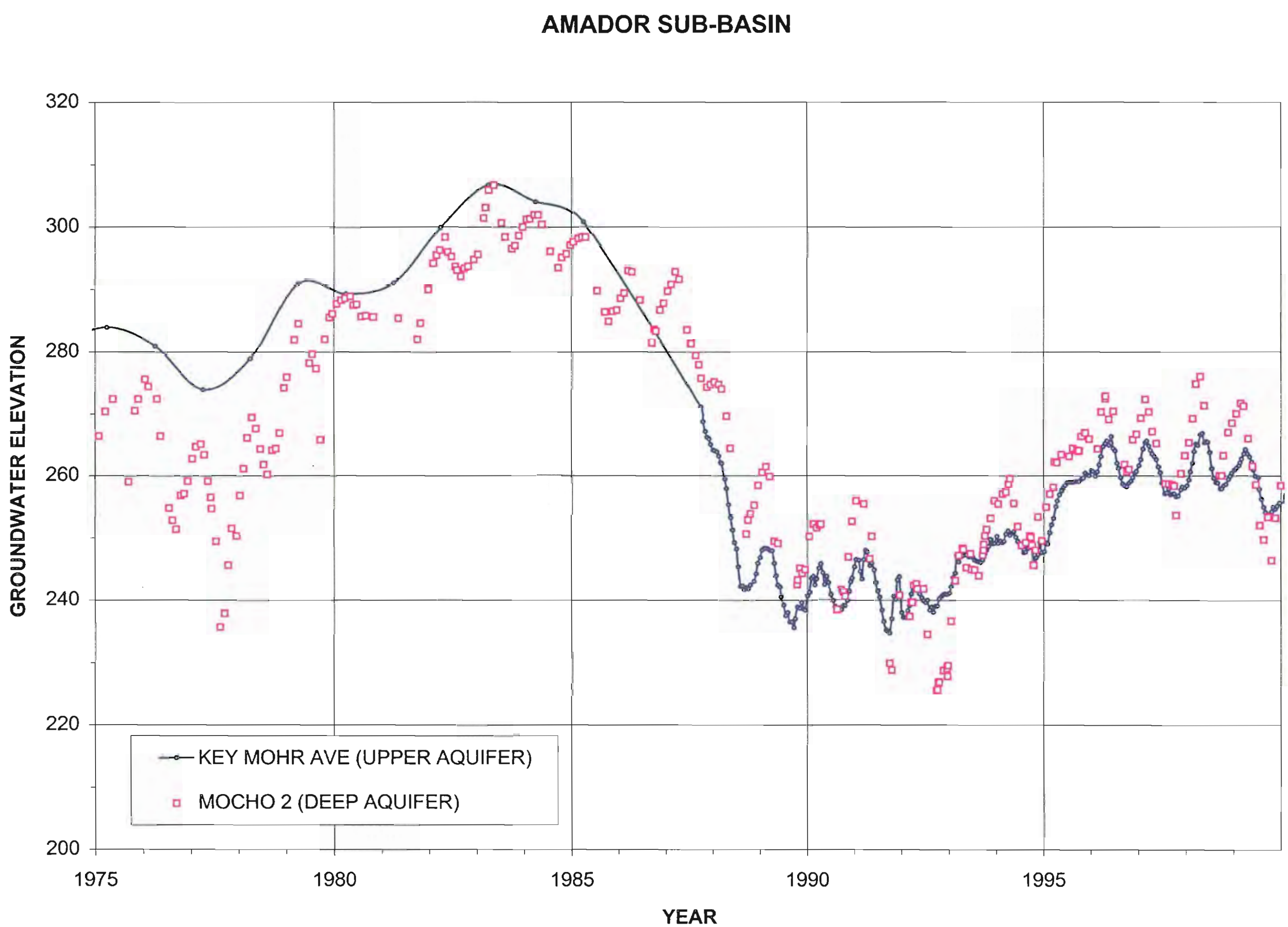
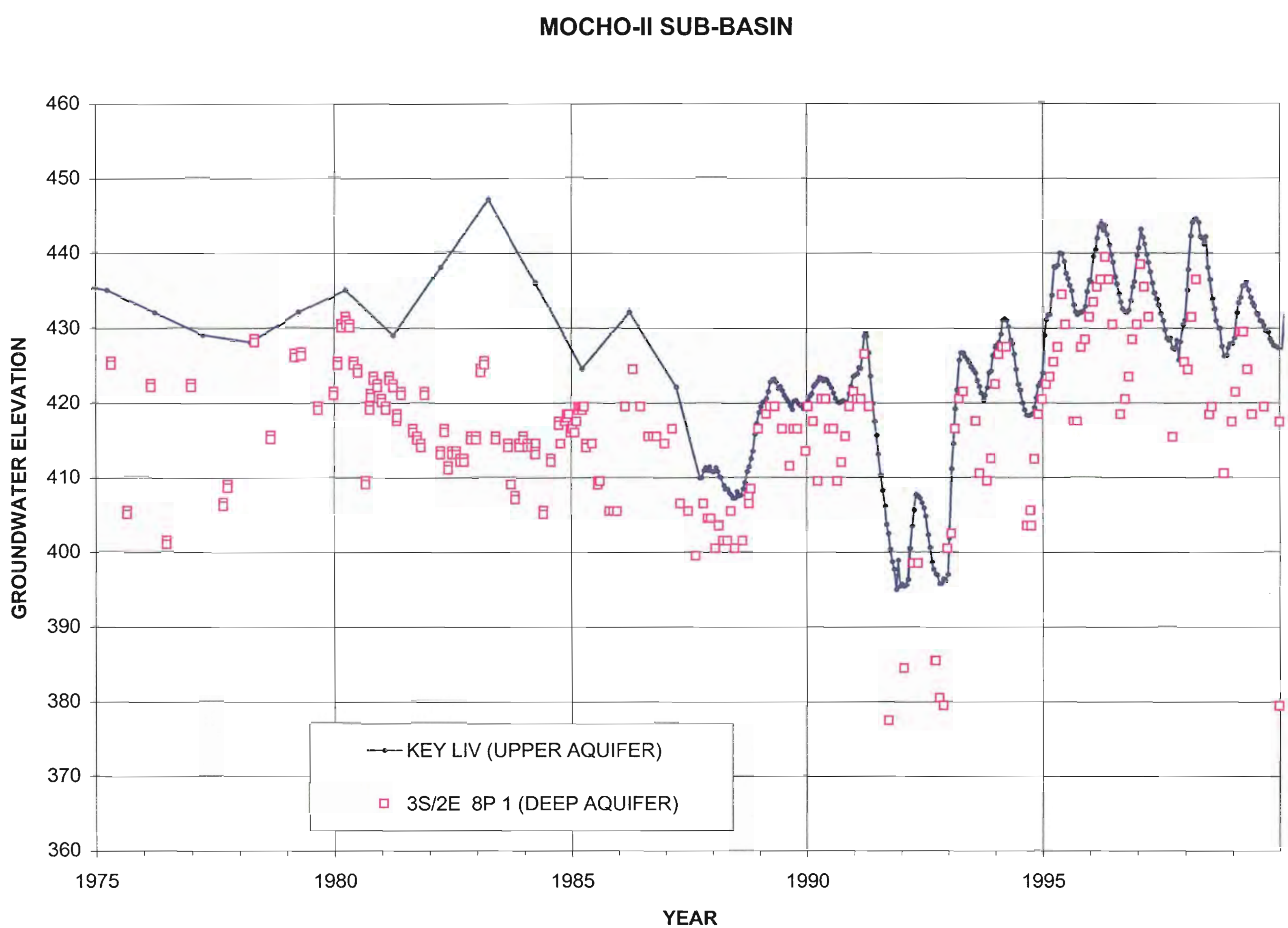

AMADOR SUB-BASIN
GROUNDWATER ELEVATION
320
300
280
260
240
220
200
1975
1980
1985
1990
1995
YEAR
KEY MOHR AVE (UPPER AQUIFER)
MOCHO 2 (DEEP AQUIFER)

Figure 3.11



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water years. The material makeup of the vadose zone soil must be established for these sites and can be ascertained from geologic logs of wells. Intermittent layers of sands, gravels, silts, and clays must be taken into account in the calibration of the model along with variation in potentiometric surfaces through time and differences in hydraulic conductivities. Input data for a model also needs to take into account land use, surface cover, annual rainfall, and applied water quality. Values must be estimated where field data is lacking, which increases the margin of error.

In 1996, Zone 7 contracted with Todd Engineers to undertake a vadose zone attenuation modeling demonstration for selected sites to define the accumulation of salts, represented by TDS, under predetermined conditions (Todd, 1996). The preliminary model results from this demonstration project were inconclusive, reaffirming the complexity and level of effort and data required to construct a representative vadose model for the Livermore-Amador Valley groundwater basin. The results did provide evidence that regardless of where water is applied in the Main Basin and regardless of the total dissolved solids (TDS) concentrations in the applied water, the results would be very similar across the basin. This showed that vadose zone attenuation in the Livermore Valley did not appear to be a function of TDS or soil type.

A literature search was also undertaken to determine if there were similar groundwater basins that had successfully created an attenuation model and ranges of attenuation found. Most notably among these were papers by Aulenbach, et.al. (1974); Bouwer, H. (1974); Rice, et.al. (1989); Runnells, D.D. (1976); Saffigna and Keeney (1977); and Tedaldi and Loehr (1992).

Aulenbach, et.al. (1974) found that the release of treated effluent into a filtration system of natural delta sands did not appreciably reduce the amount of phosphates, nitrates, and chlorides, even at a 10-foot depth. Bouwer (1974) noted that, in arid regions, salt concentrations increase as the percolate from irrigation water passes through the root zone and deeper. Rice, et.al. (1989) states that about 25% of the irrigation water applied to arid soils results in the deep percolation that recharges groundwater. They further noted that, if artificial recharge processes were undertaken in these areas, salt loading could be "very significant."

Runnells (1976) discussed the potential to use the vadose zone to attenuate certain chemicals by evaluating the soil type and adding certain amendments such as pH buffering or oxidation agents. Saffigna and Keeney (1977) found that the application of irrigation water was increasing the nitrate and chloride concentrations in the groundwater of the sand plains of central Wisconsin. Tedaldi and Loehr (1992) theorized that the dissolution of naturally occurring minerals could be a significant contributor to the amount of salts in groundwater.

A literature search and vadose zone modeling conducted for the Chino Basin indicated that 70 to 80% of the applied salt mass would reach the groundwater. The remaining mass was believed to be locked in the vadose zone as immobile mass. The fate of the immobile mass was unclear particularly under conditions such as if groundwater levels were to rise and saturate the vadose zone.

Zone 7's limited vadose attenuation literature review and preliminary modeling investigation confirmed the complexity of the issue and the likely high costs of attempting to more rigorously quantify site specific attenuation percentages. Zone 7 water quality and salt mass balance results also generally supported an assumption of minimal attenuation

Given these results and recommendations from the GMAC and TAG, a policy decision was made that instead of spending significant amounts of money on vadose zone modeling, the money should be spent on fixing the salt loading problem. It was further decided to use zero salt attenuation as a conservative management policy decision. However, several salt management strategies were evaluated (Chapter IX) that did include assumptions of 15 and 30% attenuation to determine how sensitive the results and conclusions were to the zero attenuation assumption.

3.6 Hydrogeologic Information Collection

There have been over 5,000 wells, and countless soil borings drilled in the Livermore Groundwater Basin. The record goes back approximately 110 years to the late 1800s. Basin geology, water levels, water quality, aquifer properties, and boundary conditions have been compiled, studied, and reported by the USGS, California Department of Water Resources, and Zone 7 Water Agency since the 1950's (Williams, 1912, CDWR, 1955, 1960, 1963, 1974; Zone 7 annual monitoring reports, Sorenson et al, 1985; Dibblee, 1980; Sylvester, 1983).

Zone 7 has been collecting precipitation, surface water and groundwater level, and water quality data since 1978. Currently, a network of 23 surface water gauging sites, 11 climatological stations and approximately 200 wells are monitored by Zone 7 for the purpose of groundwater management; i.e., water inventory and quality. Included in the monitoring well network are several multi-level piezometers or well clusters. Water level measurements are periodically made and water quality samples are collected annually from these wells/piezometers to evaluate vertical gradients and flow components.

Municipal water supply well data, such as production histories, water quality, and production logs are shared between local agencies and local water purveyors. Additionally through its Groundwater Protection Ordinance program (GPO), Zone 7 receives well location, well log, and pump test (when performed) information for all new wells drilled in the Zone 7 Service area from the permittees. These data are all cataloged and archived in Zone 7's historic databases.

Recently, Zone 7 conducted a well siting study to evaluate several locations in the Main Basin as potential new production well sites. During the investigation, Zone 7 drilled and tested six sites, Sites 7, 8, 9, 11, 15, and Murrieta. Lithology and borehole geophysical logging and depth-specific water quality sampling were conducted at each site. At Sites 7, 9, 11 and 15, a second well was drilled for production testing purposes. Aquifer testing, production logging, and additional water quality sampling were conducted in these wells. The data and analyses are reported in individual site-specific reports written by Fugro West, Inc. (Fugro 1999a-e) and have been added to the appropriate Zone 7 databases. Similar testing was done by DSRSD and the City of Livermore at several locations for their proposed RO recycled water injection projects. Table 3.2 summarizes the aquifer property results from recent well siting investigations, as well as those from the recycled water project aquifer tests.

Table 3.2: Summary of Recent Aquifer Test Results

Site No.	State Well No.	Ave. Transmissivity (gpd/ft)	Ave. Storage Coefficient
Site 7	3S/1E 8H 14	98,400	0.0022
Site 9			
Site 11	3S/1E 15M 4	54,300	0.0062
Site 15 (Hop 4)	3S/1E 17D 2	90,400	0.0007
Stoneridge	3S/1E 9B 1	280,500	0.00178
Mocho 1	3S/1E 9M 2	485,600	0.00031
Site 15 (Hop 9)			

Other recent data acquisitions include the collection of various geophysical log data for several private and public production or test wells that have been recently drilled in the valley. Zone 7 has encouraged, and in some instances provided for, the logging of several new key wells.

Zone 7 will continue to collect hydrogeologic data through its various monitoring and GPO programs. Zone 7 has scheduled the construction of several new production wells in the near future. As these wells are drilled and tested, Zone 7 will collect additional data from these locations. As other potential well sites are explored by Zone 7 as part of the Well Master Plan effort, staff will continue to collect lithologic, hydrologic, and geophysical data from these locations. An attempt will be made to fill in the areas where modern geophysical logs are sparse or lacking by continuing to encourage, and sometimes provide for the running of geophysical surveys in key new private wells and exploration borings as they are identified during the permitting process.

Several new monitoring wells are planned for the explicit purpose of salt impact monitoring (see Chapter 6, Salt Management Monitoring Plan). Besides providing additional water level, flow gradient and water quality data, they provide an opportunity to collect additional geological information such as: lithology, geologic heterogeneity, and aquifer thickness near the basin margins.

Lawrence Livermore National Laboratories (LLNL) has recently obtained a grant from the State Water Resources Agency to investigate the vulnerability of groundwater supplies throughout the state by age dating the water from several hundred production wells. Zone 7 and several other local groundwater producers may cooperate in this investigation. The results may be used to refine the current understanding of flow velocities and directions and aquifer mixing.

3.7 Groundwater Model

A groundwater model is a device that represents an approximation of a groundwater basin. Physical models such as laboratory sand tanks simulate groundwater flow directly. A mathematical groundwater model simulates groundwater flow indirectly by means of equations to represent the physical process that occur in the groundwater basin. A mathematical model can be solved analytically or numerically. Since analytical solutions are not suitable due to complexities in the groundwater flow modeling, numerical groundwater modeling is more often used for groundwater basin modeling.

Groundwater models are useful for predicting the consequences of a proposed groundwater basin management action. Groundwater models can also be used to learn about the controlling parameters in a site-specific setting such as establishing locations and characteristics of aquifer boundaries.

The original Main Basin groundwater model was developed by Zone 7 and the California Department of Water Resources (DWR) in the 1970's and is documented in DWR Bulletin 118-2. Davies (a Stanford graduate student) developed a groundwater model of the Amador Sub-basin in 1981. Danskin (another Stanford graduate student) extended this model into the Bernal Sub-basin in December 1985 and calibrated the model for average fluxes for the period 1977-1981. Although these models and the associated documentation provided some useful technical information, Zone 7 did not use them for basin management studies.

In 1996, Zone 7 staff retained consultant CH2M Hill to assist with the development of a groundwater flow and solute (salt) transport model for the main groundwater basin. The model was designed to be useable by Zone 7 staff for evaluating alternative Salt Management Plan (SMP) strategies (see Chapter X) and future Main Basin management options. The resultant model, as currently used by Zone 7 staff, includes the Visual MODFLOW for Windows version 2.61 by Waterloo Hydrologic, Inc. package. Visual MODFLOW uses the three-dimensional MODFLOW code to simulate groundwater flow and the three-dimensional MT3D code to simulate solute transport.

3.7.1 Model Grid and Properties

The model grid has four layers and a uniform 500 x 500 foot grid in X and Y directions covering the entire Livermore-Amador Valley Groundwater Basin. Figure 3.12 shows the modeled area. It is a three dimensional model and the thickness of the grid cells varies throughout the model area. The top three layers represent the upper unconfined aquifer, the deep confined aquifer and an intervening aquitard layer, respectively. Figures 3.13 and 3.14 present cross-sectional profiles in the North-South and East-West directions. These cross-sections illustrate typical layer geometry. The model layer elevations for the major portion of the model are based upon a number of geologic well logs.

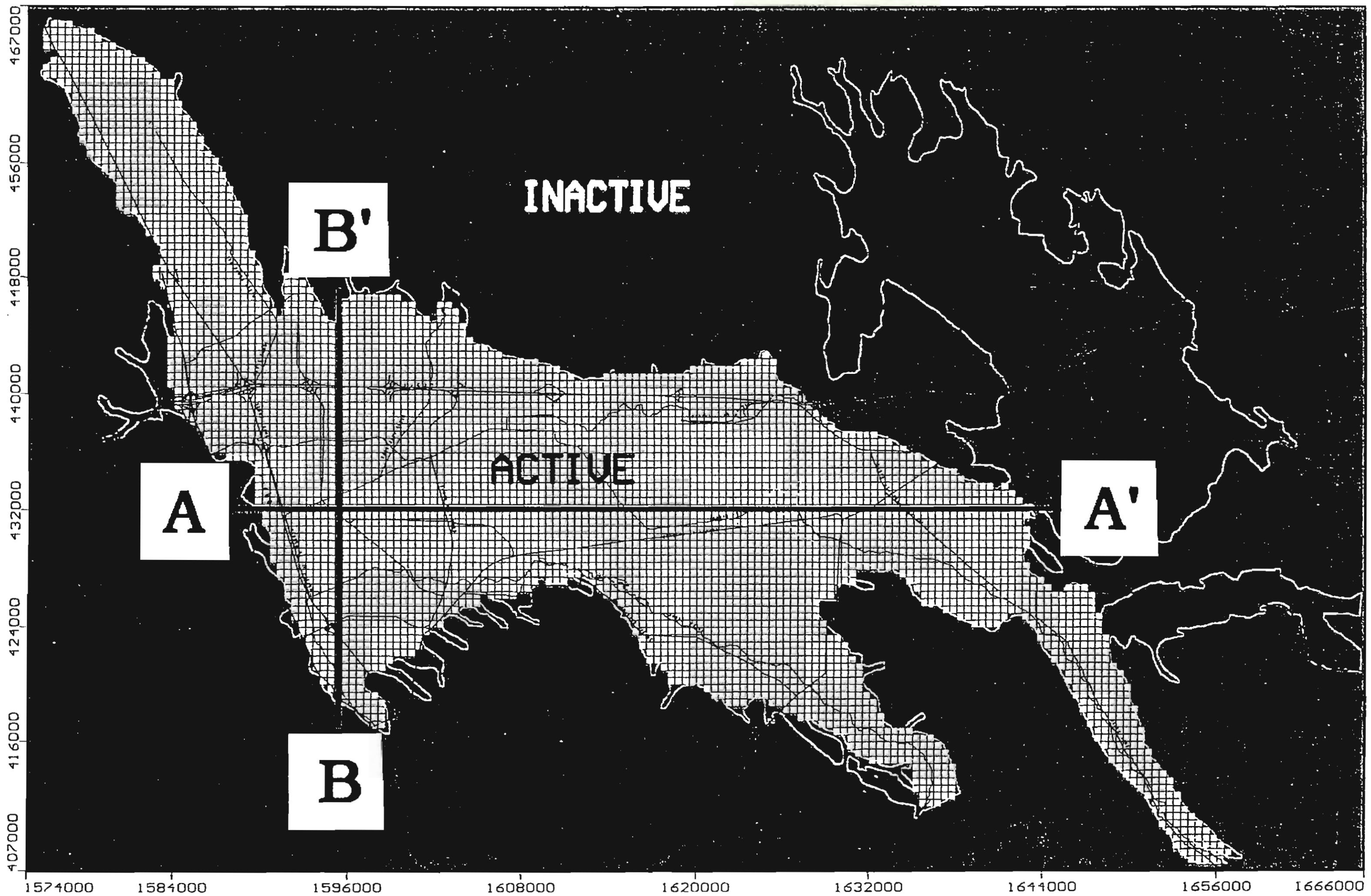
Most of the municipal wells are screened in the deep aquifer. The fourth layer of the model represents the Livermore and Tassajara formations. This layer at this time is inactive since the Livermore and Tassajara formations are low yielding it is believed that there is not any significant interaction with the deep aquifer. To further focus Zone 7 resources it was decided to activate only the Main Basin and some key fringe basins. The current active model area therefore covers the Main Basin (Amador, Bernal, Castle and Mocho II sub-basins) plus the Dublin, Camp, and Bishop fringe sub-basins. The active and inactive areas of the model are shown in Figure 3.12. The boundary between the active and inactive areas represents a no flow boundary.

Figures 3.15 through 3.17 show the hydraulic conductivity distribution for the three active model layers. The hydraulic conductivity ranges from 0.7 to 134 ft/day for model layer 1 (upper aquifer), 0.001 to 0.2 ft/day for model layer 2 (aquitard layer) and 1 to 350 ft/day for model layer 3 (deep aquifer). Figures 3.18 and 3.19 show the distribution of specific yield (Sy) in the model layer 1 and specific storage (Ss) in model layer 3.

The Livermore, Mocho, Parks and Pleasanton faults are represented in the model using the MODFLOW horizontal flow boundary package. Figure 3.20 shows the location of the faults in the deep aquifer. Groundwater monitoring data and earlier investigations indicate that these faults impede flow across them only in the deep aquifer.

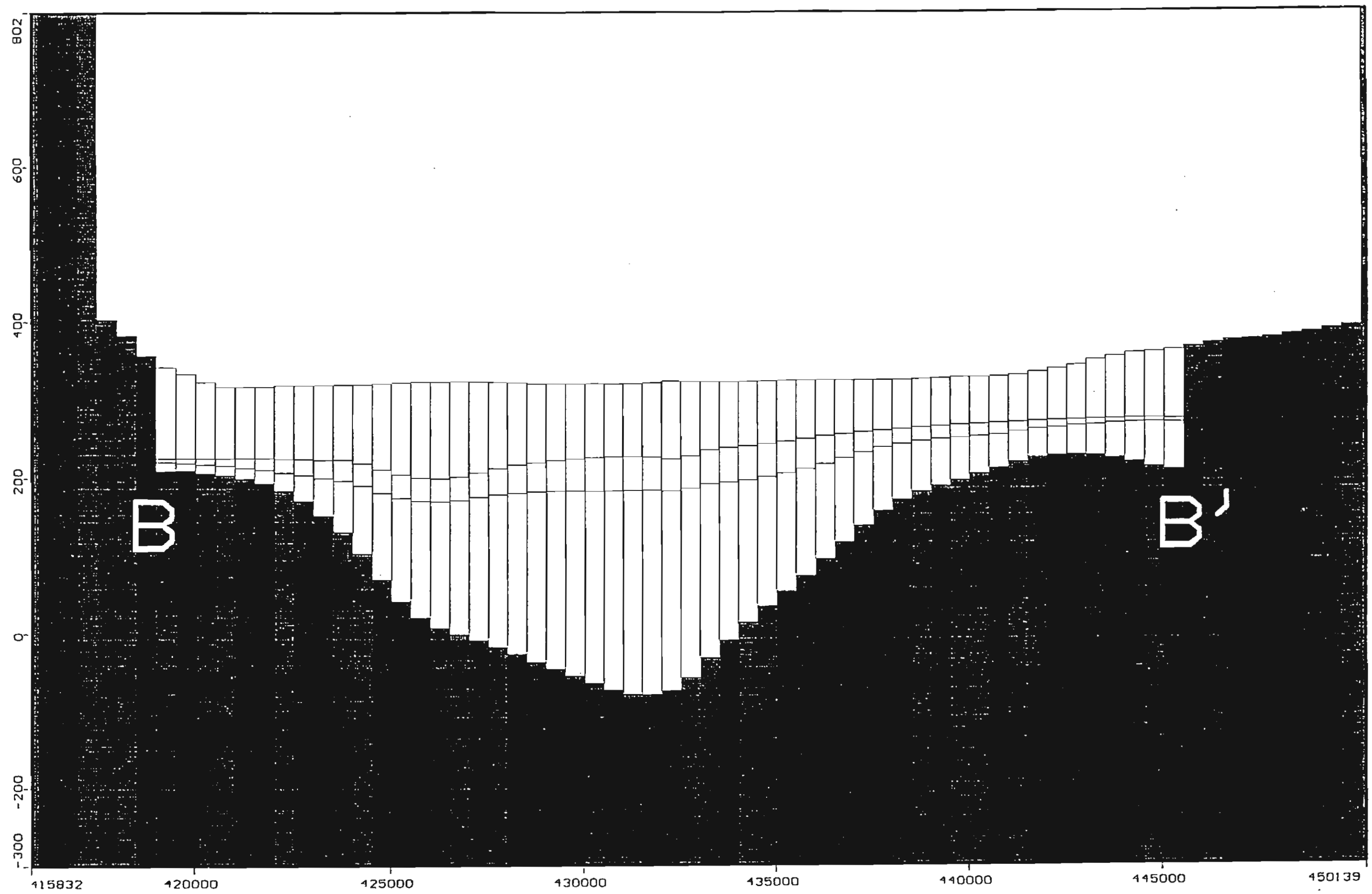
3.7.2 Model Fluxes

The model flux sources (i.e., inputs) include rainfall recharge, applied irrigation water recharge, stream recharge, and injection well recharge. Flux sinks (outputs)



CH2M Hill Inc – Oakland, CA Project: LVGWB Model v. 2.0.55 Description: Model Grid Modeller: CH2M Hill 9 Jan 98	Visual MODFLOW v.2.61, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 184 NR: 120 NL: 4 Current Layer: 1

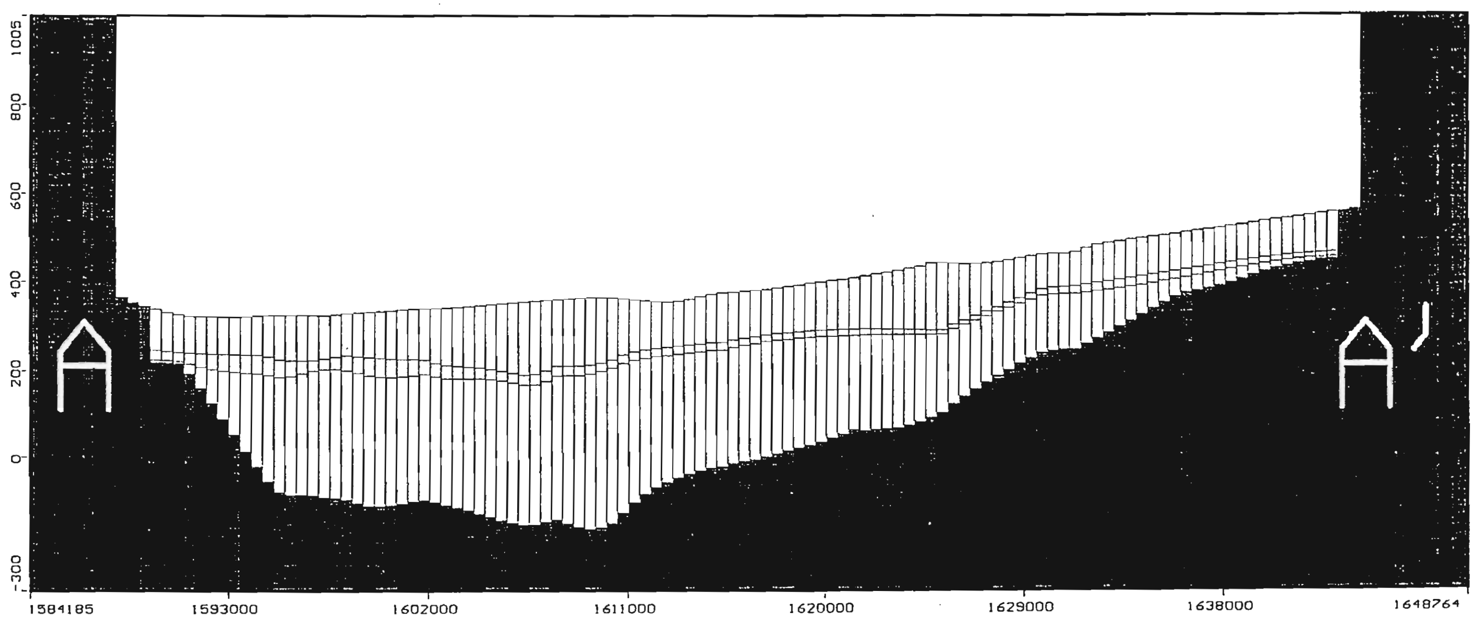
FIGURE 3.12



CH2M Hill Inc – Oakland, CA
Project: LVGWB Model v. 2.0.55
Description: Cross Section B–B' (C43)
Modeller: CH2M Hill
9 Jan 98

Visual MODFLOW v.2.61, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 184 NR: 120 NL: 4
Current Column: 43

FIGURE 3.13



CH2M Hill Inc – Oakland, CA Project: LVGWB Model v. 2.0.55 Description: Cross Section A–A' (R70) Modeller: CH2M Hill 9 Jan 98	Visual MODFLOW v.2.61, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 184 NR: 120 NL: 4 Current Row: 70 FIGURE 3.14

include groundwater well pumping, gravel mining pumping and groundwater outflow (gaining streams).

Each of these main flux components has sub-components. For example, stream recharge includes natural recharge, artificial recharge, and gravel mining recharge. Recharge on each stream is also divided into a number of reaches since recharge rates vary depending on stream location. Based upon monitoring program data, two databases were prepared that had monthly data for each component of recharge and pumpage for the period 1974-95. Tables 3.3, 3.4 and 3.5 list the components of recharge and pumpage. Each of the recharge components was also assigned a TDS value based upon the monitoring data. Table 3.6 lists the TDS in mg/L for each recharge component.

The rainfall recharge and applied water recharge in the model are combined as areal recharge. The areal recharge amounts and TDS vary with soil type and hydrologic conditions throughout the model area. To address this situation, the areal recharge was distributed using DWR model nodal zone designations. Fig 3.21 presents the node numbers and the average TDS of areal recharge for each node.

Natural stream recharge, artificial stream recharge and gravel mining stream recharge are modeled using the MODFLOW river package. The river package is used in the model in such a way that the recharging streams operate as specified flux boundaries. The gaining streams and mining gravel pits are modeled using the MODFLOW drain package. During the model application for salt management plan simulations, the mining ponds (Chain of Lakes) were modeled as evaporation boundaries with the west face (recharging face) of Lake I modeled as injection wells into the upper aquifer.

3.7.3 *Initial Conditions*

Initial conditions for the flow model were based upon Zone 7 fall 1975 groundwater level data for the upper and lower aquifers. The initial conditions for the aquitard were assumed to be the same as for the upper aquifer. The initial conditions for the solute transport model were also based upon actual Zone 7 data (generally 1990-1995 monitoring data) for the upper and lower aquifers. The aquitard TDS used was the average of upper and lower aquifer TDS.

3.7.4 *Model Flow Calibration*

Model calibration typically involves running the model, comparing the model output with the observed data, adjusting the model properties and/or model fluxes, and then redoing this repeatedly until there is a reasonable fit between the predicted and observed data. Comparisons between contour maps of measured and simulated heads provides a qualitative measure of the similarity between patterns, thereby giving an idea of the spatial distribution of error. Comparisons between

ZONE 7
WATER RESOURCES ENGINEERING

DESCRIPTION OF RECORDS IN "RECHRAGE.DBF" FILE

THE DBF FILE IS LOCATED AT E:\MODFLOW\CH2M\FLOWDATA\RECHARGE.DBF. THE FILE CONTAINS THE RECHARGE COMPONENTS FOR THE MAIN GW BASIN FOR 1974-95.

STATION	FIRST YEAR	Rech/Pump	Layer	Description
ADLL_OUT_M1	1974	Recharge	1	ADLLP outflow
ALP_RC_M1	1974	Recharge	1	ALP conservation rech. thru M1
ALP_RC_M2	1974	Recharge	1	ALP conservation rech. thru M2
ALP_RC_M3	1974	Recharge	1	ALP conservation rech. thru M3
ALP_RN_M1	1974	Recharge	1	ALP natural rech. thru M1
ALP_RN_M2	1974	Recharge	1	ALP natural rech. thru M2
ALP_RN_M3	1974	Recharge	1	ALP natural rech. thru M3
AM_RC_M1	1974	Recharge	1	AM conservation rech. thru M1
AM_RC_M2	1974	Recharge	1	AM conservation rech. thru M2
AM_RC_M3	1974	Recharge	1	AM conservation rech. thru M3
AM_RC_M4	1974	Recharge	1	AM conservation rech. thru M4
AM_RC_M5	1974	Recharge	1	AM conservation rech. thru M5
AM_RC_M6	1974	Recharge	1	AM conservation rech. thru M6
AM_RCM_M4	1974	Recharge	1	AM recharge from Calmat thru M4
AM_RKA_M5	1974	Recharge	1	AM recharge from Kaiser thru M5
AM_RN_M1	1974	Recharge	1	AM natural rech. thru M1
AM_RN_M2	1974	Recharge	1	AM natural rech. thru M2
AM_RN_M3	1974	Recharge	1	AM natural rech. thru M3
AM_RN_M4	1974	Recharge	1	AM natural rech. thru M4
AM_RN_M5	1974	Recharge	1	AM natural rech. thru M5
AM_RN_M6	1974	Recharge	1	AM natural rech. thru M6
AV_RC_M1	1974	Recharge	1	AV conservation rech. thru M1
AV_RC_M2	1974	Recharge	1	AV conservation rech. thru M2
AV_RC_M3	1974	Recharge	1	AV conservation rech. thru M3
AV_RC_M4	1974	Recharge	1	AV conservation rech. thru M4
AV_RC_M5	1974	Recharge	1	AV conservation rech. thru M5
AV_RKA_M4	1974	Recharge	1	AV recharge from Kaiser thru M4
AV_RLS_M4	1974	Recharge	1	AV recharge from Lonestar thru M4
AV_RN_M1	1974	Recharge	1	AV natural rech. thru M1
AV_RN_M2	1974	Recharge	1	AV natural rech. thru M2
AV_RN_M3	1974	Recharge	1	AV natural rech. thru M3
AV_RN_M4	1974	Recharge	1	AV natural rech. thru M4
AV_RN_M5	1974	Recharge	1	AV natural rech. thru M5
INFLOW_N15	1974	Recharge	1	Inflow into Node 15
INFLOW_N16	1974	Recharge	1	Inflow into Node 16
INFLOW_N23	1974	Recharge	1	Inflow into Node 23
RC_AW_U_N15	1974	Recharge	1	Urban Applied Water Recharge in Node 15
RC_AW_U_N16	1974	Recharge	1	Urban Applied Water Recharge in Node 16
RC_AW_U_N17	1974	Recharge	1	Urban Applied Water Recharge in Node 17
RC_AW_U_N18	1974	Recharge	1	Urban Applied Water Recharge in Node 18
RC_AW_U_N19	1974	Recharge	1	Urban Applied Water Recharge in Node 19
RC_AW_U_N20	1974	Recharge	1	Urban Applied Water Recharge in Node 20
RC_AW_U_N23	1974	Recharge	1	Urban Applied Water Recharge in Node 23
RC_AW_U_N24	1974	Recharge	1	Urban Applied Water Recharge in Node 24
RC_AW_U_N25	1974	Recharge	1	Urban Applied Water Recharge in Node 25
RC_AW_U_N26	1974	Recharge	1	Urban Applied Water Recharge in Node 26
RC_AW_U_N29	1974	Recharge	1	Urban Applied Water Recharge in Node 29
RC_AW_U_N30	1974	Recharge	1	Urban Applied Water Recharge in Node 30
RC_AW_U_N31	1974	Recharge	1	Urban Applied Water Recharge in Node 31
RC_AW_U_N33	1974	Recharge	1	Urban Applied Water Recharge in Node 33
RC_AW_U_N34	1974	Recharge	1	Urban Applied Water Recharge in Node 34
RC_AW_U_N35	1974	Recharge	1	Urban Applied Water Recharge in Node 35
RC_AW_U_N38	1974	Recharge	1	Urban Applied Water Recharge in Node 38
RC_AW_U_N39	1974	Recharge	1	Urban Applied Water Recharge in Node 39
RC_AW_U_N40	1974	Recharge	1	Urban Applied Water Recharge in Node 40
RC_AW_U_N41	1974	Recharge	1	Urban Applied Water Recharge in Node 41
RC_AW_U_N42	1974	Recharge	1	Urban Applied Water Recharge in Node 42
RC_LWRP_N29	1974	Recharge	1	LWRP Applied Water Recharge in Node 29
RC_LWRP_N30	1974	Recharge	1	LWRP Applied Water Recharge in Node 30
RC_LWRP_N33	1974	Recharge	1	LWRP Applied Water Recharge in Node 33

ZONE 7
WATER RESOURCES ENGINEERING

DESCRIPTION OF RECORDS IN "RECHRAGE.DBF" FILE

THE DBF FILE IS LOCATED AT E:\MODFLOW\CH2M\FLOWDATA\RECHARGE.DBF. THE FILE CONTAINS THE RECHARGE COMPONENTS FOR THE MAIN GW BASIN FOR 1974-95.

RC_RR_N15	1974	Recharge	1	Rainfall Recharge in Node 15
RC_RR_N16	1974	Recharge	1	Rainfall Recharge in Node 16
RC_RR_N17	1974	Recharge	1	Rainfall Recharge in Node 17
RC_RR_N18	1974	Recharge	1	Rainfall Recharge in Node 18
RC_RR_N19	1974	Recharge	1	Rainfall Recharge in Node 19
RC_RR_N20	1974	Recharge	1	Rainfall Recharge in Node 20
RC_RR_N23	1974	Recharge	1	Rainfall Recharge in Node 23
RC_RR_N24	1974	Recharge	1	Rainfall Recharge in Node 24
RC_RR_N25	1974	Recharge	1	Rainfall Recharge in Node 25
RC_RR_N26	1974	Recharge	1	Rainfall Recharge in Node 26
RC_RR_N29	1974	Recharge	1	Rainfall Recharge in Node 29
RC_RR_N30	1974	Recharge	1	Rainfall Recharge in Node 30
RC_RR_N31	1974	Recharge	1	Rainfall Recharge in Node 31
RC_RR_N33	1974	Recharge	1	Rainfall Recharge in Node 33
RC_RR_N34	1974	Recharge	1	Rainfall Recharge in Node 34
RC_RR_N35	1974	Recharge	1	Rainfall Recharge in Node 35
RC_RR_N38	1974	Recharge	1	Rainfall Recharge in Node 38
RC_RR_N39	1974	Recharge	1	Rainfall Recharge in Node 39
RC_RR_N40	1974	Recharge	1	Rainfall Recharge in Node 40
RC_RR_N41	1974	Recharge	1	Rainfall Recharge in Node 41
RC_RR_N42	1974	Recharge	1	Rainfall Recharge in Node 42
RC_SFWD_N19	1974	Recharge	1	SFWD Applied Water Recharge in Node 19
RC_SFWD_N20	1974	Recharge	1	SFWD Applied Water Recharge in Node 20
RC_UNAG_N15	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 15
RC_UNAG_N16	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 16
RC_UNAG_N17	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 17
RC_UNAG_N18	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 18
RC_UNAG_N19	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 19
RC_UNAG_N20	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 20
RC_UNAG_N23	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 23
RC_UNAG_N24	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 24
RC_UNAG_N25	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 25
RC_UNAG_N26	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 26
RC_UNAG_N29	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 29
RC_UNAG_N30	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 30
RC_UNAG_N31	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 31
RC_UNAG_N33	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 33
RC_UNAG_N34	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 34
RC_UNAG_N35	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 35
RC_UNAG_N38	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 38
RC_UNAG_N39	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 39
RC_UNAG_N40	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 40
RC_UNAG_N41	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 41
RC_UNAG_N42	1974	Recharge	1	Unmetered Ag.Water Recharge in Node 42

ZONE 7
WATER RESOURCES ENGINEERING

DESCRIPTION OF RECORDS IN "WELLPRO2.DBF" FILE

THE DBF FILE IS LOCATED AT E:\MODFLOW\CH2M\FLOWDATA\WELLPRO2 .DBF. THE FILE CONTAINS THE PRODUCTION COMPONENTS FOR THE MAIN GW BASIN FOR 1974-95.

STATION	YEAR	Rech/Pump	Layer	Description
CASTLEWOOD_G	1974	Pumpage	3	Pumpage from Well 3S/1E 19A 3
CWS#20 (18B)	1974	Pumpage	3	Pumpage from Well 3S/2E 18B 1
CWS#24 (7P3)	1974	Pumpage	3	Pumpage from Well 3S/2E 7P 3
GWP_3S1E1P3	1974	Pumpage	3	Pumpage from Well 3S/1E 1P 3
GWP_3S1E20B2	1974	Pumpage	3	Pumpage from Well 3S/1E 20B 2
GWP_3S1E20C3	1991	Pumpage	3	Pumpage from Well 3S/1E 20C 3
GWP_AG_SFWD	1974	Pumpage	3	Pumpage from Well 3S/1E 20E 1
GWP_CASTLE	1974	Pumpage	3	Pumpage from Well 3S/1E 29E 4
GWP_CM_R16	1984	Pumpage	1	Calmat Pumpage From R16
GWP_CM_R17	1983	Pumpage	1	Calmat Pumpage From R17
GWP_CM_R19	1987	Pumpage	1	Calmat Pumpage From R19
GWP_CM_R21	1994	Pumpage	1	Calmat Pumpage From R21
GWP_CM_R3	1974	Pumpage	1	Calmat Pumpage From R3
GWP_CM_R5	1976	Pumpage	1	Calmat Pumpage From R5
GWP_CM_R8	1980	Pumpage	1	Calmat Pumpage From R8
GWP_KA_K24	1980	Pumpage	1	Kaiser Pumpage From K24
GWP_KA_K28	1983	Pumpage	1	Kaiser Pumpage From K28
GWP_KA_K30	1974	Pumpage	1	Kaiser Pumpage From K30
GWP_KA_K34	1987	Pumpage	1	Kaiser Pumpage From K34
GWP_KA_K35	1990	Pumpage	1	Kaiser Pumpage From K35
GWP_KA_K36	1985	Pumpage	1	Kaiser Pumpage From K36
GWP_LS_P20	1985	Pumpage	1	Lonestar Pumpage From P20
GWP_LS_P21	1987	Pumpage	1	Lonestar Pumpage From P21
GWP_LS_P22	1974	Pumpage	1	Lonestar Pumpage From P22
GWP_LS_P23	1980	Pumpage	1	Lonestar Pumpage From P23
GWP_LS_P30	1990	Pumpage	1	Lonestar Pumpage From P30
GWP_LS_P31	1983	Pumpage	1	Lonestar Pumpage From P31
GWP_LS_P7	1979	Pumpage	1	Lonestar Pumpage From P7
GWP_TVGLF	1992	Pumpage	3	Pumpage from Well 3S/1E 2P 7
GWP_UAG_N15	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 15
GWP_UAG_N16	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 16
GWP_UAG_N17	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 17
GWP_UAG_N18	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 18
GWP_UAG_N19	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 19
GWP_UAG_N20	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 20
GWP_UAG_N23	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 23
GWP_UAG_N24	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 24
GWP_UAG_N25	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 25
GWP_UAG_N26	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 26
GWP_UAG_N29	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 29
GWP_UAG_N30	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 30
GWP_UAG_N31	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 31
GWP_UAG_N33	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 33
GWP_UAG_N34	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 34
GWP_UAG_N35	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 35
GWP_UAG_N38	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 38
GWP_UAG_N39	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 39
GWP_UAG_N40	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 40
GWP_UAG_N41	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 41
GWP_UAG_N42	1974	Pumpage	3	Unmetered Ag.Water Pumpage in Node 42
HOP 1	1974	Pumpage	3	Pumpage from Well 3S/1E 18A 1
HOP 4	1974	Pumpage	3	Pumpage from Well 3S/1E 17D 2
HOP 6	1974	Pumpage	3	Pumpage from Well 3S/1E 18A 6
MOCHO 1	1974	Pumpage	3	Pumpage from Well 3S/1E 9M 2
MOCHO 2	1974	Pumpage	3	Pumpage from Well 3S/1E 9M 3
PLEAS #5	1974	Pumpage	3	Pumpage from Well 3S/1E 16L 5
PLEAS #6	1974	Pumpage	3	Pumpage from Well 3S/1E 16L 7
PLEAS #7	1974	Pumpage	3	Pumpage from Well 3S/1E 18A 5
PLEAS #8	1993	Pumpage	3	Pumpage from Well 3S/1E 16A 2
STONERIDGE_1	1992	Pumpage	3	Pumpage from Well 3S/1E 9B 1

ZONE 7
WATER RESOURCES ENGINEERING

DESCRIPTION OF RECORDS IN " RECHG_E. DBF" FILE

THE DBF FILE IS LOCATED AT E:\MODFLOW\CH2M\FLOWDATA\RECHG_E.DBF. THIS FILE CONTAINS THE RECHARGE AND DISCHARGE COMPONENTS FOR DUBLIN, CAMP AND BISHOP SUBBASINS. IT ALSO CONTAINS THE ADDITIONAL AG APPLIED WATER RECHARGE IN NODE 40 OF MOCHO SUBBASIN DUE TO DELIVERIES FROM SBA REACH 4 OF SBA.. THIS DBF FILE FOR THE PERIOD 1974-1995.

STATION	FIRST YEAR	RECHARGE/ DISCHARGE	LAYER	DESCRIPTION
ALMO_OUT_M1	1974	DISCHARGE	1	GW OUTFLOW INTO REACH M1 OF ALAMO CANAL
ALMO_OUT_M2	1974	DISCHARGE	1	GW OUTFLOW INTO REACH M2 OF ALAMO CANAL
DUB_OUT_M2	1974	DISCHARGE	1	GW OUTFLOW INTO REACH M2 OF DUBLIN CREEK
RC_AW_U_N1	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N10	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N11	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N12	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N13	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N14	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N2	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N21	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N22	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N27	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N28	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N3	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N32	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N37	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N4	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N5	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N6	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N7	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N8	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_AW_U_N9	1974	RECHARGE	1	URBAN APPLIED WATER RECHARGE IN NODE # ---
RC_RR_N1	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N10	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N11	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N12	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N13	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N14	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N2	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N21	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N22	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N27	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N28	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N3	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N32	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N37	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N4	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N5	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N6	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N7	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N8	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_RR_N9	1974	RECHARGE	1	RAINFALL RECHARGE IN NODE # ----
RC_SBA4_N40	1974	RECHARGE	1	AG APPLIED WATER RECHARGE IN NODE 40 FROM SBA DELIVERIES IN RECCH 4 OF SBA
SMON_OUT_M2	1974	DISCHARGE	1	GW OUTFLOW INTO REACH M2 OF SAN RAMON CREEK
TJ_RN_M2	1974	RECHARGE	1	NATURAL STREAM RECHARGE IN REACH 2 OF TASAJARA CRE
DSRSD#1	1974	GW PUMPAGE		GW PUMPAGE FROM LAYER #3 BY WELL # 3S/1W 1B 1 CCE=1588899.8, CCN=442474.5
DSRSD#2	1974	GW PUMPAGE		GW PUMPAGE FROM LAYER #3 BY WELL # 3S/1W 1G 2 CCE=1589903.5, CCN=442109.7
DSRSD#3	1974	GW PUMPAGE		GW PUMPAGE FROM LAYER #3 BY WELL # 3S/1W 1H 2 CCE=1590968.1, CCN=441785.4

TABLE 3.6

RECHARGE WATER TDS IN mg/l

year	ARROYO VALLE NATURAL upper reaches AV REACHES M1 TO M3	ARROYO VALLE NATURAL lower reaches AV REACHES M4 TO M5	ARROYO VALLE ARTIFICIAL	ARROYO VALLE BLENDED TDS FOR REACHES M1 - M3	ARROYO VALLE BLENDED TDS FOR REACHES M4 - M5	ARROYO MOCHO NATURAL	ARROYO MOCHO ARTIFICIAL	ARROYO MOCHO BLENDED TDS FOR REACHES M1 - M3	ARROYO MOCHO BLENDED TDS FOR REACHES M4 - M6	ARROYO LAS POSITAS NATURAL	ARROYO LAS POSITAS ARTIFICIAL	ARROYO LAS POSITAS WASTEWATER	ARROYO LAS POSITAS ALP BLENDED TDS	TASAJARA CREEK NATURAL RECHARGE TDS	TDS OF BLENDED AREAL RECHARGE (INCLUDED AW_U, RR, AW_UNAG AND LWRP RECHARGE) ALL MAIN BASIN NODES EXCEPT NODES 29,30 & 33	NODES 29,30&33 (LWRP)	NODES 1 THROUGH 5	NODES 6 THROUGH 14	NODES 21,22,27 28, 32 & 37	SUBSURFACE INFLOW	SUBSURFACE OUTFLOW	MINING COMPANY RECHARGES
1974	597	233	150	**341**	**372**	400	150	**314**	**321**	700		650	**675**	**609**			**168**	**716**	**0**	**1,500**		450
1975	404	194	200	**268**	**280**	400	200	**335**	**355**	700		650	**670**	**609**			**171**	**659**	**0**	**1,500**		450
1976	800		200	**292**	**334**	400	200	**229**	**251**	700		650	**663**	**609**			**700**	**2384**	**0**	**1,500**		450
1977	800		500	**555**	**551**	400	500	**490**	**484**	700		650	**663**	**609**			**700**	**4807**	**0**	**1,500**		450
1978	478	209	350	**398**	**402**	400	350	**384**	**386**	700	350	650	**659**	**609**			**119**	**624**	**0**	**1,500**		450
1979	800	250	200	**295**	**295**	400	200	**234**	**265**	700		650	**670**	**609**			**370**	**1164**	**0**	**1,500**	**850**	450
1980	561	214	200	**282**	**282**	400	200	**264**	**302**	700	200	650	**590**	**609**			**125**	**332**	**0**	**1,500**	**850**	450
1981	800	250	200	**262**	**268**	400	200	**229**	**269**	700	200		**455**	**609**			**700**	**2111**	**0**	**1,500**	**850**	450
1982	441	209	200	**299**	**309**	400	200	**319**	**340**	1,000	200		**834**	**609**			**34**	**99**	**0**	**1,500**	**850**	460
1983	298	193	150	**257**	**283**	400	150	**376**	**394**	1,200			**1,200**	**609**			**25**	**58**	**0**	**1,500**	**850**	430
1984	739	247	150	**556**	**508**	400		**400**	**405**	1,200			**1,200**	**609**			**261**	**605**	**0**	**1,500**	**850**	420
1985	800	250	200	**430**	**425**	400		**400**	**404**	1,200			**1,200**	**609**			**700**	**2176**	**0**	**1,500**	**850**	420
1986	345	177	240	**320**	**394**	400		**400**	**402**	1,200			**1,200**	**609**			**69**	**257**	**0**	**1,500**	**850**	460
1987	800	250	240	**451**	**473**	400		**400**	**400**	1,200			**1,200**	**609**			**700**	**2424**	**0**	**1,500**	**850**	480
1988	800	250	330	**557**	**552**	400	330	**360**	**360**	1,200			**1,200**	**609**			**700**	**3492**	**0**	**1,500**	**850**	550
1989	800	250	270	**425**	**489**	400	270	**291**	**291**	1,200			**1,200**	**609**			**700**	**3128**	**0**	**1,500**	**900**	510
1990	850	250	320	**539**	**500**	400	295	**305**	**305**	1,070			**1,070**	**609**			**700**	**3280**	**0**	**1,500**	**920**	490
1991	535	203	320	**453**	**535**	400	360	**375**	**375**	980			**980**	**609**			**535**	**3044**	**0**	**1,500**	**900**	570
1992	710	250	330	**545**	**548**	350	330	**345**	**345**	1,180			**1,180**	**609**			**520**	**2772**	**0**	**1,500**		550
1993	377	247	240	**317**	**427**	410	260	**330**	**339**	1,150			**1,150**	**609**			**61**	**229**	**0**	**1,500**		550
1994	570	250	270	**362**	**482**	580	260	**308**	**323**	850			**850**	**609**			**700**	**2619**	**0**	**1,500**		540
1995	409	239	200	**341**	**435**	370	160	**246**	**314**	1,000			**1,000**	**609**			**47**	**146**	**0**	**1,500**	**830**	520

FOR ALL MAIN BASIN NODES, SEE TABLE 3.6A FOR AREAL RECHARGE TDS.

AREAL RECHARGE TDS FOR ALL MAIN BASIN NODES

Table 3.6A

	Model stress period		BLENDED TDS FOR EACH NODE(FOR APPLIED URBAN, APPLIED UNAG, RAIN , LWRP and AG applied water reharge)																				
			NODE NMBERS																				AVERAGE
YEAR	in days		15	16	17	18	19	20	23	24	25	26	29	30	31	33	34	35	38	39	40	41	42	
1974			1420	295	565	432	1014	885	706	600	529	1774	2427	1873	253	1844	1476	301	710	491	620	515	512	916
1975			1319	261	519	332	303	300	627	342	504	1677	2626	1872	243	2072	1348	274	631	430	642	455	460	821
1976	0.0	365.0	4115	2384	3419	2563	2717	2545	3220	2603	3229	4331	5302	4781	4800	5046	4215	1201	2511	953	946	953	953	2990
1977	365.0	730.0	4802	4807	4804	4807	4804	4805	4805	4807	4804	4801	5393	4800	4800	5567	4802	1922	4807	1923	1923	1923	1923	4182
1978	730.0	1095.0	1068	307	481	427	619	574	548	392	520	1466	2550	1706	189	2369	1256	290	645	496	861	527	528	849
1979	1095.0	1460.0	1199	404	950	565	1140	977	650	515	881	2444	3379	2604	494	3046	2126	421	838	498	689	516	520	1184
1980	1460.0	1825.0	179	132	391	163	357	326	190	170	330	1428	2369	1445	172	2464	1130	183	368	230	471	244	247	618
1981	1825.0	2190.0	844	704	1432	924	1919	1837	889	864	714	2299	4086	2974	367	3747	1398	626	1458	629	788	641	644	1418
1982	2190.0	2555.0	58	47	128	63	120	126	61	63	43	315	803	300	14	667	289	54	189	92	279	100	101	186
1983	2555.0	2920.0	33	27	71	33	231	187	35	40	29	162	636	194	0	566	177	31	84	56	182	61	70	138
1984	2920.0	3285.0	274	228	650	256	398	441	287	271	327	1087	2497	1445	0	1959	803	183	440	304	483	318	359	619
1985	3285.0	3650.0	544	524	470	622	1688	1586	573	666	866	2049	3383	2471	499	2644	2984	376	960	558	686	575	574	1205
1986	3650.0	4015.0	125	91	92	116	547	412	132	147	166	407	1028	713	0	939	686	111	241	199	402	214	215	332
1987	4015.0	4380.0	1717	1526	2564	1662	3453	3069	1792	1678	1934	2508	4644	3840	0	3998	2254	742	2197	880	919	887	891	2055
1988	4380.0	4745.0	2235	1979	1996	2162	3310	3095	2235	2253	2641	3168	5017	3790	0	4610	2489	1194	2584	1234	1288	1247	1241	2370
1989	4745.0	5110.0	1912	1825	1760	1981	3087	2948	1912	2040	2522	2976	4801	3633	0	4546	1840	1119	2283	1116	1164	1123	1124	2177
1990	5110.0	5475.0	2577	2369	2460	2492	3574	3410	2577	2589	2829	3580	5068	4000	0	4650	3265	1347	2751	1233	1236	1239	1246	2595
1991	5475.0	5840.0	252	185	172	205	955	821	269	224	170	698	2396	1080	0	2353	570	145	348	329	944	353	361	611
1992	5840.0	6205.0	1028	834	731	951	916	958	1084	1057	821	1185	3051	1452	0	3024	1140	524	1296	918	1133	947	951	1143
1993	6205.0	6570.0	130	94	92	120	109	128	137	130	117	185	1020	238	0	933	109	73	198	197	388	212	214	230
1994	6570.0	6935.0	853	702	672	837	772	841	894	924	726	801	3226	1580	0	3091	757	476	1148	721	885	739	741	1018
1995	6935.0	7300.0	86	62	61	80	72	78	91	92	66	73	596	161	0	641	61	52	124	130	282	140	140	147
			1217	899	1113	991	1459	1380	1078	1021	1126	1792	3014	2134	538	2763	1599	529	1219	619	782	633	637	1264

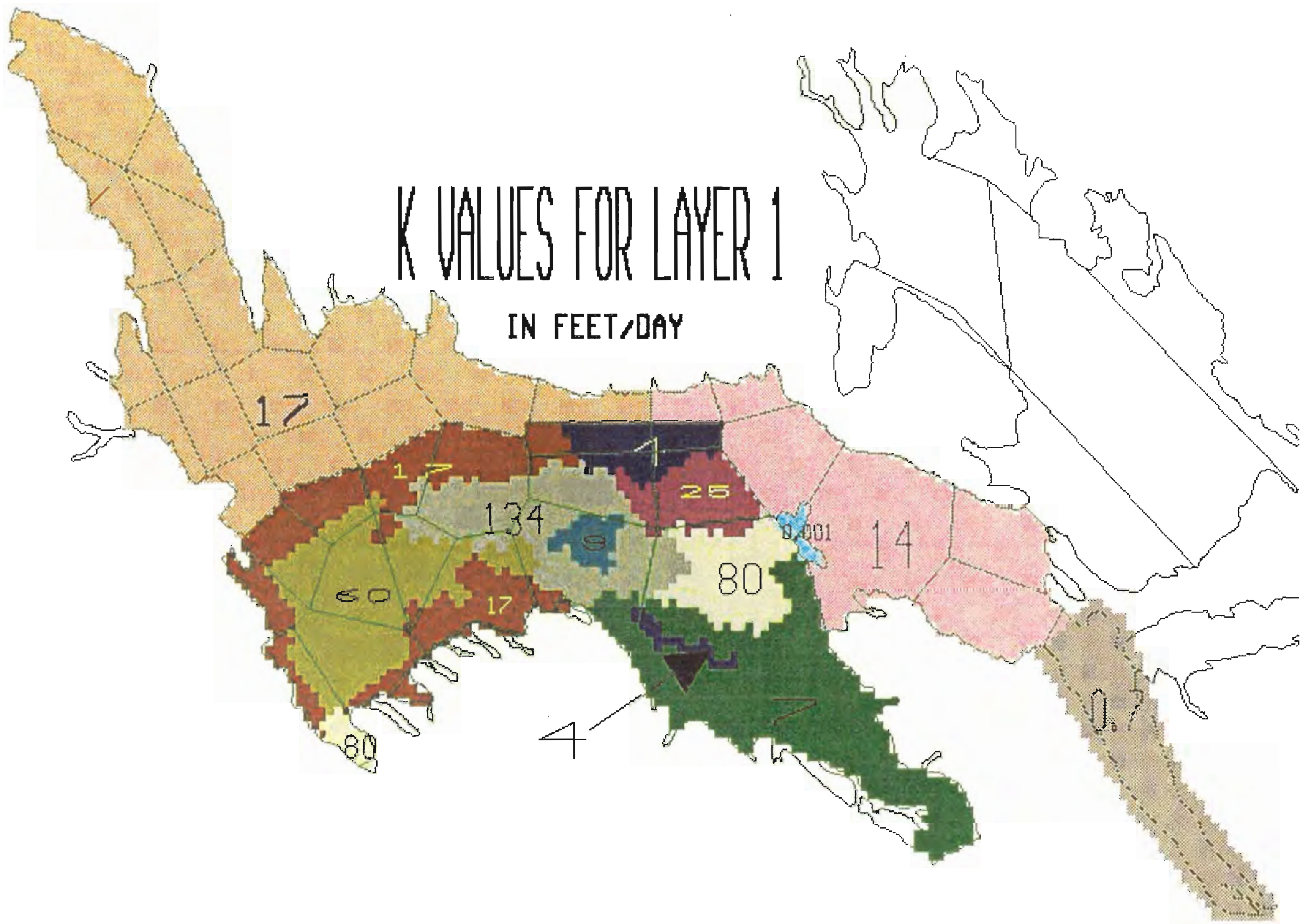
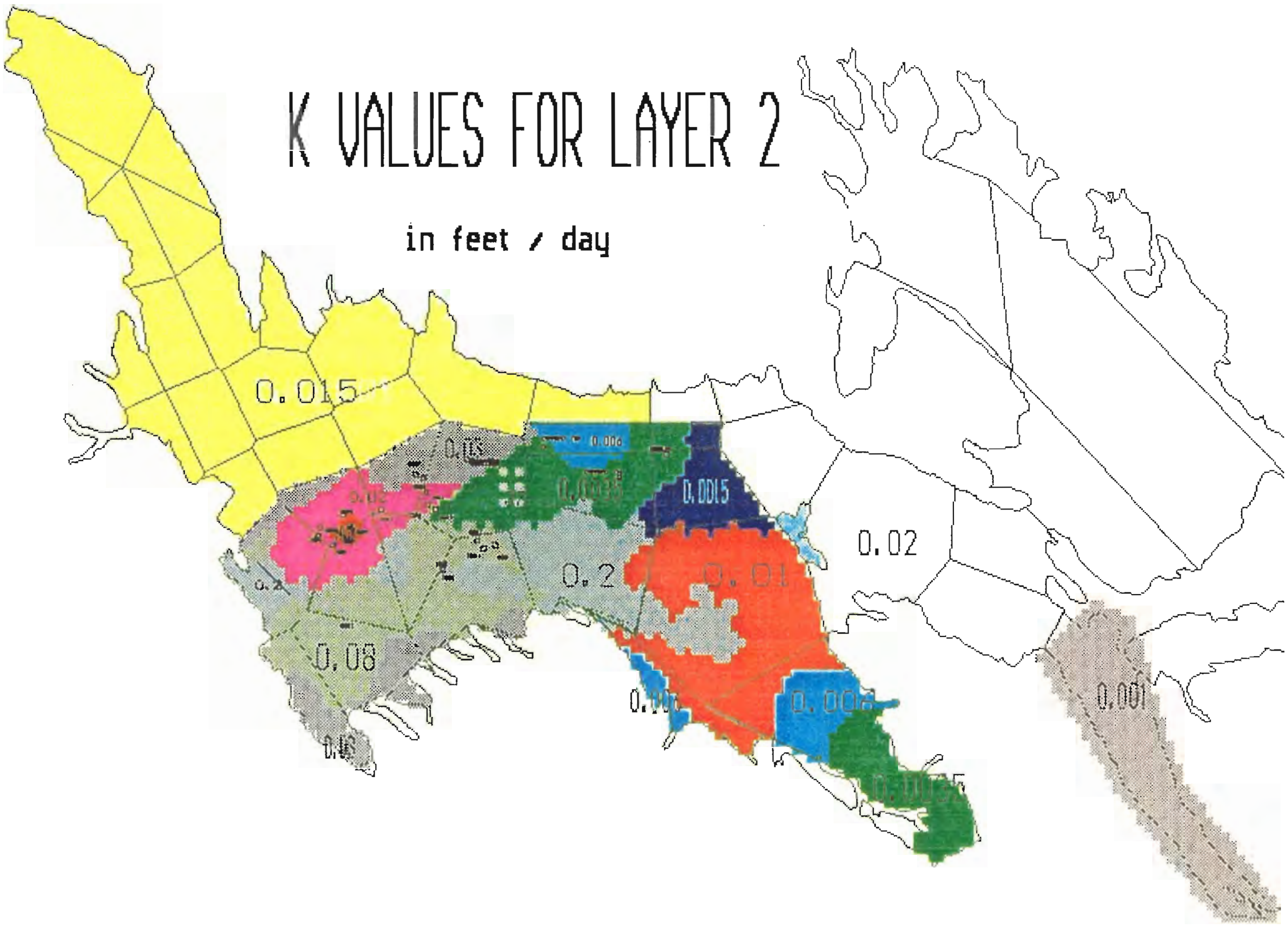

K VALUES FOR LAYER 1
IN FEET/DAY
17
17
1
25
134
9
0.001
14
80
60
17
4
7
0.7
80

FIGURE 3.15



K VALUES FOR LAYER 2
in feet / day
0.015
0.015
0.006
0.0035
0.0015
0.02
0.2
0.01
0.08
0.001

FIGURE 3.16

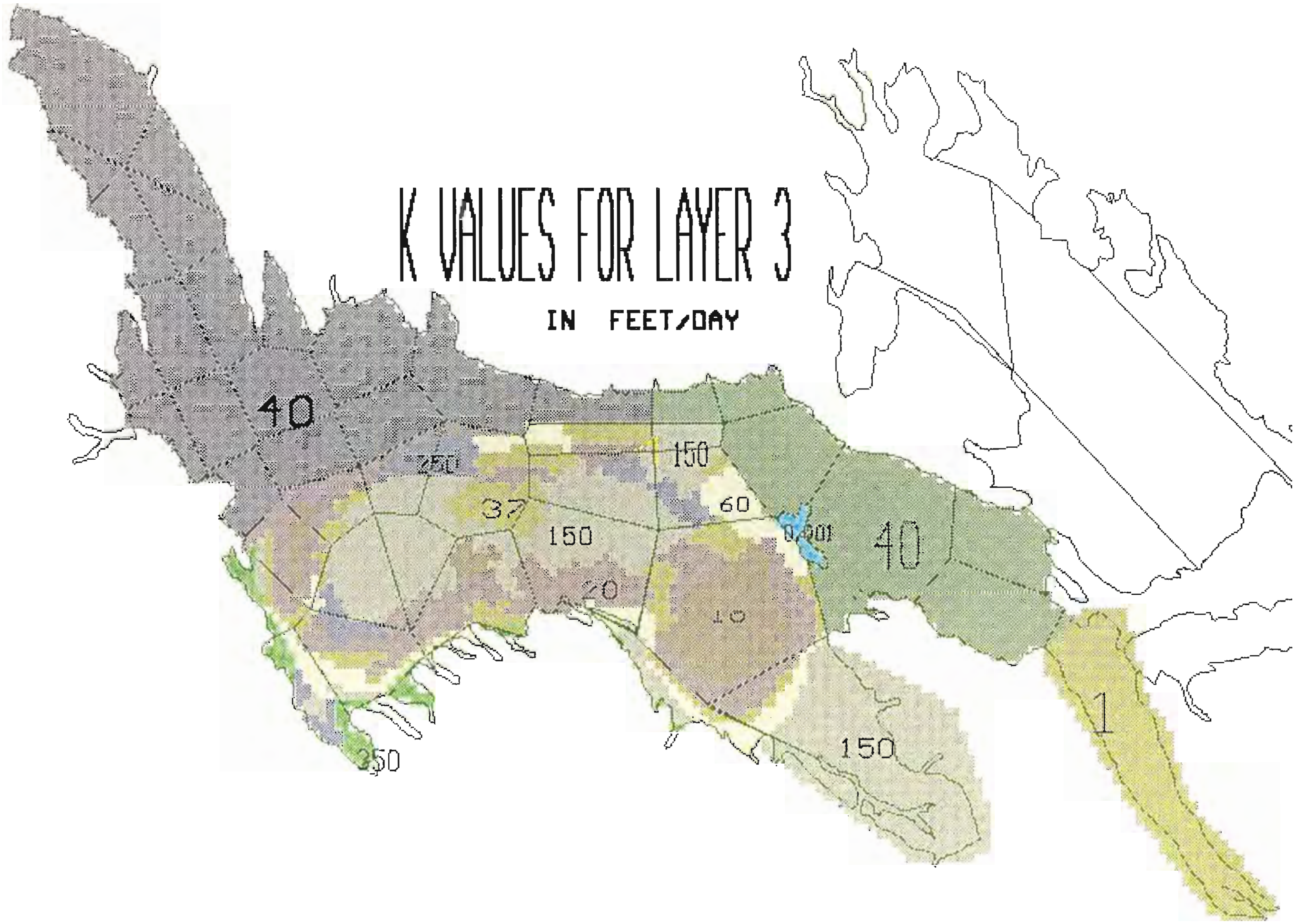

K VALUES FOR LAYER 3
IN FEET/DAY
40
250
37
150
150
60
0.001
40
20
10
150
1
250

FIGURE 3.17

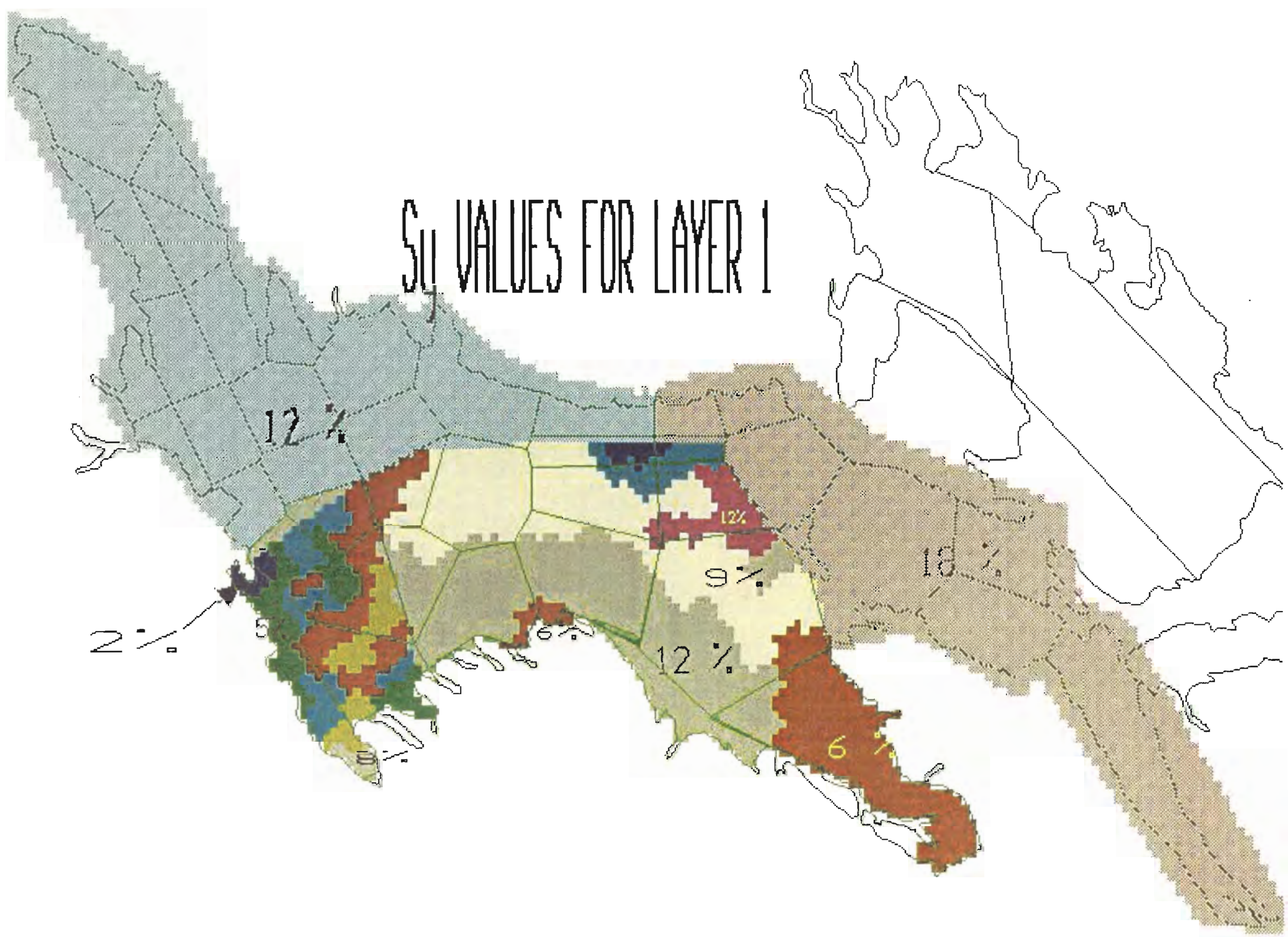


FIGURE 3.18

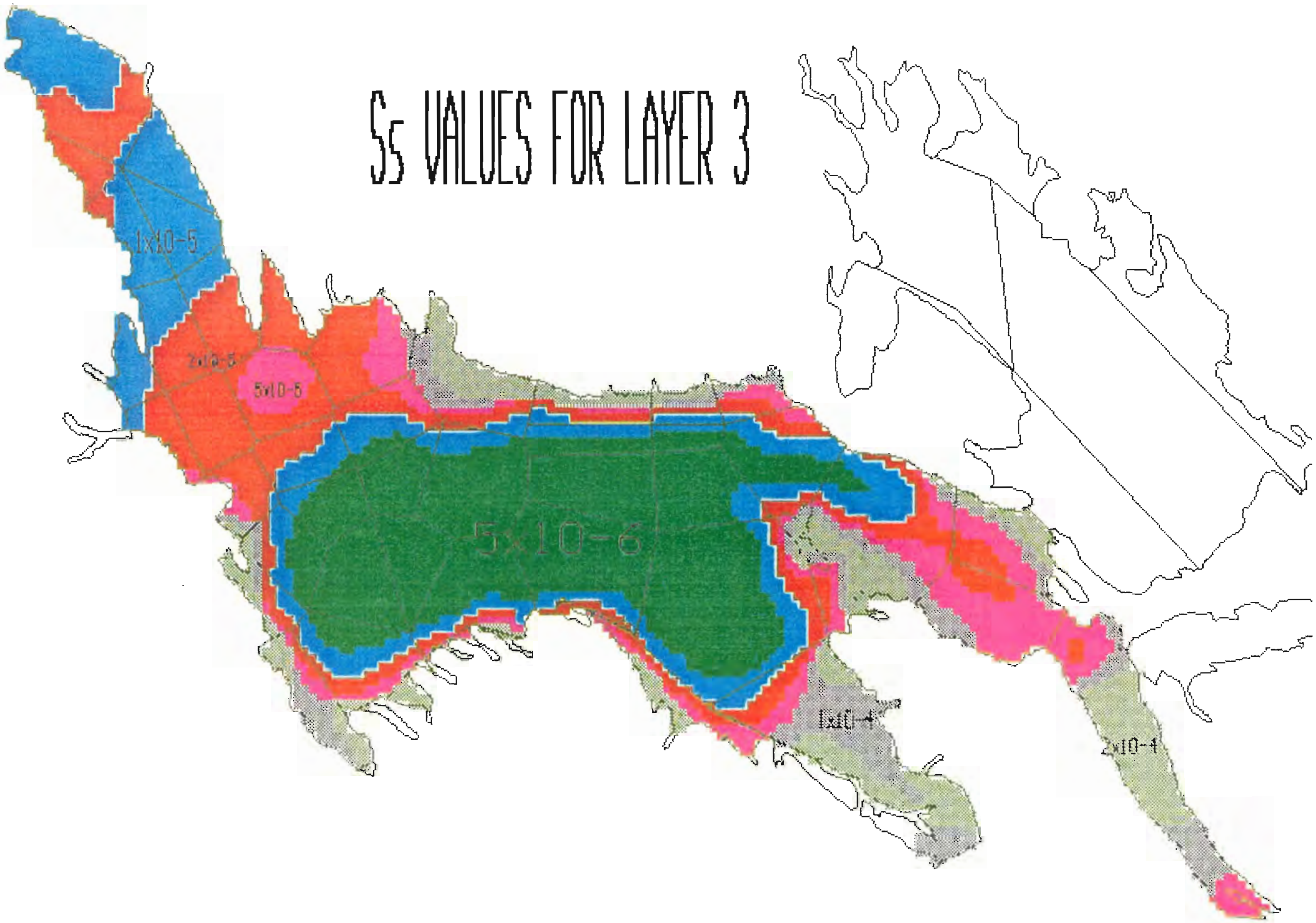
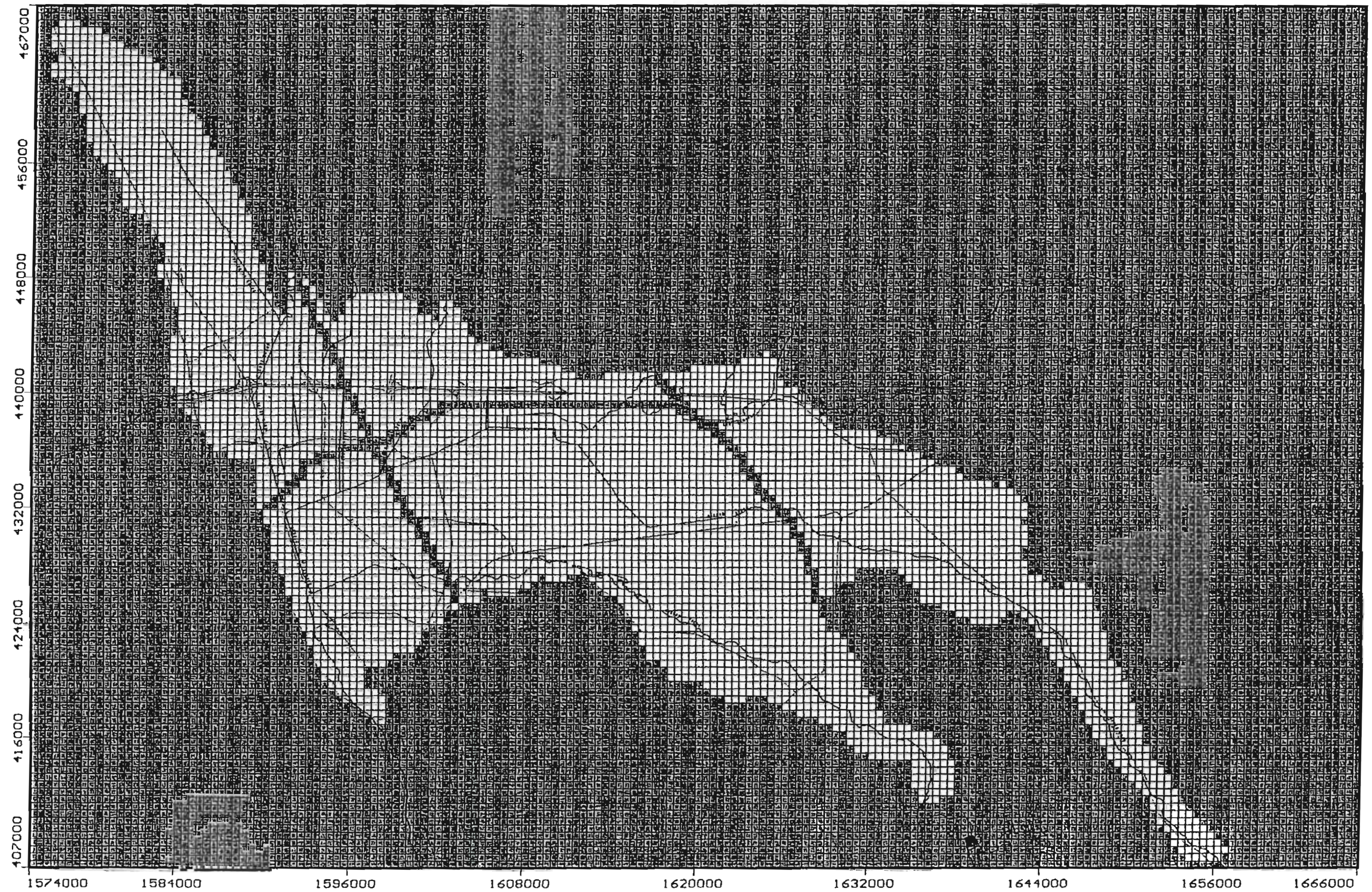


FIGURE 3.19

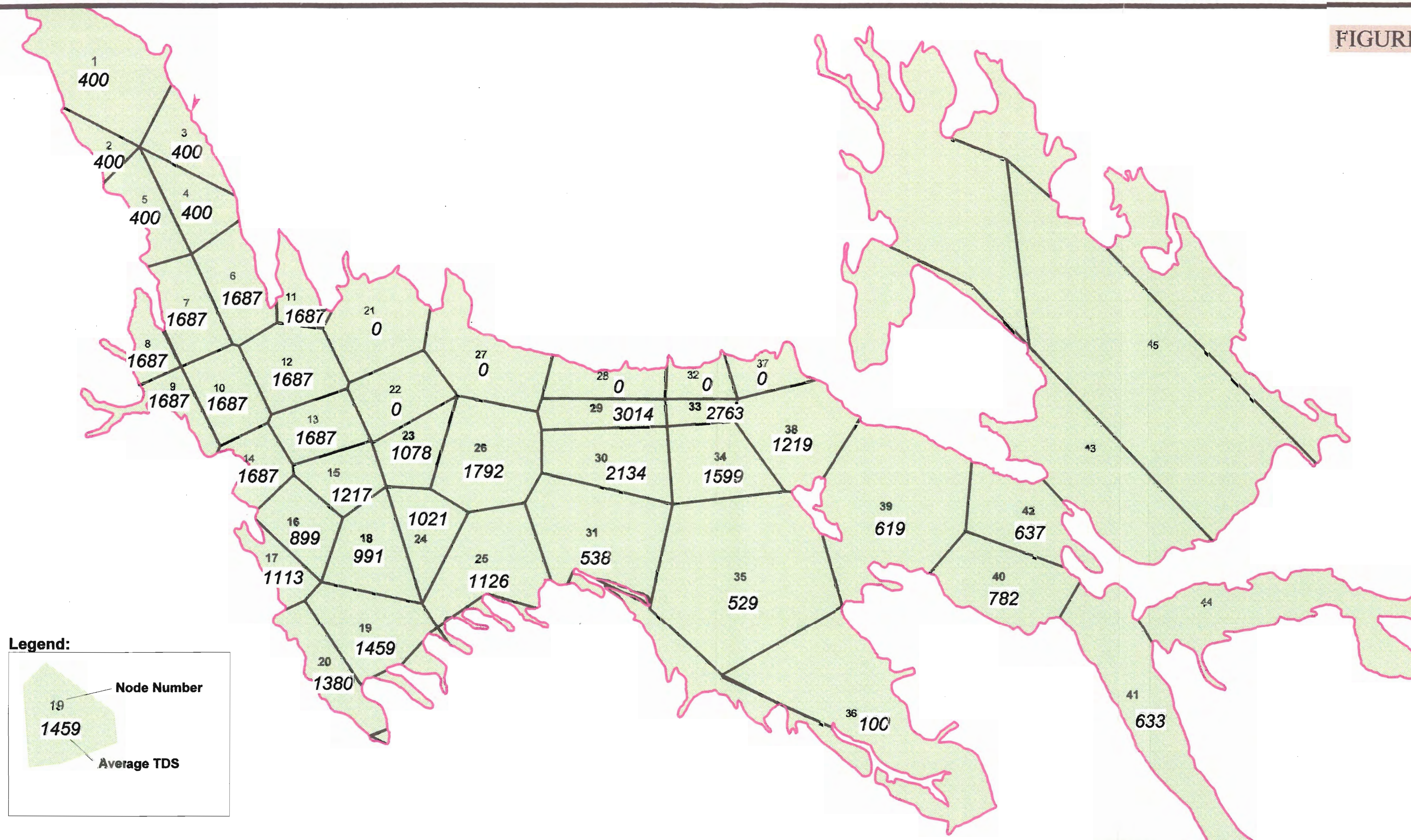


Zone 7 Water Agency – Pleasanton, CA
Project: LVGWB Model V 2.0.55
Description: Model Grid
Modeller: CH2M hILL & Zone 7
9 Jun 00

Visual MODFLOW v.2.61, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 184 NR: 120 NL: 4
Current Layer: 3

FIGURE 3.20

FIGURE 3.21



ZONE 7 WATER AGENCY **5997 Parkside Dr, Pleasanton, Ca.**	**Drawn By:** Todd Wendler **Designed By:** **Checked By:** **Approved by:**	WATER RESOURCES ENGINEERING **1974 - 95 AREAL RECHARGE (Rainfall and Applied Water) AVERAGE TDS**	**Scale:** 1"=6,000' **Date:** June 12, 2000 **File #:** H:\Geodata\avgtds2.wor

measured and simulated hydrographs at a given location help to evaluate the calibration in individual areas around the basin. Since most of the fluxes for the model were actual monitoring data, only model properties needed to be adjusted.

CH2M Hill performed 55 iterations by adjusting various model properties to calibrate the flow model. The availability of over 20 years of reliable hydrologic inventory and groundwater level data allowed for fairly precise calibration. The model properties were adjusted to match contour maps of measured and simulated heads, plus hydrographs of measured and simulated heads for nine selected wells.

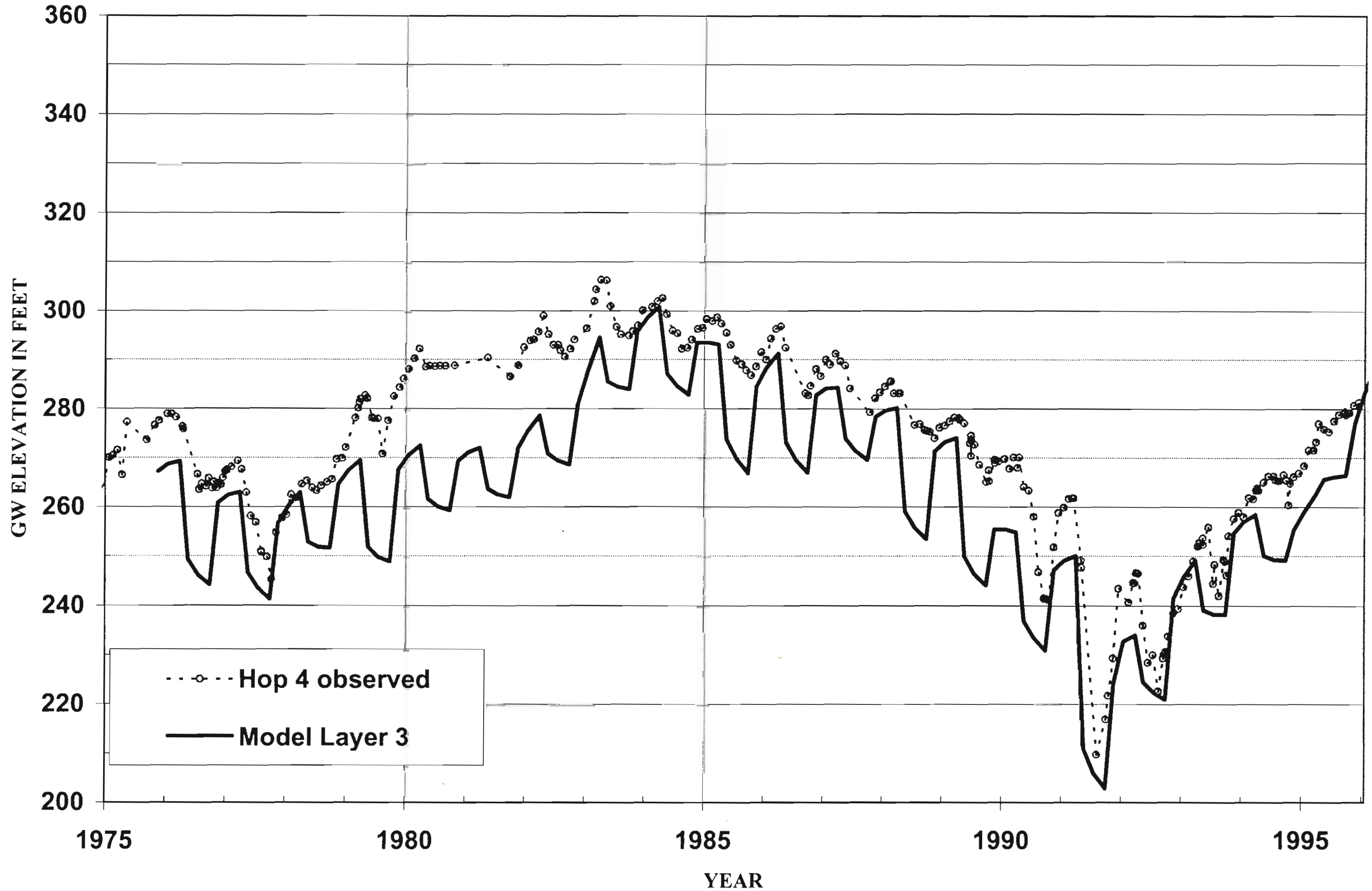
Calibration Hydrographs - As part of the calibrations, two wells from each sub-basin were selected for comparing observed and simulated outputs. Figure 3.22 presents the observed and simulated groundwater levels at the Hopyard well #4 in the Bernal sub-basin. The match between the observed and simulated groundwater levels was very good through most periods. The simulated and observed groundwater levels match very well from 1975 through 1979. During the 1980-83 period the simulated levels were about 20 feet lower than the observed groundwater levels. During 1984 the model groundwater levels recovered and by the end of 1984 and through the rest of the simulation period (1984-95) the simulated and observed groundwater levels matched well. Overall, the model acceptably matched both the long-term trends and semi-annual trends in observed groundwater levels.

Figure 3.23 presents the observed and simulated groundwater levels at the Mohr Avenue well (3s/1e 9p5) in the West Amador Sub-basin in model layer 1 (upper aquifer). The match between the observed and simulated groundwater levels is generally good. The simulated and observed groundwater levels match very well in 1978 (beginning of the observed data), show a similar trend between 1978-1995 and almost exactly match near the end of the simulation period in 1995. Overall, the model acceptably matched the long-term trend and end-of-period trend in observed groundwater levels.

Figure 3.24 presents the observed and simulated groundwater levels at the Mocho #2 well in the West Amador Sub-basin in model layer 3 (lower aquifer). The results at this location are very similar to the calibration simulation (above) for the Hop 4 location. The simulated and observed groundwater levels match very well from 1975 through the middle of 1980, while during the 1981-83 period the simulated levels were about 15 feet lower than the observed groundwater levels. During 1984 the model groundwater levels recovered and by the end of 1984 and through the rest of the simulation period (1984-95) the simulated and observed groundwater levels matched well. Overall, the model acceptably matched both the long-term trends and semi-annual trends in observed groundwater levels. The simulated groundwater levels almost exactly matched the observed levels near the end of the period.

Figure 3.25 presents the observed and simulated groundwater levels at the Hagemann key well in the East Amador Sub-basin in model layer 3 (lower

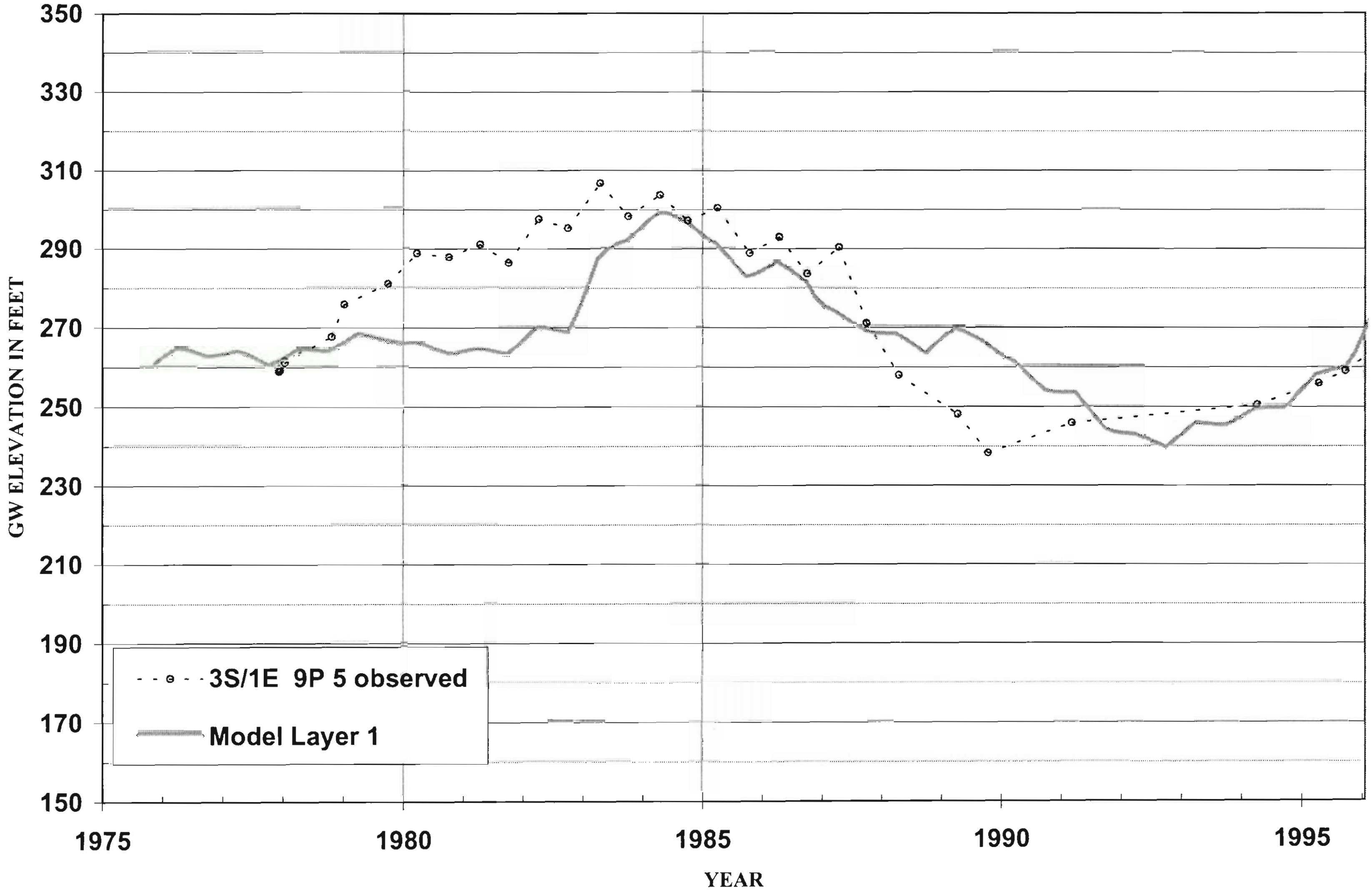
Hopyard-4 Well Hydrograph: Layer 3



6/16/00

FIGURE - 3.22

Well 3S/1E 9P 5 Hydrograph: Layer 1



6/16/00

FIGURE - 3.23

aquifer). The simulated and observed groundwater levels match very well from 1975 through the middle of 1987. During the 1987-90 and 1992-93 periods the simulated levels were about 30 feet higher than the observed groundwater levels, although at the end of 1991, the match is again very good. From the end of 1993 to the end of the simulation period the match remains very good. Although there are about six years out of 20 when the match is weaker than at the other wells shown, the overall calibration at this location appears acceptable.

These hydrographs indicate generally good agreement between simulated and observed groundwater levels. The hydrographs presented represent the Main Basin area of the model. For calibrations in the fringe basin area, see the CH2M Hill June 1998 technical memorandum that presents the complete calibration results (Reference A).

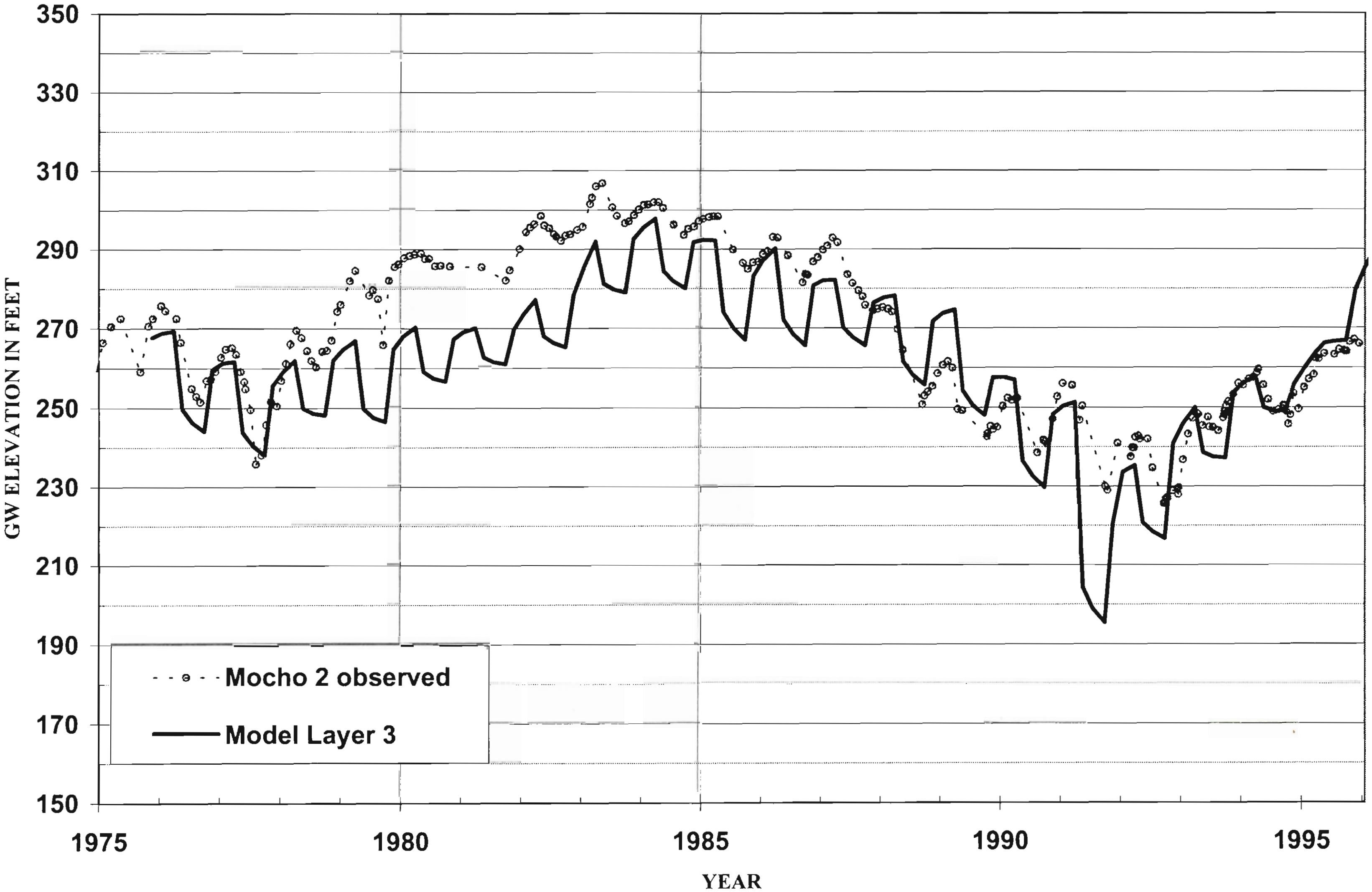
Groundwater Level Maps - Simulated groundwater level maps also show good agreement with observed groundwater level maps. Figure 3.26 is the groundwater level map prepared from the Zone 7 spring 1994 measured groundwater levels. The solid line contours represent groundwater levels in the upper aquifer and the dashed line contours (drawn only in applicable portions of the basin) represent the deep aquifer. Deep aquifer groundwater level data is limited to parts of the Main Basin.

Figure 3.27 presents the model simulated groundwater levels in the upper aquifer for spring 1994. The simulated and observed contour elevations and contour shapes match well. The elevation difference in the key high yielding basin areas is about +/- 20 feet and the contour pattern is very similar. Figure 3.28 presents the model simulated groundwater levels in the deep aquifer for spring 1994. Although there are only a few deep aquifer observed groundwater level contours drawn on Figure 3.26, the pattern and the elevations match very well with the simulated contours.

3.7.5 *Solute Transport Calibration (Non-Reactive)*

Solute transport calibration involves adjusting the solute transport model parameters and the recharge concentrations. Since most of the assigned recharge concentrations for the model were determined from actual monitored data, only model parameters were adjusted during calibration. In non-reactive (TDS) solute transport, advection is the primary mechanism responsible for TDS migration in aquifers. Advection involves transport by bulk movement where it is assumed that the dissolved solute travels in the same direction and with the same velocity as the groundwater itself. Since the model was already calibrated for flow, an acceptable level of non-reactive transport calibration was readily achievable. The calibration was checked by comparing the simulated and observed groundwater TDS hydrochemographs and groundwater TDS maps. Figures 3.29 through 3.32

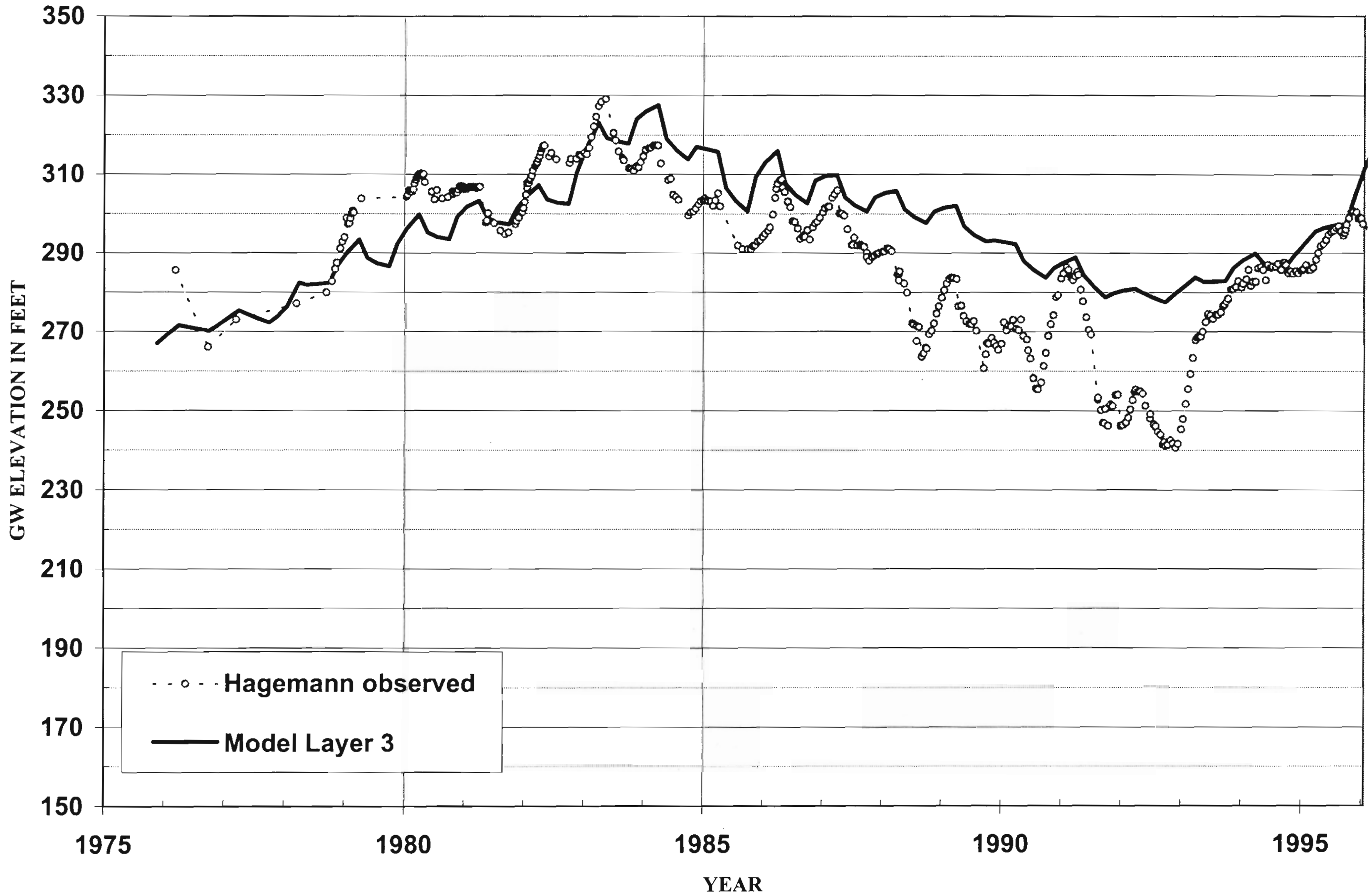
Mocho-2 Well Hydrograph: Layer 3



6/16/00

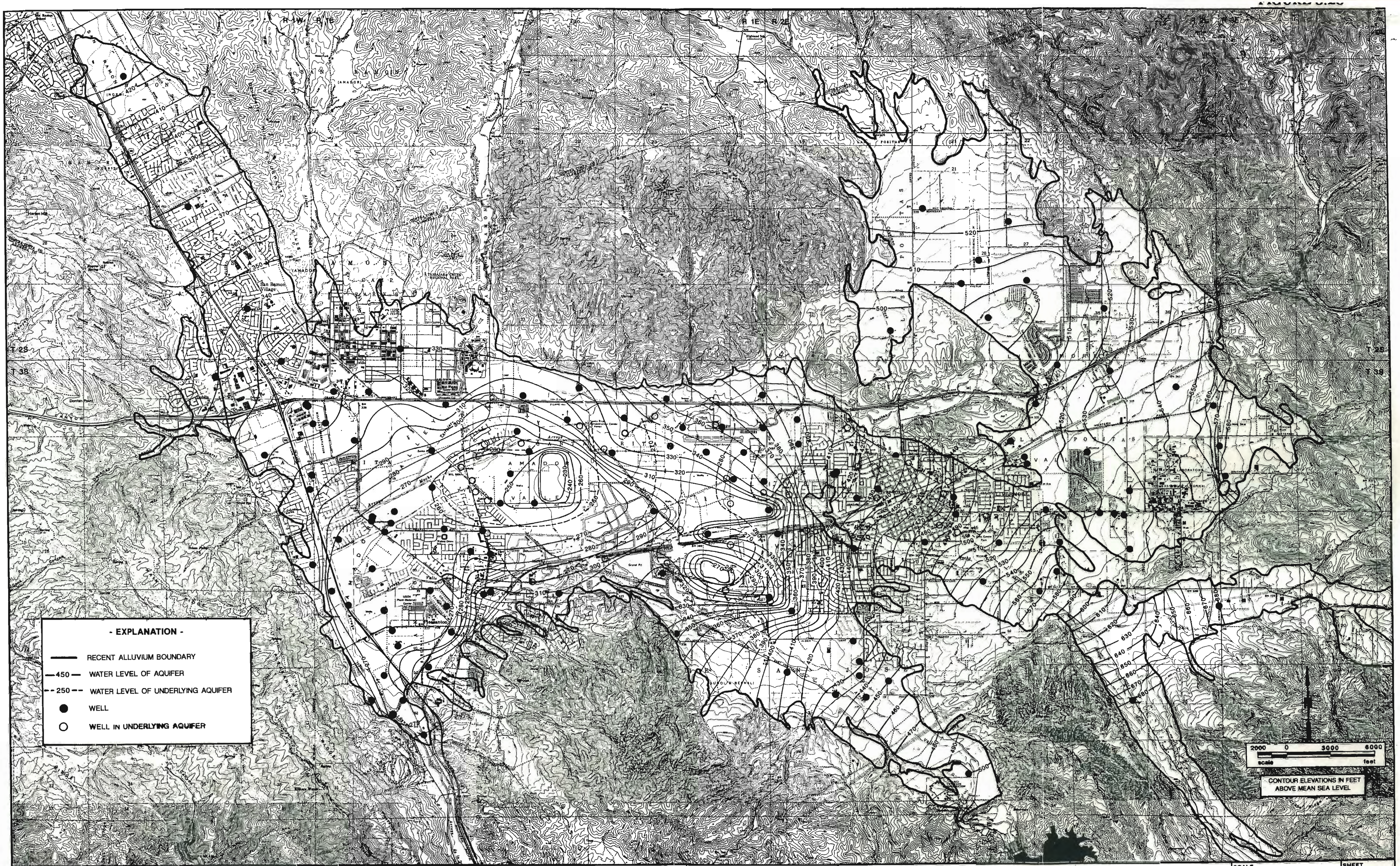
FIGURE - 3.24

Hagemann Well Hydrograph: Layer 3



6/16/00

FIGURE - 3.25



REVISIONS				
NUMBER	DESCRIPTION	BY	DATE	APVD
7				
6				
5				
4				
3				
2				
1				

ZONE 7 WATER AGENCY
5997 PARKSIDE DRIVE PLEASANTON CA 94588

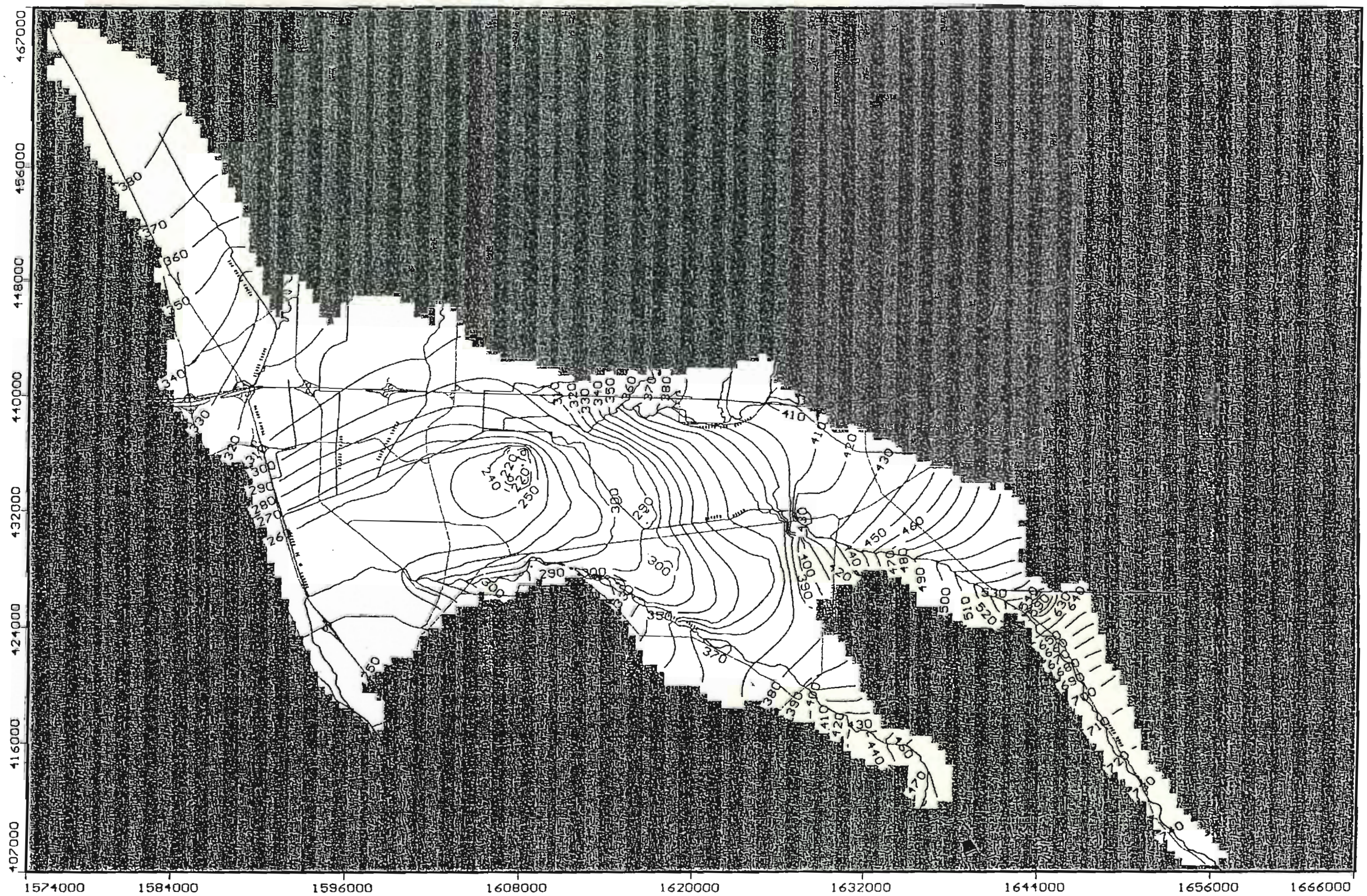
DRAWN	G GATES
DESIGNED	Steven J. Ellis
CHECKED	Steven J. Ellis
APPROVED	

WATER RESOURCES ENGINEERING

SPRING 1994

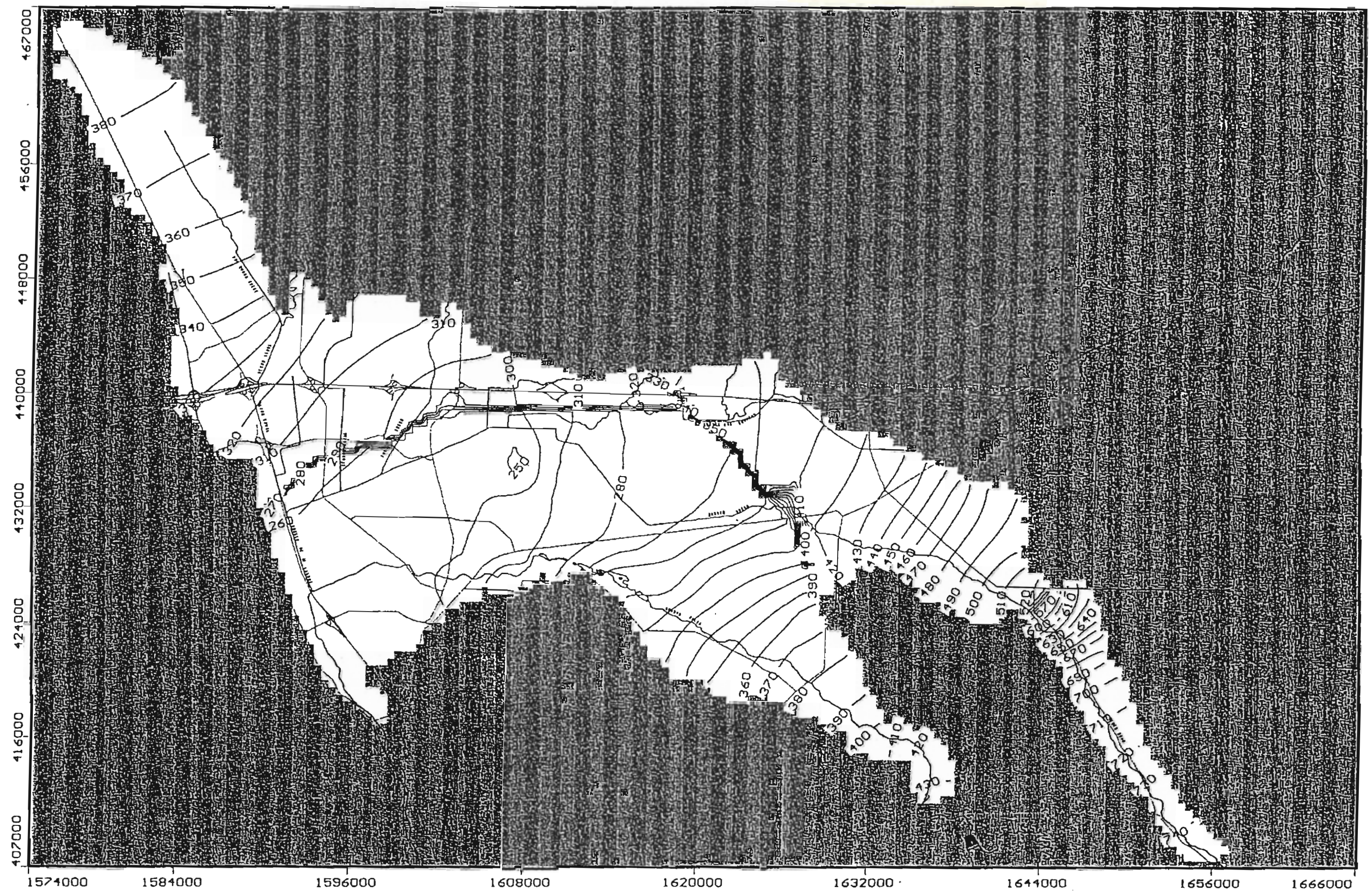
GROUNDWATER LEVEL CONTOURS

SCALE	1"=6000'
DATE	28 MAY 1994
FILE NO.	B-334
SHEET	OF SHEETS



Zone 7 Water Agency – Pleasanton, CA Project: LVGWB Model V 2.0.55 Description: L1 GWL Spring 1994 (SP37) Modeller: CH2M hILL & Zone 7 12 Jun 00	Visual MODFLOW v.2.61, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 184 NR: 120 NL: 4 Current Layer: 1

FIGURE 3.27



Zone 7 Water Agency – Pleasanton, CA
Project: LVGWB Model V 2.0.55
Description: L3 GWL Spring 1994 (SP37)
Modeller: CH2M HILL & Zone 7
12 Jun 00

Visual MODFLOW v.2.61, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 184 NR: 120 NL: 4
Current Layer: 3

FIGURE 3.28

present the observed and simulated TDS at some selected well locations. Figures 3.33 through 3.36 present the observed and simulated groundwater TDS maps.

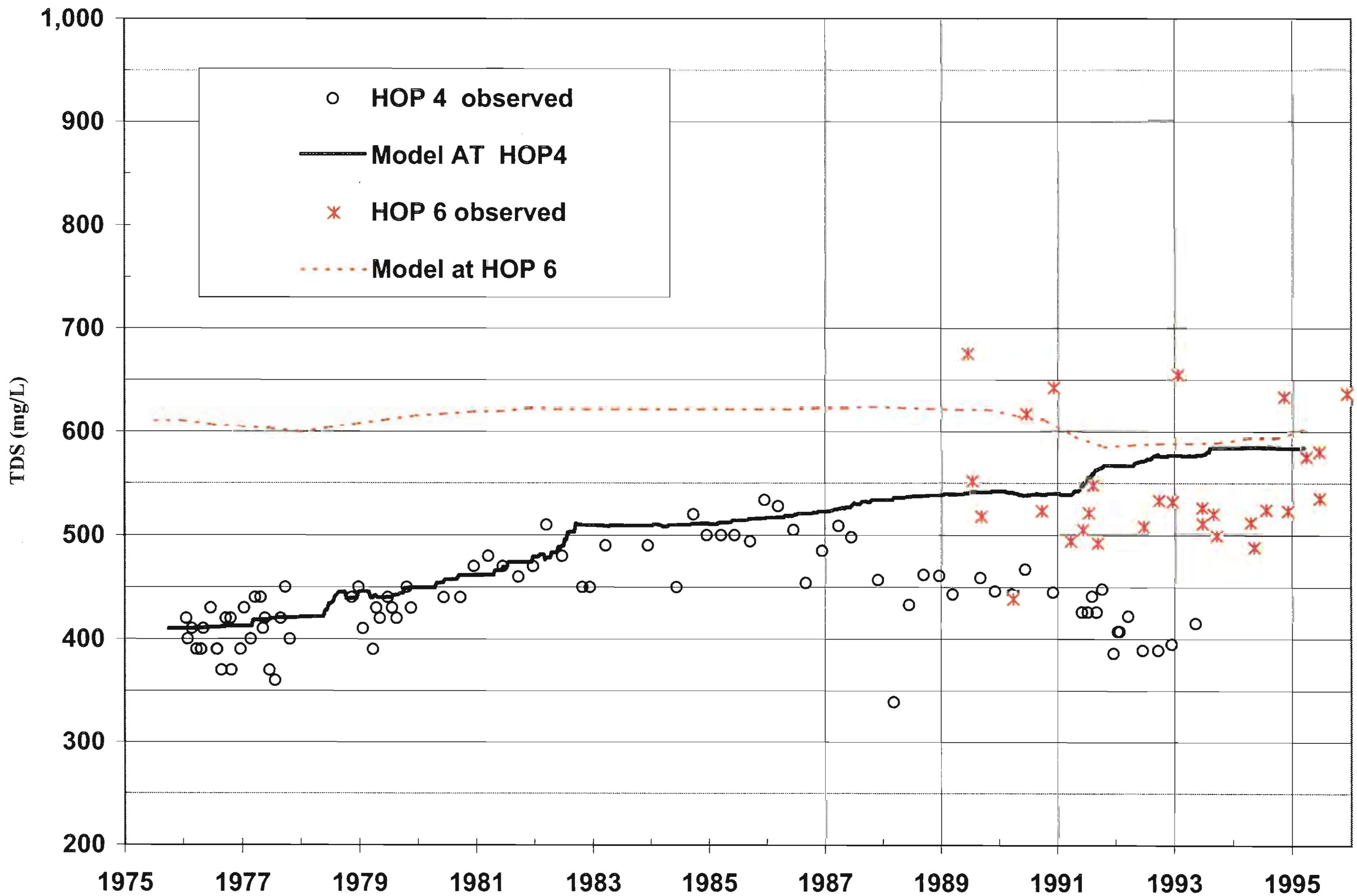
TDS Graphs (Chemographs) - The chemograph for the Hop 4 (Figure 3.29) location shows a good correlation between observed and simulated TDS for the 1975-1987 period. Both the data sets show a rising groundwater TDS trend during this period. Beginning in 1988, the observed and simulated TDS lines start diverging from each other. The simulated TDS data continue to show a rising groundwater TDS trend and the observed TDS data show a declining TDS trend for 1988-95. Based upon the data for the Hop 4 location, it can be concluded that the model tracks the observed data acceptably for the 1975-87 period but not for 1988-95.

To analyze this 1988-95 period further, the observed and simulated TDS results for the Hop 6 location were also plotted on the Hop 4 figure. The Hop 6 well is about 1,500 feet upgradient from the Hop 4 well. The simulated TDS for the Hop 6 well was a good match with the observed TDS at the Hop 6 well. This could be caused by different boundary conditions or model property assumptions along the 500-foot grids in the relatively close 1,500 feet between Hop 4 and 6. Although the model could not precisely match the observed and simulated TDS for the exact Hop 4 location for the 1988-95 period, the predicted TDS and calibration for the Hopyard well field as a whole appears adequate.

The simulated TDS line for the Mocho 2 well (Fig 3.30) appears potentially more representative of actual conditions than the observed data. The simulated data indicates a gradual increase in groundwater TDS at Mocho 2 while the observed groundwater TDS shows large fluctuations ranging from 350 mg/L to 950 mg/L over short periods of time. Groundwater quality generally does not change as rapidly as shown by the observed data. The observed data for Mocho 2 therefore seem suspect. It is possible there were problems with the sampling protocol (e.g., inadequate well purging before sampling). The primary conclusion that can be drawn at this time is that additional data need to be collected to verify the accuracy of the historic data before meaningful simulation comparisons can be made.

The chemograph for the Mohr Avenue key well (3s/1e 9p5, Fig 3.31) shows similar trends for the simulated and observed TDS lines. The simulated TDS is generally about 50 to 75 mg/L higher than the observed TDS. This difference increases to about 250 mg/L during 1983-86. However, the simulated and observed TDS lines converge again in 1987 (the end of the observed dataset). The simulated and observed TDS trend match is impressive during the most part except for 1983-86. One reason why the simulated TDS line is always above the observed line could be that due to the limited observed dataset, the initial TDS concentration used for this location was not truly representative of actual conditions. The model would have interpolated the initial TDS concentration data based upon available data points from the nearest adjacent grids that contained higher TDS actual data.

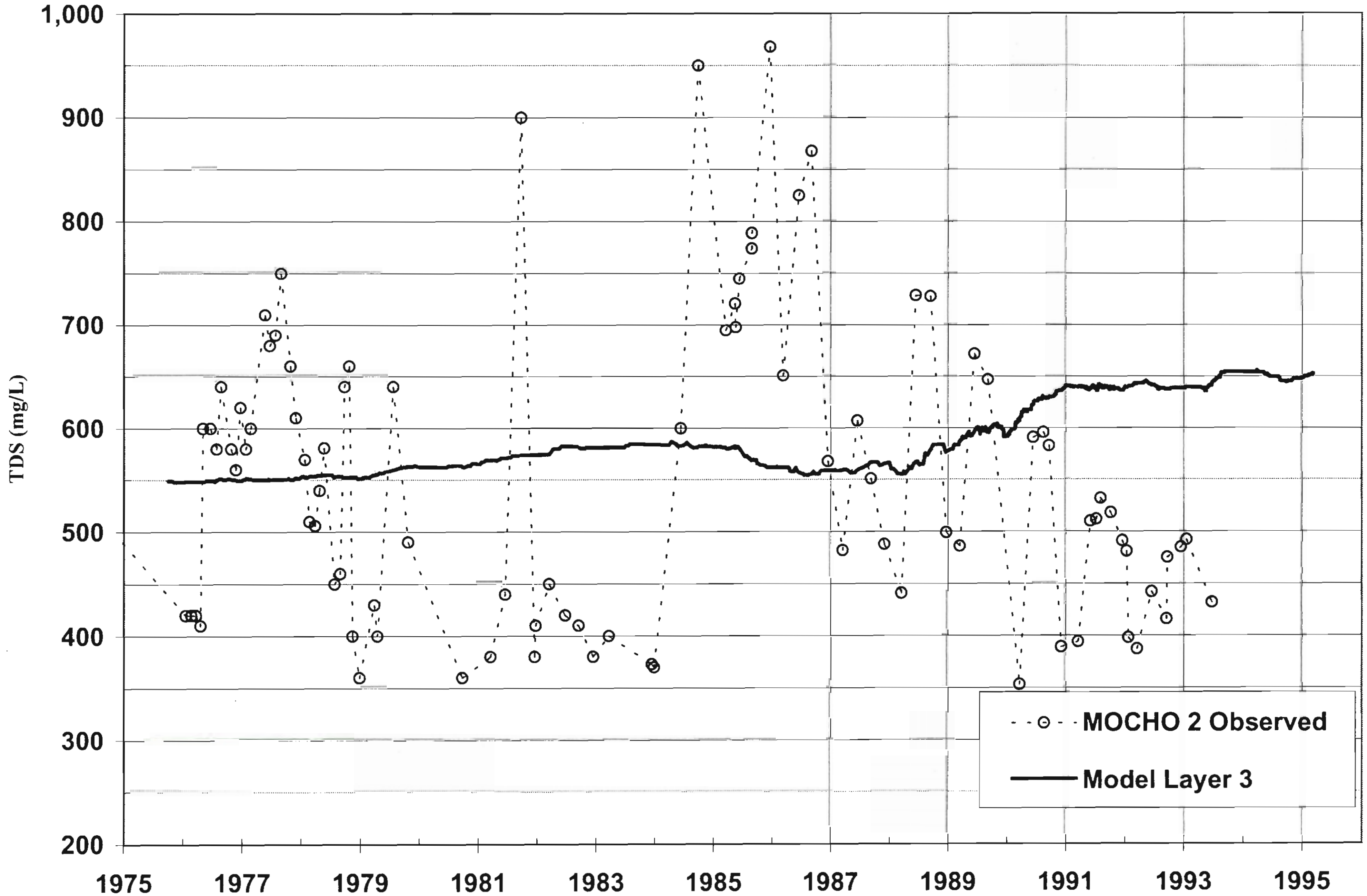
Hopyard-4 & 6 Well Chemograph: Layer 3



6/16/00

FIGURE 3.29

Mocho-2 Well Chemograph: Layer 3



6/16/00

FIGURE 3.30

The simulated and observed TDS lines for the Hagemann key well (Figure 3.32) appear to show a good correlation. This well had the same initial concentration issues as the Mohr Avenue well since the observed data does not begin until 1979. Although the model initial TDS concentration does not seem to reflect the actual TDS for this location, the simulated TDS line matches very well during the latter part of the calibration period.

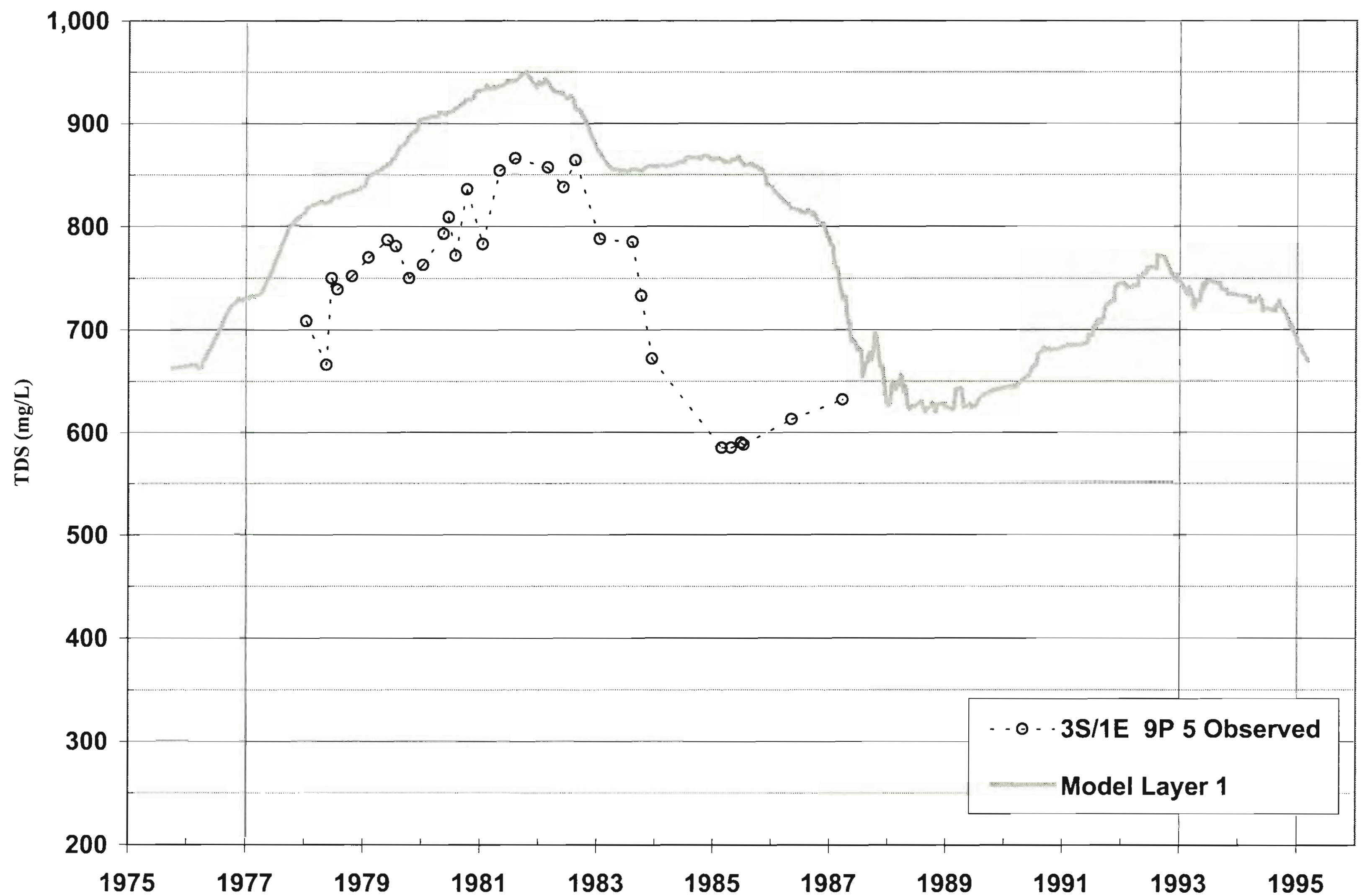
Groundwater TDS Maps - The TDS chemographs are useful in comparing the changes over time in simulated and observed TDS at a particular location. The groundwater TDS maps are useful in comparing the areal variations in simulated and observed concentrations at any time for any model layer.

Figures 3.33 and 3.34 present the observed and simulated groundwater TDS maps for the upper aquifer at approximately 1994 conditions. For the most part the two maps match reasonably well. For example, the Dublin Sub-basin has a low TDS of 400-500 mg/L in the north portion and a high TDS in the south portion in both the simulated and observed maps. Lower groundwater TDS exists along both the Arroyo Valle and Arroyo Mocho recharge zone areas on both maps.

Figure 3.35 and 3.36 present the observed and simulated groundwater TDS maps for the deep aquifer. Due to the general lack of deep aquifers in the fringe basins, the observed TDS maps present the TDS only for the Main Basin. The deep aquifer TDS maps match even better than in the upper aquifer. The blue shade on both maps represents groundwater TDS below 500 mg/L. The pink shade on the observed TDS map (Figure 3.35) represents groundwater of 500 mg/L to 700 mg/L. This same 500-700 mg/L TDS range is shown in green on the simulated TDS map (Figure 3.36). Comparing both maps, it can be concluded that there is a good overall match with the exception of one small high TDS (800-1000 mg/L) area on the simulated map in the Bernal Sub-basin near the Fairgrounds.

The technical memorandum from CH2M Hill "Livermore Valley Groundwater Basin Model v2.0, June 29, 1998" describes the model calibration in more detail (Reference E).

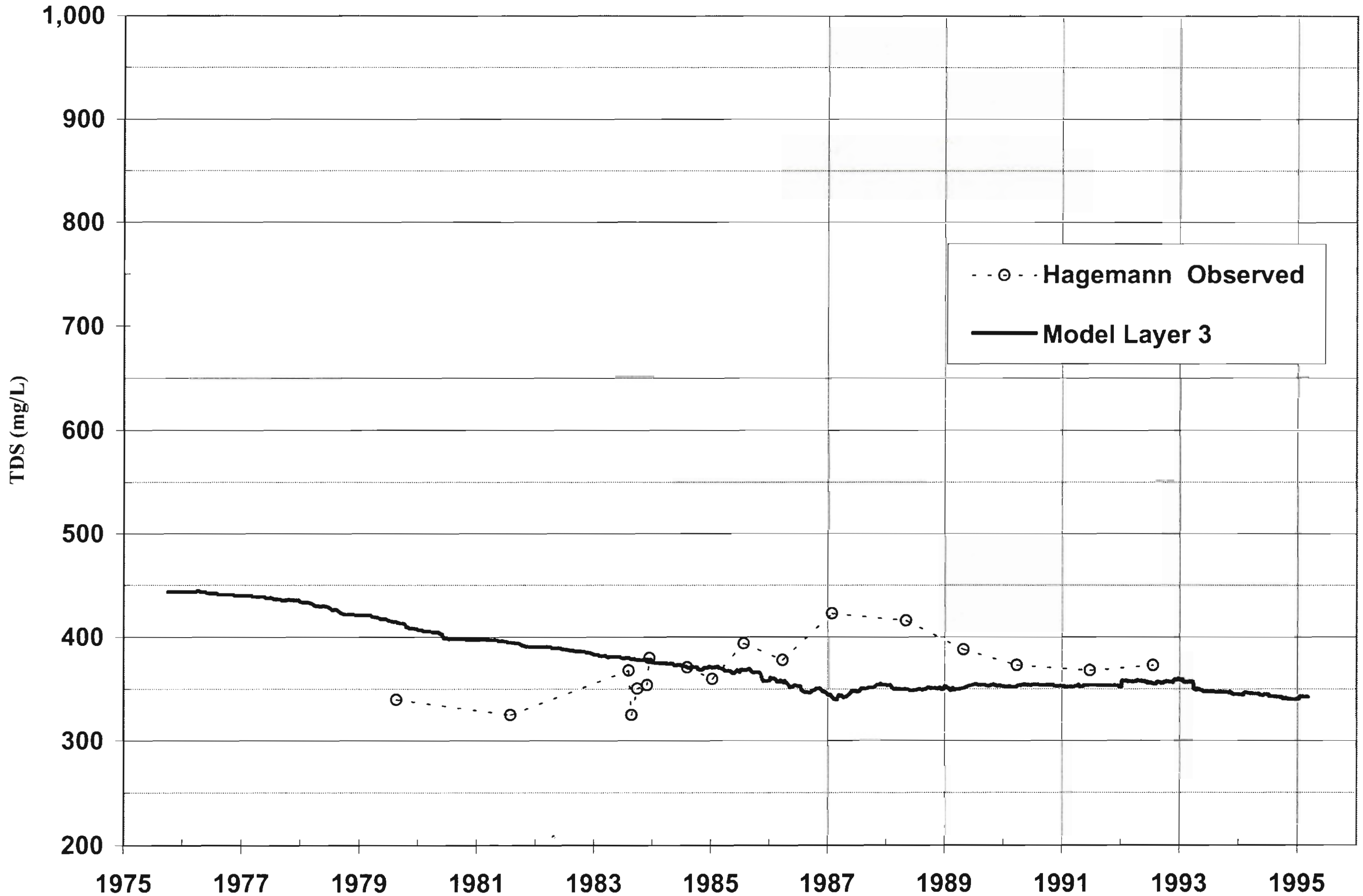
Well 3S/1E 9P 5 Chemograph: Layer 1



6/16/00

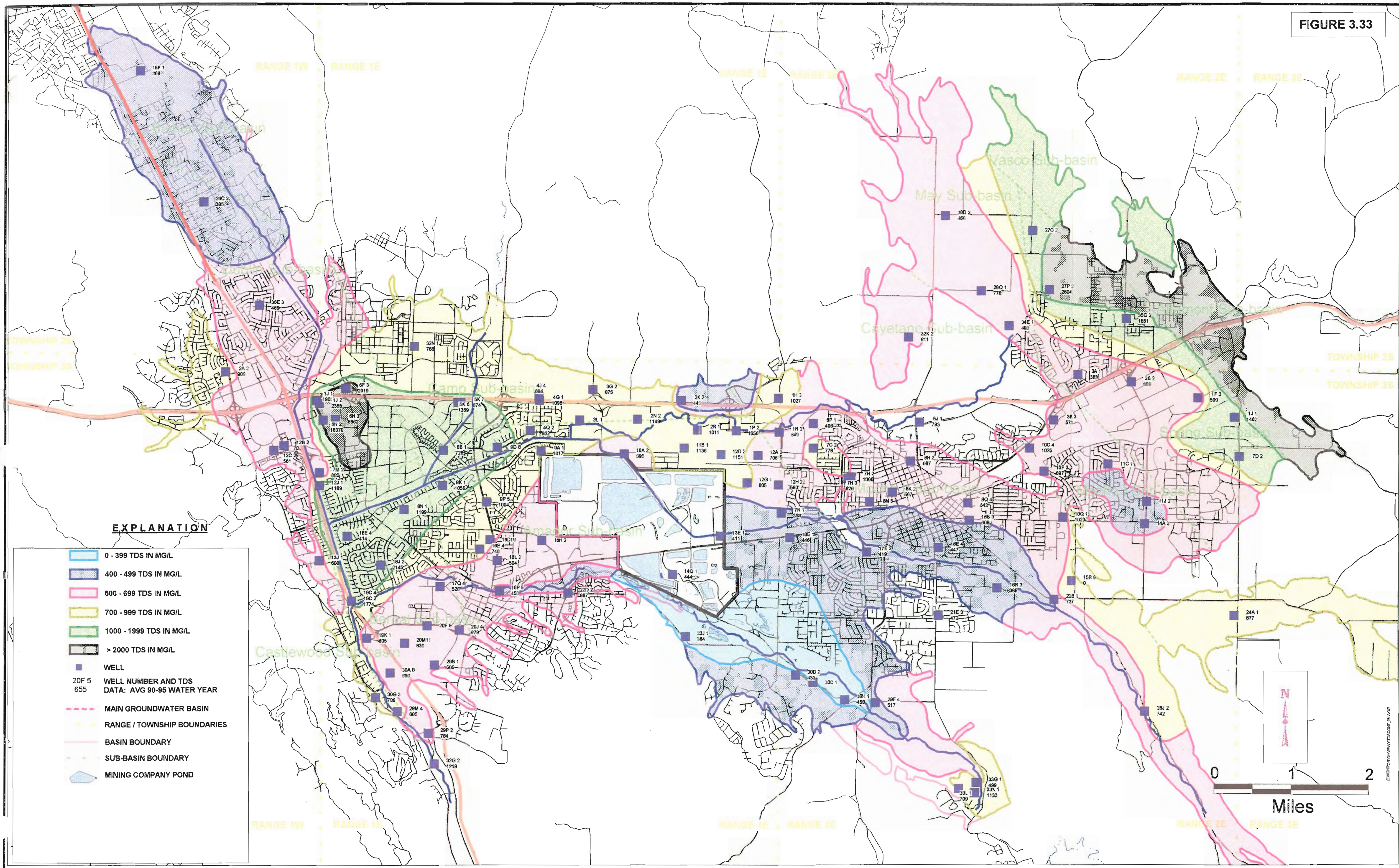
FIGURE 3.31

Hagemann Well Chemograph: Layer 3



6/16/00

FIGURE 3.32

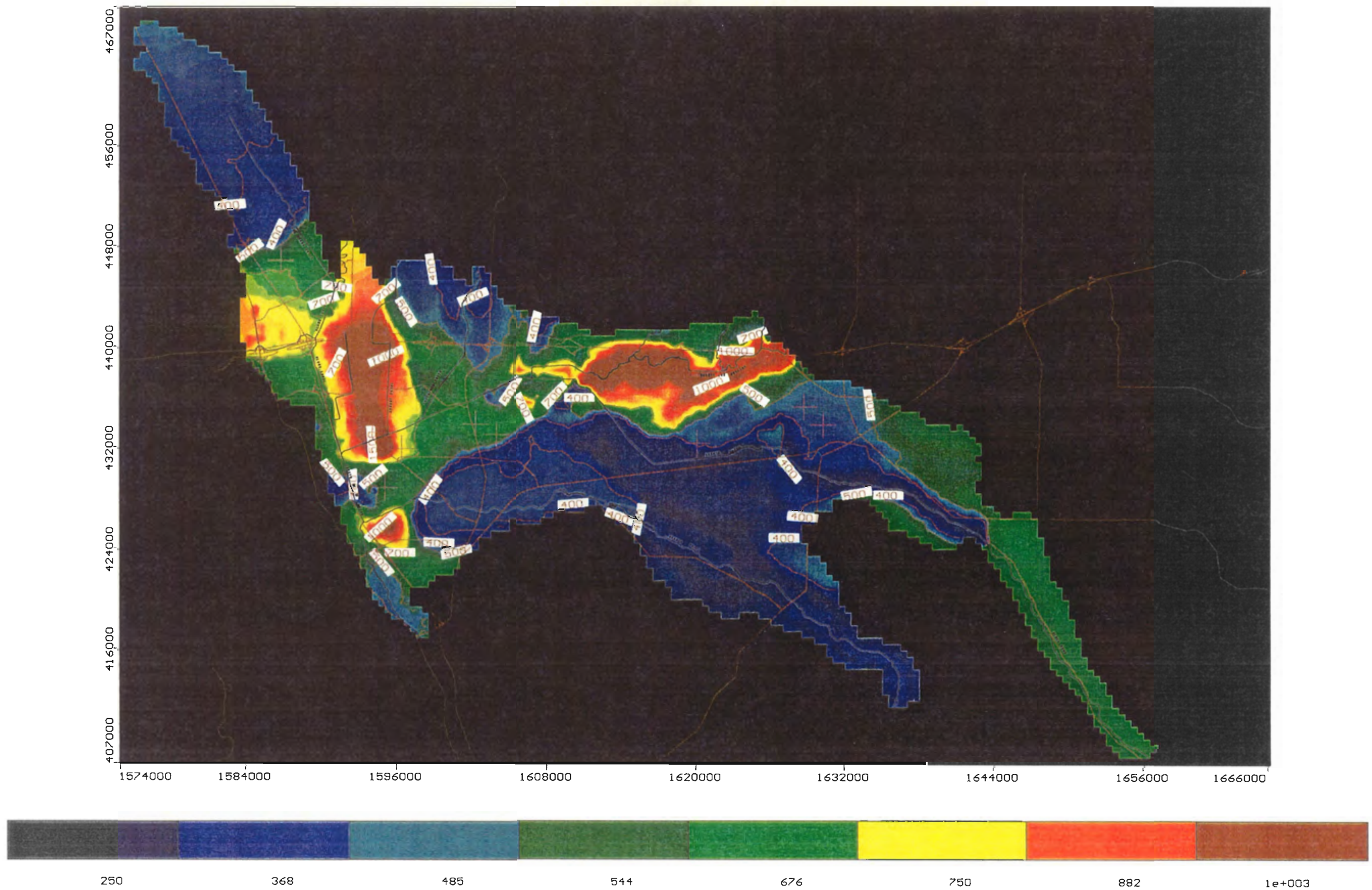


ZONE 7 WATER AGENCY
5997 PARKSIDE DRIVE PLEASANTON CA 94588

DRAWN BY:	GERALD GATES
DESIGNED BY:	D. LUNN
CHECKED BY:	
APPROVED BY:	

WATER RESOURCES ENGINEERING
UPPER AQUIFER TDS CONTOUR MAP
AVERAGE 1990-1995 TOTAL DISOLVED SOLIDS

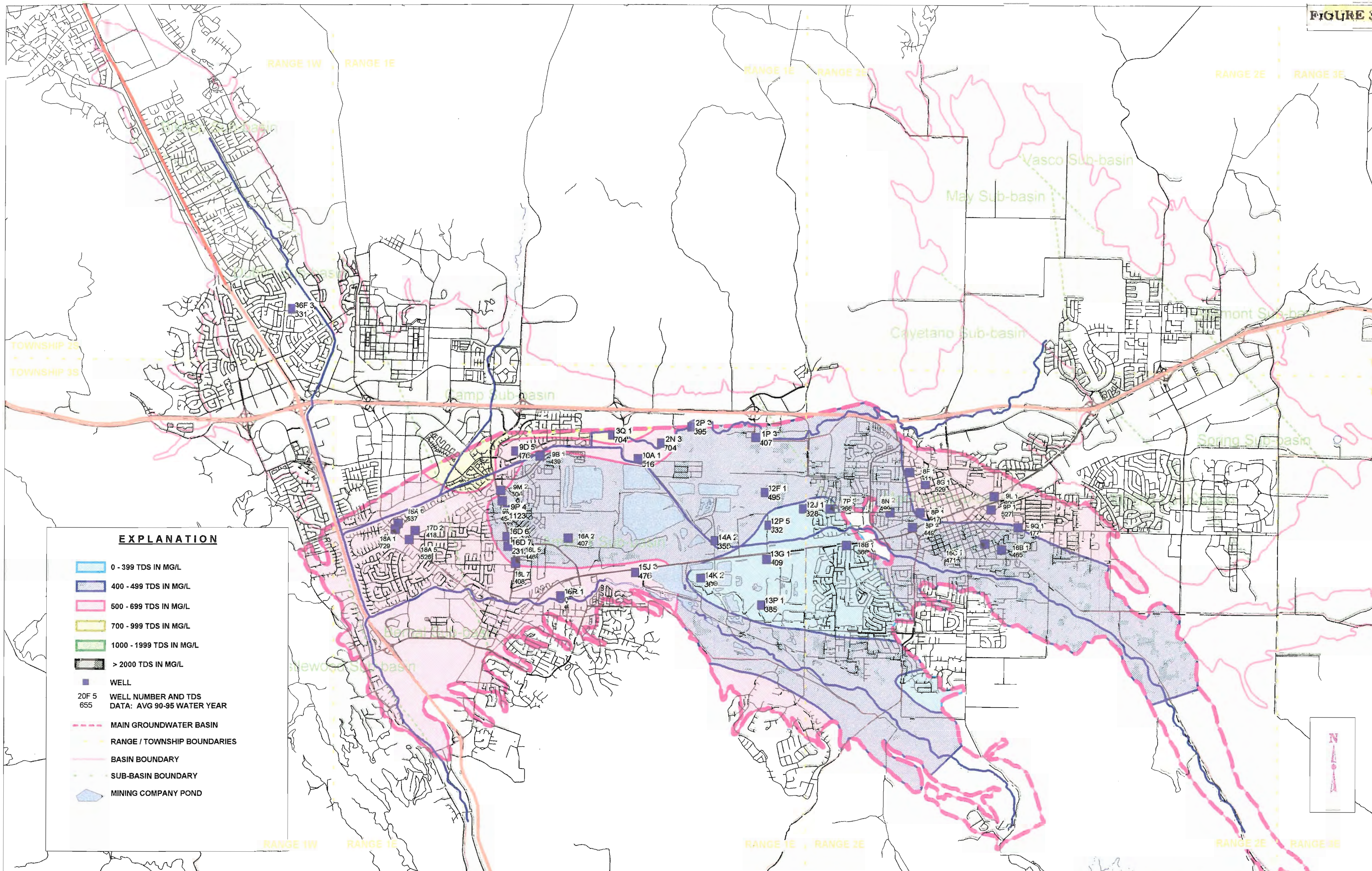
SCALE:	1" = 6000' (ON ORIGINAL)
DATE:	7 JULY 1997
FILE NO.:	H:\SMP\FIG4-6.WOR



Zone 7 Water Agency – Pleasanton, CA
Project: LVGWB Model V 2.0.55
Description: L1 TDS Fall 1995 (SP40)
Modeller: CH2M HILL & Zone 7
5 Oct 00

Visual MODFLOW v.2.61, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 184 NR: 120 NL: 4
Current Layer: 1

FIGURE 3.34



ZONE 7 WATER AGENCY

5997 PARKSIDE DRIVE PLEASANTON CA 94588

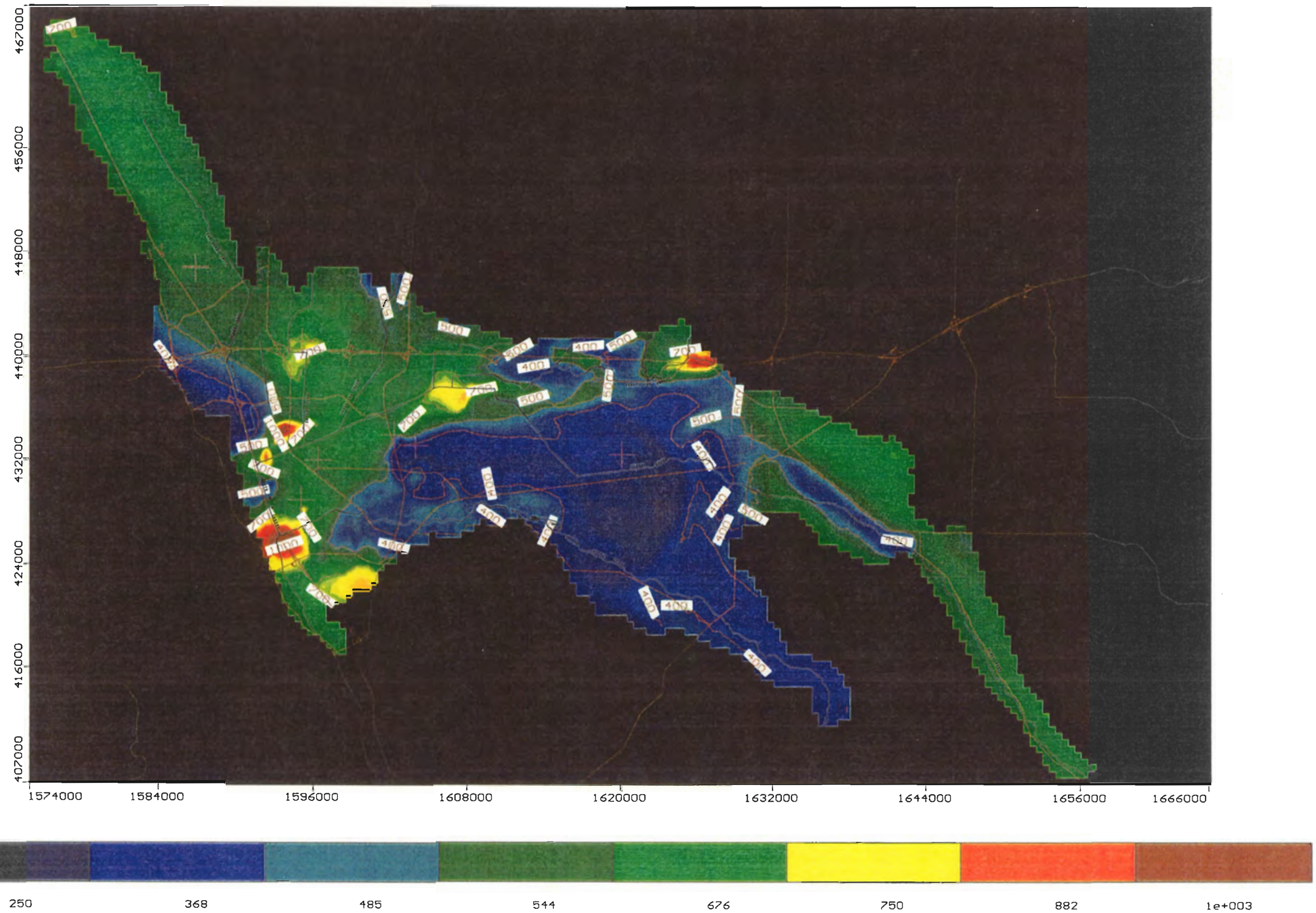
DRAWN BY: GERALD GATES
DESIGNED BY: D. LUNN, G. GATES
CHECKED BY:
APPROVED BY:

WATER RESOURCES ENGINEERING

MAIN BASIN LOWER AQUIFER TDS CONTOURS

AVERAGE 1990-1995 TOTAL DISOLVED SOLIDS

SCALE: 1" = 6000' (ON ORIGINAL)
DATE: 7 JULY 1997
FILE NO.: H:\SMP\FIG4-7.WOR



Zone 7 Water Agency – Pleasanton, CA
Project: LVGWB Model V 2.0.55
Description: L3 TDS Fall 1995 (SP40)
Modeller: CH2M HILL & Zone 7
5 Oct 00

Visual MODFLOW v.2.61, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 184 NR: 120 NL: 4
Current Layer: 3

FIGURE 3.36