Appendix L

2006 Draft Fox Canyon Groundwater Management Plan

Public Review Draft October 2006

Fox Canyon Groundwater Management Agency

Groundwater Management Plan

Prepared by

Fox Canyon Groundwater Management Agency
United Water Conservation District
Calleguas Municipal Water District

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EXECUTIVE SUMMARY

The Fox Canyon Groundwater Management Agency (FCGMA) was initially created to manage the groundwater in both overdrafted and potentially seawater-intruded areas within Ventura County. The prime objectives and purposes of the FCGMA are to preserve groundwater resources for agricultural, municipal, and industrial uses in the best interests of the public and for the common benefit of all water users. Protection of water quality and quantity along with maintenance of long-term water supply are included in those goals and objectives.

Prior to the creation of the FCGMA, the State Water Resources Control Board (SWRCB), as a condition to a State grant for the Seawater Intrusion Abatement Project, ordered the United Water Conservation District (UWCD) and Ventura County as grantees, to develop a Groundwater Management Plan for the purpose of controlling extractions and balancing water supply and demand in both the Upper and Lower Aquifer Systems. In response to this order, the Fox Canyon Groundwater Management Agency Act was submitted to the California State Legislature, which enacted and passed State Assembly Bill No. 2995 on Sept. 13, 1982 creating the FCGMA. The FCGMA began operations on January 1, 1983, and the enabling legislation is now contained in the California State Water Code Appendix, Chapter 121.

Initial goals of the FCGMA included balancing water supply and demand in the Upper Aquifer System (UAS) by the year 2000 and in the Lower Aquifer System (LAS) by year 2010. These goals and the GMA's basic purpose remain relatively unchanged today.

The Groundwater Management Plan for the Fox Canyon Groundwater Management Agency was prepared in 1985. This current document is an update to that initial Plan. We now have a better understanding of the aquifers within the FCGMA through focused monitoring programs, studies, and modeling. There has also been a period of time to observe how FCGMA policies and water conservation facilities have improved groundwater conditions.

The goals of this Management Plan are to set specific, measurable management objectives for each basin, identify strategies to reach these goals, and set future FCGMA policy to help implement these strategies. The FCGMA cannot itself build and operate conservation facilities, so the focus of this Plan is on strategies and policies that can assist conservation projects implemented by other agencies. Thus, the FCGMA acts as a partner with the other agencies in improving conditions in the aquifers within the Agency.

The main focus of the initial Groundwater Management Plan was to contain seawater intrusion in the south Oxnard Plain basin. At the time, seawater intrusion was forecast to contaminate aquifers as far inland as the City of Oxnard. The combination of FCGMA policies and new water conservation facilities, which included the FCGMA pumping reductions, shifting of pumping from the Upper Aquifer System to the Lower Aquifer

System, the construction of the Freeman Diversion, and the operation of the Pumping Trough and Pleasant Valley pipeline systems, has dramatically altered seawater intrusion in at least a portion of the aquifers. The major success was the reduction of the lobe of seawater in the Upper Aquifer System at Port Hueneme. Monitoring wells drilled into this lobe indicate that seawater intrusion has retreated in this area, with groundwater in one well improving from near-seawater back to drinking-quality water.

However, the containment of saline waters is not complete. In the Lower Aquifer System of the Pleasant Valley and south Oxnard Plain basins, saline waters both from the ocean and from adjacent fine-grained sediments have expanded the area of saline intrusion since 1985. This increase occurred in the Upper Aquifer System near Point Mugu and the Lower Aquifer System in the Port Hueneme and Point Mugu areas. Thus, continuation of current strategies and the implementation of additional strategies are required to fully contain saline intrusion.

This updated Management Plan reviews the efficacy of both current and additional FCGMA strategies. Current strategies that are recommended for continuation include pumping reductions, the system of pumping allocations-credits-irrigation efficiency, moving pumping from intruded areas to areas more-easily recharged, and increased recharge of the aquifers. New strategies recommended include:

- Increase Recharge in Forebay (Riverpark Recharge Pits)
- Use of Recycled Water for Recharge (GREAT Project)
- Non-Export of FCGMA Water
- Separate Management Strategies for Some Basins
- Adjust FCGMA Boundary
- Shift Some Pumping Back to Upper Aquifer System
- Import Additional State Water
- Increase Diversions from Santa Clara River
- Policy on Recovery of Credits from Oxnard Plain Forebay Basin
- Shift Pumping to Northwest Oxnard Plain
- Injection of Treated River Water into Overdrafted Basins
- Additional Storage Projects in Overdrafted Basins
- Barrier Wells in South Oxnard Plain
- Modify Irrigation Efficiency Calculations
- Shelf Life for Conservation Credits
- Penalties Used to Purchase Replacement Water
- Further Destruction of Abandoned or Leaking Wells
- Verification of Extraction Reporting
- Additional Water Conservation
- Additional Reductions in Pumping Allocations
- Additional Monitoring Needs

In addition to saline intrusion near the coast, new threats to the aquifers have been recognized. These include saline intrusion from surrounding sediments in inland areas, salts introduced into the aquifers during historically-high groundwater levels in the Las Posas and northeastern Pleasant Valley basins, increasing salinity in the Santa Clara River as it flows from Los Angeles County, and seasonally-high nitrates in the Oxnard Plain Forebay basin. Recommended FCGMA strategies to deal with these issues include:

- South Las Posas Basin Pump/Treat
- Development of Brackish Groundwater, Pleasant Valley Basin
- Limitation on Nitrate Sources in Portions of the Oxnard Plain Forebay Basin
- Additional In-Lieu Recharge to South Oxnard Plain

Another potential threat to the FCGMA aquifers is the potential loss of a portion of the recharge waters that currently replenish the aquifers. These potential losses include decreased diversions at the Freeman Diversion required for fisheries and changed operations of Santa Felicia Dam mandated by federal regulators. In order to preserve these important sources of recharge, the FCGMA should emphasize to politicians and regulators the importance of this recharge in protecting the health of the natural water supplies of the County.

This management plan calls for a set of actions to implement recommended strategies. Recommendations to modify existing FCGMA policies include:

- Credits for In-lieu Recharge to be Used in Forebay Basin
- Shift Some Pumping from Lower Aquifer System to Upper Aquifer System
- Modify Irrigation Efficiency Calculation
- Additional Monitoring
- Use Penalties to Purchase Replacement Water

Recommendations to add new FCGMA policies include:

- Separate Management Plans for Some Basins
- Adoption of Basin Management Objectives
- Extractions of Poor-Quality Water Without an Allocation
- Barrier Wells
- Protecting Recharge Supplies
- Nitrate Sources in Oxnard Plain Forebay Basin
- Additional Conservation Measures
- Verification Procedure for Extraction Reporting

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INTRODUCTION

The original Fox Canyon Groundwater Management Agency (FCGMA) Management Plan was adopted in 1985. The Annotated California Codes Water Appendix, Chapter 121-102 et seq. required the FCGMA to develop, adopt, and implement a plan to control groundwater extractions from the Upper Aquifer System (UAS) to achieve a balanced water supply and demand in the Upper Aquifer System by the year 2000. Additionally, the Water Code required the FCGMA to adopt a Lower Aquifer System (LAS) Management Plan for future extractions from the Lower Aquifer System, including a policy for issuing well permits and a Contingency Plan for seawater intrusion into the Lower Aquifer System. The original FCGMA Groundwater Management Plan specified several major items or tasks for accomplishment.

At the time of the initial Management Plan development in 1984-1985, the primary threat to the aquifers of western Ventura County was seawater intrusion in the Upper Aquifer System. Since that time, a number of studies have identified other water quality problems, including saline intrusion in the Lower Aquifer System (LAS) in the Pleasant Valley basin, and in the Las Posas basin. This update to the groundwater management plan is designed to look at a broader range of problems and to suggest potential solutions to these problems.

Since 1985, there have been a number of studies conducted within the FCGMA, the most comprehensive being the Regional Aquifer System Analysis (or RASA Study) done by the U.S. Geological Survey (USGS) in the late 1980s and 1990s. This study, conducted with the cooperation of local agencies, consisted of drilling monitoring wells with individual casings perforated in selected aquifers or water-bearing zones, constructing a groundwater model, and conducting hydrogeologic studies. Monitoring wells, most constructed along the coastline of the Oxnard Plain, continued to provide critical information on the status of saline intrusion. In addition, a number of more specific or follow-up studies have been conducted by the United Water Conservation District (UWCD) and other agencies. These studies have helped characterized seawater intrusion along the coastline, saline contamination in more inland areas, and nitrate contamination in the Upper Aquifer System. The USGS MODFLOW groundwater model has been used and refined by the groundwater staff at UWCD to test a variety of projects that could help mitigate the water quality problems within the FCGMA.

This Groundwater Management Plan update incorporates all previous work and the specific studies that were undertaken as part of this most-recent planning process. The Plan is organized with the results of past and current studies followed by an evaluation of both current management strategies and potential future management strategies for the FCGMA. Various groundwater management ideas and strategies have been evaluated first by FCGMA staff, and UWCD staff, then reviewed by Calleguas Municipal Water District (CMWD) management and staff and consultants from the water purveyors within the FCGMA. Extensive public review by stakeholders was also a critical part of the planning process.

Included as Appendix C is an addendum or more detailed sub-Management Plan for the East Las Posas basin resulting from discussions between CMWD and the Las Posas Basin Users Group (farm well owners, mutual water companies, and the Ventura County Water Works Districts that supply water to the City of Moorpark and others). This Appendix C plan particularly addresses the interaction of CMWD's Aquifer Storage and Recovery (ASR) project with other basin pumpers regarding both basin-wide and local effects of the project.

BACKGROUND OF GROUNDWATER MANAGEMENT AND OVERDRAFT WITHIN THE FCGMA

Although high chloride levels were first documented near Port Hueneme in the 1930s (Department of Water Resources, 1954), the conditions for widespread seawater intrusion on the Oxnard Plain were initiated as early as the 1940s, when groundwater levels beneath the southern portion of the Oxnard Plain basin dropped below sea level (see Appendix A). Within 5 to 10 years, chloride concentrations in wells in the Port Hueneme area started to increase rapidly. At that time, seawater had only affected a few wells in the Port Hueneme area, encompassing an area less than one square mile (Appendix A).

Within 20 years, seawater intrusion in the Port Hueneme area had extended as much as 3 miles inland. In some of the affected wells, chloride concentrations were as high as those of seawater (just less than 20,000 mg/L). Appendix A documents the progression of seawater intrusion beneath the southern portion of the Oxnard Plain basin. This seawater intrusion into the Upper Aquifer System was located adjacent to the Hueneme Submarine Canyon that is directly offshore of Port Hueneme (Figure 1). Seawater intrusion also occurred in the Point Mugu area, adjacent to the Mugu Submarine Canyon that extends offshore from Mugu Lagoon. This intrusion in the Point Mugu area first impacted Upper Aquifer System wells in late 1950s (Appendix A).

In the Port Hueneme area, seawater in the Upper Aquifer System reached its farthest point inland in the early 1980s (Appendix A). Following the high rainfall year of 1983, chloride levels began to decrease in many of the Port Hueneme area wells perforated in the UAS. Coupled with pumping allocations and management strategies imposed by the FCGMA, this improving trend in chloride reductions was accelerated in the 1990s, as the Freeman Diversion was completed by UWCD and several wet years occurred, which allowed increased recharge available from the diversion, helping restore aquifer pressures and pushing seawater back toward the coast.

Groundwater levels in the Lower Aquifer System also dropped below sea level in the late 1950s. This Lower Aquifer System intrusion was first detected in wells in the late 1980s (Appendix A). As with the Upper Aquifer System, the intrusion in the Lower Aquifer System spread into the aquifer both near Port Hueneme and at Point Mugu. Further exacerbating the drops in groundwater levels in the LAS was an increase in drilling and production in the Lower System – partly in search of better quality water supplies and partly because new or replacement wells were required to be drilled in the LAS as a strategy to lessen pumping in the intruded Upper Aquifer System.

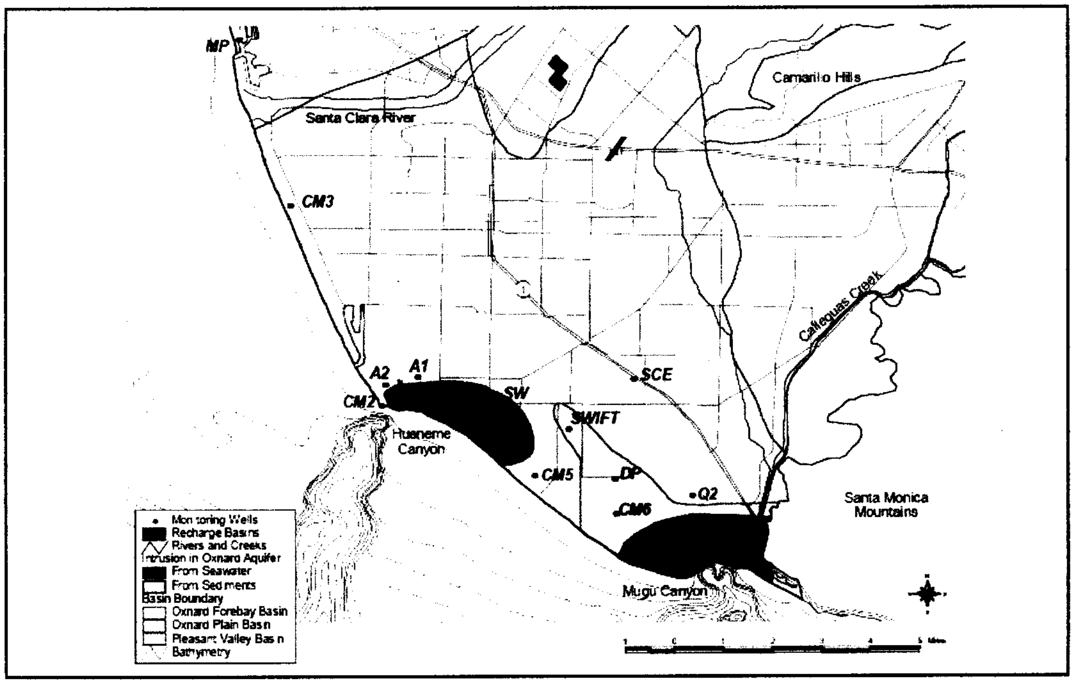

Figure 1. Areas of saline intrusion (indicated in red-brown and gold) beneath the Oxnard Plain basin in 2005. The sources of the saline intrusion are discussed in the *Seawater Intrusion* section.

The overpumping of the aquifers that led to seawater intrusion also created land subsidence of up to 2.2 feet in the Pleasant Valley area north and northwest of Mugu Lagoon by the early 1970s as dewatered clay layers between aquifer zones collapsed from reduced hydrostatic pressures. This subsidence is permanent – refilling of the sand and gravel aquifers cannot force water back into the dewatered clay layers.

In the Point Mugu area, chlorides have not lessened over the past two decades. Instead, chloride concentrations continued to increase in the area of Mugu Lagoon, reaching concentrations almost as high as seawater in some wells. The CM1A monitoring well (Figure 1) showed an increase in chloride concentrations from several hundred mg/L to 4,600 mg/L in a little more than one decade.

As the USGS began their work in Ventura County in late 1980s, they proposed that the increase in chlorides in the UAS and LAS was caused not just from seawater intrusion but also from the intrusion of saline waters being pulled from surrounding sediments and from deeper depths along fault zones (Izbicki, 1991, 1992; discussed in more detail in section *Current Issues – Seawater Intrusion*). The cause of this additional saline contamination was the same as for seawater intrusion, that is, very low groundwater levels. This additional saline contamination of groundwater inland from the lobes of seawater intrusion was caused by excessive groundwater pumping and lowered groundwater levels. This finding raised the possibility that saline contamination could occur in inland areas wherever groundwater levels are particularly depressed.

There was some initial concern chloride concentrations measured in some of the producing wells were simply detecting high chloride waters flowing downward from failed well casings. To ensure monitoring results were accurately depicting saline intrusion, a series of monitoring wells were drilled along the coastal portions of the Oxnard Plain. These multiple-completion wells consist of a single well bore containing several smaller-diameter PVC wells completed at varying aquifer depths. These monitoring wells give discreet depth-dependent data from the aquifers and form the basis of much of the current monitoring program.

Several trends in saline intrusion are evident on the south Oxnard Plain. The Port Hueneme lobe of seawater intrusion has decreased considerably in size and chloride concentration in the Upper Aquifer System. However, Lower Aquifer System chloride concentrations have somewhat increased in this Port Hueneme lobe. In the more southeastern Point Mugu lobe, concentrations of chloride are generally higher than in the past both in the UAS and LAS; the areal extent of the intrusion of seawater is not known with precision. The area affected by saline intrusion from surrounding sediments has increased both in size and in chloride concentration. This increase in size has prompted United Water Conservation District to drill new monitoring wells inboard of this saline intrusion to detect further movement of salts.

Local and State Actions – The increasing seawater intrusion prompted the State Water Resources Control Board to consider adjudication in the early 1980s, with the result that local agencies, working with the State Board, created a series of physical solutions and institutions to tackle the problem. The physical solutions included adding artificial recharge capability for the aquifers and providing additional in-lieu surface water to groundwater pumpers. The institutional solution was the formation of the Fox Canyon Groundwater Management Agency to bring water usage into balance with recharge sources to prevent overdraft conditions.

Formation of the Fox Canyon Groundwater Management Agency – In 1982, State Senate Bill 2995 was approved creating the Fox Canyon Groundwater Management Agency (FCGMA). The agency's activities were defined as "planning, managing, controlling, preserving, and regulating the extraction and use of groundwater within the territory of the agency." That directive also went on to say, "shall not involve itself in activities normally and historically undertaken by its member agencies, such as the construction and operation of dams, spreading grounds, pipelines, flood control facilities, and water distribution facilities, or the wholesale and retail sale of water." This prohibition of water conservation and distribution facilities along with water sales by the FCGMA was clearly meant to delineate the separate powers of the various agencies within the County (see following section).

The FCGMA officially began operations on January 1, 1983 with the County of Ventura contracting to provide staffing and related services to the new agency. In May 1983, Ordinance No. 1 was adopted requiring all wells within the agency to register and begin reporting groundwater extractions. This ordinance also set extraction management fees (at $0.50/AF), becoming the sole source of income to the fledgling agency sans any minor penalty or surcharge fees that would be instituted in later ordinance revisions. Ordinance No. 2 (October 1983) was a short amendment to Ordinance No. 1 establishing semi-annual groundwater extraction reporting to cover the first and second half of each calendar year, with statements due within 30 days following each period.

A groundwater management plan was adopted in 1985 to set goals and to help guide FCGMA policies. In February 1987, Ordinance No. 3 was adopted to require flow meters on all but domestic wells. Ordinance No. 4 (July 1987) soon followed that protected the aquifer outcrop areas in the East and West Las Posas basin (formerly collectively referred to as the North Las Posas basin) and regulated groundwater extractions in the basin via more detailed rules than those in any previous ordinance. The adoption of Ordinance No. 5 in August 1990 completed the first steps for the FCGMA by setting up a system of scheduled extraction reductions, allowing for the use of Historical, Baseline, and Agricultural Efficiency Allocations, and establishing a credit system to encourage cutbacks in pumping, along with a penalty system for overpumping beyond the established annual allocation.

Agencies' responsibilities - Several agencies are responsible for managing water resources in Ventura County. The FCGMA has responsibility for groundwater management planning, managing pumping allocations and credits, and developing policies related to groundwater extractions and recharge. United Water Conservation District (UWCD) has responsibility for managing groundwater resources in seven basins in the county, including most of the basins within the Fox Canyon Groundwater Management Agency (FCGMA). UWCD's responsibilities include groundwater and surface water monitoring, constructing and maintaining water conservation and recharge facilities, reporting on groundwater conditions, and groundwater management and planning activities. Groundwater management and planning functions overlap between the FCGMA, UWCD, and other local agencies, with the FCGMA focusing on extractions and policy and UWCD focusing on planning and implementing projects. Calleguas Municipal Water District (CMWD) is responsible for providing State Water to portions of Ventura County and providing water management strategies to ensure a reliable source of water for its customers. The Ventura County Watershed Protection District (VCWPD) is responsible for flood control functions, groundwater/surface water monitoring, and water well permitting. The water purveyors (cities and water districts) decide how much and from where their groundwater supplies are extracted, as well as plan projects that benefit the aquifers. There has been a remarkable amount of cooperation among these organizations in addressing groundwater issues over the last 20+ years.

In practice, groundwater management functions within the boundaries of the FCGMA are performed in the following ways:

1) Groundwater levels and groundwater quality sampling and analysis are conducted by UWCD, VCWPD, and individual water purveyors;

2) Groundwater extraction records are collected by both the FCGMA and UWCD, with the FCGMA maintaining records on extraction allocations and credits;

3) An annual report on groundwater conditions is prepared by UWCD within UWCD boundaries and CMWD prepares reports on groundwater conditions within the West, East, and South Las Posas basins (in conjunction with the Las Posas Basin Users Group;

4) Water purveyors prepare regular plans on current and future water use and supplies (e.g., Urban Water Management Plans);

5) The FCGMA prepares this Groundwater Management Plan to evaluate basin management objectives, strategies, and policies;

6) UWCD and some of the water purveyors construct and operate water conservation facilities; and

7) The VCWPD (and the City of Oxnard within its boundaries) oversees all well drilling, well destruction, and monitoring well requirements and permitting.

The initial Groundwater Management Plan (September 1985) prepared by the FCGMA recommended groundwater pumping be reduced by 25% over a 20-year period to help bring the aquifers into balance or to reach safe yield by year 2010 and to mitigate seawater intrusion by that same target date. This plan was based on groundwater demand projections for the period of time between 1980 and 2010. Subsequent Board ordinances (Ordinance No. 5) formulated an extraction allocation for all groundwater pumpers within the FCGMA, based on average extractions during the years 1985 to 1989. Starting in 1990, these pumping or "Historical" allocations were to be reduced by 5% every five years, with a planned 25% total reduction by the year 2010.

A program of "Conservation" and "Storage" credits allows well operators to vary their annual pumping in accordance with crop changes and/or annual hydrologic conditions. In addition, agricultural pumpers are allowed the option of using Irrigation Efficiency instead of the allocation/credit program. Agricultural efficiency for individual pumpers (later deemed as "operators" of one or more wells) is required to be at least 80% or better (20% or less going to leaching, deep percolation, or runoff), when compared to FCGMA allowed water for particular crop water demand based on daily evapotranspiration and precipitation measurements from a series of weather stations installed throughout the FCGMA. A surcharge fee, based on the extraction reporting, was formulated to penalize individual pumping above allowed annual allocations or not meeting the required irrigation efficiency percentage minimum. These penalties have been seldom used since their inception, largely because of widespread cooperation among pumpers to reduce groundwater extractions.

In cooperation with the Watershed Protection District, the FCGMA also helped formulate requirements that new wells be completed in specific aquifers to help control seawater intrusion. A similar cooperative program that utilized Federal 319(h) grant funds coupled with matching local funds helped destroy a number of abandoned wells across the

Oxnard Plain which had potential to act as conduits allowing inter-aquifer mixing. A total of 49 old abandoned or leaking wells were destroyed under this program.

GROUNDWATER BASINS & HYDROGEOLOGY

The basins within the FCGMA are part of the Transverse Ranges geologic province, in which the mountain ranges and basins are oriented in an east-west rather than the typical northeast-southwest trend in much of California and the western United States. Active thrust faults border the basins of the Santa Clara River, causing rapid uplift of the adjacent mountains and downdropping of the basins. The alluvial basins are filled with substantial amounts of Tertiary and Quaternary sediments deposited in both marine and terrestrial (non-marine) settings. The basins beneath the Oxnard Plain are filled with sediments deposited on a wide delta complex formed at the terminus of the Santa Clara River and was heavily influenced by alternating episodes of advancing or retreating shallow seas that varied with world-wide sea level changes over many millions of years.

There are seven main or significant groundwater basins within the FCGMA (Figure 2). These groundwater basins have been called by somewhat different names historically; this Plan uses the terminology of the U.S. Geological Survey from their work in the 1990s and early 2000s (e.g., Hanson and others, 2003) because it is the most recent comprehensive study of the basins. The historical terminology is discussed in the *Glossary of Terms* section. These groundwater basins include the Oxnard Plain, the Oxnard Plain Forebay, the Pleasant Valley, the Santa Rosa, and the East, West and South Las Posas basins. These basins generally contain two major aquifer systems, the Upper Aquifer System (UAS) and the Lower Aquifer System (LAS). Separate aquifers locally named within these systems include the Oxnard and Mugu aquifers (UAS) and the Hueneme, Fox Canyon, and Grimes Canyon aquifers (LAS). A shallower, unconfined aquifer is also present locally underlying rivers and creeks. Underlying the Oxnard Plain and Pleasant Valley basins are sand layers of the "semi-perched zone," which may locally contain poor-quality water. This zone extends from the surface to no more than 100 ft in depth. These sands overlie confining clay of the upper Oxnard Aquifer which generally protects the underlying aquifers from contamination from surface land uses. The Semi-perched zone is rarely used for water supply.

The aquifers are comprised of sand and gravel deposited along the ancestral Santa Clara River, within alluvial fans along the flanks of the mountains, or in a coastal plain/delta complex at the terminus of the Santa Clara River and Calleguas Creek. The aquifers are recharged by infiltration of streamflow (primarily the Santa Clara River), artificial recharge of diverted streamflow, mountain-front recharge along the exterior boundary of the basins, direct infiltration of precipitation on the valley floors of the basins and on bedrock outcrops in adjacent mountain fronts, return flow from agricultural and household irrigation in some areas, and in varying degrees by groundwater underflow from adjacent basins.

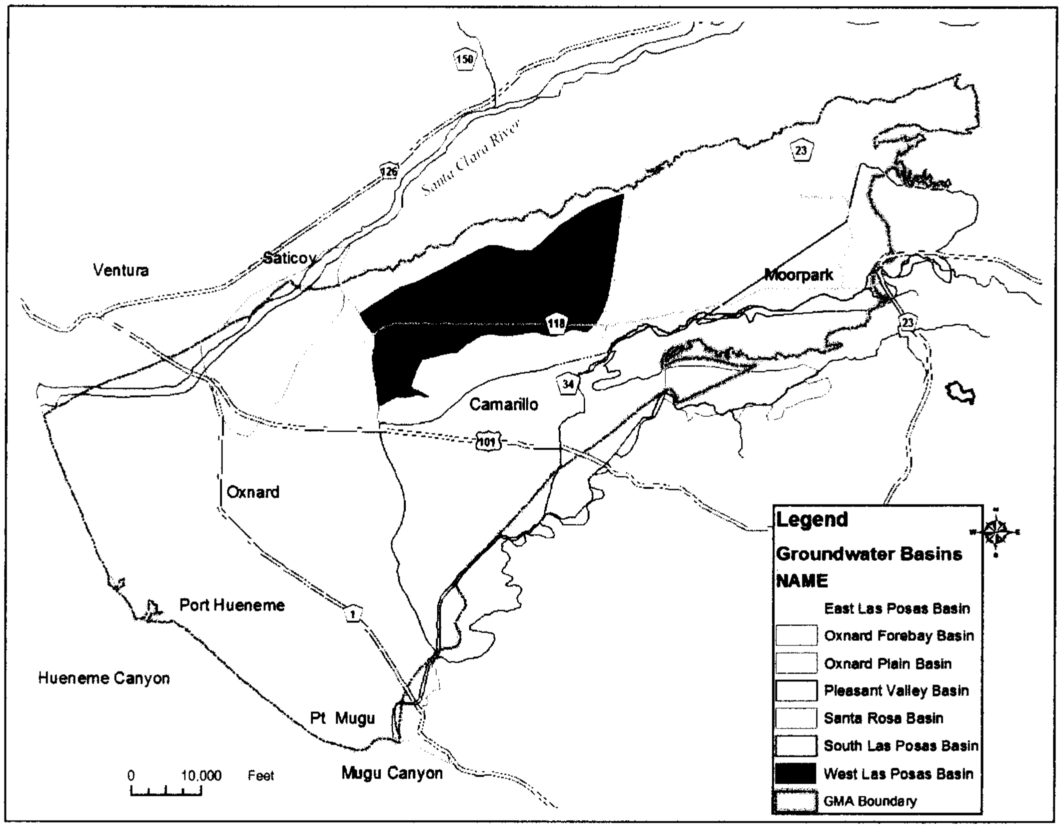

Figure 2. Groundwater basins within the Fox Canyon Groundwater Management Agency.

LOWER AQUIFER SYSTEM – The Lower Aquifer System (LAS) consists of the Grimes Canyon, Fox Canyon, and Hueneme aquifers (Figure 3) from the deepest to the shallowest. The LAS is part of the Santa Barbara, San Pedro, and Saugus formations of Plio-Pleistocene age (Hanson et al, 2003). The lowest water-bearing unit of the East Las Posas and Pleasant Valley basins is commonly referred to as the Grimes Canyon aquifer (California Department of Water Resources, 1954; Turner, 1975). The Fox Canyon aquifer underlies all of the groundwater basins beneath the FCGMA, but is most significant in the East and West Las Posas, Pleasant Valley, Oxnard Plain Forebay, and Oxnard Plain basins. The Hueneme aquifer is considered to underlie most coastal areas of the southern Oxnard Plain (Hanson et al, 2003), and is an important source of water in the Oxnard Plain, Pleasant Valley, and the West Las Posas basins.

The aquifers within the LAS are commonly isolated from each other vertically by low-permeability units (silts and clays) and horizontally by regional fault systems. There is active tectonism (faulting and folding) within the area of the FCGMA, caused by compressional and lateral forces as the Transverse Ranges are caught in a vise between the Pacific and North American tectonic plates. As a result, the LAS is folded and tilted in many areas, and has been eroded along an unconformity separating the Upper and Lower aquifer systems.

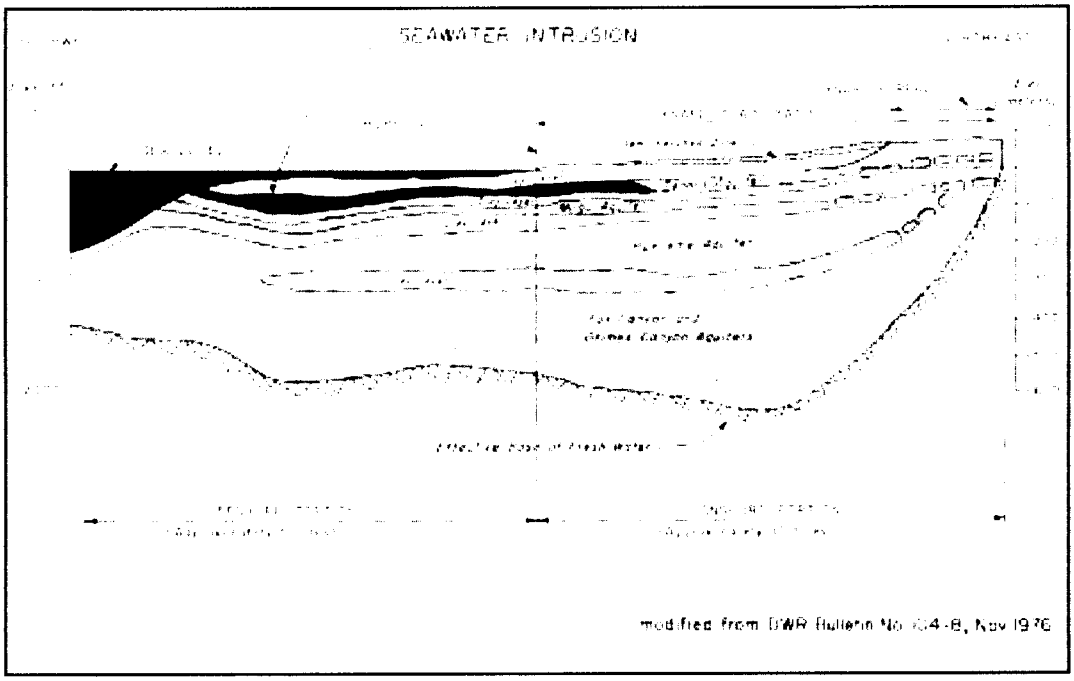

Figure 3. Simplified, highly-stylized cross-section of the aquifers of the Oxnard Plain; saltwater intrusion also exists in the Mugu, Hueneme and Fox Canyon aquifers, not illustrated in this schematic.

UPPER AQUIFER SYSTEM – The Upper Aquifer System (UAS) within the FCGMA consists of the Mugu and Oxnard aquifers (Figure 3), from deepest to most shallow, of Late Pleistocene and Holocene age. The UAS rests unconformably on the Lower Aquifer System, with basal conglomerates in many areas (Hanson et al, 2003). In the Oxnard Plain, these coarse-grained basal deposits have been referred to as the Mugu aquifer (Turner, 1975). The Mugu aquifer is generally penetrated at a depth of 255 ft to 425 ft below land surface. The younger Oxnard aquifer is present throughout the Oxnard Plain. The Oxnard aquifer is the primary aquifer used for groundwater supply on the Oxnard Plain. This highly-permeable assemblage of sand and gravel is generally found at a depth of approximately 100 ft to 220 ft below land surface elevation.

OXNARD PLAIN FOREBAY AND OXNARD PLAIN BASINS – Both Upper and Lower aquifers are present in the Oxnard Plain Forebay and Oxnard Plain basins. The Oxnard Plain basin extends several miles offshore beneath the marine shelf, where outer edges of the aquifer are in direct contact with seawater. In areas near Port Hueneme and Point Mugu where submarine canyons extend nearly to the coastline (Figure 1), the fresh-water aquifers are in direct contact with seawater only a short distance offshore.

The Oxnard Plain Forebay basin is the main source of recharge to aquifers beneath the Oxnard Plain. The absence of low-permeability confining layers (no continuous clay or silt layers) between surface recharge sources and the underlying aquifers (sand and gravel layers) in the Forebay basin allows for effective recharge of the basin and subsequent recharge of aquifers further to the south and southwest. Recharge to the Forebay basin comes from a combination of percolation of Santa Clara River flows, artificial recharge from United's spreading grounds at Saticoy and El Rio, agricultural and household irrigation return flows, percolation of rainfall, and lesser amounts of underflow from adjacent basins. In the area of the Forebay between the El Rio and Saticoy spreading grounds, the Lower Aquifer System has been folded and uplifted and then truncated (eroded away) along its contact with the Upper Aquifer System. In this area, recharge from surface sources may enter both the Upper Aquifer System and the underlying Lower Aquifer System. It is estimated that about 20% of the water recharged to this area reaches the Lower Aquifer System, with the remainder recharging the Upper Aquifer System (USGS, unpublished 1997 RASA study).

The Oxnard Plain Forebay basin accepts large quantities of recharge water in a single year, and the basin was filled to near-capacity during several recent wet years (UWCD, 2003). High groundwater elevations in the Oxnard Plain Forebay basin increase the hydraulic head (pressure) in the confined aquifers of the Oxnard Plain, raising water levels throughout the Plain and promoting natural offshore flow in coastal areas.

The Oxnard Plain Forebay basin is hydrologically connected with the aquifers of the Oxnard Plain basin. Thus, the primary recharge to the Oxnard Plain basin is from underflow from the Forebay rather than the deep percolation of water from surface sources on the Plain. When groundwater levels are below sea level along the coastline, there may also be significant recharge by seawater flowing into the aquifers. When Lower Aquifer System (LAS) water levels are substantially lower than Upper Aquifer System (UAS) water levels (creating a downward gradient), there may be substantial leakage of UAS water into the LAS both through discontinuities within the silts and clays between aquifers on the Oxnard Plain and as slow vertical percolation directly through the silt and clay material itself. Some amount of downward percolation can also occur via wells that are perforated in both aquifer systems and via compromised (failed or leaking) well casings.

One of the more recent findings associated with groundwater beneath the Oxnard Plain basin is a zone with a steeply-dipping groundwater gradient in the Lower Aquifer System that extends across the Oxnard Plain from just south of Port Hueneme northeastward to the south flank of the Camarillo Hills. This steep gradient is apparently caused by a lower-conductance zone that bisects the Oxnard Plain at the depth of the Lower Aquifer System (e.g., UWCD, 2003). This zone, likely a fault or other structural feature, reduces recharge flowing from the Oxnard Plain Forebay basin to the south Oxnard Plain and Pleasant Valley. This zone may be an extension of the Simi-Santa Rosa fault that extends along the southern flank of the Camarillo Hills. The presence of this subsurface feature that reduces groundwater flow also limits the effectiveness of management strategies that rely on groundwater flowing in the LAS from recharge areas in the Oxnard Plain Forebay basin to the south Oxnard Plain and to Pleasant Valley. This Management Plan proposes specific strategies to overcome this geologic hurdle to recharging the LAS in these southern areas of the FCGMA.

PLEASANT VALLEY BASIN – The Pleasant Valley groundwater basin has been historically differentiated from the Oxnard Plain basin by a general lack of Upper Aquifer System aquifers (Turner, 1975). However, there may be local water-producing Upper Aquifer System units within the Pleasant Valley basin (Turner, 1975; Hanson et al, 2003). The Pleasant Valley basin is confined by thick fine-grained deposits overlying the aquifers of the basin. The Fox Canyon aquifer is the major water-bearing unit in the basin. Despite the fault barrier to the west, the Lower Aquifer System is in hydrologic continuity with the adjacent southern portion of the Oxnard Plain basin.

Historically it was assumed that the LAS of the Pleasant Valley Basin was relatively confined and received little overall recharge across the fault that extends from the Camarillo Hills to Port Hueneme. However, since the early 1990s, water levels have begun to rise in the northern adjacent basins. The City of Camarillo has two existing wells in the northeast portion of the Pleasant Valley Basin (hereafter called the Somis Area) and these wells confirm that rising water levels in northern adjacent basins directly impact recharge rates, water quality, and water levels in the Somis Area. The recharge in the Somis Area may be a result of uplift and folding of Lower Aquifer units that allow rapid stream flow percolation. It is recommended that additional monitoring and studies be conducted to determine if this theory is correct.

The groundwater hydrology of the portion of the Pleasant Valley basin east of the city of Camarillo is not well understood because there are not many wells drilled in the area. Along Calleguas Creek near California State University Channel Islands, water has been produced historically from aquifer depths that are shallower than the typical LAS well, suggesting that water-bearing strata are not limited to the LAS in this area.

It is clear that the eastern and northeastern portions of the Pleasant Valley basin need to be better understood. Past studies have considered the basin as largely confined, with perhaps some perched water along a portion of its eastern edge. The conceptual hydrogeology that was the basis for the Ventura Regional Groundwater Model used the conclusions from these studies. As suggested above, additional monitoring and studies are needed to better determine the hydrogeology of the area, with these results integrated into the groundwater model.

SANTA ROSA BASIN – The Santa Rosa basin is the smallest basin within the FCGMA. Groundwater levels are heavily influenced by flows in the overlying Conejo Creek; discharges from a wastewater treatment plant and dewatering wells in Thousand Oaks have considerably increased year-round flows in the creek. Aquifers in the basin include a shallow alluvium aquifer and portions of the Lower Aquifer System. The structure of this basin is dominated by the east-trending Santa Rosa syncline that folds the San Pedro and Santa Barbara Formations (CSWRB, 1956). This syncline helps direct groundwater flow in the San Pedro Formation. The Santa Rosa fault zone forms a barrier to groundwater flow into the basin from the north. A sharp change in water level in the western part of the basin may be caused by a roughly north-trending fault that restricts groundwater flow (CDWR, 2003). Elevated nitrate and sulfate have been a problem in the basin.

LAS POSAS BASIN –The Las Posas groundwater basin is bounded on the south by the Camarillo and Las Posas Hills and on the north by South Mountain and Oak Ridge (CSWRB, 1956). The basin has been variously subdivided into north and south basins (e.g., Mukae, 1988) or by west, east, and south basins (e.g., Hanson, 1998). The U.S. Geological Survey terminology (Hanson, 1998) is used in this Management Plan. Productive aquifers in this basin include a shallow unconfined aquifer that is most transmissive along the Arroyo Las Posas and a lower confined aquifer system that is considered to be the equivalent of the Lower Aquifer System on the Oxnard Plain.

South Las Posas Basin – This basin is separated from the East Las Posas basin by an east-trending anticline (fold) that affects all but the shallowest alluvium. This fold may affect groundwater flow between the East and South Las Posas basins at some aquifer depths, although recharge from the South Las Posas basin flows readily into the East Las Posas basin at Lower Aquifer System (LAS) depths. To the south, the Springville and Santa Rosa fault zones produce disrupted and tightly folded rocks along the edge of the basin, restricting groundwater flow to the south (CSWRB, 1956). There is a shallow alluvial aquifer that follows the trend of Arroyo Las Posas as it crosses the South Las Posas basin; this shallow aquifer is in hydrologic connection with the underlying LAS and is the main source of recharge to the LAS.

There has been a significant change in average groundwater levels over the past 40 years in the South Las Posas basin, with groundwater levels rising more than 100 ft during this period. The mechanism for this rise in groundwater elevations is the increased recharge from percolation beneath the Arroyo Las Posas as discharges from the Moorpark and Simi Valley wastewater treatment plants and dewatering wells in Simi Valley have increase year-round flow in the arroyo. The entire alluvial aquifer near the arroyo has progressively filled to the elevation of the arroyo, starting in the easternmost portion of the basin in the 1960s and moving westward through the 1990s (Bachman, 2002). Water from the filled alluvial aquifer has percolated downward into the underlying Lower Aquifer System, creating a recharge mound in the Lower Aquifer System that extends from the arroyo northward into the East Las Posas basin (Ch2MHill, 1993; Bachman, 1999).

Salts in the groundwater have increased in the South Las Posas basin and the southwestern portion of the East Las Posas basin as the shallow aquifer filled along Arroyo Las Posas. These salts apparently were leached from the shallow aquifer as groundwater levels reached record highs, saturating sediments that have been unsaturated for the historic period. These salts apparently migrated vertically with percolating groundwater into the LAS and then laterally into the main portion of the East Las Posas basin as the recharge mound developed. Some of this groundwater is unsuitable for irrigation without being blended with better-quality water.

East Las Posas Basin – The East Las Posas basin is separated from the West Las Posas basin by a north-trending unnamed fault running through Somis (CH2MHill, 1993; Hanson, 1998), across which groundwater levels differ by as much as 400 feet. The fault also acts as a barrier to transport of saline waters from the East Las Posas basin to the West Las Posas basin (Bachman, 1999).

The source of recharge to the East Las Posas basin has changed significantly since urban development of the Simi Valley and Moorpark areas over the last 30 years. Prior to this time, recharge was predominantly from rainfall on outcrop areas and from percolation of winter floodwater along the Arroyo Las Posas. Geochemical studies show that groundwater in the central portion of the East Las Posas basin is hundreds to thousands of years old (Izbicki, 1996), indicating a slow rate of historical recharge along the flanks of the basin. As discussed for the South Las Posas basin, urban development has brought increased discharges of both treated wastewater and shallow groundwater into Arroyo Las Posas, providing a year-round recharge source for the South and East Las Posas basins (CH2MHill, 1993; Bachman, 2002). This increased percolation from the arroyo has created a recharge mound that extends northward into the East Las Posas basin, where groundwater levels have risen by 125 ft to 200 ft during the past 30 years.

Conversely, pumping in the basin has resulted in falling groundwater levels in the eastern portion of the basin, away from the recharge mound. The largest drop in groundwater levels (190 ft) over the period 1973 to 1998 occurred in this region (Bachman, 1999). Groundwater levels have stabilized somewhat across the basin since the late 1990s, at least in part because of the addition of in-lieu and injected recharge by CMWD as part of the Las Posas Basin Aquifer Storage and Recovery (ASR) project.

West Las Posas Basin – The West Las Posas basin is isolated from the recharge sources of the East and South Las Posas basins by the north-south fault discussed in the previous paragraphs. Instead, the West Las Posas basin is hydrologically connected to the Oxnard Plain basin, with groundwater levels in the western portion of the basin rising and falling with wet and dry climatic cycles of recharge. Groundwater elevation contours are interpreted to extend continuously in the LAS from the Oxnard Plain basin into the West Las Posas basin, suggesting that there is no hydrologic boundary at the western end of the basin. Instead, the western boundary of the basin is defined by surface features – the end of the Las Posas Valley and the beginning of the flat terrain of the Oxnard Plain.

In the eastern portion of the basin, just to the west of the north-trending fault at Somis, a groundwater level trough that was 35 ft below sea level in 1973 had dropped to 150 ft below sea level by 1998 (it has since leveled out). Groundwater elevations slope from their highest point at the western end of the basin to their lowest point at the eastern end of the basin, indicating that recharge water flows from the Oxnard Plain eastward into the basin. There is a flow component from the northern flank of the basin, suggesting that there is also significant mountain-front recharge.

GROUNDWATER EXTRACTIONS

The FCGMA has collected records of extraction for wells within the Agency for semi-annual periods since 1985. These extraction records are entered into a computer database, and individual wells that reported any pumping between 1985 and 1989 (known as the FCGMA "Base Period") have been assigned Historical Allocations based on those extractions. These extraction records are also used to calculate Conservation Credits and to determine pumping trends within the FCGMA.

Extractions vary from year to year based largely on the amount and patterns of rainfall for any year. This natural variation makes it difficult to compare pumping from one year to the next without factoring in the climate variations. However, now that there are historic records available that were gathered over at least a 20-year period, similar climatic years can be compared to determine trends in pumping. For instance, comparing the dry years 1987 and 2002 indicate that overall reported pumping has declined by about 37,000 acre-feet per year (164,700 to 127,700 AFY) within the Agency. Likewise, comparing average precipitation years 1988 and 2000 indicate that reported pumping has been reduced by 36,800 acre-feet per year (160,500 to 123,700 AFY).

This decreasing trend in FCGMA pumping is also evident in Figure 4, which shows reported annual FCGMA extractions by major water use (e.g., agricultural, municipal/industrial). Figure 5 shows the pumping proportion by major water use. Agricultural pumping shows the largest decrease, which was realized in the early years of the FCGMA (Figure 4). This decrease in agricultural pumping has also been documented by UWCD (2002) in a study of agricultural efficiencies within the FCGMA. The increased irrigation efficiency is likely the result of improved irrigation systems such as drip tape and micro sprinklers, as well as overall grower awareness of groundwater conservation issues. A portion of the decrease in agricultural pumping can also be attributed to land conversion to urban uses (see discussion below) and increased yields from the Freeman Diversion and the Conejo Creek project.

Municipal and Industrial (M&I) pumping is somewhat less affected by annual rainfall changes than agricultural irrigation. M&I pumping has also been decreasing, with a reduction of about 8,300 acre-feet per year from 1988 to 2000 (from 44,000 to 35,700 AFY). This reduction has occurred as overall urban acreage has been increasing (with an accompanying increase in potential water demand) as agricultural land has converted to urban use. An analysis of changes in land use during the pried between aerial photos taken in 1998 and 2002 indicates that about 1,150 acres converted from agriculture to M&I in the Oxnard Plain and Pleasant Valley areas. At the FCGMA conversion rate of 2 AFY per acre, that represents about 2,300 AFY of new allocation to M&I during this four-year period.

The M&I decrease in reported pumping is comparable to the 15% reductions in pumping that have been required by the FCGMA during this period. However, the additional pumping that would be expected to have accompanied additional M&I acreage did not happen, indicating that M&I per-acre pumping has been reduced more than 15%.

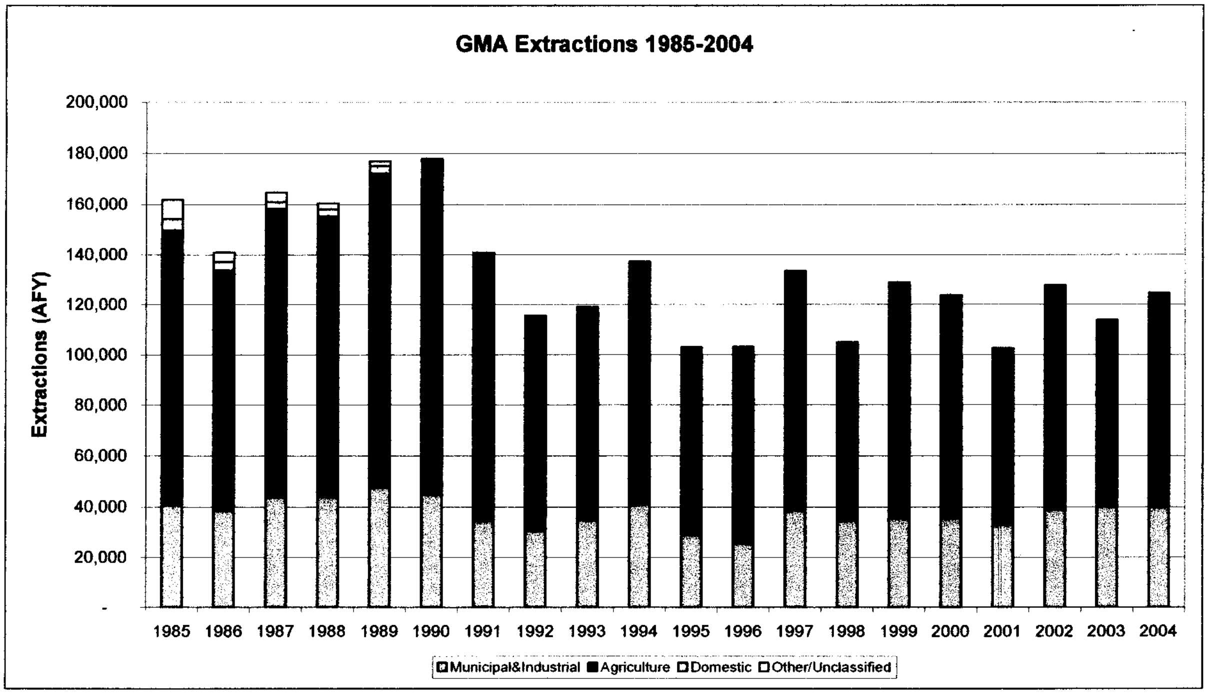

Figure 4. Reported extractions within the FCGMA for years 1985 to 2004.

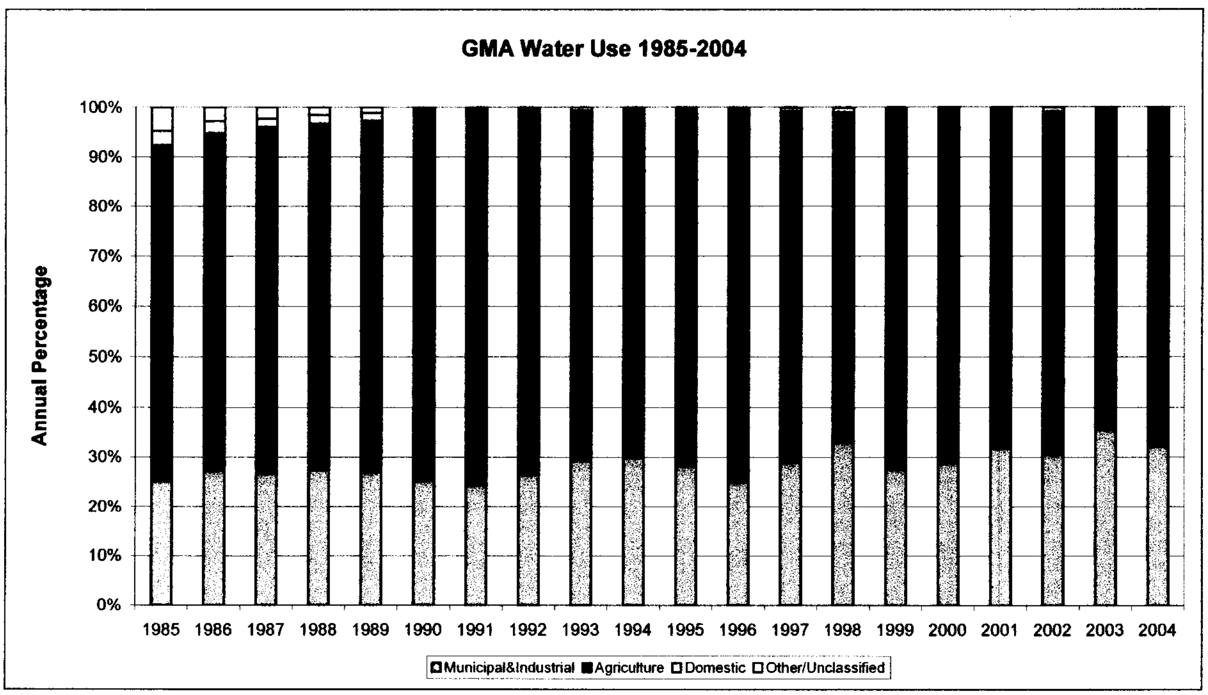

Figure 5. Water use in FCGMA 1985-2004, displayed as percentage of total extractions for that year.

WATER QUALITY ISSUES

Water quality issues are discussed in two parts: current issues that are evident today and potential future threats that could occur within the basins of the FCGMA if proactive steps are not taken now through management strategies.

CURRENT WATER QUALITY ISSUES

Seawater intrusion has long been the primary water concern within the FCGMA and was the problem for which the FCGMA was originally formulated to help fix. The intrusion occurs exclusively along the coastline in the Oxnard Plain basin. The U.S. Geological Survey also identified another type of saline intrusion on the Oxnard Plain – salts moving from the surrounding marine clays and older geologic units as pressure in the aquifers is reduced from overpumping. This type of intrusion may also be occurring on a minor scale in the Pleasant Valley basin. Chloride has also become a problem along Arroyo Las Posas, where groundwater from an area in the East and South Las Posas basins must be blended with lower-chloride water to meet irrigation suitability. This problem appears to have migrated downstream, with some of the City of Camarillo's wells now affected.

Chloride is also a problem in the Piru basin near the Los Angeles County line, where high chlorides from discharge of wastewater treatment plants along the Santa Clara River have degraded the recharge water for the basin. This chloride problem is currently isolated to the Piru basin, although long-term recharge of poorer quality water could eventually move through the groundwater basins along the Santa Clara River and reach the Freeman Diversion.

High nitrate concentrations in groundwater are a localized problem in the Oxnard Plain Forebay and Santa Rosa basins. In and adjacent to the Forebay, nitrates affect drinking water wells of UWCD's Oxnard-Hueneme wellfield, mutual water companies, and the City of Oxnard, particularly during and following dry periods.

SEAWATER INTRUSION

High chloride levels from intrusion of seawater were induced by lowered groundwater levels that formed a distinct pumping trough in the southern Oxnard Plain (Figure 6).

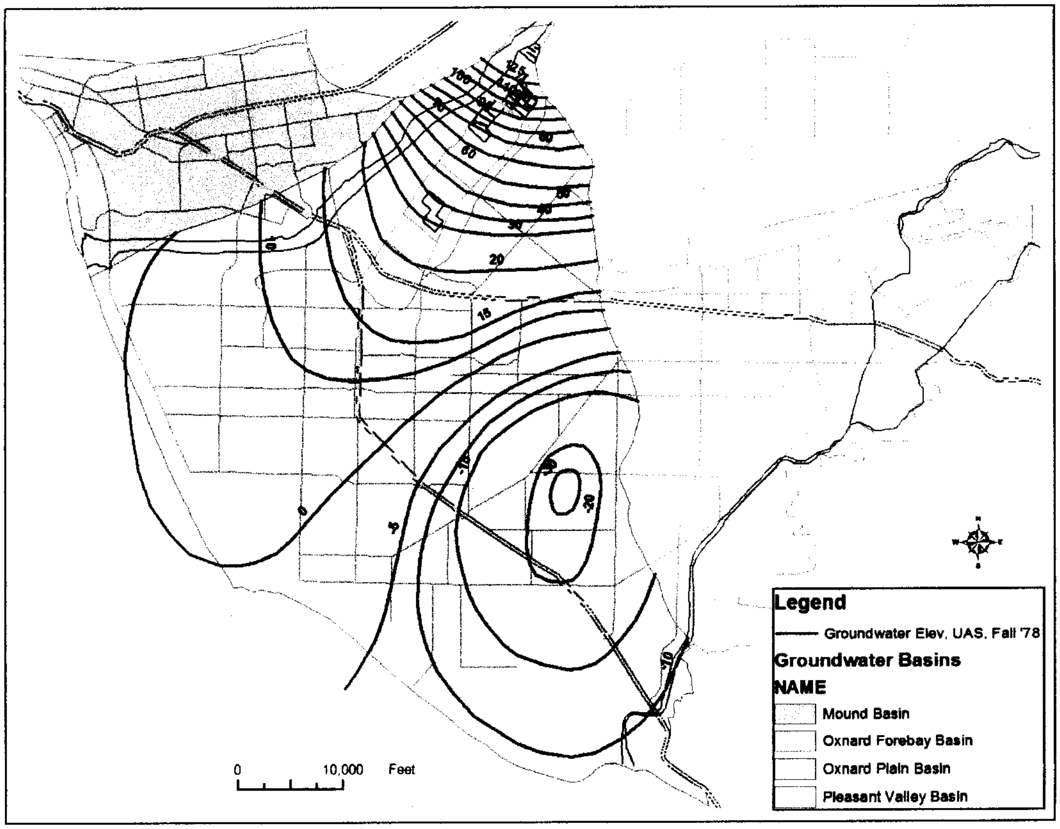

Figure 6. Groundwater elevations in the Upper Aquifer System in fall 1978, indicating the large pumping trough in the south Oxnard Plain (water levels as much as 30 feet below sea level). This pumping trough, created by overpumping, pulled in seawater from the ocean.

In 1989, the U.S. Geological Survey initiated their Regional Aquifer-System Analysis (RASA) study in a cooperative effort with local agencies. As part of this and companion cooperative studies, a series of 14 nested well sites with three or more wells installed at each site, were drilled and completed at specific depths in the Oxnard Plain, Oxnard Plain Forebay, Pleasant Valley, and Las Posas basins (Densmore, 1996).

Figure 7 shows the locations of the RASA well sites on the Oxnard Plain. Prior to the RASA study, it was believed an area extending from approximately 3 miles north of Port Hueneme to well SCE (near Highway 1) and south to Point Mugu was intruded by seawater. The installation of a dedicated monitoring network and detailed chemical analysis of water samples from the new wells and other wells yielded new interpretations on the extent of seawater intrusion on the Oxnard Plain. It is now known some areas of the southern Oxnard Plain are not intruded by seawater, but that high chloride readings from older production wells were the result of perched water leaking down failed well casings and contaminating the aquifer (Izbicki, 1992; Izbicki and others, 1995; U.S. Geological Survey, 1996). As a partial result of these findings, many of the older wells on the Oxnard Plain have since been destroyed via a cooperative FCGMA-initiated program using Federal 319(h) grant money and matching funds contributed by the City of

Oxnard, UWCD, FCGMA, and the County of Ventura. Figure 7 delineates the approximate extent of high-chloride water in the Oxnard aquifer (Upper Aquifer System). Figure 8 delineates the approximate extent of high-chloride water in the Lower Aquifer System.

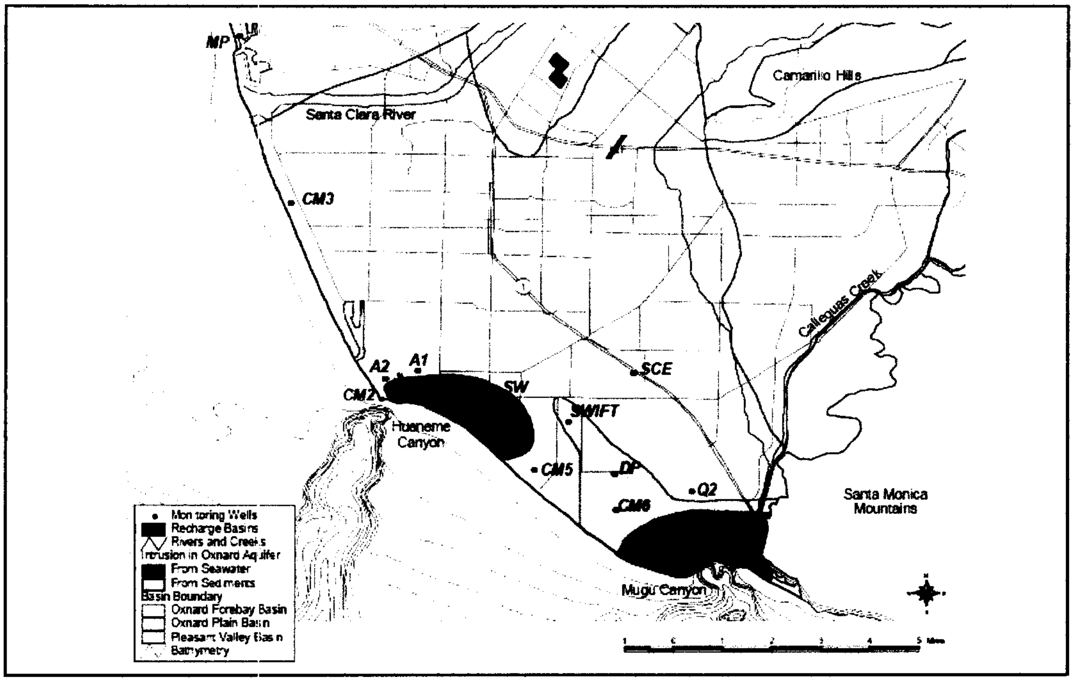

Figure 7. Area of saline intrusion in the Upper Aquifer System of the Oxnard Plain. The red areas represent seawater intrusion and the orange areas represent saline intrusion from surrounding sediments. The offshore contour lines indicate the submarine canyons where the aquifers are eroded along the canyon walls and exposed to seawater.

In addition to drilling and installing the nested monitoring wells, the USGS conducted geophysical surveys to determine the general extent of the high-saline areas (Stamos and others, 1992; Zohdy and others, 1993). This work indicated high-saline areas consisted of two distinct lobes, with relatively fresh water separating the lobes (U.S. Geological Survey, 1996). The lobes identified by the USGS form the basis of the areas of high chloride concentration shown on UWCD maps.

Additional down-hole conductivity surveys by the USGS indicate the edges of the lobes are relatively distinct, with the first saline intrusion occurring in thin individual beds of permeable sand and gravel. As intrusion continues, more individual beds or geologic layers are impacted, resulting in increasing chloride levels within the affected aquifer. Thus, the interpretation of high-chloride areas shown on the maps combine measured concentrations from the monitoring wells, geophysical measurements, and study results about the nature of the intrusion front.

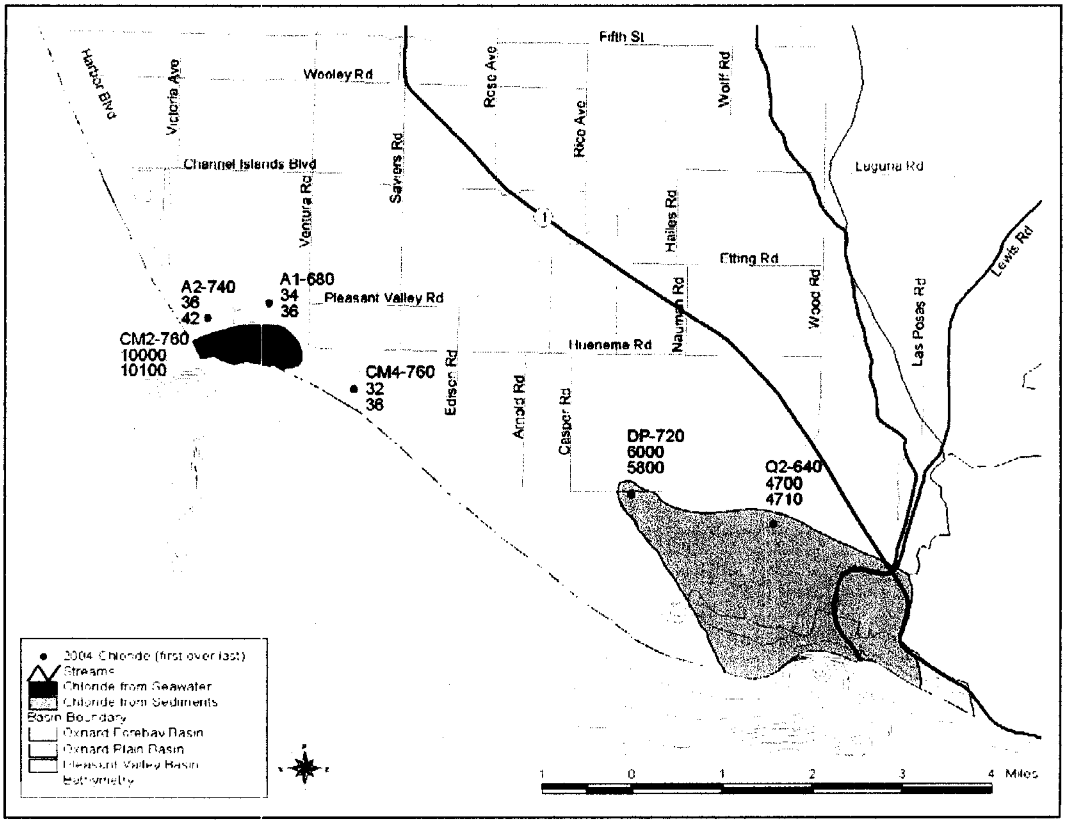

Figure 8. Saline intrusion in a portion of the Lower Aquifer System. The red areas represent seawater intrusion and the orange areas represent saline intrusion from surrounding sediments (this area may be larger than shown). The offshore contour lines indicate the submarine canyons where the aquifers are eroded along the canyon walls and exposed to seawater.

In addition to monitoring wells and geophysical measurements, isotope studies of groundwater samples from the nested wells indicate that the cause of the elevated chloride levels varies in the Oxnard Plain basin (Izbicki, 1991, 1992). Four major types of chloride degradation were documented:

Lateral Seawater Intrusion - the inland movement of seawater adjacent to the Hueneme and Mugu submarine canyons.

Cross Contamination - the introduction of poor-quality water into the fresh water supply via existing well bores improperly constructed or improperly destroyed, or via corroded casings caused by poor-quality water in the Semi-Perched zone.

Salt-Laden Marine Clays - the dewatering of marine clays, interbedded within the sand and gravel-rich aquifers and containing salts from their marine deposition, yields high concentrations of chloride-enriched water. This dewatering is the result of decreased pressure in the aquifers, caused by regional pumping stresses (excessive groundwater withdrawals).

Lateral Movement of Brines from Tertiary-Age Geological Formations - the lateral movement of saline water from older geologic formations caused by uplift along faults. An example is where older Tertiary rocks are in contact with younger aquifers across a buried fault face near Pt. Mugu.

SALINE INTRUSION FROM SURROUNDING SEDIMENTS

A significant portion of the salinity in the aquifers of the Oxnard Plain basin is coming from salts pulled from the surrounding sediments, as discussed in the previous section. Near the coastline, the trends in saline solution and the mitigation measures are the same for both seawater intrusion and intrusion of salts from the surrounding sediments. In more inland areas such as the Pleasant Valley basin, chloride levels are generally lower, with only a few wells showing any increase in chloride. It is too early to know whether chlorides in the Pleasant Valley basin will escalate to a problem affecting local pumpers.

HIGH SALINITY ASSOCIATED WITH HIGH GROUNDWATER LEVELS

Increased salt concentrations in aquifers underlying the Arroyo Las Posas in the East Las Posas, South Las Posas, and northern Pleasant Valley basins correspond in time with rising groundwater levels along the arroyo. This rise in groundwater levels has been created by increased recharge as natural streamflow was augmented by the addition of the upstream discharge of treated waste water and aquifer dewatering projects along the arroyo. The shallow groundwater levels, which are higher than any historic levels, apparently leach salts from the previously-unsaturated portions of the aquifer. The problem caused by high groundwater levels in the shallow aquifer has migrated down Arroyo Las Posas across the Las Posas basin and into the northern part of the Pleasant Valley basin, where water levels have risen and salts have increased. Solutions to this salinity problem will likely be based on removing and treating the high-salinity water.

NITRATE IN GROUNDWATER

High nitrates in groundwater primarily affect the Oxnard Plain Forebay and Santa Rosa basins. Nitrate is a primary drinking water standard (45 mg/L as NO_3), so high nitrate concentrations directly affect the potable water supply. Nitrate is largely introduced into groundwater by man's activities in overlying recharge areas where the nitrate travels directly into the aquifers. Nitrate concentrations are a balance between nitrate input and the amount of recharge water available for dilution. Nitrate concentrations commonly increase during dry periods when there is less recharge water for dilution. In groundwater away from recharge areas, nitrates have generally been diluted and are at concentrations well below drinking water standards. An exception to this occurred in the 1990s, when nitrate occurred in City of Oxnard wells in the Oxnard Plain basin, just outside of the Forebay basin. This nitrate may have migrated downward from the Semi-Perched zone through improperly-abandoned private wells.

The primary sources of nitrate are septic systems (especially if they are poorly-maintained or being used above design capacity) and agricultural fertilizer. These are both being addressed. As discussed below, septic systems have been prohibited in the Oxnard Plain Forebay basin. In addition, agricultural nitrate, contributed largely from fertilizers, will be monitored in 2006 as part of the Agricultural Irrigated Lands

Conditional Waiver program adopted by the Los Angeles Regional Water Quality Control Board. If nitrates are shown to be entering groundwater from agricultural fertilizers through the monitoring program, the waiver requires the implementation of Best Management Practices.

WATER QUALITY ISSUES BY BASIN

OXNARD PLAIN FOREBAY BASIN

The primary water quality concern in the Oxnard Plain Forebay basin is nitrate concentrations above the Department of Health Services' Maximum Contaminant Level. Nitrate concentrations in the Upper Aquifer System spike in the Forebay basin during dry periods when there is reduced recharge to the basin. Nitrate concentrations periodically exceed the primary drinking water standard of 45 mg/L (as NO_3) in individual wells (Figure 9). Because much of the pumping in the Forebay delivers potable water through the Oxnard-Hueneme (O-H) pipeline (a potable water delivery line that provides groundwater to the cities of Oxnard and Port Hueneme), the drinking water standard is of prime importance. The O-H system has been able to deliver potable water by blending lower-nitrate water and by temporarily shutting down impacted high-nitrate wells.

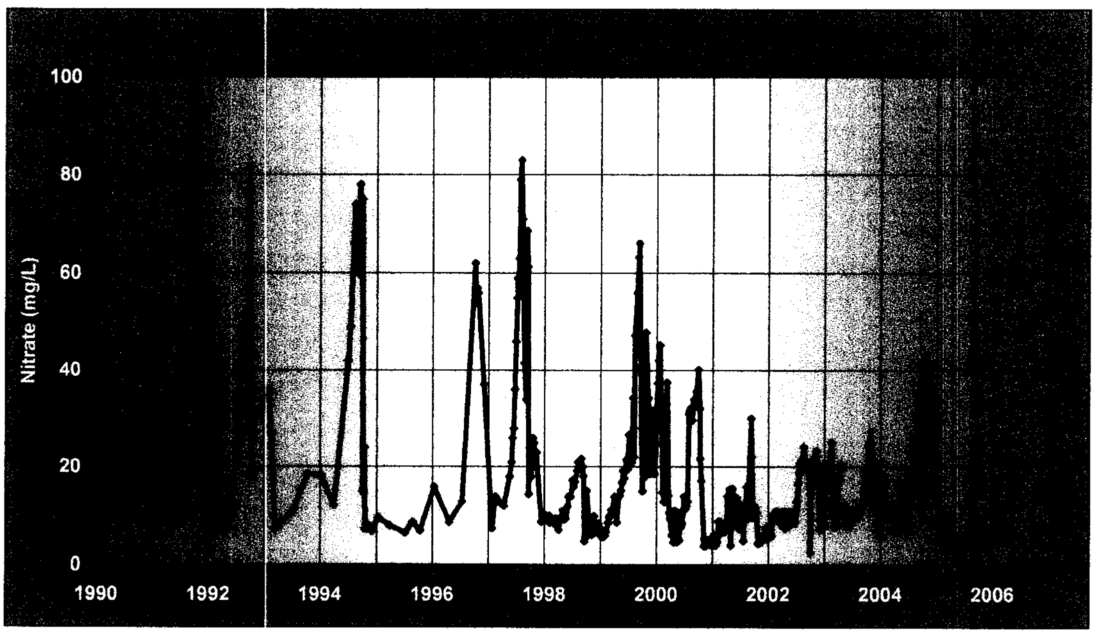

Figure 9. Nitrate concentrations (as NO_3) in Oxnard-Hueneme El Rio well #5. Note that nitrate increases during dry portion of year, when nitrate input from overlying land uses is less diluted by low-nitrate recharge water. When nitrate levels are high, this well is either not used or the produced groundwater is diluted with low-nitrate water from other wells in the system.

These nitrates have been attributed to both agricultural activities (fertilizer application) and adjacent septic systems (leach-line effluent discharges). The nitrate problem will continue to be a water quality issue for drinking water wells as long as the sources of nitrate continue to contribute this mineral salt into the groundwater resources. As a result of the high nitrate concentrations, the Regional Water Quality Control Board enacted in 1999 a prohibition on septic systems in portions of the Forebay, with orders that most such disposal systems be eliminated from the Oxnard Plain Forebay basin before 2008. Since that time, disconnecting the nearby El Rio septics and connecting to a sanitary sewer system has been a high priority water quality improvement project for the County.

OXNARD PLAIN BASIN

The significant water quality issue in the Oxnard Plain basin is saline intrusion from both seawater and from surrounding marine sediments. Chloride degradation is directly related to groundwater levels in the basin. The water balance of the Oxnard Plain and the offshore component of the aquifer units is a dynamic balance between groundwater recharge, groundwater extraction, and change in aquifer storage. High groundwater levels in the recharge zone in the Oxnard Plain Forebay basin exert a positive pressure on the confined aquifers of the Oxnard Plain, and water flows from the recharge areas toward the coast (Figure 10). Whereas the pressure exerted by high water levels in the Forebay propagates rapidly through the aquifers, the actual movement of the water itself is slow, at approximately 3 feet per day or less in the Forebay (Izbicki et al, 1992). The pressure (piezometric) surface of the confined aquifer is diminished by the extraction of water from the system. If pressure heads at the coast fall below sea level, the lateral intrusion of seawater will occur. The dewatering of marine clays can occur if heads in the surrounding sediments remain below their historic levels for prolonged periods.

Chloride levels in coastal monitoring wells in the Upper Aquifer System show a direct relationship to groundwater levels – with the continued lowering of groundwater levels, chloride levels in these wells increased into the early 1990s (Figure 11). However, as the Freeman Diversion on the Santa Clara River began operation in 1991 and a series of wet years followed, the amount of recharge to the former pumping trough area and to the Port Hueneme area increased significantly. This has resulted in a drastic reduction in seawater in some coastal monitoring wells (Figure 11). In fact, the significantly-intruded well A-1 has returned to its pre-intrusion water quality levels and is currently (2006) within drinking water standards. This may be the first documented instance of such a reversal of seawater intrusion in a coastal basin.

Despite some encouraging gains, however, the Upper Aquifer System is not completely restored. Although high recharge rates related to the increased flows from the Freeman Diversion have improved water levels and water quality south to Port Hueneme and the higher water levels appear to have eliminated the pumping trough, groundwater levels are still below sea level and water quality continues to degrade in the southern portion of the Oxnard Plain near Point Mugu (Figure 10, Figure 11 – CM6 well). It is likely that the pumping trough situation is similar to the one discussed next for the Lower Aquifer System – namely, that this portion of the Upper Aquifer System may be too far from the

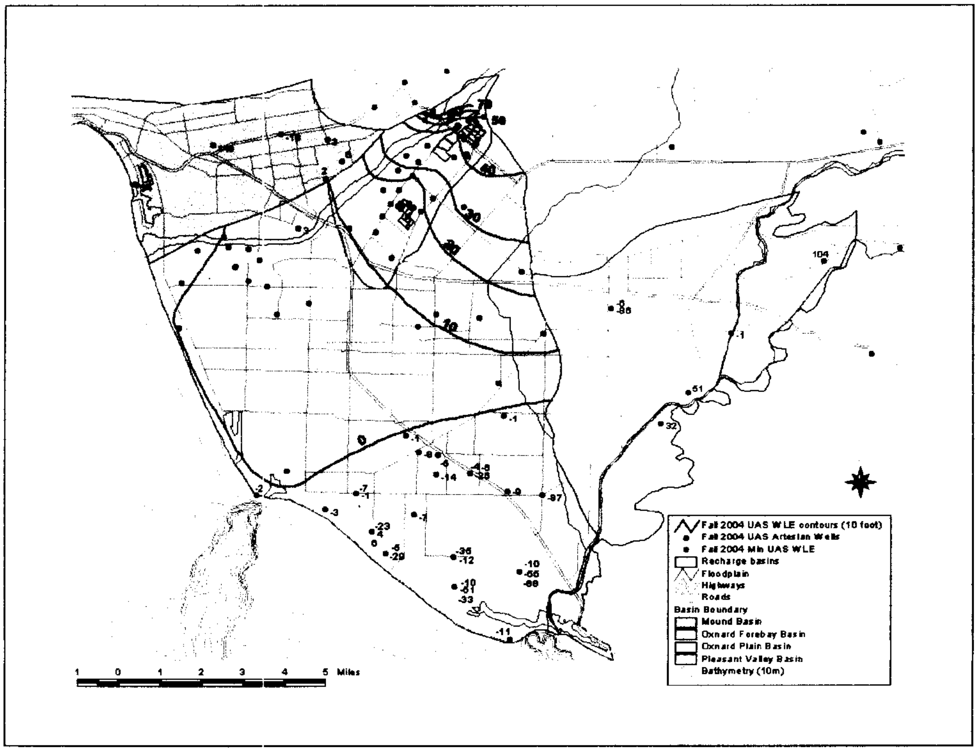

Figure 10. Groundwater elevation contours in the Upper Aquifer System, fall 2004. Note that southeastern portion of Oxnard Plain remains below sea level (line labeled "zero") and is susceptible to continued seawater intrusion.

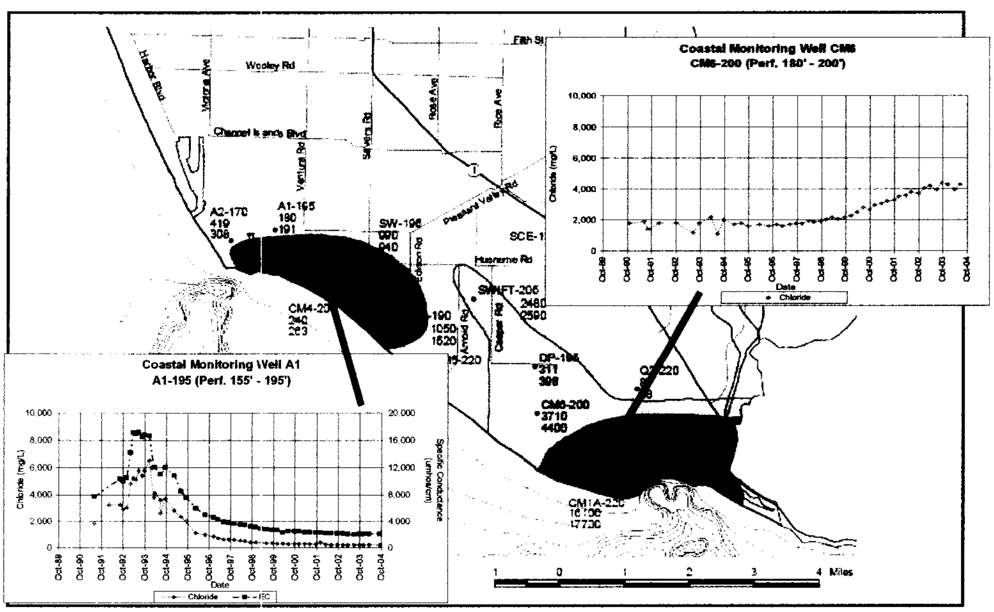

Figure 11. Chloride levels in two Upper Aquifer System coastal monitoring wells. Note that chloride levels have improved to drinking water quality in the A-1 well (Port Hueneme lobe), whereas chloride levels continue to increase in the Point Mugu lobe.

recharge areas for direct recharge to be effective, and must rely on artificial or in-lieu recharge methods to transport replacement water from the Oxnard Plain Forebay basin or other sources of supply.

Groundwater levels in the Lower Aquifer System in the south and southeast Oxnard Plain and central and southern portions of the Pleasant Valley areas have been consistently below sea level since at least the early 1950s (Mann, 1959). The strategy to switch pumping from the Upper Aquifer to the Lower Aquifer has apparently been at least a portion of the cause for the low water levels and high chlorides that were encountered when the RASA monitoring wells were completed at LAS depths. These high chloride levels occur in several wells at the position of the two Upper Aquifer System seawater lobes (Figure 12, Figure 13).

U.S. Geological Survey studies indicated that the chloride in the LAS occurred not just from seawater intrusion, but also from slow dewatering of the surrounding volcanics and older sediments, as well as chloride-rich marine clays that serve as the aquitard between the Upper and Lower aquifer zones. After the U.S. Geological Survey findings became known and there was the realization the shift in pumping was actually mining LAS groundwater, the County of Ventura took action to change the County Well Ordinance (May 1999) so that only replacement wells or special situations would be allowed to draw water from the LAS; new wells would have to be drilled in the UAS.

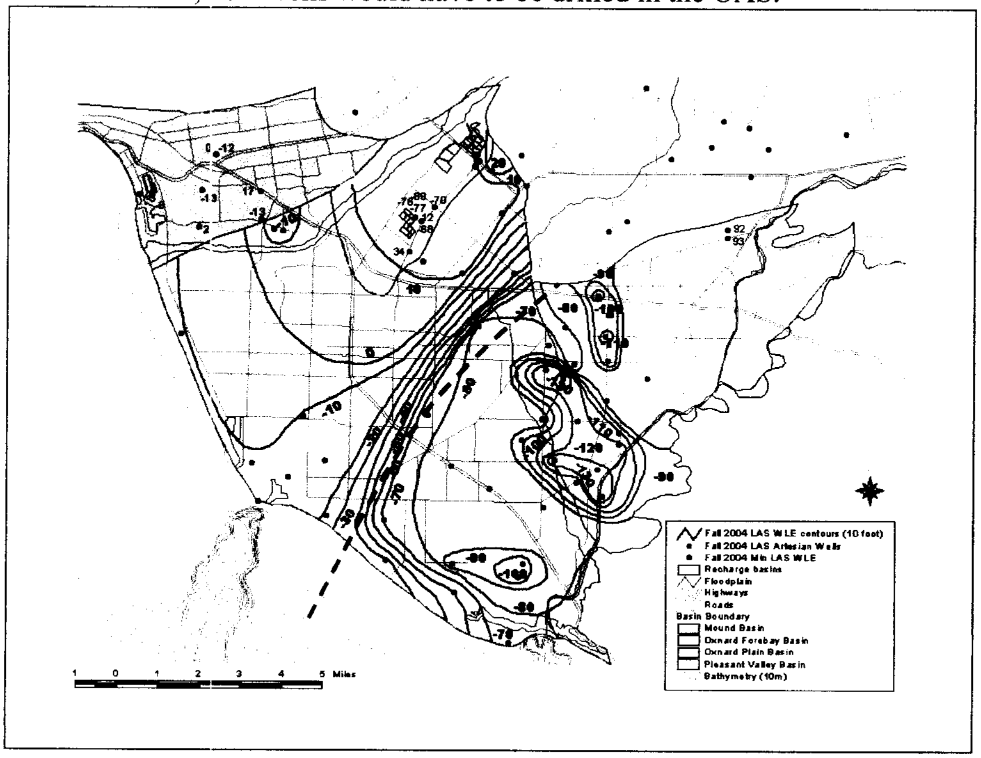

Figure 12. Groundwater elevation contours in the Lower Aquifer System, fall 2004. Note the distinct series of troughs that extend from the ocean in the south Oxnard Plain northeastward toward Camarillo. These troughs are entirely below sea level. The dashed line indicates the

approximate trend of the steep groundwater flow gradients that separate the recharge area in the Forebay from the south Oxnard Plain and Pleasant Valley pumping trough.

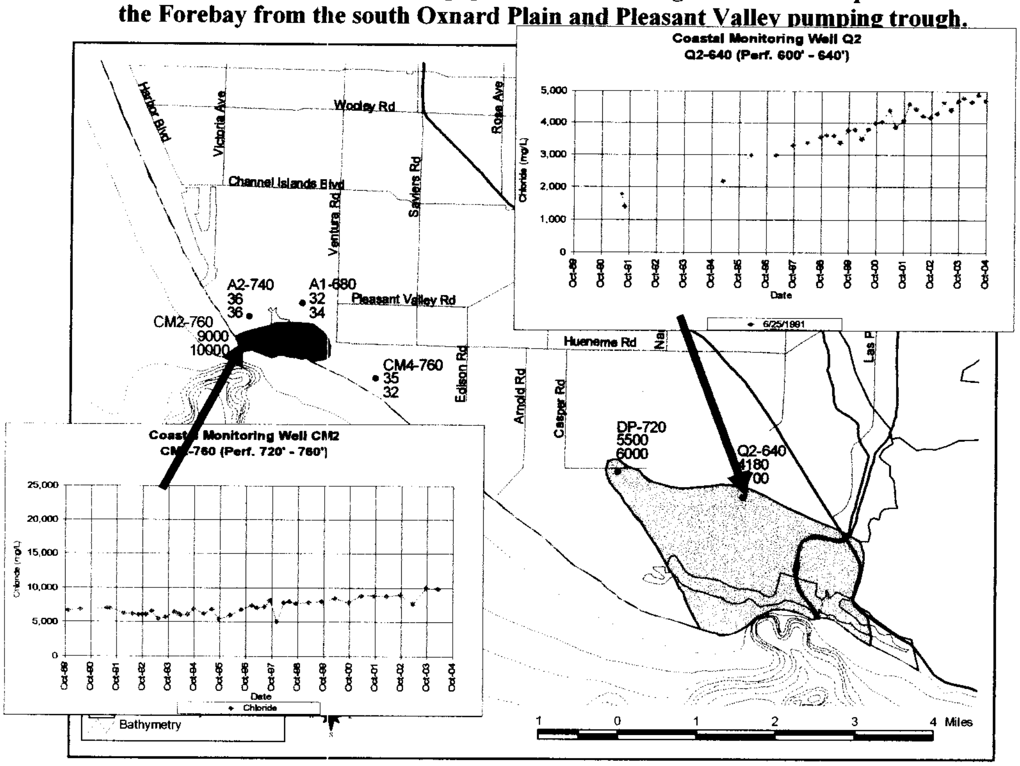

Figure 13. Chloride levels in two Lower Aquifer System coastal monitoring wells. Chloride levels continue to rise in the Point Mugu lobe, requiring new monitoring wells to be drilled inland of current wells to determine the extent of landward movement of high-chloride groundwater.

The decline in Lower Aquifer System water levels from the late 1980s into the 2000s exacerbated a pumping trough extending from the coastline northeastward to the city of Camarillo (Figure 12). This trough is typically well below sea level, with the deepest portion as much as 180 feet below sea level during the drought of the late 1980s and early 1990s. Despite above-average rainfall in many of the preceding ten years, this pumping trough was still as much as 130 feet below sea level in the fall of 2004 (Figure 12).

Although FCGMA policies and new UWCD recharge facilities built over the last 20 years have significantly improved conditions in the Upper Aquifer System, the Lower Aquifer System continues to experience intrusion by saline waters. This saline intrusion comes both from seawater entering the aquifers along the coastline and from saline waters intruded from surrounding sediments. Any solution to this saline intrusion must include raising water levels in the Lower Aquifer System while concurrently keeping water levels in the Upper Aquifer System at their current elevations. One of the biggest groundwater challenges is to provide either additional recharge or an alternative source of water to the south Oxnard Plain and Pleasant Valley to prevent further water quality degradation in the Lower Aquifer System.

PLEASANT VALLEY BASIN

Saline intrusion from surrounding sediments and salinity associated with high groundwater levels are the primary water quality concern in the Pleasant Valley basin. The potential for saline intrusion exists in the depressed groundwater elevations in the Lower Aquifer System of the Pleasant Valley basin (see previous section for discussion of these depressed groundwater levels). The area of depressed groundwater elevations extends from the City of Camarillo to the ocean (Figure 12). Chloride levels within the Pleasant Valley basin are generally less than 150 mg/L, but several wells have shown an increase in chloride. City of Camarillo wells near the Camarillo airport have been affected by the rising chlorides, with one well taken out of service. Increasing chlorides in other wells in the Pleasant Valley basin have recently been shown to have the geochemical signature of "oil-field production water" that underlies the fresh-water bearing aquifers in the basin (Izbicki and others, 2005). This poor-quality water likely was pulled up along fault zones or other conduits towards the lower pressures of the LAS aquifer that were created by overpumping of the basin.

Where Arroyo Las Posas crosses into the Pleasant Valley basin in the northern area of the City of Camarillo, the increased flows in the arroyo have raised groundwater levels in the area to historic highs (Figure 14). Coincident with this, salts also increased, especially sulfate, chloride (Figure 14), iron, and manganese. As in the South Las Posas basin, this higher-salinity water will need to be treated for potable or irrigation use. The City of Camarillo has evaluated the feasibility of treating this poor-quality water, while reducing pumping in the areas of depressed groundwater levels (discussed in section *Development of Brackish Groundwater, Pleasant Valley*).

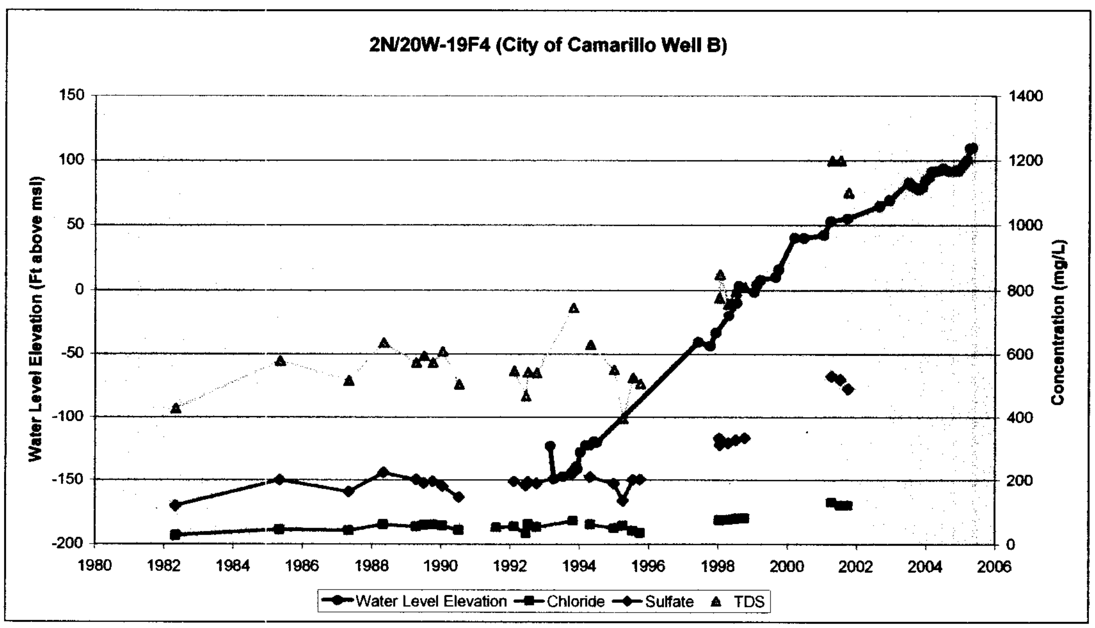

Figure 14. Salts increasing with groundwater elevations, northern Pleasant Valley basin.

Santa Rosa Basin

The Santa Rosa basin has had long periods where nitrates in some areas were well above drinking water standards (as high as 200 mg/L). Chloride concentrations in the basin are generally between 100 and 150 mg/L, although they have spike locally above 200 mg/L. High chloride concentrations can affect crop production.

West Las Posas Basin

The water quality of the West Las Posas basin currently meets standards for irrigation and drinking water use. Within the pumping depression in the far eastern portion of the basin, samples from two wells have had increased chloride concentrations since 2004. It is not clear if this is the beginning of a trend or if these chlorides were transported into the basin from the shallow aquifer that is generally located along Arroyo Las Posas in the East Las Posas basin (the wells themselves are not along the arroyo).

East Las Posas Basin

High chloride levels in the portion of the basin along the Arroyo Las Posas continue to be a problem in the East Las Posas basin. Chloride concentrations in the shallow aquifer beneath the arroyo can reach 360 mg/L, whereas chloride concentrations in the surface waters in the arroyo are in the range of 120-180 mg/L (Bachman, 2002). These high chloride concentrations in the shallow aquifer are associated with historically-high groundwater levels (see discussion in section *High Salinity Associated with High Groundwater Levels*) that apparently leach salts from previously-unsaturated sediments in the shallow aquifer along the arroyo. The groundwater that contains these chloride-rich salts recharges the Lower Aquifer System by moving downward from the shallow aquifer into the LAS, then northward into the basin. This recharge has formed a chloride-rich recharge mound beneath the Arroyo Las Posas (Figure 15) and northward into the main portion of the East Las Posas basin (Bachman, 2002). Individual wells along the south flank of the basin show a progression of filling of the shallow aquifer, with a coincident increase in chloride concentration (Figure 16). The following section on the South Las Posas basin discusses the age progression of this filling.

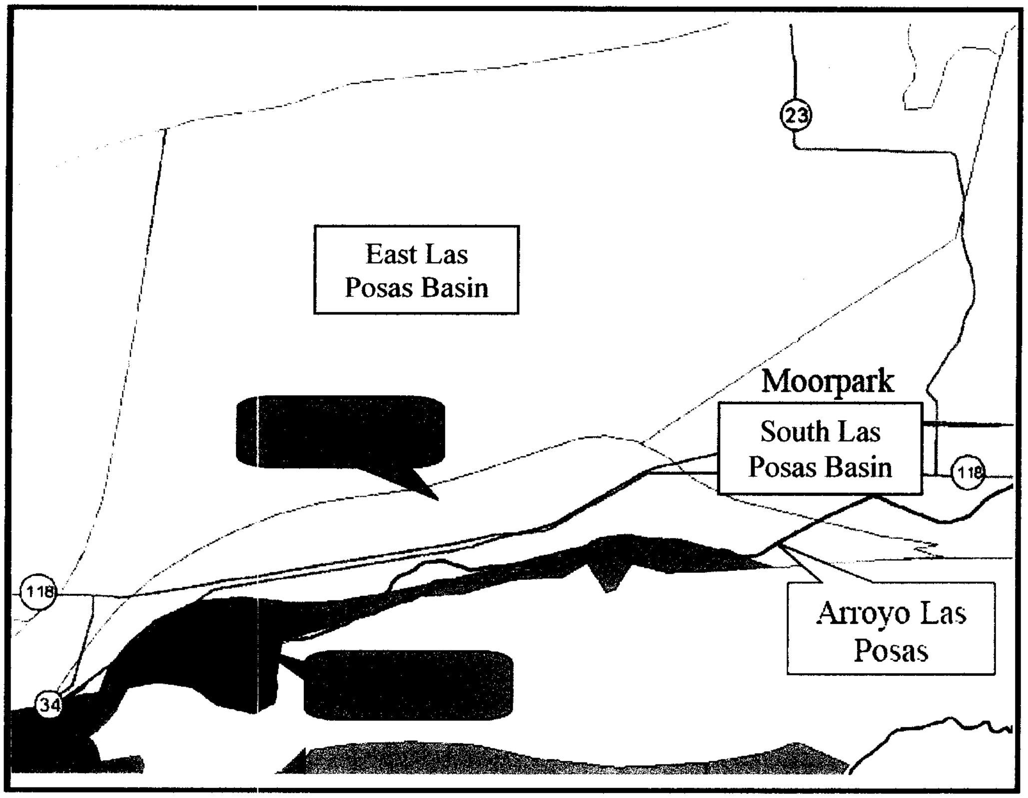

Figure 15. Chloride concentrations have increased in aquifers beneath the Arroyo Las Posas in the East and South Las Posas basins (Bachman, 2002).

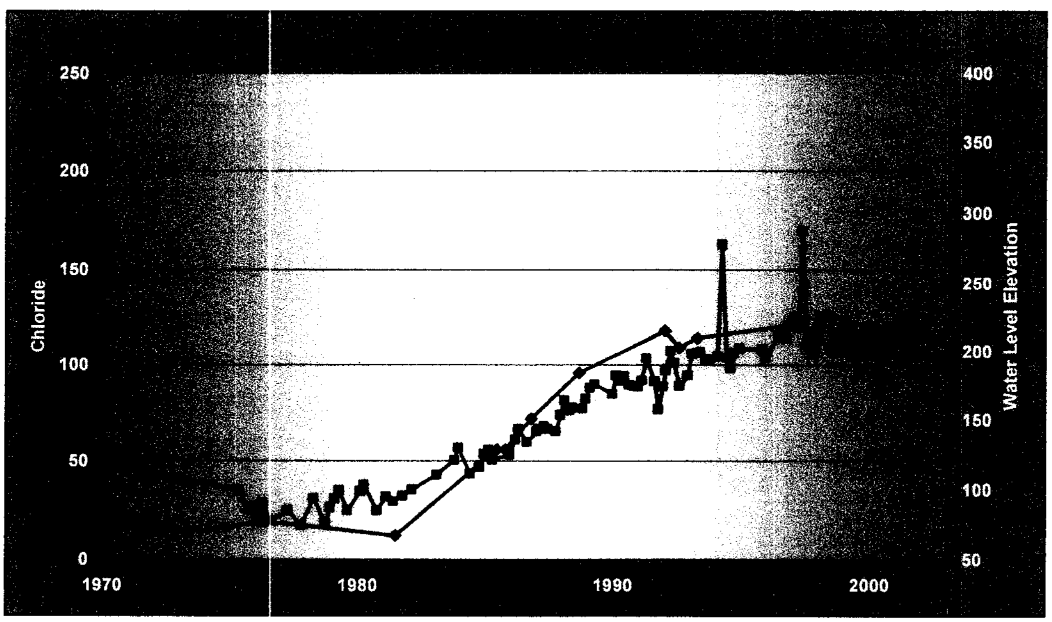

Figure 16. Coincidence of groundwater level rise (blue line with squares) and chloride concentrations (red line with diamonds) in a well in the shallow aquifer along Arroyo Las Posas (Bachman, 2002).

SOUTH LAS POSAS BASIN

Water quality in the South Las Posas basin is dominated by the movement of salts discussed in the previous section. The progressive filling of the shallow aquifer of the South Las Posas basin progressed from the upstream to the downstream portions of the basin (Figure 17). With continuing dissolution of salts in the previously-unsaturated sediments, water quality could improve as the salts are expended. Two wells completed in the shallow aquifer beneath the arroyo that have had elevated salts for 20 years have shown a lessening of salinity in the past two years. It is not yet clear if these wells may

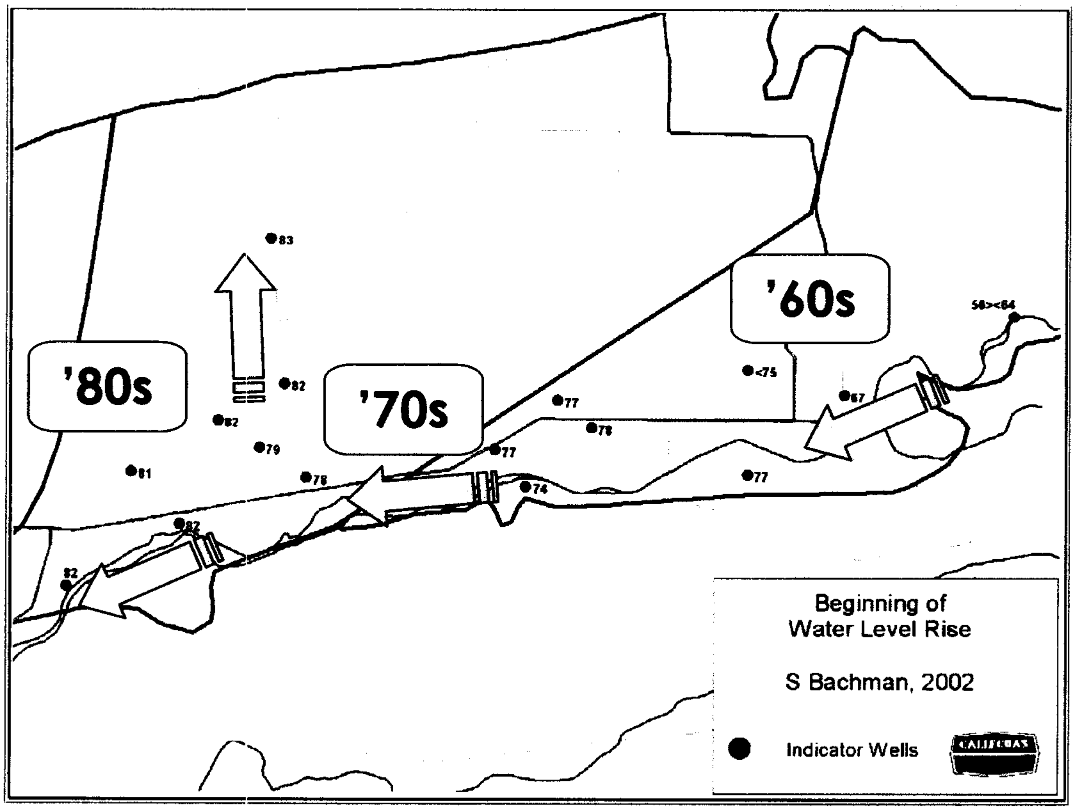

Figure 17. Beginning time of the progressive filling of the shallow aquifer along the Arroyo Las Posas in the South and East Las Posas basins. The number next to each well is the year when groundwater levels started to rise during the filling episode.

be a precursor of further salt reduction as salts in the sediments are dissolved and the shallow aquifer begins to reflect the chemistry of surface water in the arroyo (which is higher in chlorides than pre-development conditions, but lower than the groundwater with dissolved salt).

POTENTIAL FUTURE WATER QUALITY THREATS

An area of concern, discussed in the previous section, is potential water quality problems in the Pleasant Valley basin. With groundwater elevations as low as 160 feet below sea level, there exists the potential to pull significant amounts of lower-quality water from surrounding sediments, across or along faults, and from deeper depths (high salinity and/or petroleum-tainted water). Mitigation of these low water levels is important to avoid future water quality problems.

In the northern portion of the Pleasant Valley basin, within the City of Camarillo, increasing chloride levels could migrate into the main portion of the basin. However, the details of the hydrogeologic connections from the shallow aquifer to the Lower Aquifer System are still somewhat unclear. Likewise, salt-laden groundwater in proximity to California State University Channel Islands could also migrate from the shallow aquifers to deeper aquifers. This connection is also not well known and the mechanics of transport have yet to be adequately determined, although water level and quality monitoring from wells in the vicinity of the university suggests that the water quality in Lower Aquifer System wells is not affected by poor-quality water in the shallow aquifers. This suggests some barrier to vertical flow between the aquifers in this area.

A matter of future water quality concern is the maintenance of current recharge projects that positively affect the Oxnard Plain. Environmental issues in the Santa Clara River and its tributary Piru Creek have the potential for reducing useable water resources – the amount of water available from stored water in Lake Piru and river water at the Freeman Diversion. Since these projects play an integral role in the current FCGMA water management strategies, any loss of yield from these projects would likely reduce some of the gains used in mitigating saline intrusion within the Oxnard Plain.

BASIN MANAGEMENT OBJECTIVES

CURRENT OBJECTIVES

Basin Management Objectives (BMOs) are numeric targets established in a groundwater basin to measure and evaluate the health of the basin. For groundwater basins with seawater intrusion, a critical BMO is maintaining groundwater levels along the coastline to prevent intrusion of seawater. In addition, another BMO would be to maintain low concentrations of chloride at critical coastal monitoring wells. In inland areas, a BMO would be to insure groundwater levels do not create conditions that would cause groundwater quality degradation and that chemical constituents such as nitrate and chloride remain below levels that are human health concerns or will damage crops irrigated with this water. Within the FCGMA, several BMOs are appropriate to measure and evaluate the health of the basins. Wells used as monitoring points for the Basin Management Objectives are shown in Figure 18 and described in the following paragraphs.

Oxnard Plain Basin – The BMO most critical for coastal areas of the FCGMA is the maintenance of groundwater levels high enough to prevent further seawater intrusion. Because the source of seawater is likely from offshore submarine canyons where the aquifers are truncated and in contact with seawater, coastal aquifers must have groundwater elevations high enough to prevent movement of seawater from the canyons to nearby onshore areas (see discussion in sections *Seawater Intrusion* and *Oxnard Plain Basin*). However, seawater is denser than fresh water and the heavier seawater exerts pressure on the fresh water aquifers exposed on the canyon walls – much like water pressure pushes on a diver's mask when the diver descends.

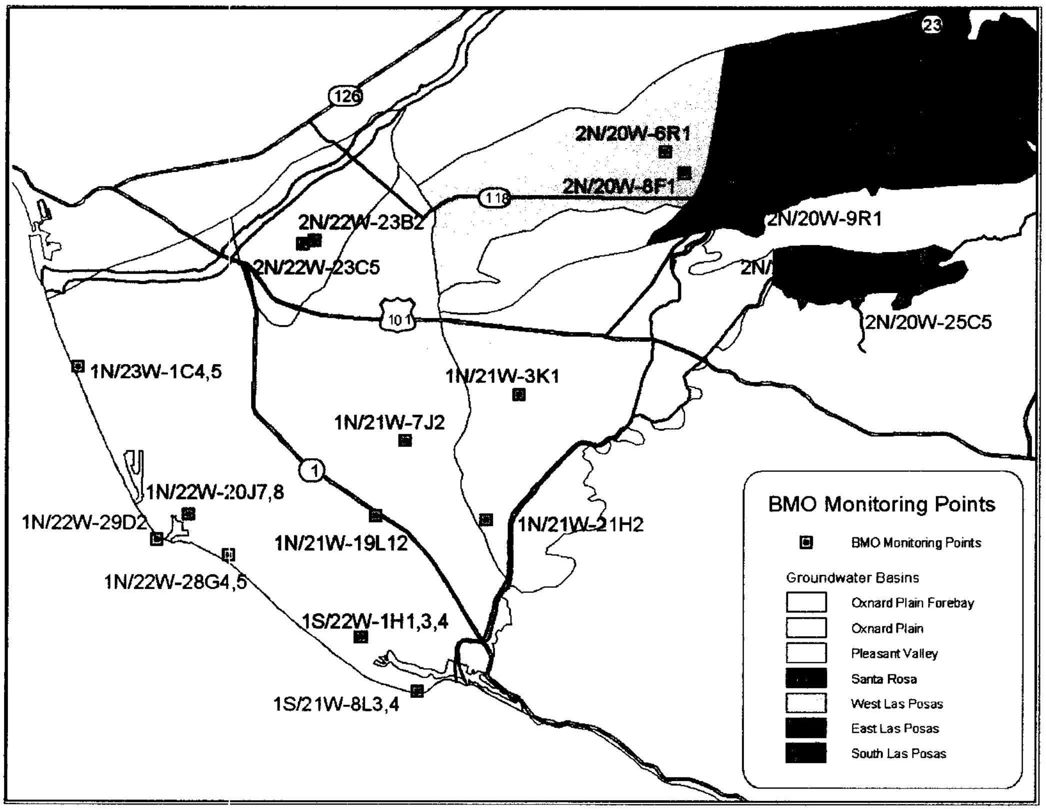

Figure 18. Wells used as monitoring points for Basin Management Objectives.

The pressure differential exerted on the fresh water aquifer depends upon the ocean depth where the aquifer is truncated along the canyon wall – there is the equivalent of 2.5 ft of head (pressure) exerted for every 100 ft of ocean depth. Therefore, an aquifer that is exposed on a submarine canyon wall at 200 ft ocean depth has 5 ft of head exerted on the aquifer by the more-dense seawater. To prevent seawater from intruding from the canyon wall and flowing through the aquifer to the coastline, coastal groundwater elevations must be, on average, at least as high as the head exerted by seawater. Thus, for the example given above, groundwater elevations in monitoring wells at the coastline must average at least 5 ft above sea level to prevent seawater intrusion. The greater ocean depth where the aquifer is exposed to seawater, the higher the average groundwater elevation required to prevent seawater intrusion.

A set of wells was selected to establish the BMOs for the Oxnard Plain basin (Figure 18). Many of these are coastal monitoring wells, completed at different aquifer depths within the Upper (Table 1) and Lower Aquifer Systems (Table 2). There are also several inland wells to detect if a new pumping depression forms in the UAS and if the existing pumping depression in the LAS dissipates. Coastal groundwater elevation objectives were determined using the criteria in the preceding paragraph; inland groundwater elevation objectives were determined such that there is a slight groundwater gradient from the inland areas to the coastline, preventing the existing saline intrusion from migrating landward. The tables list the management objectives for each of the well completions. If these groundwater levels were maintained, further saline intrusion would be prevented. In addition, chloride objectives for these wells are also listed in the tables; they follow the Regional Water Quality Control Board's Basin Plan Objective of 150 mg/L for chloride.

Well	*Groundwater Level*	*Current**	*Chloride (mg/L)*	*Current*
1N/23W-1C5 (CM3-145)	Average 3' msl	9.2	<150	41
1N/22W-20J8 (A1-195)	Average 4' msl	14.6	<150	177
1N/22W-20J7 (A1-320)	Average 8' msl	15.5	<150	81
1N/22W-28G5 (CM4-200)	Average 5' msl	9.0	<150	237
1N/22W-28G4 (CM4-275)	Average 7' msl	8.4	<150	6536
1N/21W-19L12 (SCE-220)	Average 5' msl	11.3	<150	67
1S/22W-1H4 (CM6-200)	Average 5' msl	1.8	<150	4089
1S/22W-1H3 (CM6-330)	Average 8' msl	-12.5	<150	1630
1S/21W-8L4 (CM1A-220)	Average 5' msl	-4.9	<150	16,917

Table 1. Basin Management Objectives for Upper Aquifer System wells in the Oxnard Plain basin.

Well	*Groundwater Level*	*Current**	*Chloride (mg/L)*	*Current*
1N/23W-1C4 (CM3-695)	Average 17'msl	15.4	<150	36
1N/22W-29D2 (CM2-760)	Average 19' msl	0.2	<150	9783
1S/22W-1H1 (CM6-550)	Average 13' msl	-33.3	<150	3512
1S/21W-8L3 (CM1A-565)	Average 14' msl	-42.3	<150	4161
1N/21W-7J2 (PTP #1)	Average 20' msl	-52.0	<150	42

Table 2. Basin Management Objectives for Lower Aquifer System wells in the Oxnard Plain basin.

Pleasant Valley Basin – In the Pleasant Valley basin, groundwater elevation objectives were calculated to be slightly higher than coastal objectives to prevent landward migration of existing saline intrusion, and to minimize vertical groundwater gradients that

* Groundwater levels are average for last 10 years; chemical concentrations are average for last 3 years.

pull salts from encasing marine clays, from surrounding older marine and volcanic rocks, or from deeper waters within the oil fields of the basin. An additional BMO is to maintain chloride concentrations at the Regional Water Quality Control Board's Basin Plan Objective of 150 mg/L. These objectives are indicated in Table 3.

Well	*Groundwater Level*	*Current*[†]	*Chloride (mg/L)*	*Current*
1N/21W-3K1 (PV #4)	Average 20' msl	-47.2	<150	107
1N/21W-21H2 (PV #10)	Average 20' msl	-51.9	<150	93

Table 3. Basin Management Objectives in the Pleasant Valley basin.

Oxnard Plain Forebay Basin – In the Oxnard Plain Forebay basin, high nitrates have historically been a recurring problem. BMOs in the Forebay basin focus on protection of public drinking water wells (nitrate and TDS) and irrigation suitability (TDS). The management objectives are chosen for wells in the Oxnard-Hueneme wellfield (operated by UWCD) because this is the largest potable water system in the Forebay. The management objectives will maintain nitrate concentrations at one-half or less of the Maximum Contaminant Level for drinking water (45 mg/L of NO_3 which is a primary drinking-water standard); above the BMO of 22.5 mg/L, water purveyors must increase monitoring and reporting to the California Department of Health Services. The TDS objective is set at the Regional Board's Basin Plan Objective of 1,200 mg/L. These BMOs are set at two representative pumping wells (Figure 18) in the O-H Wellfield (Table 4).

Well	*Nitrate (as NO_3)(mg/L)*	*Current*[†]	*TDS (mg/L)*	*Current*
2N/22W-23B2	<22.5	13	<1200	1044
2N/22W-23C5	<22.5	8	<1200	1010

Table 4. Basin Management Objectives for the Oxnard Plain Forebay basin.

Las Posas Basins – In the South and East Las Posas basins, BMOs cannot be linked directly to observed groundwater levels, because the Calleguas MWD aquifer storage project (in-lieu deliveries and direct injection into the aquifer) creates artificially-high groundwater levels that are not indicative of the state of the basin. Instead, the proposed East Las Posas Basin Management Plan (Appendix C) contains a method to use groundwater levels along with a computerized groundwater model to monitor the health of the basins.

The recharge mound that is moving northward from the Arroyo Las Posas (Bachman, 2003) has mobilized salts from the shallow aquifer (primarily located along the Arroyo) vertically downward into the Lower Aquifer System and then north into the main portion of the basin. This subsurface movement of groundwater occurs because the head (pressure) in the LAS are lower than in the UAS. Therefore, an appropriate BMO for the East and West Las Posas basins is to maintain a chloride concentration that is suitable for agricultural irrigation use (this concentration is well below the standard for drinking water).

[†] Groundwater levels are average for last 10 years; chemical concentrations are average for last 3 years.

Monitoring points for these BMO chloride concentrations (Figure 18) were selected both in the degraded southern portion of the basin, as well as in areas unaffected by the migrating salts. The East and West Las Posas basins' objective for the chlorides is set at 100 mg/L to protect salt-sensitive crops such as avocados and berries (Table 5). It should be noted that salt levels, and especially chloride, are already high within the South Las Posas basin. This chloride is caused by historically high water levels apparently dissolving salts from sediments that were historically unsaturated (see section on *High Salinity Associated with High Groundwater Levels*). Specific management strategies to address the South Las Posas basin are discussed later in this Plan. The BMOs for chloride and TDS in the South Las Posas basin are set at the average concentration of the surface water in Arroyo Las Posas, which is the concentration that would likely be attained when salts dissolved from sediments are either removed or have migrated elsewhere, and the groundwater then reflects the chemistry of its primary recharge source.

Well	*Chloride (mg/L)*	*Current*[‡]	*TDS (mg/L)*	*Current*
2N/20W-9F1 (ELP)	<100	164	<500	1196
2N/20W-9R1 (ELP)	<100	187	<500	1330
2N/20W-1E1 (ELP)	<100	28	<500	638
2N/20W-6R1 (WLP)	<100	12	<600	520
2N/20W-8F1 (WLP)	<100	34	<600	410
2N/19W-6N3 (SLP)	<160	150	<1500	1500

Table 5. Basin Management Objectives for the Las Posas basins.

There are also specific water quality criteria for water injected into the East Las Posas basin as part of the Las Posas Basin ASR project. These criteria are included in a letter from the FCGMA to Calleguas MWD dated July 12, 1994 that approved the project as an injection/extraction facility. These criteria include: sodium absorption ratio 1-4 meq/L, TDS 100-800 mg/L, electrical conductivity not to exceed 1100 uMHO, chloride not to exceed 120 mg/L, boron not to exceed 1 mg/L, and nitrate (presumably as NO_3) less than 45 mg/L.

Santa Rosa Basin – Basin Management Objectives for the Santa Rosa basin follow the Regional Board's Basin Plan Objectives (Table 6).

Well	*Nitrate (mg/L)*	*Current*[‡]	*Chloride (mg/L)*	*Current*
2N/20W-25C5	<45	116	<150	145
2N/20W-25D1	<45	60	<150	78

Table 6. Basin Management Objectives for the Santa Rosa basin.

[‡] Groundwater levels are average for last 10 years, chemical concentrations are average for last 3 years.

ASSESSMENT OF BASIN MANAGEMENT OBJECTIVES

The parameters for the proposed Basin Management Objectives (BMOs) are currently monitored on a regular frequency throughout the FCGMA, primarily by the VCWPD and UWCD. Along the coastline of the southern portion of the Oxnard Plain basin, BMOs are being met only in a portion of the Upper Aquifer System (see description and discussion of the Oxnard Plain basin in the section *Groundwater Basins and Hydrogeology*). Within the Lower Aquifer System, BMOs are significantly different than observed measurements. Groundwater levels are well below sea level both near the coastline and in a wide trough that extends into the Pleasant Valley basin beneath the City of Camarillo.

The Ventura Regional Groundwater Model was used to determine the effectiveness of current and future management strategies in meeting BMOs for groundwater levels. These results are reported under each management strategy and are summarized in Table 7 within the sections on management strategies. The model results were compared to the groundwater level goals set in the BMOs for each strategy that was amenable to evaluation by the model. For instance, strategies that involve shifting the place or amount of recharge and/or pumping can be effectively simulated using the model. Strategies that deal exclusively with water quality, such as reductions in nitrate sources, are not amendable to evaluation using the groundwater flow model.

When current management strategies are applied in the model, BMOs for groundwater levels are met or exceeded 51% of time during the 55-year model period for the Upper Aquifer System (meaning that about half of the time groundwater levels are at or above the BMO values and half the time they are below) and only 5% of the time for the Lower Aquifer System. Successful management strategies are those where groundwater levels meet or exceed the BMOs at least half the time – meeting BMOs all the time is a more conservative approach, but requires much larger and more expensive strategies and does not take into account the natural climatic variations in groundwater levels that occurred even before the basin was pumped extensively. When coastal groundwater levels are below the BMOs during dry periods, seawater could be pulled into the aquifers, but would then be pushed out during wet periods as groundwater levels rose above the BMOs. This has been the experience in the Upper Aquifer near Port Hueneme, where seawater moved inland and then receded with climatic variations in groundwater levels below and above the BMOs for that area.

BMOs for groundwater levels are not being met in the Pleasant Valley basin because of this wide trough of depressed groundwater levels. BMOs for chloride concentrations are not currently being met in all portions of the basin, with chlorides rising in several wells. A study conducted by UWCD (see following section) indicate some of these chlorides might be pulled from depth with "oil-field production water"[§] that underlies the fresh-water bearing aquifers in the basin (Izbicki et al, 2005). Chloride concentrations are being carefully monitored in the Pleasant Valley basin.

[§] Izbicki compared the isotopic composition of the sampled groundwater with that of water produced with the oil that was pumped from nearby shallow oil wells.

In the Oxnard Plain Forebay basin, BMOs are being met most of the time. However, nitrate concentrations in individual wells in the Oxnard-Hueneme wellfield have periodically been at or above the drinking water standard during drought. Currently, these high nitrates have been evident only during the driest portions of the year when pumping water levels were at their maximum depth. Both fertilizers from overlying agriculture operations and numerous individual septic tanks are likely contributors to the recurring high nitrate levels in the Forebay, as discussed in the following section. Nitrate problems continue to plague the Santa Rosa basin as well. The high nitrate concentrations in the Santa Rosa basin are also believed to be caused by excessive fertilizer use and numerous individual septic systems.

Two emerging processes could significantly improve source control of nitrate within the FCGMA. Ventura County is in the process of eliminating hundreds of concentrated leach-line septic systems located in the El Rio area of the southern portion of the Oxnard Plain Forebay basin and the northern Oxnard Plain basin; the homes will be connected instead to the adjacent City of Oxnard wastewater system. In addition, the Conditional Discharge Waiver for Irrigated Lands is being put into effect in 2005-2006 by the Los Angeles Regional Water Quality Control Board. This process, with sub-watershed sampling of runoff from agricultural lands, will likely decrease the loading of nitrates from fertilizer through Best Management Practices and education. In 2010, the required monitoring will likely extend to agricultural waters that are percolating to groundwater, in addition to the current emphasis on surface waters.

In the East Las Posas basin, chloride concentrations are above the basin management objective in the two wells closest to the Arroyo Las Posas (wells 9F1 and 9R1, Figure 18). Chloride concentrations as high as 273 mg/L have been detected in these wells. Farther into the main portion of the basin, well 1E1 has chloride concentrations of less than 30 mg/L, well below the BMO. In the West Las Posas basin, chloride concentrations remain below the BMO largely because the fault that separates the West and East Las Posas basins appears to be an effective barrier to groundwater flow and the poor-quality water in the East Las Posas basin does not flow into the western basin. Of concern, however, is the recent transient occurrence of higher chlorides in two wells just to the west of the fault. It is not yet known if this is the beginning of wider-spread degradation or if this is caused by periodic overtopping of the fault by poor quality waters in the shallow aquifer along the Arroyo Las Posas.

YIELD OF THE GROUNDWATER BASINS

ORIGINAL FCGMA CALCULATION

The approximate yield of all basins within the FCGMA was calculated for the original management plan as approximately 120,000 AFY. This yield was based on a water budget for the year 1980, with estimates of the water balance for every fifth year to 2010. In the year 2010, there were estimated to be extraction rates 25% higher than recharge rates. This calculation is the origin of the 25% pumping reduction required by the FCGMA. The potential inaccuracies in the assumptions that went into the original balance calculation were not discussed in the previous Management Plan, but they are likely to be relatively high (e.g., Bachman et al, 2005). Note that this yield is not basin-specific, which is discussed in more detail below.

DEFINITION OF BASIN YIELD

The yield of a basin is the average quantity of water that can be extracted from an aquifer or groundwater basin over a period of time without causing undesirable results. Undesirable results include permanently lowered groundwater levels, subsidence, or degradation of water quality in the aquifer. A basin is in overdraft if the amount of water pumped from the basin exceeds the yield of the basin over a period of time. This does not mean that the same amount of water must be pumped each year – pumping in individual years may vary above or below the yield of the basin during drought or wet years, or as part of basin management plans. If water management in the basin changes, the yield of the basin may change.

The term "safe yield" is often used in judicial proceedings for basin yield; it is determined by technical professionals and subsequently interpreted by courts to define the legal rights to extract groundwater in a basin (further discussion in Bachman et al, 2005). Outside of judicial proceedings, terms such as "perennial yield" are commonly used for basin yield. For the purpose of this Management Plan, the term "yield" is synonymous with "perennial yield" which follows the definition in the previous paragraph.

METHOD OF CALCULATING BASIN YIELD

To evaluate whether falling groundwater levels are likely to cause an undesirable result (i.e., whether the basin is presently in overdraft), a basin's water levels are evaluated over at least one complete hydrologic cycle to establish a trend. Since hydrologic conditions vary throughout each year and over long periods of time spanning multiple years, conditions must be analyzed over a long period (generally several decades) to accurately determine if the yield has been exceeded such that overdraft is present. If the trend suggests a continual drop in water levels over time, even after wet year conditions, then undesirable results are likely to eventually occur and the basin is considered to be in a state of overdraft.

Methods to determine basin yield include (e.g., Bachman et al, 2005):

- Hydrologic balance,
- Change in groundwater levels over an average hydrologic base period,
- Zero net groundwater level fluctuation,
- The correlation between groundwater levels and extractions,
- Change of storage vs. extractions,
- Calculation of groundwater inflow,

- Groundwater modeling,
- Annual retained inflow and change in groundwater levels,
- Pumping trough in a coastal aquifer.

The yield calculation for the 1985 FCGMA Management Plan used the hydrologic balance method – summing up all the water inputs and outputs to determine how much could be extracted from the basins. The calculation was not done over a period of wet and dry years, which is the current standard. The basin yield for this Management Plan was calculated using the groundwater modeling method. This method integrates aspects of some of the other methods:

- A hydrologic balance is calculated in the model,
- One of the model outputs is a change in groundwater levels over an average hydrologic base period,
- A pumping trough in a coastal aquifer is one of the criteria to determine if the basin yield has been exceeded.

The groundwater model technique is superior to the 1985 hydrologic balance calculation because the calculation of a water budget depends upon inputs and outputs to the groundwater basins which can be difficult to estimate independently. The groundwater model also has similar inputs and outputs, but the groundwater model is calibrated to match actual measured groundwater levels over a long period of wet and dry years. This calibration of the groundwater model lessens some of the potential errors in a water budget calculation.

The groundwater model used was constructed by the U.S. Geological Survey as part of their RASA study (Hanson et al, 2003), which has since been updated and upgraded by UWCD. The groundwater model is described in more detail in Appendix B. The model was also used to test the efficacy of various management strategies. The base period used for the model runs was 1944 to 1998, which encompasses several wet and dry cycles; this period was also used as a base period in the Santa Paula basin and Santa Maria basin adjudications during the last decade. The base period is only used in the model to simulate the natural hydrology over the 55-year period – modern and future man-made inputs and outputs such as water facilities, pumping, and artificial recharge are added to the model to determine both the current state of the basin and the future state of the basin with new management strategies applied.

There is little doubt that the coastal basins within the FCGMA have exceeded their yield and been in overdraft for several decades. The over-arching undesirable result of lowered groundwater levels has been seawater and other saline intrusion. A key aspect of the modeling was to determine the basin yield such that these undesirable results caused by lowered groundwater levels were eliminated.

Basins within the FCGMA that do not abut the coastline and do not themselves have saline intrusion cannot be evaluated directly for this undesirable result. The 1985 FCGMA Management Plan handled this by treating all the basins of the FCGMA as a common pool – an action in one of the basins would also affect the other basins – so