EXECUTIVE SUMMARY

The objective of this study was to gain additional knowledge of the water resources within the Arroyo Grande - Nipomo Mesa area in San Luis Obispo County (Plate ES1). The Department of Water Resources conducted the study under an agreement with the San Luis Obispo County Flood Control and Water Conservation District to update the Department's 1979 report "Ground Water in the Arroyo Grande Area."[1]

San Luis Obispo County delineated the study area for the new investigation, setting the southern study area boundary at the Santa Barbara/San Luis Obispo County line. The study area encompasses 184 square miles (117,940 acres) within San Luis Obispo County and includes part of the watershed of Pismo Creek, the watersheds of Arroyo Grande and Nipomo Creeks, and that portion of the watershed of Santa Maria River within the county. It lies within the following hydrologic (watershed) areas and subareas:[2] Pismo Hydrologic Subarea (HSA) containing Pismo Creek watershed, Oceano HSA drained by Arroyo Grande Creek and its tributaries, Nipomo Mesa HSA containing Black Lake Canyon and Black Lake, and Guadalupe Hydrologic Area (HA) drained by Nipomo Creek and the Santa Maria River.

Underlying part of the study area is a portion of the Santa Maria Groundwater Basin, which extends into Santa Barbara County.[3] The basin consists of the main basin, Santa Maria, lying between the Pacific Ocean and Wilmar Avenue fault, and three subbasins-- Arroyo Grande Valley, Pismo Creek Valley, and Nipomo Valley, which extend north and east of the Wilmar Avenue fault (Plate ES1).

The data assembled from various sources for this study are for the period of record through water year 2000 (October 1, 1999-September 30, 2000), except for water demand and supply data. The determination of water demand and supply and groundwater inflow and outflow was for the

[1]The agreement for the three-year study with San Luis Obispo County was executed in September 1993. The agreement stipulated that as soon as practical, after execution of the agreement, the Department commence work on the investigation. The Department began work in January 1996 and provided San Luis Obispo County with a draft report in April 1998, a second draft report in January 1999, and a final draft report in January 2000. Only the January 2000 report received widespread review and comment.

[2]Hydrologic Area and Hydrologic Subarea are the hierarchical nomenclature of watershed divisions in California. HSA is a subdivision of a HA. The hydrologic boundary for Nipomo Mesa HSA was field checked for this study.

[3]The results of this study are valid for the portion of the Santa Maria Groundwater Basin within San Luis Obispo County. No existing published investigations of the Santa Maria Basin analyzed the basin in its entirety within both San Luis Obispo and Santa Barbara Counties.

study period. The study period begins with water year 1975, the last year of data for the Department's 1979 investigation, and ends with water year 1995, the last year of the hydrologic base period. The hydrologic base period, which represents long-term average hydrologic conditions, was determined to be water years 1984 through 1995.

Because of the study area's size and differences in hydrologic and topographic characteristics and to provide applicable information for San Luis Obispo County, the Santa Maria Groundwater Basin and the portions of the study area outside the basin were divided and evaluated based on the hydrologic boundaries (Plate ES1). The divisions of the main Santa Maria Basin are: (1) the Tri-Cities Mesa - Arroyo Grande Plain portion that includes the lower Pismo Creek portion of the basin lying within Pismo HSA and the Tri-Cities Mesa, Arroyo Grande Plain, and Los Berros Creek portions of the basin lying within Oceano HSA; (2) the Nipomo Mesa portion of the basin, lying entirely within Nipomo Mesa HSA; and (3) the Santa Maria Valley portion of the basin, lying within Guadalupe HA.[4] The subbasins were evaluated within their respective hydrologic area or subarea: Arroyo Grande Valley Subbasin, lying within Oceano HSA; Pismo Creek Valley Subbasin, within Pismo HSA; and Nipomo Valley Subbasin, within Guadalupe HA. Those remaining portions of the study area outside the groundwater basin were also evaluated within their respective hydrologic area or subarea.

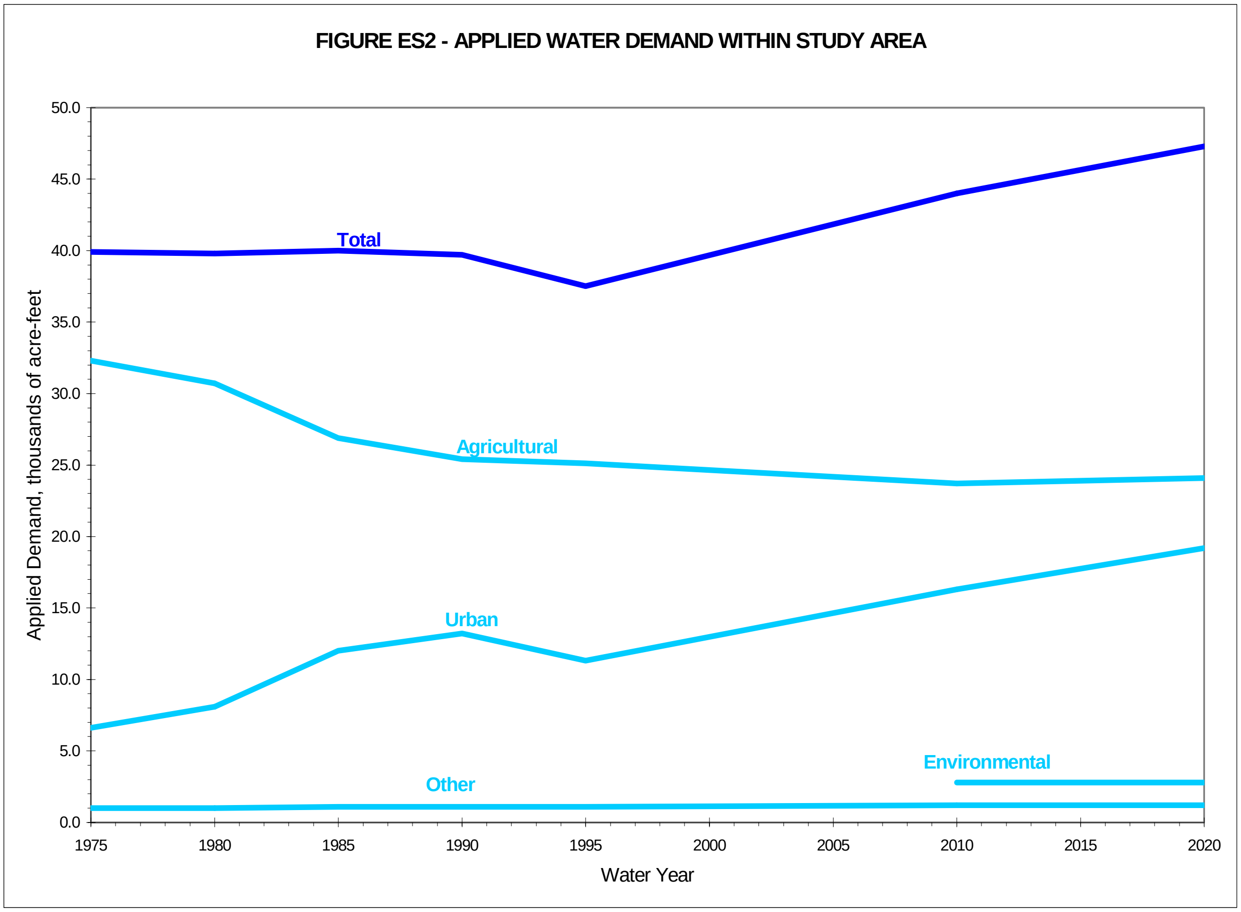
The knowledge of the water resources within the study area gained in this investigation is summarized below.

Water Demand

Within the study area, total applied water demand decreased by 2,400 acre-feet (AF) from 39,900 AF in 1975 to 37,500 AF in 1995 (Figure ES1). The decrease includes demand reduction achievable through implementing water conservation programs. Agricultural demand constituted the largest demand, accounting for about 70 percent, or 25,100 AF, of the 1995 total demand. Most of the rest of the demand was for urban uses, estimated to be 11,300 AF in 1995 for an estimated population of about 62,000. Conveyance losses, cooling, miscellaneous, and recreational demands used about 1,100 AF in 1995.

Year 2020 total applied water demand is projected to be 47,300 AF, an increase of about 9,800 AF more than 1995 amounts. The increase in total applied demand from 1995 to 2020 is attributable to increased urban and environmental demand. Year 2020 urban applied water demand is expected to increase to 19,200 AF for an estimated population of 98,740. Environmental demand, estimated at 2,800 AF, was identified for maintaining steelhead habitat on Arroyo Grande Creek for 2010 and 2020. Projections are that the demand for agriculture will decline to 24,100 AF by 2020, and will account for only about 50 percent of the total demand.

[4] Geographic names were used for the divisions of the groundwater basin because, with the exception of Nipomo Mesa, the basin underlies only portions of the hydrologic areas.



Conveyance losses, cooling, miscellaneous, and recreational demands were projected to increase to about 1,200 AF in 2020.

Total applied water demand overlying the main Santa Maria Groundwater Basin increased about 12 percent between 1975 and 1995 and by 2020 demand was projected to be 36,200AF, an increase of about 30 percent over the 1995 total demand of 27,500 AF.

Water Supply

Groundwater is the major source of supply in the study area. Other available supplies are Lopez Reservoir water, imported State Water Project water, and recycled water.

Total water supply in the study area decreased by 2,500 AF, from 40,100 AF in 1975 to 37,600 AF in 1995, because of decreased groundwater extractions. Year 2020 water supply is expected to increase 9,700 AF over 1995 levels with the additional water supply coming from increased groundwater extractions, State Water Project deliveries, environmental releases from Lopez Reservoir, and recycled water. Supplies appear adequate to meet water demands through water year 2020.

Total groundwater supply (extractions) in the study area decreased by 4,600 AF, from 34,800 AF in 1975 to 30,200 AF in 1995, but year 2020 groundwater extractions are expected to increase 4,700 AF over 1995 levels.

Santa Maria Groundwater Basin

The Santa Maria Groundwater Basin underlies more than 280 square miles (181,790 acres) in the southwestern corner of San Luis Obispo County and the northwestern corner of Santa Barbara County. This study considered only the portion of the groundwater basin within San Luis Obispo County, about 61,220 acres (Plates ES1). Within the study area, the main Santa Maria Basin underlies about 49,910 acres; Arroyo Grande Valley Subbasin, 3,860 acres; Pismo Creek Valley Subbasin, 1,220 acres; and Nipomo Valley Subbasin, 6,230 acres. Both the surface area and the underlying permeable sediments form the basin.

The boundaries of the Santa Maria Basin were delineated based on mapped surface limits of Quaternary deposits and the Wilmar Avenue fault. The boundaries represent the surface expression of the basin and do not imply that the boundaries extend vertically downward in a third dimension. Arbitrary boundaries for the basin are eliminated by using mapped surface geologic contacts and faults.[5]

Within San Luis Obispo County, the main Santa Maria Basin is bounded on the north and east by the Wilmar Avenue fault, separating it from Arroyo Grande Valley, Pismo Creek Valley, and Nipomo Valley Subbasins. The western boundary of the basin is the Pacific Ocean, although the basin is hydraulically continuous offshore beneath the ocean. On the south, the county line with Santa Barbara County forms a political boundary within the basin, but it has no hydraulically physical significance to the groundwater system.

The Arroyo Grande Valley Subbasin is bounded by the alluvial contact with older geologic units between Lopez Dam and the Wilmar Avenue fault. The Pismo Creek Valley Subbasin is bounded by the alluvial contact with older geologic units between the southern boundary of Edna Basin, where bedrock narrows the creek channel, and the Wilmar Avenue fault. The Nipomo Valley Subbasin is bounded on the north and east mainly by the contact of the older alluvium and Orcutt Formation with older geologic units and is separated from the main basin on the west by the Wilmar Avenue fault. The southern boundary of the subbasin, which is the watershed boundary for Nipomo Creek, is the study area boundary.

The potentially water-bearing sediments of the groundwater basin are underlain by bedrock. The bedrock base of the groundwater basin is vertically displaced across the Oceano, Santa Maria River, and Wilmar Avenue faults.

[5]Boundaries for the Santa Maria Basin in existing published studies are not based on mapped geologic contacts and faults and are arbitrary.

Groundwater occurs within the pore spaces in the semi-consolidated to unconsolidated sediments filling the basin to a maximum thickness of about 1,600 feet under the Santa Maria River. In the main groundwater basin, these deposits include the Squire Member of the Pismo Formation; the Careaga, Paso Robles, and Orcutt Formations; alluvium; and dune sands.[6] These sediments consist of discontinuous sedimentary layers or lenses of varying composition, texture, and thickness, ranging from clays to boulders.

The main groundwater basin is considered a composite aquifer system of unconfined conditions, with localized semi-confined to confined conditions and perched zones. Discontinuous clayey layers separate the multiple aquifer zones. The most productive and developed aquifers are in the alluvium and Paso Robles Formation. Aquifers in the Squire Member of the Pismo Formation and the Careaga Formation have, over time, become more important.

In Arroyo Grande Valley and Pismo Creek Valley Subbasins, groundwater occurs in the alluvium, ranging in thickness from negligible to a maximum of about 175 feet in Arroyo Grande Valley Subbasin. Groundwater is mainly unconfined. In some parts of the subbasins, the alluvium may be saturated only during rainfall.

In Nipomo Valley Subbasin, groundwater occurs in the older alluvium, which covers the floor of the valley up to about 90 feet thick, thinning to negligible thickness toward the eastern edges of the subbasin. Groundwater in the older alluvium is unconfined with local semi-perched conditions. The older alluvium stores a notable amount of groundwater and continues to supply some wells, although the older alluvium may be saturated only during rainfall at the eastern edges of the subbasin. The bedrock formations underlying the older alluvium have, over time, become a more important source of groundwater supply in Nipomo Valley Subbasin.

Both natural and incidental sources recharge groundwater in the main Santa Maria Basin. Stream infiltration, deep percolation of direct precipitation, and subsurface inflow are sources of natural recharge. Incidental recharge to the basin includes deep percolation of urban and agricultural return water, treated wastewater returns, and septic tank effluent.

Stream infiltration from Arroyo Grande Creek, regulated by Lopez Dam since 1969, and from unregulated Pismo Creek recharges the Tri-Cities Mesa - Arroyo Grande Plain portion of the main groundwater basin. Stream infiltration from Santa Maria River, regulated in part by Twitchell Dam since 1958, recharges the Santa Maria Valley portion of the main basin. The amount of recharge is related to the availability of streamflow.

Recharge to the groundwater basin by deep percolation of direct precipitation is intermittent, occurring during and immediately following periods of sufficient precipitation and varying from year to year depending on amount and frequency of rainfall, air temperature, land use, and other

[6] The Pismo and Careaga Formations are found only within their respective geologic depositional basins--the Pismo Formation within the Pismo Basin and the Careaga Formation within the Santa Maria Basin, separated in the study area by the Santa Maria River fault.

factors. Because no surface waters flow into Nipomo Mesa, deep percolation of direct precipitation is the major source of natural recharge.

Subsurface inflows from Arroyo Grande Valley and Pismo Creek Valley Subbasins and the adjoining San Luis Range recharge the Tri-Cities Mesa - Arroyo Grande Plain portion of the basin. Arroyo Grande Plain is also recharged by subsurface inflow from the Nipomo Mesa portion of the basin. The Nipomo Mesa portion of the basin may be recharged by subsurface inflow from the adjoining Nipomo Valley Subbasin; however, the potential hydraulic continuity across the Wilmar Avenue fault is unknown. In addition, Nipomo Mesa may be recharged by subsurface inflow from the Santa Maria Valley portion of the basin within San Luis Obispo County.[7] The Santa Maria Valley portion of the basin within the study area is recharged by subsurface inflow from the upstream part of the groundwater basin, outside the study area, and may also be recharged by subsurface inflow from the southern end of Nipomo Valley Subbasin; however, the potential hydraulic continuity across the Wilmar Avenue fault is unknown.

Groundwater is discharged from the main basin by extractions from wells, subsurface flow to the ocean, evapotranspiration losses, rising water, springflow, percolation into the underlying bedrock, and diffuse upward leakage at the Dune and Oso Flaco Lakes

In Arroyo Grande Valley, Pismo Creek Valley, and Nipomo Valley Subbasins, groundwater is recharged by stream infiltration from surface flows in their respective creeks and tributaries, deep percolation of direct precipitation, deep percolation of applied water and septic tank effluent, subsurface flows from the San Luis Range into Arroyo Grande Valley and Pismo Creek Valley Subbasins, subsurface flow from Edna Basin into Pismo Creek Valley Subbasin, and subsurface flow from Temattate Ridge into Nipomo Valley Subbasin. Discharge from the subbasins consists of surface and subsurface outflow to the main Santa Maria Groundwater Basin, evapotranspiration losses, and extractions from wells.

Groundwater elevation contours in the springs of 1975, 1985, 1995, and 2000 revealed that groundwater of the principal water body moved seaward to the Pacific Ocean in a generally westerly or west-northwesterly direction.[8] Coastal groundwater elevations were above mean sea level (msl) and subsurface outflow from the basin to the ocean was occurring, apparently precluding any sea water intrusion along the coast. Within the main groundwater basin,

[7]Subsurface flow from Santa Maria Valley into Nipomo Mesa will occur whenever the groundwater elevations beneath Nipomo Mesa are below those of Santa Maria Valley, altering the hydraulic gradient and direction of flow.

[8]Most of the wells are perforated continuously in multiple aquifers. Thus, groundwater elevations do not reflect a single aquifer, but represent the surface of the principal groundwater body. Perched groundwater levels were not considered. Locations of wells monitored for groundwater levels were from field descriptions of the locations as plotted on USGS 7.5-minute quadrangles and reference elevations were approximated using either the 7.5-minute quadrangles or digital aerial surveys at five- or two-foot contour intervals, where the surveys were available. In 2000, San Luis Obispo County located wells in their monitoring program using GPS (Global Positioning System). Unrectifiable problems with the GPS data resulted in erroneous well locations and elevations and thus could not be used in this study.

groundwater flows from northern Nipomo Mesa to Arroyo Grande Plain. Groundwater flows southwesterly in Arroyo Grande Valley and Nipomo Valley Subbasins.[9]

In spring 1995, enlargement of a pumping depression in the south-central part of Nipomo Mesa locally altered the direction of flow, moving groundwater from Santa Maria Valley into the mesa, but not affecting the westward direction of flow near the county line. With the significant recharge from the record rainfall of water year 1998, the magnitude of the depression lessened.

The magnitude of the depression is not well defined because wells with groundwater level data are limited and reference elevations for all wells were not surveyed. The dynamics of the groundwater system (transmitting properties of the aquifers and potential boundary conditions, such as the Santa Maria River fault) in this part of the basin likely affect development of pumping depressions, which have been documented on the mesa since 1965. In addition, pumpage is concentrated in this part of the mesa. Furthermore, the lateral extent of the depression will fluctuate depending on hydrologic conditions, amount of groundwater extractions in the area, and dynamics of the groundwater system, as the basin continuously seeks a new equilibrium. Subsurface flow from Santa Maria Valley into Nipomo Mesa will occur whenever groundwater elevations beneath the mesa are below those of the valley, altering the hydraulic gradient and direction of flow.

It is conjectural whether, in the future, sea water intrusion will threaten because of the pumping depressions in Nipomo Mesa. Sea water will intrude when the freshwater head is insufficient to counterbalance the greater density of sea water, even when the freshwater head is above msl.

Within the Santa Maria Basin, faults displace the water-bearing sediments, namely the Squire Member of the Pismo Formation and the Careaga and Paso Robles Formations. The Santa Maria River fault may affect groundwater flow in parts of the basin. Significant differences are found in groundwater elevations on opposite sides of the fault from near Highway 1 along the edge of Nipomo Mesa to about a mile east of Zenon Way (Plate ES1) and the fault appears to be a barrier or impediment to groundwater flow in the formations below the older dune sands. However, groundwater levels are in the older dune sands on the northerly side of the fault and groundwater may be able to cascade over the fault along this segment. Along other segments of the fault, determining the impact of the fault on groundwater flow with the available data was not possible.

With the available data, it could not be determined if the Oceano fault affects groundwater flow. Because the basin-fill deposits are the same on opposite sides of the fault and have similar hydraulic properties, the fault may have no impact.

The Wilmar Avenue fault does not affect groundwater flow in the alluvium from Arroyo Grande Valley and Pismo Creek Valley Subbasins to the main groundwater basin, but data were not available to determine whether the fault impacts subsurface flow from Nipomo Valley Subbasin

[9] Groundwater levels in wells in the Pismo Creek Valley Subbasin are not monitored by the county; therefore, no data were available to determine groundwater elevations.

into the main groundwater basin.

Groundwater levels in wells fluctuate over time representing the continuous adjustment of groundwater in storage to changes in recharge and discharge. Groundwater level measurements from wells over their period of record through 2000 were analyzed to determine their net changes over time.[10]

In the Tri-Cities Mesa - Arroyo Grande Plain and Santa Maria Valley portions of the main Santa Maria Basin and the Arroyo Grande Valley and Nipomo Valley Subbasins, the long-term fluctuations in water levels in wells reflect hydrologic variations, following alternating periods of decline and recovery, and indicate that recharge is balancing discharge over the long term.

In some parts of the Nipomo Mesa portion of the basin (the part between the Santa Maria River fault and the Oceano fault and the part north of the Santa Maria River fault around El Campo Road-- Plate ES1), the volume of groundwater withdrawn has increased over time and is reflected in the declining trends in groundwater levels in some wells,[11] despite periods of 40 percent above average precipitation. In those parts of the basin, concentrated pumpage, the dynamics of the groundwater system, and sources of recharge influence groundwater level trends. The localized declines in groundwater levels reflect decreases in estimated amounts of groundwater in storage between 1975 and 1995. If declines in groundwater levels continue in the future and expand to additional parts of the basin, the groundwater resources of the basin could be threatened by sea water intrusion. However, in other parts of Nipomo Mesa, the long-term fluctuations in water levels in wells reflect hydrologic variations, following alternating periods of decline and recovery, and indicate that recharge is balancing discharge over the long term.

Specific yield of the Santa Maria Basin, a measure of the ability of aquifers in the basin to supply groundwater, ranges from 3 to 21 percent, with a median value of 12 percent. Values varied the most in the Nipomo Mesa portion of the basin, ranging from 6 to 18 percent, and Arroyo Grande Valley Subbasin, ranging from 9 to 21 percent. The median specific yield value for wells north of the Santa Maria River fault was two percent lower than for the wells southerly of the Oceano fault. Storativity calculated from aquifer test analyses ranged from 0.001 to 0.0001.

Amounts of groundwater in storage in the basin, both above and below msl, were estimated for the water years 1975, 1985, 1995, and 2000 from the volume of saturated sediments in the groundwater basin and the specific yield of those saturated sediments ("specific yield method").[12] Figure ES2 shows the estimated amounts of groundwater in storage above msl. The amount in storage above msl is important, because of the need to protect this coastal basin from sea water intrusion.

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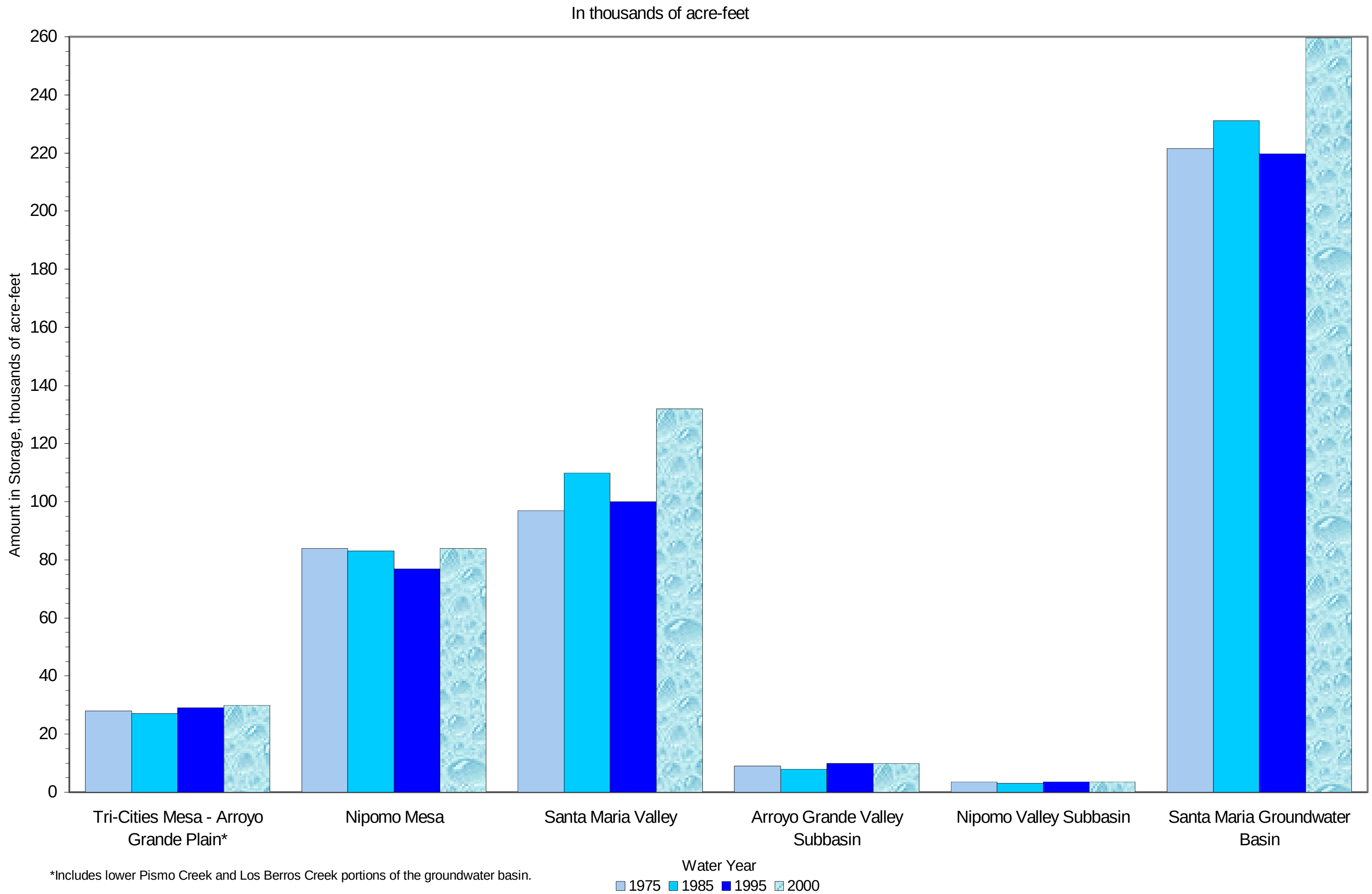
[10] Groundwater level monitoring data were not available for Pismo Creek Valley Subbasin.

[11] Declining water levels in wells can lead to increased pumping costs, localized well interference, loss of production capacity, and possible quality degradation.

[12] Water level data were not available to estimate an amount of groundwater in storage in Pismo Creek Valley Subbasin.

FIGURE ES2 - ESTIMATED AMOUNTS OF GROUNDWATER IN STORAGE ABOVE MEAN SEA LEVEL
SANTA MARIA GROUNDWATER BASIN, SAN LUIS OBISPO COUNTY



*Includes lower Pismo Creek and Los Berros Creek portions of the groundwater basin.

In the Santa Maria Groundwater Basin within San Luis Obispo County, the estimated amount of groundwater in storage in 1995, both above and below msl, was about 3.4 million AF, of which only about seven percent, or approximately 220,000 AF, was above msl. This amount is about 2,000 AF less than the amount in storage in 1975.

For the Tri-Cities Mesa - Arroyo Grande Plain portion of the basin, the estimated amount of groundwater in storage above msl for 1975, 1985, and 1995 was almost the same, 27,000 to 29,000 AF. In this portion of the basin, the amount of groundwater in storage, between 1975 and 1985, declined 1,000 AF and between 1985 and 1995, increased 2,000 AF. The changes in storage coincide with hydrologic conditions, 1985 a dry year and 1995 a wet year.

In the Nipomo Mesa portion of the basin, the amount of groundwater in storage above msl in 1995 was estimated to be 77,000 AF. The 1995 amount above msl is about eight percent less (6,000 AF) than the amount in storage above msl in 1985. Because Nipomo Mesa's major source of recharge is deep percolation of precipitation, the loss in storage reflects variations in hydrologic conditions. The average rainfall during the period from water year 1985 through water year 1995 was about two inches less than the average rainfall during the period from water year 1975 through water year 1985. Also, the loss is primarily associated with those areas of pumping depressions and declining trends found in groundwater levels in some wells in parts of the mesa. As mentioned earlier, the magnitude of the depression in the south-central part of the mesa is not well defined because wells with groundwater level data are limited and reference elevations for all wells were not surveyed. The mesa also showed a small decline in storage above msl of 1,000 AF between 1975 and 1985.

In the Santa Maria Valley portion of the basin, the amount of groundwater in storage above msl in 1995 was estimated to be 100,000 AF. This amount is 3,000 AF more than the amount estimated to be in storage in 1975. In 1985, the valley was estimated to have 110,000 AF of groundwater in storage above msl, 13,000 AF more than in 1975, because of the 1983 wet year and substantial stream infiltration from the Santa Maria River that year and from Twitchell Reservoir releases in 1984. Stream infiltration from the Santa Maria River in the 1995 wet year was not yet fully reflected in groundwater elevations in the valley that year. Based on the trend in groundwater elevations, the amount in storage increased in the succeeding years as the recharge mound traveled away from the river. Part of the change in storage from 1985 to 1995 in Santa Maria Valley reflects movement of groundwater from the valley into Nipomo Mesa.

Arroyo Grande Valley Subbasin was estimated to have 8,000 to 10,000 AF of groundwater in storage in the alluvium and Nipomo Valley Subbasin, 3,100 to 3,700 AF of groundwater in storage in the older alluvium and Orcutt Formation. Both subbasins had losses in storage in the 1985 dry year and small gains in storage in the wet year 1995.

Because of the very wet year 1998, the estimated amount of groundwater in storage above msl in the basin in 2000 was 40,000 AF more than the 1995 amount and about 38,000 AF more than the 1975 amount. Estimated amounts above msl in the basin were: 30,000 AF in the Tri-Cities Mesa - Arroyo Grande portion of the basin, 84,000 AF in the Nipomo Mesa portion of the basin (this is the same amount as in 1975 despite the continued presence of the pumping depression in the south-central part on the mesa), 132,000 AF in the Santa Maria Valley portion of the basin, 10,000 AF in Arroyo Grande Valley Subbasin, and 3,700 AF in Nipomo Valley Subbasin.

In the Santa Maria Groundwater Basin, a dynamic balance exists between recharge and discharge, as the basin continuously seeks a new equilibrium. Changes in the amount of groundwater in storage are the response of the basin to variations in hydrologic conditions and recharge and discharge and to changes in land and water uses within the basin. To protect the basin from sea water intrusion, it is important that the amount of groundwater in storage in the basin be of sufficient quantity for the freshwater head to counterbalance the greater density of sea water and subsurface outflow to the ocean to occur.

Hydraulic conductivity and transmissivity quantify the rate at which groundwater flows. The highest hydraulic conductivity values, ranging from less than 100 up to about 7,000 gallons per day per foot squared, are generally found in the alluvium. Hydraulic conductivity for the Paso Robles Formation ranged from 1 to almost 3,000 gallons per day per foot squared. Lower conductivity values are generally found in the oldest formations--the Careaga Formation and the Squire Member of the Pismo Formation, ranging from 1 to about 300 gallons per day per foot squared. Also, lower values of conductivity tended to be found for the basin deposits north of the Santa Maria River fault underlying Nipomo Mesa.

Aquifer transmissivities of the basin were found to range over several orders of magnitude, from 100 to more than 400,000 gallons per day per foot. Transmissivity values of the alluvial aquifers in Santa Maria Valley were the highest, ranging from 200,000 to 400,000 gallons per day per foot. Transmissivity values of the Paso Robles Formation ranged from 100 to 160,000 gallons per day per foot, with the higher values found south of the Oceano fault, in both the Nipomo Mesa and Santa Maria Valley parts of the basin. Transmissivity of the Squire Member in the Tri-Cities Mesa - Arroyo Grande Plain portion of the basin ranged from about 3,000 to 30,000 gallons per day per foot. The Careaga Formation had transmissivity values similar to those for the Paso Robles Formation. The lowest transmissivity values were typically found in the Nipomo Mesa part of the basin, north of the Santa Maria River fault, where values ranged from 100 to about 4,000 gallons per day per foot.

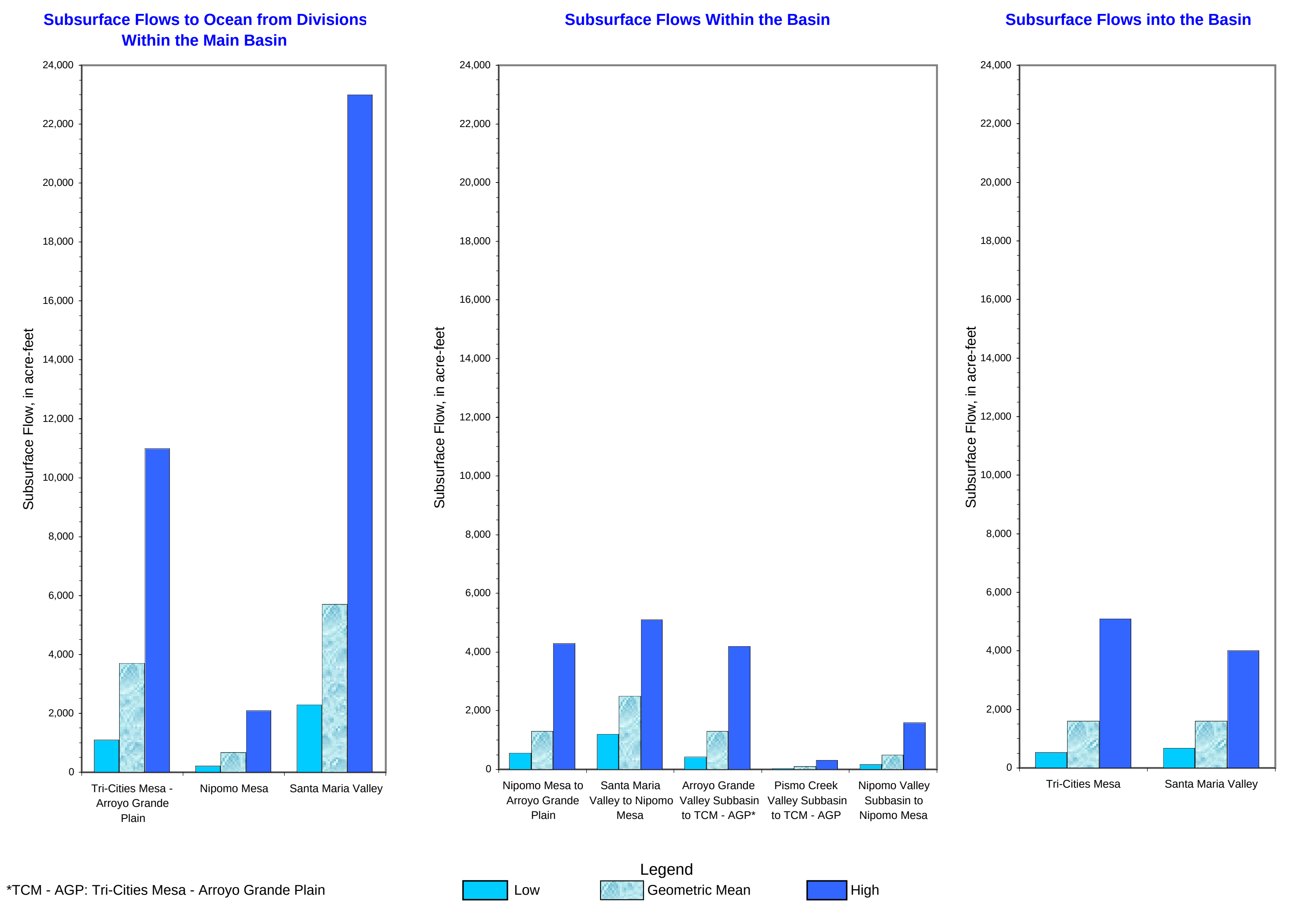
Amounts of subsurface flows out of, into and within the groundwater basin were estimated for water years 1975, 1985, and 1995 of the study period. Because hydraulic conductivity of the deposits ranges over several orders of magnitude, low, high, and geometric mean[13] subsurface flow amounts were estimated. Figure ES3 illustrates water year 1995 subsurface flow estimates.

The largest estimated amounts of subsurface outflow to the Pacific Ocean are from Santa Maria Valley, where the depth of the basin is greatest and the alluvium has high values of hydraulic conductivity. The estimated mean amount was about 6,000 AF in 1995 and also in 1975, and

[13]The geometric mean is determined by taking the natural log of each value, finding the mean of the natural logs, and then obtaining the exponential of that value.

FIGURE ES3 - 1995 ESTIMATED SUBSURFACE FLOWS

In acre-feet



about 7,000 AF in 1985. Estimated amounts of subsurface outflow from Tri-Cities Mesa - Arroyo Grande Plain to the ocean were about half the outflow that occurs from Santa Maria Valley, with a mean amount of 3,700 AF in 1995 and about 3,000 AF in 1975 and 1985. The smallest estimated amounts of subsurface outflow to the ocean occur from Nipomo Mesa. The estimated mean amount was about 700 AF in 1995 and about 900 and 500 AF in 1975 and 1985, respectively.

Within the main groundwater basin, estimated amounts of subsurface flow from Nipomo Mesa to Arroyo Grande Plain ranged between 560 and 4,300 AF, with a mean amount of 1,300 AF in 1995 and also in 1975 and 1985. Estimated amounts of subsurface flow from Santa Maria Valley to Nipomo Mesa ranged between 1,200 to 5,100 AF, with a mean amount of 2,500 AF in 1995 and a mean amount of 1,200 AF in 1985.[14]

The mean amount of subsurface flow from Arroyo Grande Valley Subbasin to the main groundwater basin was estimated to be 1,300 AF in 1975 and 1995 and 1,100 AF in the dry year 1985. Based on very limited data, the mean amount of subsurface flow from Pismo Creek Valley Subbasin to the main groundwater basin was estimated to be 100 AF in 1995 and also in 1975 and 1985. If hydraulic continuity occurs across the Wilmar Avenue fault between Nipomo Valley Subbasin and Nipomo Mesa, the mean amount of subsurface flow into the mesa from the valley was estimated to be 500 AF in 1995 and also in 1975 and 1985.

Mean amounts of subsurface flow into the Tri-Cities Mesa part of the basin from bedrock were estimated to be 1,600 AF in 1995 and also in 1975 and 1985. Mean subsurface flows into Santa Maria Valley from upstream were estimated to be 1,600 AF in 1995 and 1,400 and 2,300 AF in 1975 and 1985, respectively.

Groundwater in Bedrock

The areas overlying bedrock are experiencing increasing development and associated utilization of groundwater. These areas, bordering the Santa Maria Groundwater Basin, consist primarily of the semi-consolidated to consolidated sandstone Pismo Formation in the northern part of the study area (generally north of the Wilmar Avenue fault and Tar Spring Creek and west of the Edna fault zone, Plate ES1) and the consolidated shale Monterey Formation and the volcanic tuff and lava Obispo Formation in the eastern part of the study area, including the area underlying the older alluvium in Nipomo Valley Subbasin (generally south of Tar Spring Creek and east of the Wilmar Avenue fault, Plate ES1).

The bedrock has a limited capacity to store and transmit water, but fracturing can augment its capacity. Well yields from the Pismo Formation range from 10 to 100 gallons per minute and from the Obispo and Monterey Formations, 5 to 750 gallons per minute. “Dry” boreholes can be

[14] Subsurface flow will occur from the valley to the mesa depending on the lateral extent of the pumping depression in the mesa and groundwater elevations and hydraulic gradients.

encountered in both the Obispo and Monterey Formations.

Groundwater in bedrock is recharged mainly by intermittent deep percolation of precipitation and runoff and is discharged by well extractions, evapotranspiration, and subsurface outflow to the adjoining Santa Maria Groundwater Basin.

Of the bedrock formations, the Pismo Formation had the highest estimates of hydraulic conductivity, up to 1,000 gallons per day per foot squared. Estimates of hydraulic conductivity for the fractured tuff Obispo Formation were between 65 and 85 gallons per day per foot squared and for the Monterey Formation, between 15 and 25 gallons per day per foot squared.

Specific yield values of the Pismo Formation ranged from 5 to 20 percent, with a median value of 10 percent. The total storage capacity (the total volume of water that could theoretically be held in underground storage) of the Pismo Formation was estimated to be possibly about 270,000 AF. Specific yield values of the Obispo and Monterey Formations ranged from three to six percent, with a median value of four percent. The total groundwater storage capacity of the Monterey and Obispo Formations was estimated to be possibly about 360,000 AF.

Artificial Recharge

Artificial recharge (*in lieu* method) has been operating for more than 30 years in the study area. Surface water from Lopez Reservoir is supplied to agencies that would otherwise extract groundwater from the Tri-Cities Mesa -Arroyo Grande Plain part of the Santa Maria Basin.

Hydrogeologically, artificial recharge projects in the study area could be sustained. In Nipomo Mesa, a project (including *in lieu*) would be beneficial in alleviating declining trends in groundwater levels in some wells and associated loss in groundwater in storage that occurs in some parts of the mesa. The Nipomo Mesa portion of the basin has adequate space to store artificially recharged waters (only about 16 percent of its theoretical total storage capacity above msl is filled with groundwater). Potential development of this total storage capacity would be limited by the need to avoid groundwater leakage from the edges of the mesa. The high infiltration rates of the dune sands are favorable for artificial recharge projects. Identifying a source of water supply would be a foremost consideration for a recharge project on the mesa.

Water Quality

The groundwater quality data compiled from various sources for this study cover the period of record through 2000. Recent (1990 through 2000) groundwater quality data were available only from water agency wells (in the Tri-Cities Mesa[15] and Nipomo Mesa parts of the main Santa

[15] No recent quality data were available for the Arroyo Grande Plain and Los Berros Creek parts of the Tri-Cities Mesa - Arroyo Grande Plain portion of the main Santa Maria Basin; therefore this portion of the basin is referred to as Tri-Cities Mesa in this section.

Maria Groundwater Basin and in Nipomo Valley Subbasin) and the seven sea water intrusion monitoring wells sampled in 1996 for this study. Elsewhere in the basin, groundwater from wells was last sampled and analyzed in the late 1960s or 1970s, except for a few wells sampled in 1987. Groundwater in some parts of the basin has never been sampled.

The available groundwater quality data represent samples obtained from production wells, except for samples from the sea water intrusion monitoring wells. Thus, the water quality samples represent mixtures of groundwater from different aquifers. Only the sea water intrusion monitoring wells have piezometers at selected depths and represent depth-dependent samples.

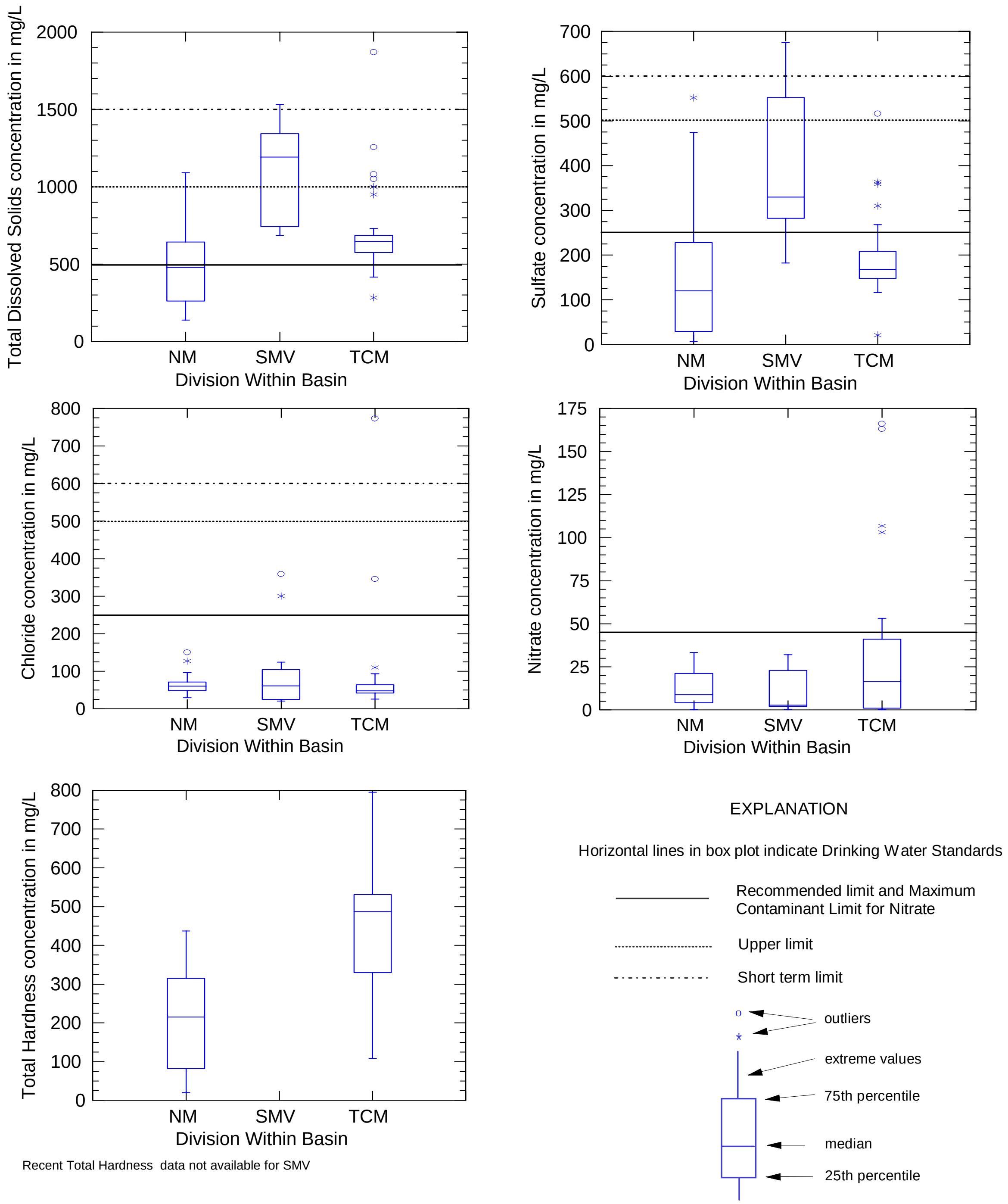
The chemical character of a water, the relative abundance of the major ions in a water, may be considered as a unique signature that often persists even after mixing with another water. Sampled groundwater in the Santa Maria Basin is often a mixed ion type, no one cation or anion dominates, reflecting the complex hydrogeological environment of the basin. However, some distinctions in chemical character of the groundwater exist between different parts of the basin. Groundwater in the Santa Maria Valley part of the basin is typically characterized as calcium-magnesium sulfate type. In the Tri-Cities Mesa part of the basin, groundwater can be dominated by the calcium cation and either the bicarbonate or sulfate anions. In the Nipomo Mesa part of the basin, many wells north of Black Lake Canyon extract groundwater with sodium as the dominant cation and chloride or bicarbonate as the dominant anion. In the Arroyo Grande Valley Subbasin, the chemical character of groundwater is either calcium-magnesium bicarbonate or calcium-magnesium sulfate. In Pismo Creek Valley Subbasin, the dominant ions of groundwater sampled historically were sodium and chloride-bicarbonate or sulfate-chloride. The chemical character of groundwater in Nipomo Valley Subbasin is mixed.

Boxplots, shown in Figure ES4, depict concentrations of Total Dissolved Solids, sulfate, chloride, nitrate, and total hardness found between 1990 and 2000 in sampled well waters in the main part of the basin. The figure shows that most sampled groundwater meets California Department of Health Services' Drinking Water Standards. The higher concentrations of TDS, sulfate, and chloride were found mainly in groundwater from the sea water intrusion monitoring wells and wells near faults. Groundwater is classified as moderate to very hard, although about one-third of the sampled wells in the Nipomo Mesa part of the basin extract groundwater classified as soft. In the Santa Maria Valley part of the basin, recently sampled groundwater was not analyzed for total hardness concentrations; however, historical data indicate most groundwater was very hard.

As can be seen on Figure ES4, groundwater with nitrate concentrations exceeding the maximum contaminant level is found in the Tri-Cities Mesa part of the basin. Those wells extracting groundwater exceeding the Maximum Contaminant Limit (MCL) have a top-perforated interval of less than 100 feet in depth.

Large portions of the basin lack recent nitrate data, particularly agricultural areas where historical data indicate nitrate concentrations in groundwater exceeded the MCL. The high nitrate concentrations had been attributed to ongoing agricultural activities.

FIGURE ES4 - BOX PLOTS OF TOTAL DISSOLVED SOLIDS, SULFATE, CHLORIDE, NITRATE, AND TOTAL HARDNESS CONCENTRATIONS IN WELL WATERS IN SANTA MARIA GROUNDWATER BASIN, 1990-2000 DATA



Division Within Basin
NM: Nipomo Mesa, 1990-2000 data from 35 wells (including 5 piezometers in 2 sea water intrusion monitoring wells)
SMV: Santa Maria Valley, 1992-1998 data from 4 wells (including 11 piezometers in 2 sea water intrusion monitoring wells)
TCM: Tri-Cities Mesa, 1995-2000 data from 25 wells (including 7 piezometers in 3 sea water intrusion monitoring wells)

Analyses of depth-dependent groundwater samples collected in March 1996 from the piezometers in the sea water intrusion monitoring wells show some vertical variability in groundwater quality. In the Tri-Cities Mesa part of the basin, a mineral gain with depth in the Paso Robles Formation was found, while little variation in quality with depth in the Squire Member of the Pismo Formation was found. In the Nipomo Mesa part of the basin, groundwater from the Paso Robles Formation shows a small mineral gain with depth and TDS concentrations could be lower in the Careaga Formation than in the Paso Robles Formation. In the Santa Maria Valley part of the basin, groundwater in the alluvium was as much as about 800 mg/L higher in TDS content than groundwater in the Paso Robles Formation. Also, the quality of groundwater in the Paso Robles Formation was generally about the same regardless of depth, except where it could be affected by downward percolation of poorer quality water from the alluvium or possibly oil field activity.

In the basin, sampled groundwater is typically classified as suitable to marginal under water quality guidelines for agricultural irrigation. However, historical data indicate that sampled groundwater in the Santa Maria Valley portion of the basin was classified as marginal to unsuitable for agricultural irrigation.

No recent quality data were available for Arroyo Grande Valley Subbasin, except for a partial analysis of a sample from one well in 1996. Historical groundwater quality data show a progressive deterioration of the groundwater quality in a downstream direction. Above Tar Spring Creek, the historical data show that concentrations of TDS, sulfate, and chloride in sampled groundwater met Drinking Water Standards and the water was classified as suitable under water quality guidelines for agricultural irrigation. Below Tar Spring Creek, TDS concentrations in extracted groundwater were typically more than 1,500 mg/L and sulfate concentrations were more than about 500 mg/L. The concentrations of these constituents also led the groundwater to be classified as marginal to unsuitable for agricultural irrigation. Most of the historical nitrate concentrations in groundwater met the MCL. Groundwater in the valley was classified as very hard.

No recent groundwater quality data were available for Pismo Creek Valley Subbasin. Historical data indicate that sulfate, chloride, and TDS concentrations generally did not meet Drinking Water Standards.

In Nipomo Valley Subbasin, TDS concentrations in groundwater extracted from the Obispo and Monterey Formations ranged between 750 and 1,300 mg/L; sulfate concentrations, between 200 and 340 mg/L; chloride concentrations, between 64 and 130 mg/L; and nitrate concentrations, between not detected and 3.5 mg/L. The groundwater is classified as very hard and as suitable to marginal under water quality guidelines for agricultural irrigation.

Because chloride concentrations in groundwater may indicate quality changes over time, this parameter was used to evaluate trends in the groundwater quality. Chloride concentrations in sampled groundwater in the main basin typically showed no significant trends of increasing concentrations over time. The generally stable chloride quality over time is indicative of a net outflow of groundwater to the ocean. Data were not available to show any reduction in the quality of groundwater in Nipomo Mesa from subsurface inflow of groundwater from Santa Maria Valley.

No evidence of sea water intrusion was found with the available data.

The use and reuse of groundwater for irrigation have been considered the major factors affecting quality of groundwater in parts of the basin. In addition, groundwater quality in wells may be affected by mineralized zones, residual saline deposits, or waters influenced by tidal action.

Surface water within the study area has not been sampled for quality since the 1960s and 1970s and this historical sampling was very infrequent. The quality of surface waters of the various creeks and the Santa Maria River varied, depending on the flow, with TDS concentrations measured at up to about 2,000 mg/L. Lopez Reservoir (not within the study area) is an important supply source within the study. Water from Lopez Reservoir is of high quality and meets Drinking Water Standards. TDS concentrations of the water range between 400 and 600 mg/L and the chemical character is calcium-magnesium bicarbonate.

Water Budget, Dependable Yield, and Overdraft

Water budgets, itemized accountings of all inflows and outflows occurring in hydrologic systems, were developed for this study to provide information for water supply planning within the main Santa Maria Groundwater Basin in San Luis Obispo County. The investigators had sufficient data to develop valid water budgets for each of the three portions into which the main groundwater basin was divided: Tri-Cities Mesa - Arroyo Grande Plain, Nipomo Mesa, and Santa Maria Valley (Plate ES1).

Using the general equation "*Inflow - Outflow = Surplus/Deficiency,*" the components of groundwater inflow and outflow were determined for each year of the 1975 through 1995 study period and for future years 2010 and 2020. The future water budgets are based on projected land use changes and associated changes in water demands and on the base period 1984 through 1995, which represents long-term average hydrologic conditions.[16]

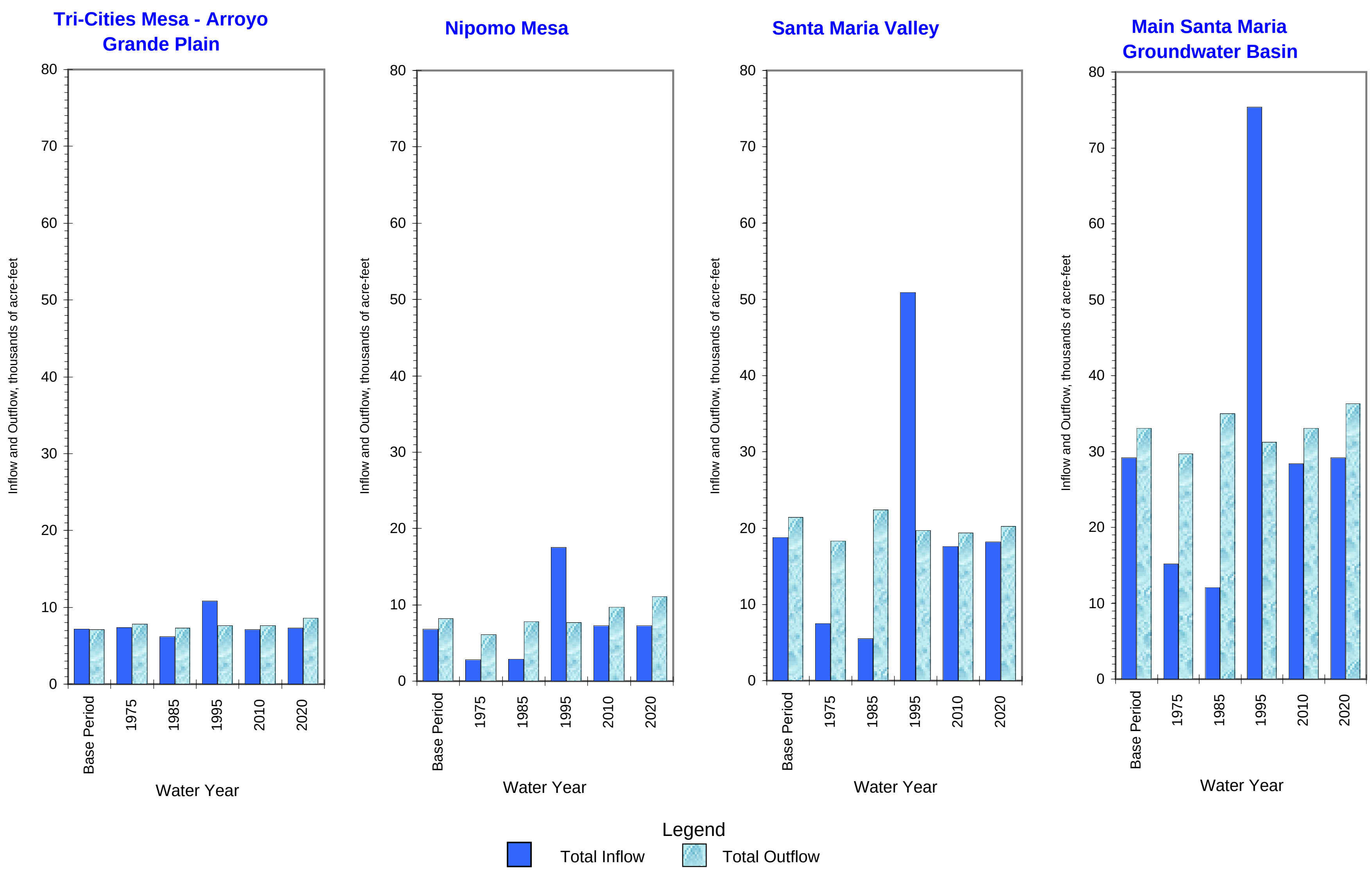
The surplus or deficiency for each year of the water budget is actually the amount of change in groundwater in storage that takes place. Thus, for this study, the water budgets show the amount of change in groundwater in storage in the Tri-Cities Mesa - Arroyo Grande Plain, Nipomo Mesa and Santa Maria Valley portions of the main groundwater basin.

Figure ES5 illustrates estimated inflow and outflow amounts for the divisions of the main basin

[16]Because of the wet water year 1998, the long-term mean for the period of record through water year 1995 is about 0.4 inch less than the long-term mean for the period of record through water year 2000 at precipitation station Nipomo 2NW.

FIGURE ES5 - INFLOW AND OUTFLOW WITHIN THE MAIN SANTA MARIA GROUNDWATER BASIN, SAN LUIS OBISPO COUNTY

In thousands of acre-feet



and for the main basin as a whole for 1975; for 1985, a dry year; for 1995, a wet year; for the base period, 1984 through 1995; and for future years 2010 and 2020. The water budget for the main groundwater basin was arrived at by totaling the applicable components of the budgets for the three divisions of the basin.

Within the main Santa Maria Basin, total outflow (33,100 AF) exceeded total inflow (29,200 AF) by about 4,000 AF in the base period. Outflow is projected to exceed inflow by 4,700 AF in 2010 and by 7,100 AF in 2020.

In Tri-Cities Mesa - Arroyo Grande Plain, total inflows about equaled total outflows in the base period. Projected amounts show total outflow exceeding total inflow by 500 AF in 2010 and 1,300 AF in 2020.

Total outflow in Nipomo Mesa exceeded total inflow by 1,400 AF in the base period. Outflow is projected to exceed inflow in the future by 2,400 AF in 2010 and by 3,800 AF in 2020.

In Santa Maria Valley, total outflow exceeded total inflow by 2,600 AF in the base period. In the future, outflow is projected to exceed inflow by 1,800 AF in 2010 and by 2,000 AF in 2020.

In Tri-Cities Mesa - Arroyo Grande Plain, both the cumulative surplus/deficiency method and the "specific yield" method[17] estimated a gain of groundwater in storage of 1,000 to 6,000 AF between 1975 and 1995. In Nipomo Mesa, both methods estimated a loss of groundwater in storage of 7,000 to 11,000 AF between 1975 and 1995. In Santa Maria Valley, both methods estimated a gain of groundwater in storage of 3,000 to 5,400 AF between 1975 and 1995.

The projected deficiencies in the water budgets in 2010 and 2020 for Tri-Cities Mesa - Arroyo Grande Plain, Nipomo Mesa, and Santa Maria Valley (1,300, 3,800, and 2,000 AF in 2020, respectively) represent the potential losses in groundwater in storage if hydrologic base period conditions of this study occurred in those years with the projected land use and water demand changes. The projected deficiencies would amount to about one-tenth of a foot decline in groundwater levels in 2020 over the entire Tri-Cities Mesa - Arroyo Grande Plain and Santa Maria Valley portions of the basin and two-tenths of a foot decline in groundwater levels in 2020 over the entire Nipomo Mesa portion of the basin.

In Tri-Cities Mesa - Arroyo Grande Plain, the projected increase in urban extractions is the major factor contributing to projected deficiencies in 2010 and 2020. Reductions in subsurface outflow to the ocean will likely offset future negative imbalances between inflow and outflow and loss of groundwater in storage. In addition, recharge enhancement of Arroyo Grande Creek could increase stream infiltration amounts and potentially offset future deficiencies. However, if in the future, subsurface outflow to the ocean is not of sufficient quantity for the freshwater head to counterbalance the greater density of sea water, sea water intrusion of the groundwater basin

[17]Method used to estimate groundwater in storage, discussed in section on Santa Maria Groundwater Basin.

could occur.

In Nipomo Mesa, the projected increase in urban extractions is the major factor contributing to projected deficiencies in 2010 and 2020. Reductions in subsurface outflows to the ocean and to Tri-Cities Mesa - Arroyo Grande Plain and increased subsurface inflow from Santa Maria Valley will likely offset the future negative imbalances between inflow and outflow and reduce the amount of loss in groundwater in storage. Subsurface outflow to the ocean was only 600 AF in the base period and reductions in this outflow would need to be small because of the concern regarding sea water intrusion.

In Santa Maria Valley, the projected deficiencies are not the result of future increased extractions (extractions were projected to increase only 200 AF between 1995 and 2020). Projected subsurface outflows in 2010 and 2020 are substantial (6,200 AF to the ocean and 2,300 AF to Nipomo Mesa) from this portion of the basin. Potential future deficiencies will likely be offset by reduced subsurface outflow to the ocean, which accounts for about 30 percent of the total outflow in the future. However, if in the future, subsurface outflow to Nipomo Mesa increases above the projected amount, water budgets for this portion of the basin could show larger deficits (loss of groundwater in storage). The same concern regarding sea water intrusion applies. In addition, restoration and maintenance of the storage capacity of Twitchell Reservoir could improve future recharge amounts from the Santa Maria River to the groundwater basin.

The dependable yield of a groundwater basin is the average quantity of water that can be withdrawn from the basin over a period of time (during which water supply conditions approximate average conditions) without resulting in adverse effects, such as sea water intrusion, subsidence, permanently lowered groundwater levels, or degradation of water quality. Dependable yield is determined for a specified set of conditions and any changes in those conditions require a new calculation.

For this study, estimates of dependable yield for each division of the main groundwater basin were determined from the hydrologic equation for the 1984 through 1995 base period and for the 1975 through 1995 study period. Because subsurface flows to the ocean could be reduced and subsurface flows between portions of the basin increased or decreased, the dependable yield is given as a range. Thus, the dependable yield is estimated to range between 4,000 and 5,600 AF for the Tri-Cities Mesa - Arroyo Grande Plain portion of the basin, between 4,800 and 6,000 AF for the Nipomo Mesa portion of the basin, and between 11,100 and 13,000 AF for the Santa Maria Valley portion of the basin. These estimates of dependable yield for each portion of the main groundwater basin are more meaningful if they are considered as a unified whole because the estimates are directly affected by the amounts and nature of the subsurface flows occurring between portions of the basin. Thus, the dependable yield for the main Santa Maria Basin within San Luis Obispo County ranges between 19,900 and 24,600 AF.

Overdraft is defined as the condition of a groundwater basin or subbasin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years, during which the water supply conditions approximate average conditions. Droughts or periods of less than normal rainfall do not cause overdraft. Basically, overdraft means that extractions exceed the dependable yield of the basin.

This study refrains from finding that the Santa Maria Groundwater Basin within San Luis Obispo County is currently in overdraft because of consistent subsurface outflow to the ocean and no evidence of sea water intrusion. The periodic recovery of the basin provides sufficient recharge to preclude long-term adverse conditions. The basin was estimated to have about 38,000 AF more groundwater in storage in water year 2000 than in 1975. In the Nipomo Mesa portion of the basin, the amount of groundwater in storage in 2000 was estimated to be the same as in 1975, despite the continued presence of the pumping depression in the south-central part of the mesa. Pumping depressions and declines in groundwater levels in some wells in some parts of the Nipomo Mesa portion of the basin do not imply that a condition of overdraft exists in the entire groundwater basin, but are more likely indicative of the dynamics of the groundwater system and sources of recharge in the mesa. Other recent investigations also found that the basin is not in a condition of overdraft.

The projected deficiencies in the water budgets in water years 2010 and 2020 for the three portions of the main Santa Maria Basin do not necessarily imply overdraft conditions in those years. Projected extractions are within the range of dependable yield estimates, with the exception of Nipomo Mesa in 2020. Because the basin continuously seeks a new equilibrium, reductions in subsurface outflow to the ocean and changes in subsurface flow between portions of the basin will likely compensate for deficiencies (loss of groundwater in storage). Such changes in subsurface flows as the basin seeks a new equilibrium will not likely result in overdraft provided that sea water intrusion and other adverse effects are avoided. However, because of the potential for adverse effects, increasing amounts of subsurface flow from the Santa Maria Valley portion of the basin into the Nipomo Mesa portion of the basin to meet projected water demands should not be used as a long-term solution to water supply needs in Nipomo Mesa. The projected deficiencies in the water budgets do indicate the need for continued planning, improved data, periodic reevaluation of the water budgets, artificial recharge programs, and expanded use of recycled water.

The groundwater basin is an area of dynamic growth, subject to constantly changing conditions, which affect water supply, use, and disposal. Human activities that can modify water supply conditions and consequently water budgets include items such as: extent of extractions, transfers of water use, increases in impermeable areas, land use changes, and alteration of groundwater hydraulic gradients. Also, because precipitation is the single most important item related to availability of water in the groundwater basin, protracted dry or wet periods will significantly affect future water budgets. Therefore, it needs to be recognized that any water budgets and dependable yield values will be superseded in the future as conditions change.

Recommendations

On the basis of the information gained in this investigation, it is recommended that San Luis

Obispo County consider the following:

- Continue the groundwater level monitoring program and expand the program to include key wells in Pismo Creek Valley Subbasin, the eastern part of Nipomo Mesa (bounded by Summit Station Road, Hetrick Avenue, the Santa Maria River fault, Highway 101, and Joshua Road), and the areas overlying bedrock, and also expand the coverage of the south-central part of Nipomo Mesa;
- Undertake a comprehensive water quality assessment of the water resources in the study area and develop a water quality monitoring program with the information provided by the comprehensive assessment;
- Annually monitor both groundwater levels and quality in the 23 piezometers within the seven wells along the coast for sea water intrusion;
- Install a precipitation station on the Nipomo Mesa near Highway 1 and Willow Road to gain needed precipitation data for this area;
- Undertake infiltration and soil moisture studies to more accurately determine the amount of deep percolation of precipitation and stream infiltration that occurs within the study area;
- Undertake studies to more precisely determine the location of the Santa Maria River fault and its impact and the impacts of the Oceano fault and the Wilmar Avenue fault on groundwater flow within the basin;
- Reconcile the reference elevations for the groundwater level monitoring wells;
- Expand the monitoring of streamflow with needed gages at the confluence with the Pacific Ocean on Pismo and Arroyo Grande Creeks and at Guadalupe on the Santa Maria River;
- Investigate the feasibility of an artificial recharge program using supplemental water in the study area; and
- Expand the use of recycled water as a source of supply within the study area.

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