3 Basin Setting

The LSCR is the lower reach of the Santa Clara River that flows through Ventura County. The river flows in a westerly direction and discharges to the Pacific Ocean near the Ventura Harbor. **Figure 3-1** provides a conceptual model of water movement within the LSCR. The LSCR basin is composed of five groundwater sub-basins:

- Piru basin;
- Fillmore basin;
- Santa Paula basin;
- Mound basin; and
- Oxnard Forebay basin.

This section provides the setting for the SNMP study area, including the characterization of factors that have bearing on the salt and nutrient loads in the basin: basin physiography, geology, and hydrogeology, climate, surface water hydrology, land use and land cover; and water sources.

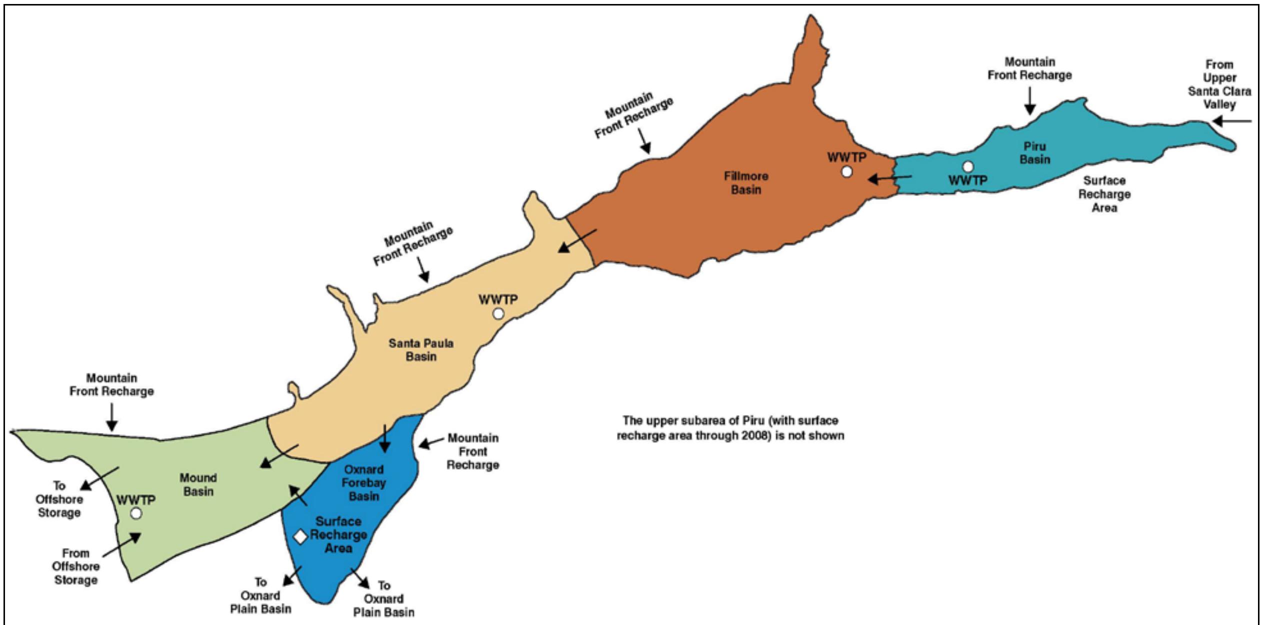

Figure 3-1 Conceptual Model of Water Movement between LSCR Sub-Basins

3.1 GROUNDWATER BASIN DESCRIPTION

The groundwater basin description provides the geologic, hydrogeologic, and hydrologic framework for the SNMP and in particular, provides the basis for the analytical flow and transport assessment required by the SNMP. Key sources of information used to establish the study area boundaries and develop the groundwater basin description include the California Department of Water Resources (DWR) and UWCD.

The California DWR Bulletin 118 delineations of groundwater basins for the Lower Santa Clara Valley used in the current Basin Plan differ from the basin delineations used by UWCD for their groundwater management. The primary difference between the two sources is UWCD's exclusion of the partially consolidated San Pedro formation and parts of the lower canyons. Additionally, the UWCD basins have different upgradient and downgradient boundaries compared to the DWR delineation, and UWCD separates DWR's Oxnard sub-basin into two: the Oxnard Forebay and Oxnard Plain basins. The Oxnard Forebay basin is included in the LSCR SNMP, however, the Oxnard Plain basin has been omitted at the request of the Oxnard stakeholders. **Figure 3-2** shows an overlay map of the DWR and UWCD basin boundaries. Given the lack of hydrogeologic data in the area between the DWR and UWCD boundaries, the LSCR SNMP uses the DWR defined basins with UWCD's Oxnard Forebay basin for the study planning area, and the UWCD basin boundaries are used for the salt and nutrient loading analysis.

The SCR valley occurs within the Ventura Basin, which is a well-defined east to west trending structurally complex sedimentary syncline within the Transverse Range province (Yeats, et al., 1981). The five groundwater sub-basins are hydrologically connected and delineated based on topographic and hydrogeologic features described in the following sections.

As part of the Transverse Ranges geologic province, the SCR valley is an east-west orientated valley that is bordered by active thrust and reverse faults. These faults have caused uplift of the adjacent mountains relative to the SCR valley (UWCD, 2012b). The valley occurs in the Transverse Range geomorphic province's Ventura Basin, which is a major sedimentary basin that formed within the structurally complex Ventura syncline. Both terrestrial and marine Tertiary and Quaternary sedimentation contributed to valley filling. The Piru, Fillmore, and Santa Paula basins are bounded by the San Cayetano and Oak Ridge faults. The Mound and Oxnard Plain basins extend offshore as a gently sloping submarine shelf of the Santa Barbara Channel (Hanson et al., 2003). The Oxnard Forebay basin is delineated as the unconfined portion of the Oxnard Plain basin (UWCD, 2008).

The water-bearing sediments in the LSCR groundwater basins are both recent and older alluvium overlying the San Pedro formation (**Figure 3-3**). The Santa Barbara formation underlies the San Pedro formation. The valley groundwater basins include the surface outcrop of San Pedro formation along their northern boundaries (**Figure 3-3**). The groundwater basins are underlain by a mostly non-water bearing basement of upper Cretaceous and Tertiary sediments and volcanics that are exposed in the surrounding mountains.

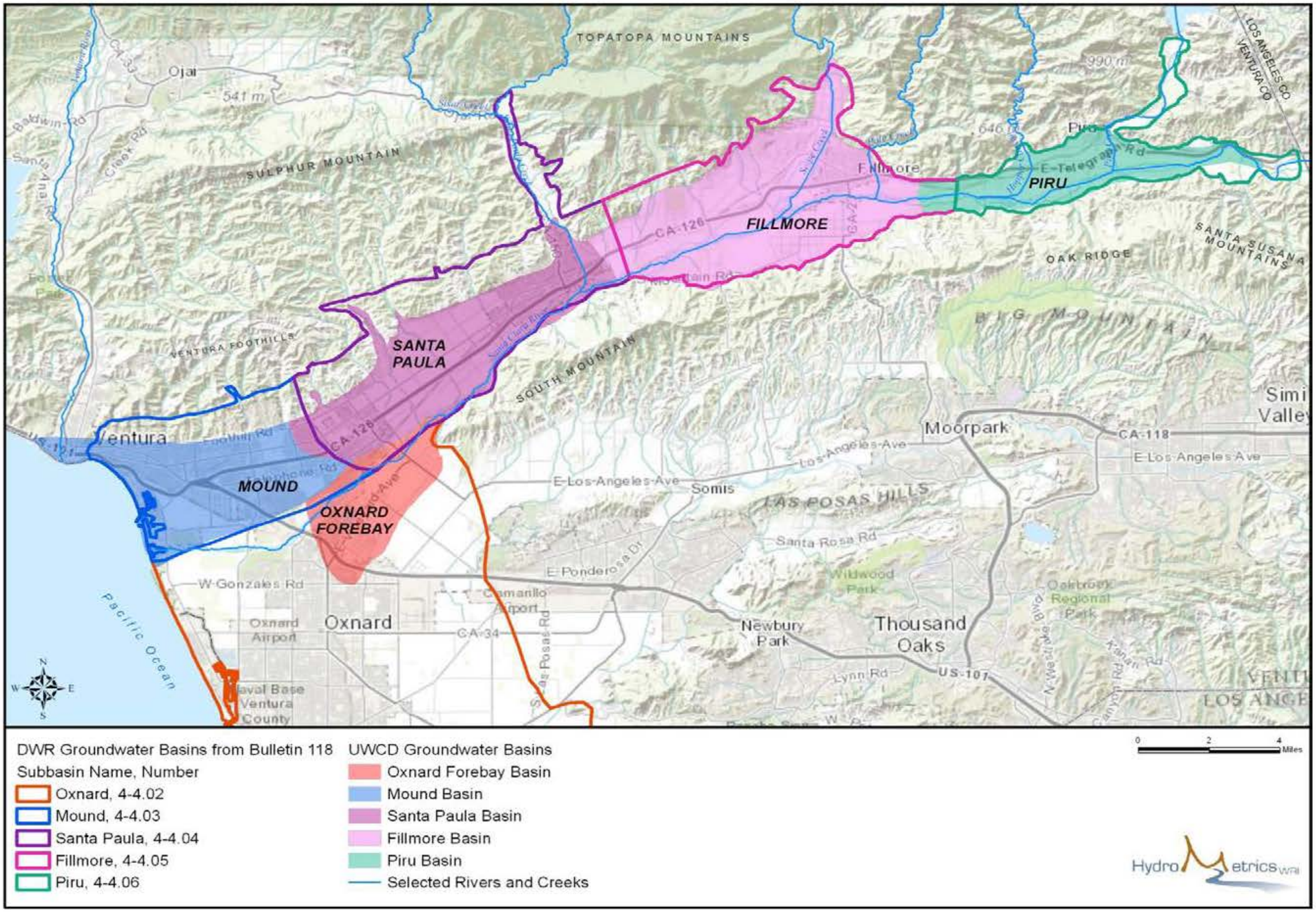

Figure 3-2 Comparison of DWR and UWCD Groundwater Basin Delineations

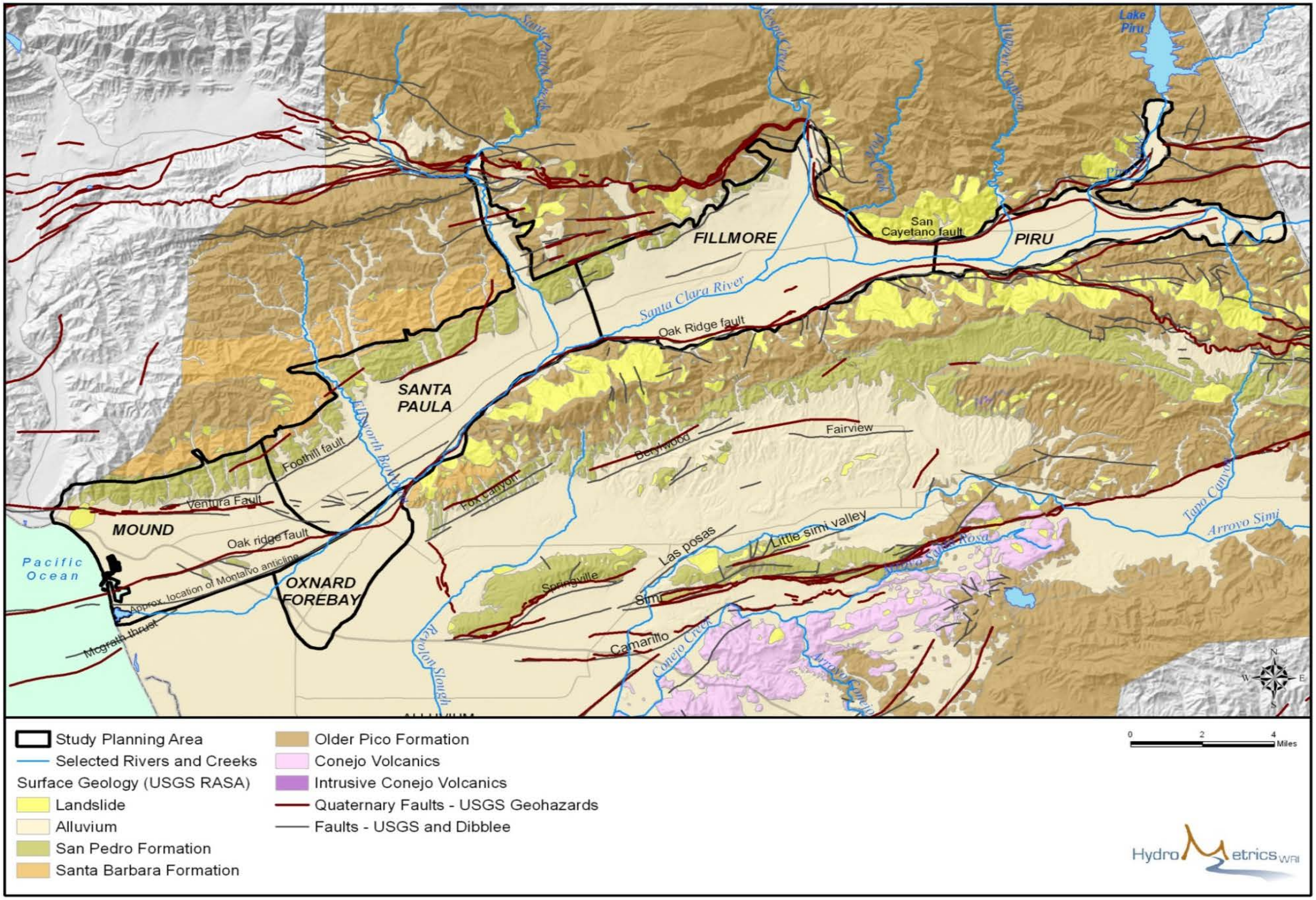

Figure 3-3 Lower Santa Clara River Surface Geology

The aquifers occurring in the study planning area can be classified as part of an Upper Aquifer System (UAS) and Lower Aquifer System (LAS) (Turner, 1975; Mukae and Turner, 1975). **Figure 3-4** illustrates the hydrostratigraphic and geologic relationship of the UAS and LAS with the regional geology.

Recent alluvium of the Oxnard aquifer and older alluvium of the Mugu aquifer comprise the UAS (**Figure 3-4**). The Oxnard aquifer generally occurs at a depth of 100 to 250 feet below ground surface (bgs) (UWCD, 2012b). Separating the two UAS aquifers is an unconformity and discontinuous clay layer. The Mugu aquifer below the Oxnard aquifer can reach a thickness of 250 feet.

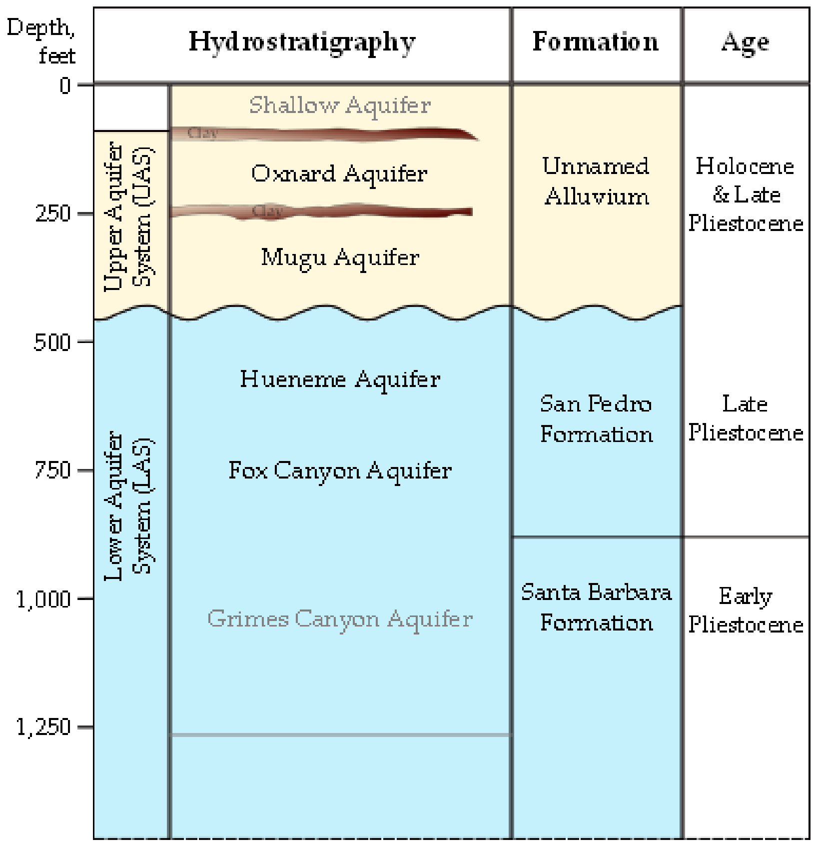

Figure 3-4 Lower Santa Clara River Aquifer Systems (UWCD, 2012b)

An unconformity separates the UAS and LAS. Below the UAS, the LAS comprises the Hueneme, Fox Canyon, and Grimes Canyon aquifers which are part of the San Pedro and Santa Barbara formations (**Figure 3-4**). The Hueneme aquifer is the uppermost aquifer of the LAS and occurs extensively across the study area. It is generally considered to be the San Pedro formation in the valley basins and the Saugus formation more inland (UWCD, 2012b). The Fox Canyon aquifer, comprised of marine shallow regressive sands and some clays, underlies the Oxnard Forebay basin but is not present in other portions of the study area (UWCD, 2012b). It is the lowermost aquifer unit in the San Pedro formation. The Grimes aquifer which underlies the Fox Canyon Aquifer shown in **Figure 3-4** does not occur in the study area.

The LSCR aquifers are primarily recharged by a combination of streambed percolation, managed aquifer recharge from diverted stream flow, mountain front recharge, deep percolation of precipitation into the alluvial sediments and rock outcrops, and irrigation return flow.

3.1.1 Piru Basin

The Piru basin is the uppermost groundwater basin in the LSCR. Its upstream or eastern extent is just downstream of the Ventura/Los Angeles County (**Figure 3-5**). The Piru basin is narrower than downstream basins and is confined to the north by the Topatopa Mountains and to the south by the Oak Ridge and Santa Susana Mountains. The basin's western extent is marked by an area of groundwater discharge into the SCR, approximately two miles east of the City of Fillmore. Locally this is referred to as "rising water", which does not mean groundwater is actually rising up but rather the groundwater level intersects the streambed and causes migrating groundwater to discharge into the river channel. The change in surface elevation on the SCR from east to west in the Piru basin is 315 feet, or on average 32 feet per mile. The Piru basin is approximately 9.8 miles long and 1.8 miles wide at its widest point at the Piru Creek/SCR confluence, and covers an area of approximately 8,915 acres.[1]

Recent and older alluvium consisting of 60 to 80 feet of coarse sand and gravel covers almost the entire Piru basin (UWCD, 2005). Underlying almost all of the recent and older alluvium are permeable sands and gravels of the San Pedro formation. The San Pedro formation persists to an approximate depth of 8,800 feet, with only the top portion of this being useable for groundwater extraction. Impermeable Pico formation underlies the older alluvium in the very eastern portion of the basin (UWCD, 2013b). The basin is structurally bound by the San Cayetano fault to the north and Oak Ridge fault to the south (**Figure 3-3)**.

During dry and normal SCR flow conditions, surface water percolates completely below the streambed between just downstream of the County line and Piru Creek (**Figure 3-5**). As a result of the complete percolation, surface water quality has a strong influence on groundwater quality in the Piru basin.

Groundwater discharges to the SCR approximately two miles east of the City of Fillmore where the basin narrows at the boundary of the Piru and Fillmore basins. Groundwater level fluctuations are much less in the area of rising groundwater than in other areas (**Figure 3-6**). The SCR in the Piru basin is in direct connection with the underlying aquifer and there are no laterally continuous confining layers to impede percolation (UWCD, 2005). This results in groundwater levels that respond rapidly to recharge from streambed percolation and rainfall events (**Figure 3-6**). When the basin fills in high precipitation years, the percolation rate decreases and surface flows are able to reach the Fillmore basin (UWCD, 2005).

Groundwater in the alluvium flows mostly parallel to the river channel (**Figure 3-6**). In the San Pedro formation, the predominant flow direction is also parallel to the river channel but also includes some north to south flow perpendicular to the axis of the Ventura syncline (UWCD, 2012b). Groundwater levels in **Figure 3-6** display data from wells screened either in the alluvium or in the San Pedro formation because there is almost no vertical hydraulic gradient between deep and shallow wells, as seen in the hydrograph displaying groundwater elevations

---

[1] Other authors have listed different areas for the Piru basin based on different extents (UWCD, 1996; DWR, 2003). The area presented here is the surface area of the study planning area basin depicted in **Figure 3-2.**

for UWCD monitoring wells (wells 04N18W31D03S and 04N18W31D07S, screened from 590 to 610 feet bgs and 50 to 70 feet, respectively.

Groundwater levels in the area of rising water in wet and average years intersect the streambed causing flow in the SCR, and occur at approximately 60 feet below the streambed west of the Piru Creek confluence. In dry years, groundwater levels in the eastern part of the discharge area can fall to 50 feet below the streambed elevation, which means that rising water does not occur at that location, and occurs at 150 feet below the streambed west of Piru Creek (UWCD, 2005). The basin is considered full when the area of rising water extends eastwards to the Hopper Creek confluence (UWCD, 2005).

Streambed recharge from the SCR and Piru Creek (from both natural flows and water released from Santa Felicia Dam) are major sources of groundwater recharge, with other sources from smaller streams, mountain front recharge from the upland areas to the north and south, irrigation return flow, septic tanks, and underflow from the upstream Eastern Santa Clara River Valley basin in Los Angeles County. Historically, there has also been diverted Piru Creek water recharged at the Piru Spreading Grounds (**Figure 3-5**).

The Piru spreading grounds are not used at present due to the diversion structure not being in compliance with National Marine Fisheries Service (NMFS) standards. When the structure is permitted in the future, it will be used again for managed aquifer recharge.

Sources of discharge from the basin include groundwater pumping, rising groundwater that becomes surface water in the SCR, and subsurface groundwater outflow to the Fillmore basin.

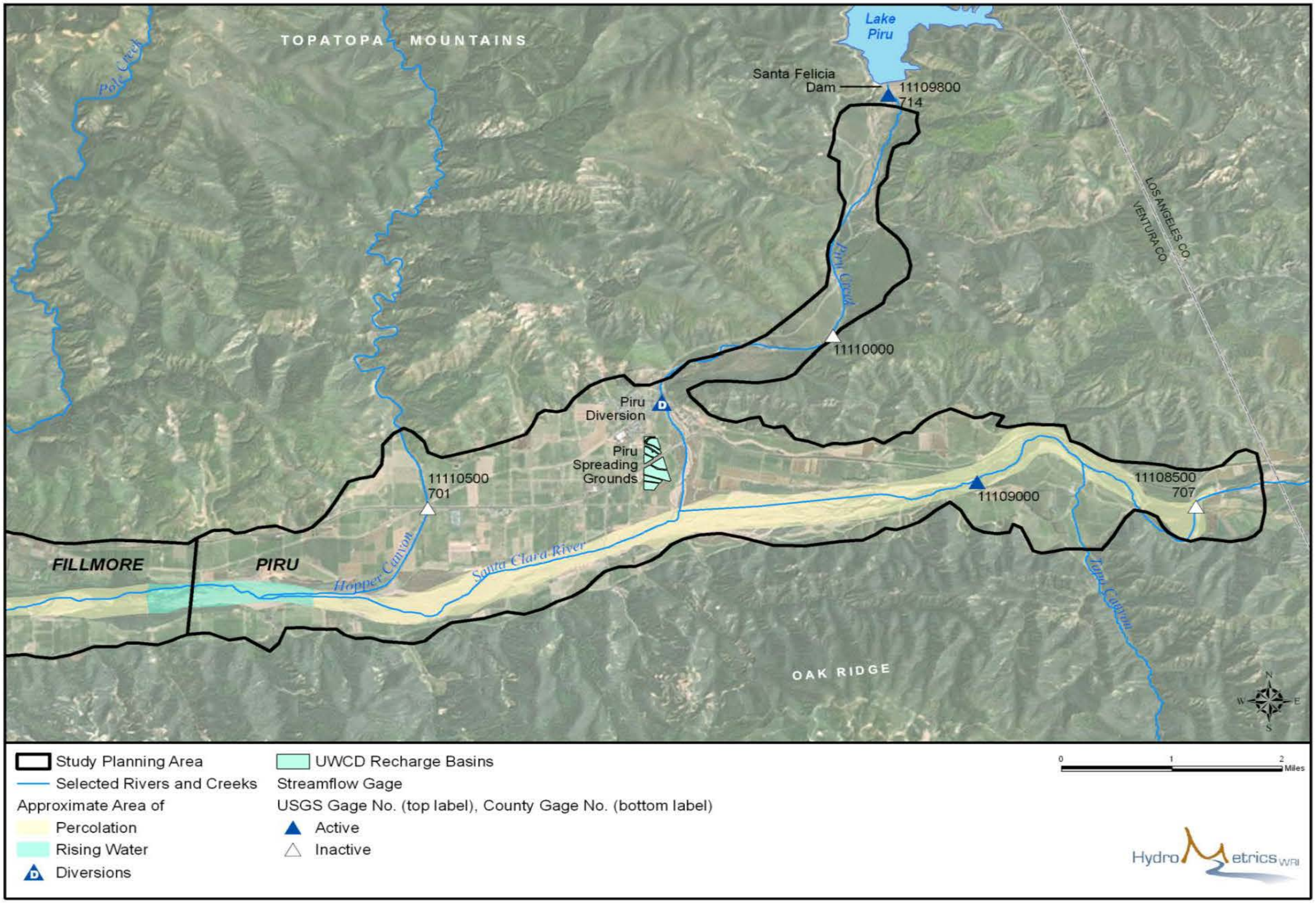

Figure 3-5 Piru Basin

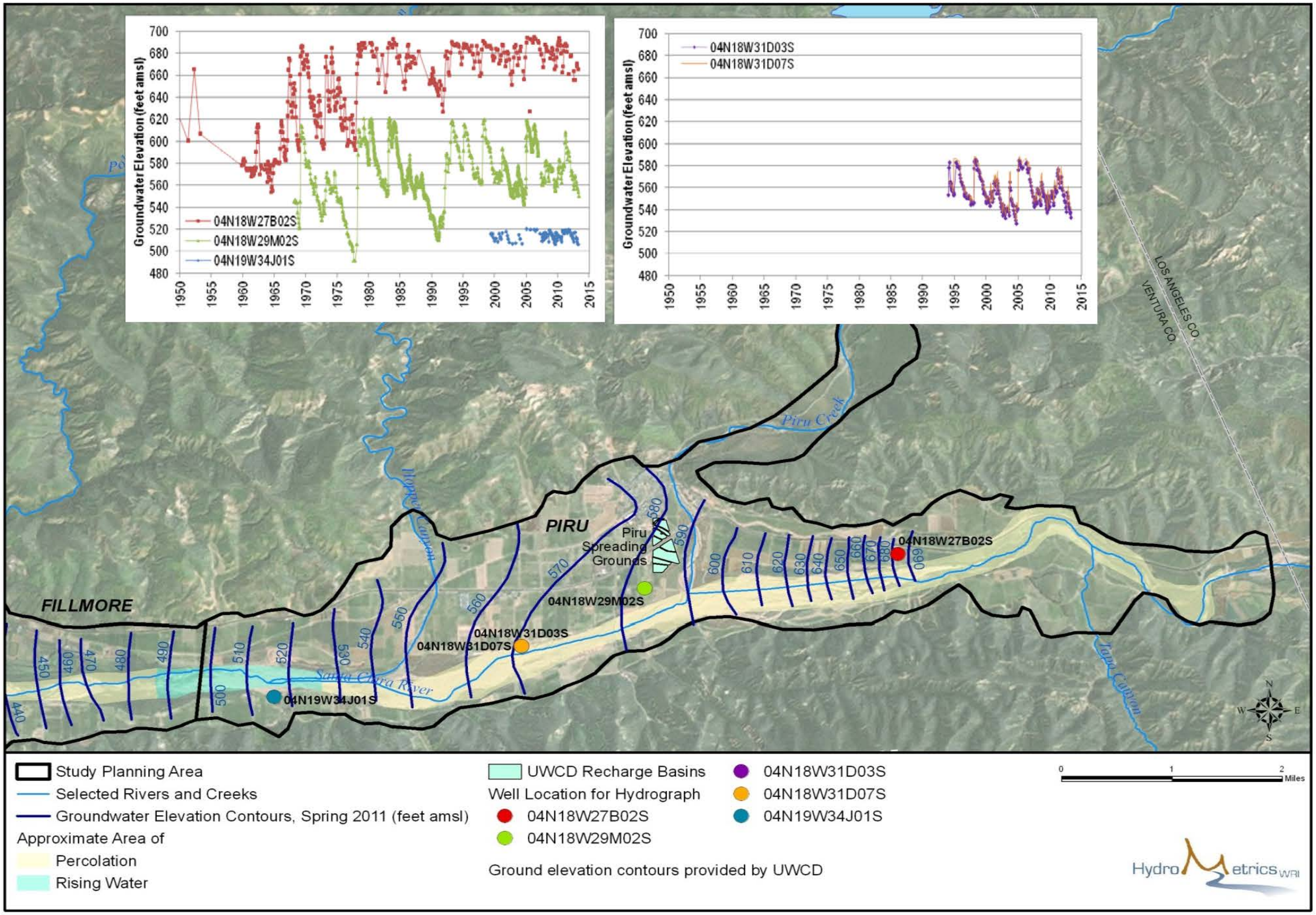

Figure 3-6 Piru Basin Groundwater Elevations

3.1.2 Fillmore Basin

The Fillmore basin is immediately downstream of the Piru basin, sharing its eastern boundary with the Piru basin's western boundary (**Figure 3-7**). It is confined to the SCR valley by the Topatopa Mountains on the north, and Oak Ridge to the south. Its widest width is 5.2 miles across due to coarse-grained southward-sloping alluvial fan sediments deposited by the Sespe Creek in an area called the Sespe Uplands. The basin is approximately 9.8 miles long and covers an area of approximately 20,840 acres[2]. The basin's western boundary occurs where narrowing of the valley just northeast of the City of Santa Paula, at Willard Road, constricts groundwater flow causing groundwater levels to flatten and to intersect the streambed (rising water). Rising water is clearly seen in aerial photographs where the streambed is highly vegetated. The area of rising water varies based on how full the basin is at any particular time. The change in surface elevation on the SCR from the east to the west of the Fillmore basin is 240 feet, at an average gradient of 25 feet per mile.

The Fillmore basin contains sediments that have filled the Ventura syncline. Younger alluvial sediments comprising recent sands and gravels deposited by the SCR and Sespe Creek overlie the southern and eastern portions of the basin. The Pole Creek Fan area, between Sespe Creek and the SCR (**Figure 3-7**), overlies the northern portion of the basin, and comprises typical alluvial fan materials. The Sespe Uplands, which includes the areas north of Sespe Creek and the SCR (**Figure 3-7**), are comprised of complex terrace deposits, older alluvial fan deposits, and recent alluvial fan deposits (UWCD, 2013b). Up to 120 feet of alluvial and fan deposits unconformably overlie the San Pedro formation. The basin is structurally bound by the San Cayetano and Oak Ridge faults, to the north and south, respectively (**Figure 3-3**).

The basin is considered an unconfined aquifer system. Groundwater generally flows from east to west down the axis of the basin, with southwesterly flow occurring in the Sespe Creek area. Within the San Pedro formation there is a southerly flow component as groundwater moves from the northern part of the basin towards the valley axis. Once at the axis, flow continues in a westerly direction. A contour map showing typical groundwater elevations throughout the basin is shown in **Figure 3-8**. Similar to the Piru basin, vertical hydraulic gradients in this basin are very small, therefore alluvium and San Pedro formation groundwater elevations are displayed on the graph.

The streambed percolation from the SCR and Sespe Creek, and underflow from Piru basin are major sources of recharge to the Fillmore basin. Minor sources of recharge include percolation through smaller streambeds, mountain front recharge from the upland areas to the north and south, irrigation return flow, septic tanks, and percolation of treated wastewater. Discharge from the basin includes groundwater pumping, rising water that becomes surface water in the SCR, and subsurface outflow to the Santa Paula basin.

[2] Other authors have listed different areas for the Fillmore basin based on different extents (UWCD, 1996; DWR, 2003). The areas presented here are the surface area of the study planning area basins depicted in **Figure 3-2**.

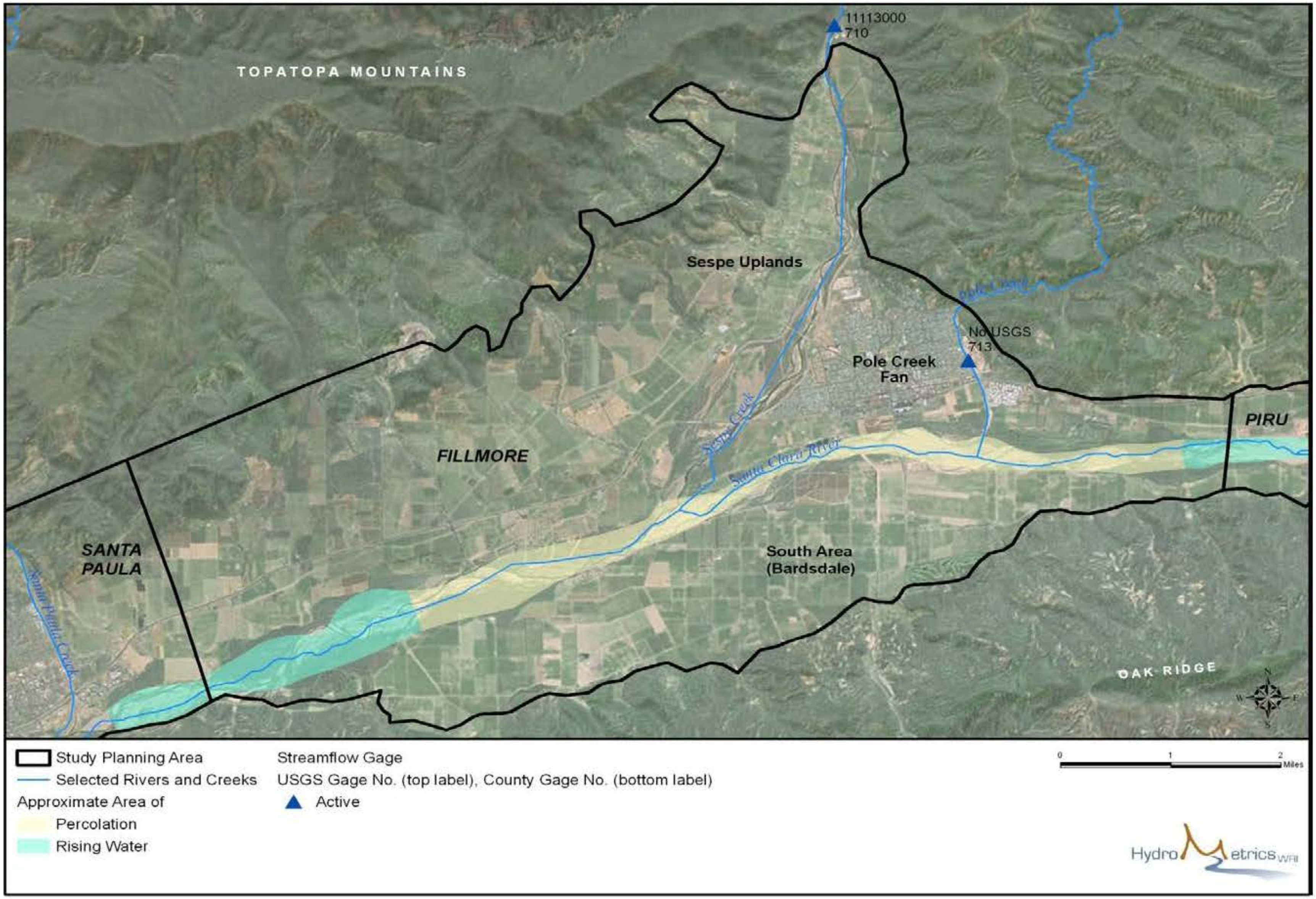

Figure 3-7 Fillmore Basin

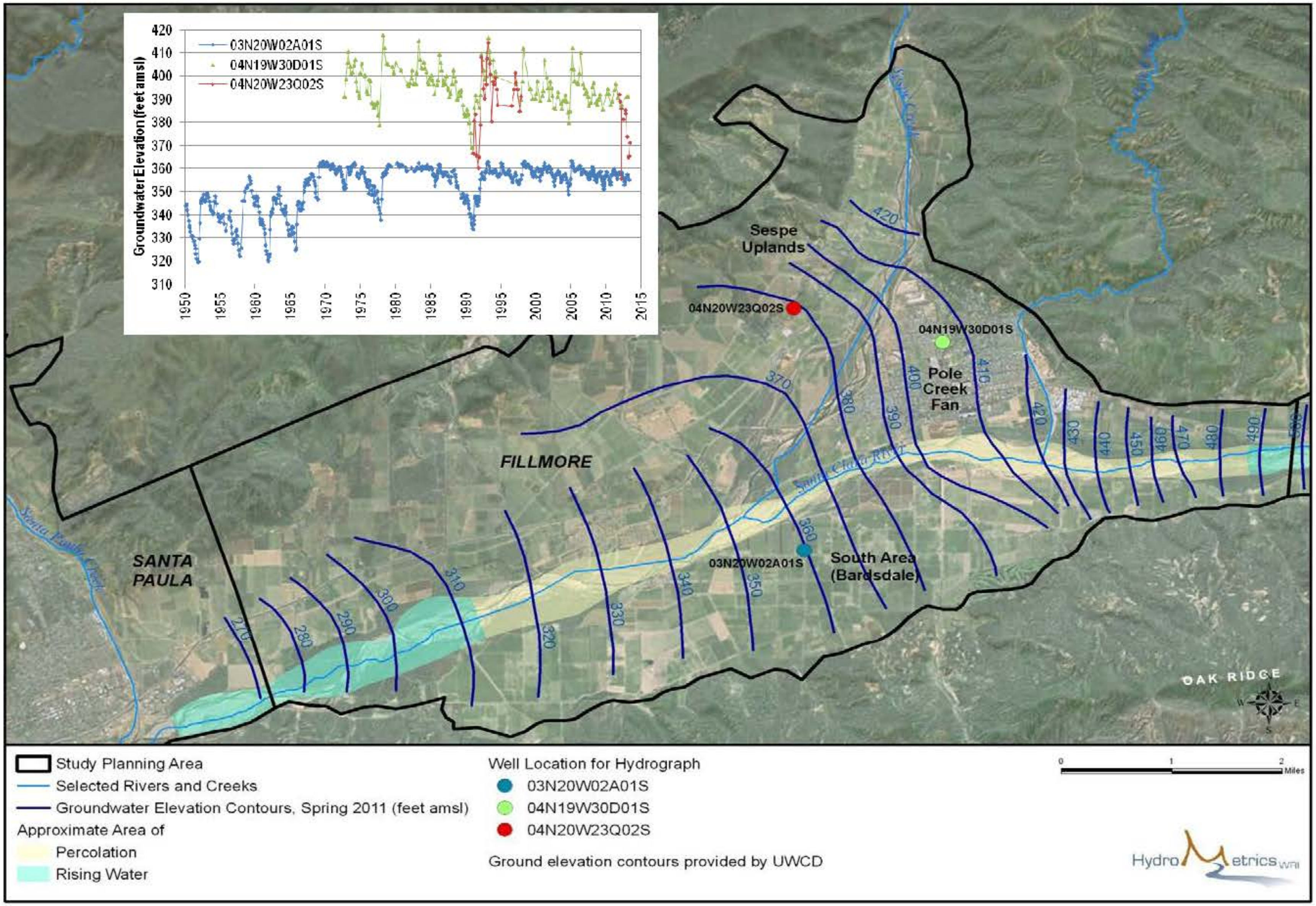

Figure 3-8 Fillmore Basin Groundwater Elevation

3.1.3 Santa Paula Basin

The Santa Paula basin is downstream of the Fillmore basin, sharing its eastern boundary with Fillmore basin's western boundary (**Figure 3-9**). The basin is bounded by the Sulphur Mountain foothills on the north and South Mountain on the south. It is approximately 10.5 miles long and borders the Mound basin to the west and the Oxnard Forebay basin to the south.[3] The western boundary is geologically complex and the aquifers in this portion of the basin are locally uplifted and faulted, with artesian conditions mapped by some investigators (UWCD, 2013a). Hydraulic connection is believed to exist between Santa Paula basin and the down-gradient Mound basin and Oxnard Forebay, but flow between these basins remains unquantified. (UWCD, 2013a). The area of the Santa Paula basin covers approximately 22,900 acres. Surface elevation over the length of the SCR changes 170 feet, which equates to a gradient of approximately 16 feet per mile.

The Santa Paula basin contains the San Pedro Formation and overlying alluvial sediments deposited by the SCR and its tributaries (**Figure 3-3**). An alluvial fan associated with the Santa Paula Creek occurs in the northeast portion of the basin.

A recent study by UWCD (2013c) of groundwater levels in Santa Paula basin concluded that wells with shallow screens near the SCR had the least variability in levels, as shown by the hydrograph in **Figure 3-10**. This is likely due to the buffering effect of the SCR as a recharge source. Wells located farther from the SCR and in deeper portions of the aquifer had more variable groundwater levels and greater dry-year responses. The report also documented a long-term decline of approximately 20 feet over the last 67 years in wells screened in the San Pedro Formation and older alluvium sediments located farther away from the SCR. The contour map in **Figure 3-10** displays alluvium and San Pedro formation groundwater levels.

The Santa Paula basin is primarily recharged by percolation of surface water from the SCR and Santa Paula Creek, direct percolation of precipitation on the exposed San Pedro Formation, and underflow from Fillmore basin. Other sources of recharge include irrigation return flow and septic tanks.

Discharge from the Santa Paula basin includes groundwater pumping and outflow to the Mound and Oxnard Forebay basins. Some rising water occurs in the eastern portion of the basin, although this could be considered groundwater that is discharged from the upstream Fillmore basin.

---

[3] Other authors have listed different areas for the Santa Paula basin based on different extents (UWCD, 1996; DWR, 2003). The areas presented here are the surface area of the study planning area basins depicted in **Figure 3-2**.

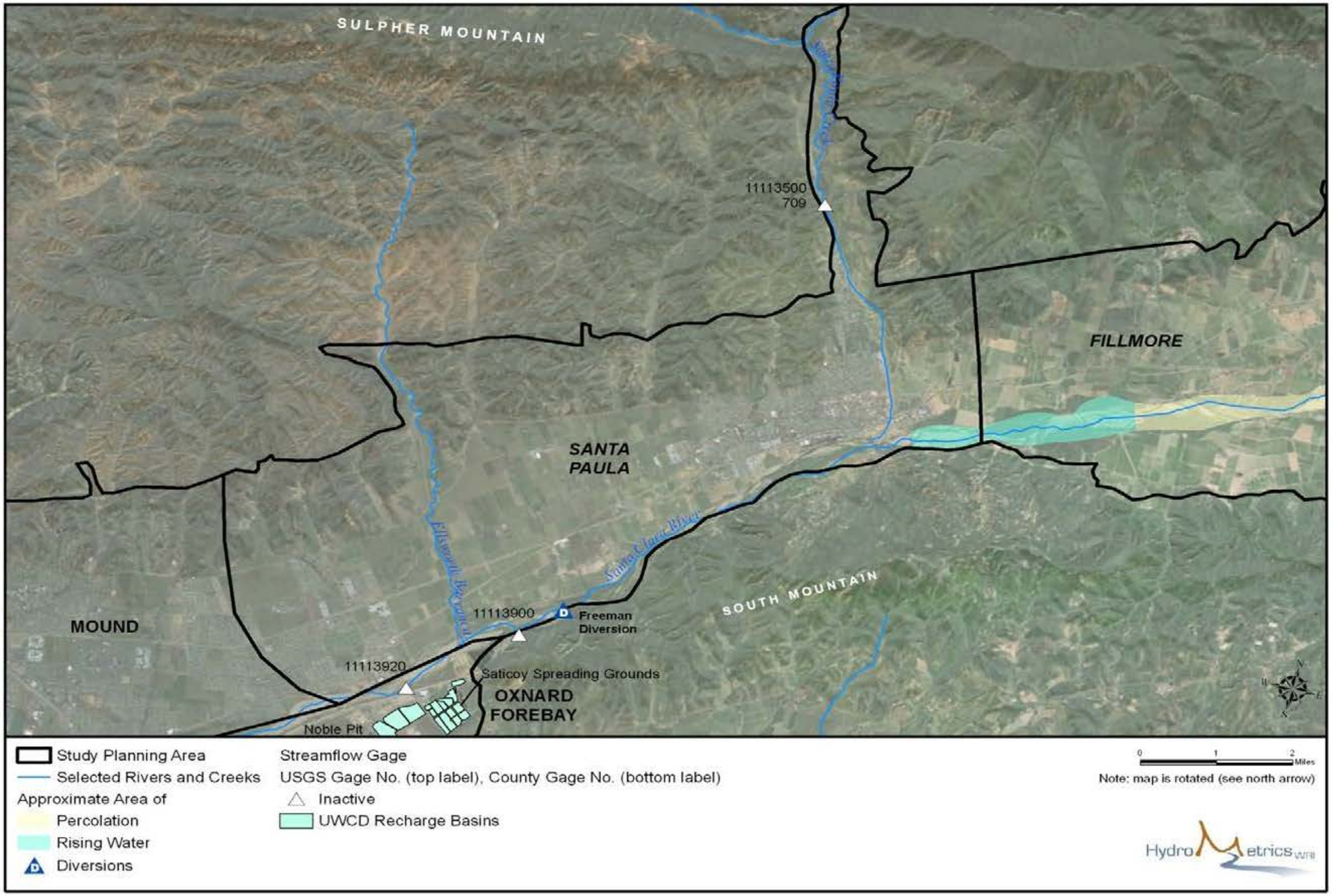

Figure 3-9 Santa Paula Basin

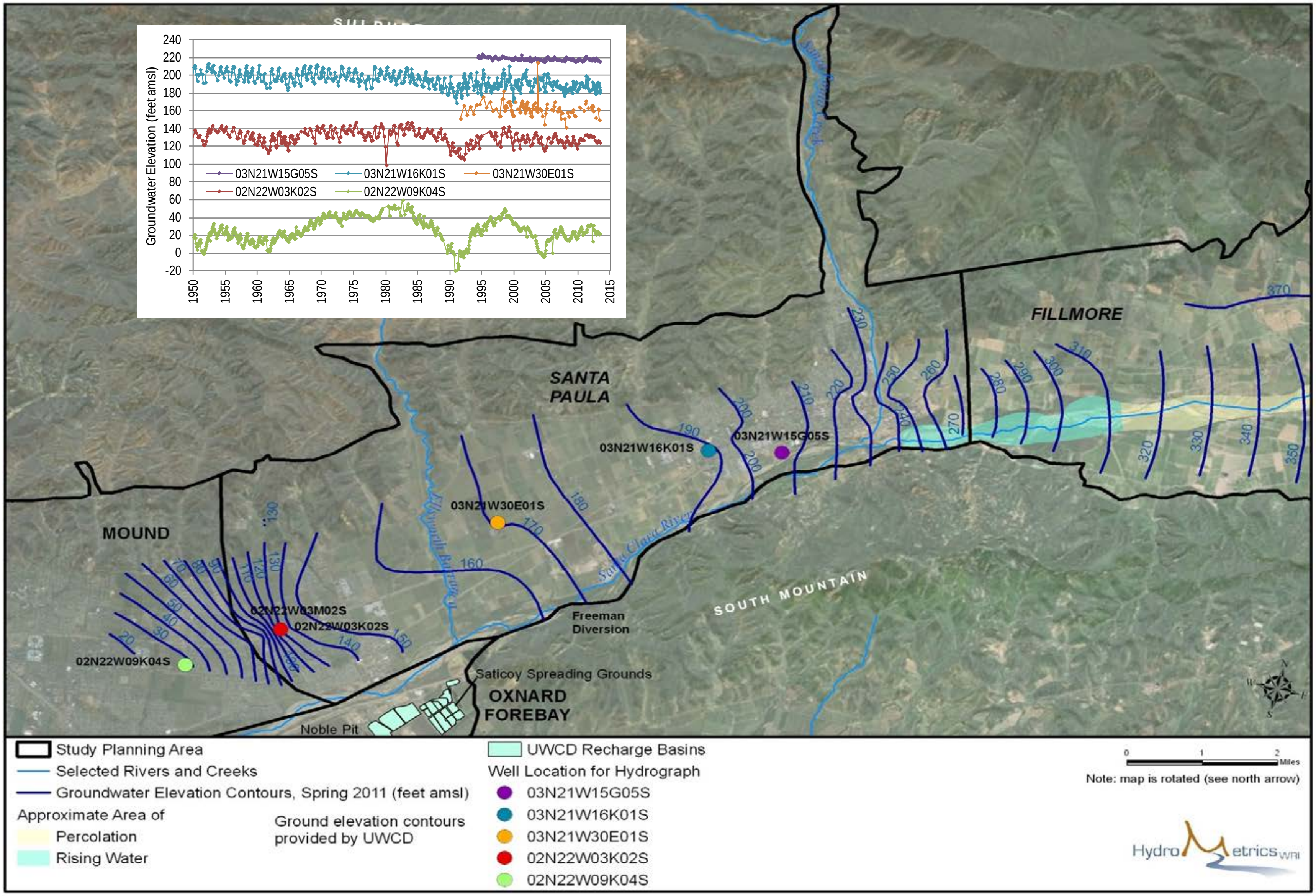

Figure 3-10 Santa Paula Basin Groundwater Elevations

3.1.4 Mound Basin

The Mound basin, overlying a low lying alluvial plain, is immediately downstream of the Santa Paula basin and shares its eastern boundary with Santa Paula basin's western boundary (**Figure 3-11**). The basin's northern boundary is confined to the valley by the Ventura Foothills, north of the City of Ventura. Its southern boundary coincides approximately with the Montalvo anticline (UWCD, 2012b), which separates it from the Oxnard Forebay and Oxnard Plain basins to the south (**Figure 3-11**). The lowermost portion of the SCR transects the southern boundary of the Mound basin; this is the only part of the SCR that flows through the Mound basin. The Pacific Ocean bounds the basin on the west. The Mound basin is approximately 5.5 miles long by 4 miles wide, with an area of 14,850 acres.[4] Surface elevation along the SCR changes approximately 100 feet over its length, resulting in a gradient of approximately 18 feet per mile.

The Mound basin fills a portion of the east-west trending, west plunging Ventura syncline (UWCD, 2012a). The northern basin boundary extends to include the exposed area of the San Pedro formation in the Ventura foothills, and its southern boundary coincides with the axis of the Montalvo anticline (**Figure 3-3**). There are several faults in and around the Mound basin, but none have displacements large enough to juxtapose the San Pedro formation against the low-permeability Santa Barbara formation (UWCD, 2012a). UWCD believes that groundwater flow across the Oak Ridge and Ventura faults is probable (UWCD, 2012a).

The Mound basin contains Quaternary sediments deposited on a wide delta complex that formed at the terminus of the SCR. This depositional environment has resulted in a wide variety of alluvial sediments comprising lagoonal, beach, flood plain, alluvial fan, terrace, and marine terrace deposits (UWCD, 2012a). The underlying San Pedro formation comprises marine and continental clays, silts, sands and gravels. The San Pedro formation is exposed at surface outcrops along the northern boundary of the basin and in two mounds in the south-central portion of the basin. These mounds are the namesake of the Mound basin (UWCD, 2012a).

The alluvium and San Pedro formation contain the basin's primary aquifers. The UAS comprises undifferentiated younger alluvium (Oxnard aquifer) and older alluvium (Mugu aquifer). The younger alluvium is made up of interbedded clays with some silts, sands, and gravels deposited in active river plain and fan environments (UWCD, 2012a). Coarser sediments are sparse and occur as lenticular deposits within the predominantly finer-grained materials.

Up to 450 feet of undifferentiated older alluvium unconformably underlies the younger alluvium and unconformably overlies the San Pedro formation. The upper portion of the older alluvium is predominantly fine-grained and the lower portion is predominantly coarse-grained (UWCD, 2012a). It is within this coarse-grained unit, which is considered the Mugu aquifer, that the majority of the Mound basin's productions wells are screened (UWCD, 2012a). Lateral facies changes in the UAS result in the sediments becoming more finely bedded and fine-grained in a northerly direction from the basin's southern boundary (UWCD, 2012a).

The LAS is comprised of the San Pedro formation which has a maximum thickness of approximately 4,500 feet in the center of the Ventura syncline (UWCD, 2012a). Its thickness

[4] Other authors have listed different areas for the Mound and Oxnard Forebay basins based on different extents (UWCD, 1996; DWR, 2003). The areas presented here are the surface area of the study planning area basins depicted in **Figure 3-2**.

decreases towards the sides of the syncline (i.e., north and south boundaries of the basin), with the southern boundary having considerably less thickness due to a history of folding, faulting, and subsequent erosion (UWCD, 2012a). The upper San Pedro formation contains the Hueneme aquifer, which comprises a series of interconnected water-bearing sands which are limited to the northern portion of the basin (UWCD, 2012a). The lower portion of the San Pedro formation is primarily sands and gravels that comprise the Fox Canyon aquifer which extends to the Oxnard Plain. The nature of these sediments changes across the Mound basin, with beds becoming thinner and more lenticular to the north.

Groundwater flows parallel to the basin axis, from east to west, and has a relatively gentle gradient. Because of a lack of wells and groundwater level records in the northern and eastern portions of the basin, there is an "imperfect understanding of groundwater source and movement in some locations" (UWCD, 2012a). Where data are available, they show that groundwater elevations decrease from east to west across the basin, and there can be variability in groundwater levels between wells close together. The groundwater gradient across the basin is relative flat during dry periods, and increases slightly following periods of above-average precipitation (UWCD, 2012b). Due to the lack of groundwater data and poor distribution of available data, groundwater elevation maps have not been prepared for this basin. **Figure 3-12** provides hydrographs for representative wells in the basin.

Sources of recharge to the Mound basin include underflow from adjacent basins (Santa Paula, Oxnard Plain, and Oxnard Forebay), mountain front recharge from the Ventura Foothills, irrigation return flow, and direct percolation of precipitation on the San Pedro formation exposed along the basin's northern boundary.

Sources of discharge from the Mound basin include groundwater production and outflow to the ocean.

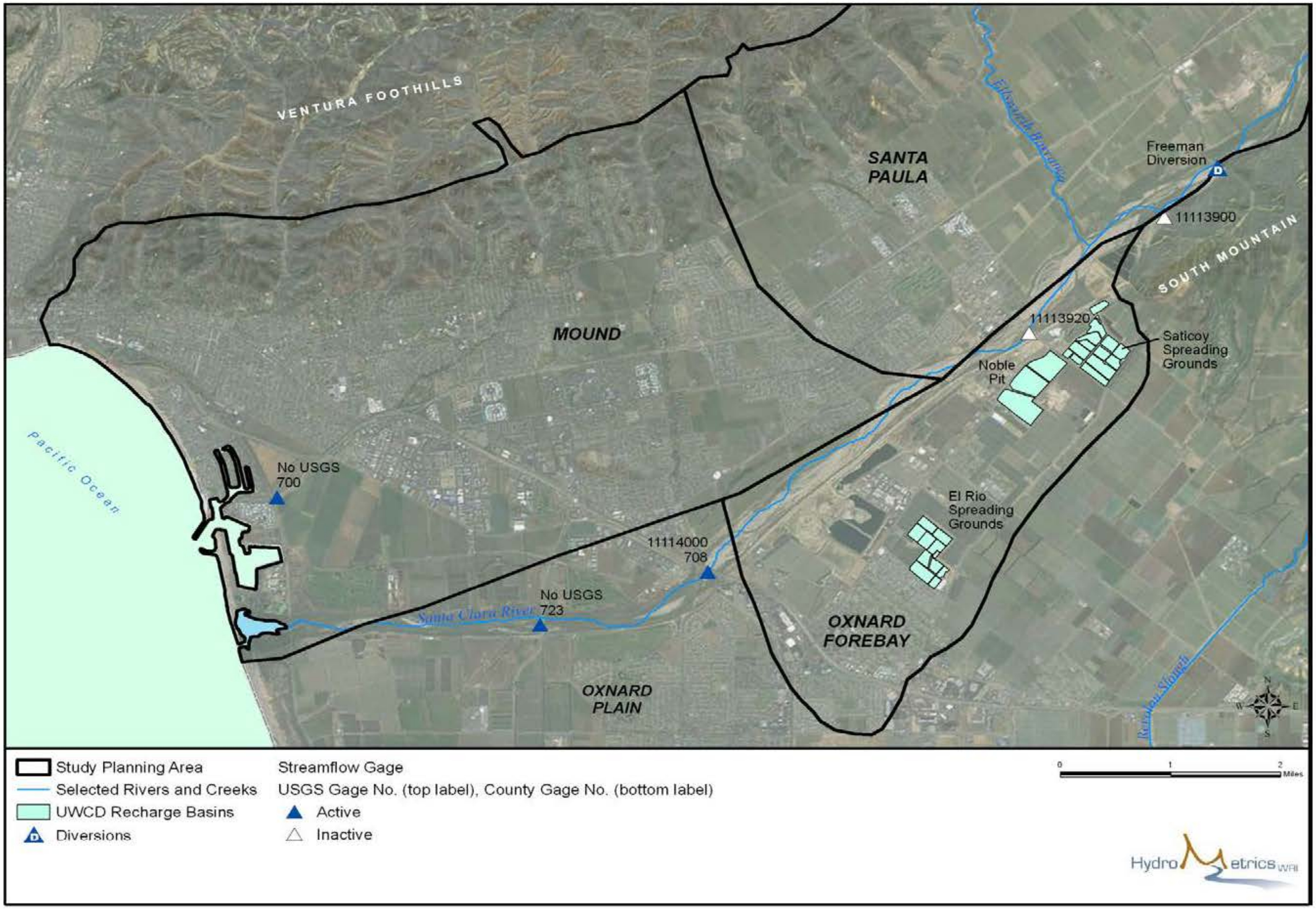

Figure 3-11 Mound and Oxnard Forebay Basins

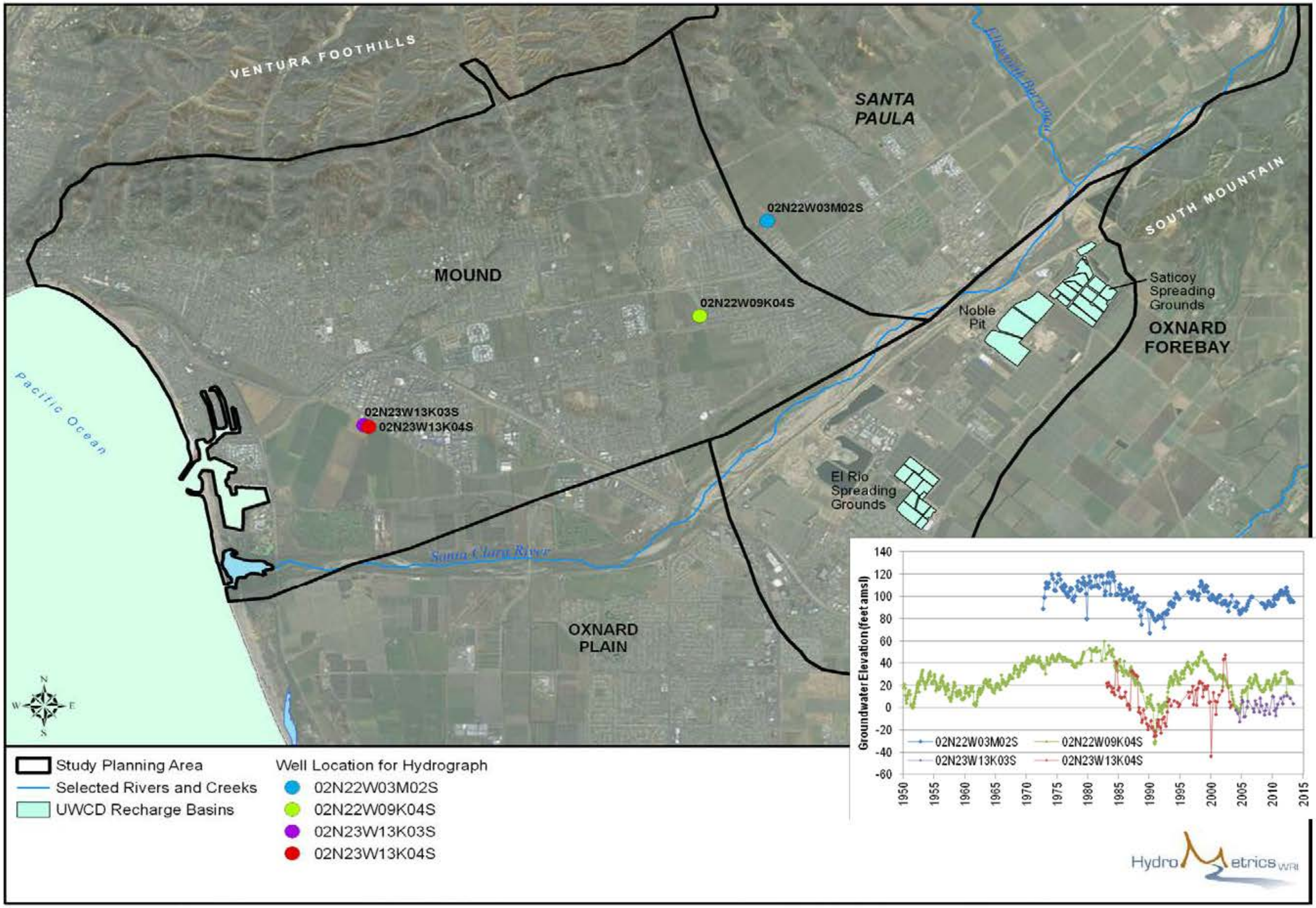

Figure 3-12 Mound Basin Groundwater Hydrographs

3.1.5 Oxnard Forebay Basin

The Oxnard Forebay is bordered by the Santa Paula and Mound basins on its northern boundary and surrounded by the Oxnard Plain basin on its west and south boundary (**Figure 3-11**). The nose of the South Mountain occurs at the northeastern extent of the basin. The Oxnard Forebay is delineated as the unconfined portion of the Oxnard Plain basin (UWCD, 2008), and is the main source of recharge to the Oxnard Plain. The Oxnard Forebay basin has an approximate area of 5,370 acres[5] with a length of approximately 5.5 miles and width of 2.4 miles. Surface elevation along the SCR changes approximately 40 feet over its length within the basin, resulting in a gentle gradient of approximately 7 feet per mile.

The unconfined Oxnard Forebay contains both the UAS and LAS (**Figure 3-13**). As the Oxnard Forebay basin aquifers are in direct hydraulic connection with the confined aquifer of the Oxnard Plain basin, it is the primary source of recharge to that basin (**Figure 3-13**). The Oxnard Forebay basin is also a source of recharge to other adjacent and regional basins: Mound, West Las Posas, and Pleasant Valley, but the majority of its groundwater underflow is downgradient to the Oxnard Plain basin (UWCD, 2012b).

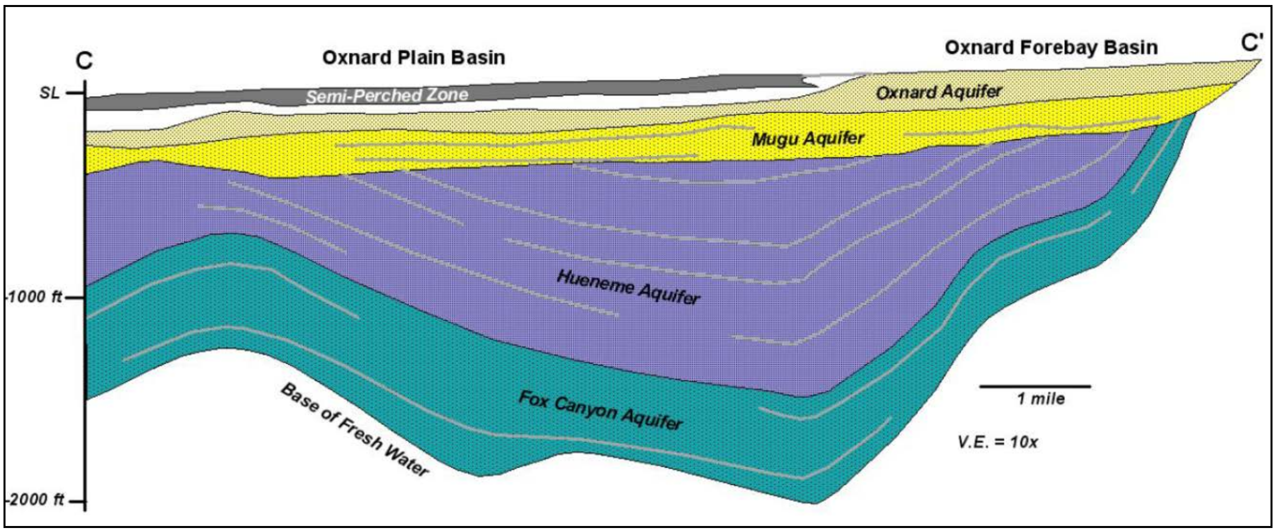

Figure 3-13 Schematic Cross Section of Aquifer Systems of the Oxnard Plain and Forebay Basin (from UWCD, 2012a)

The UAS (Oxnard and Mugu aquifers) in the Oxnard Forebay basin consists primarily of coarse-grained alluvium deposited by the ancestral Santa Clara River and is laterally extensive over the entire basin. A geophysical investigation in the basin has shown the Oxnard aquifer to range in thickness from roughly 200 to 280 feet (UWCD, 2013c). The UAS lies unconformably over the LAS. Along the Montalvo anticline, the LAS in the area between the El Rio and Saticoy spreading grounds has been uplifted and truncated along its contact with the UAS (UWCD, 2013c). It is estimated that 20% of surface recharge in this area percolates into the LAS, with the remainder recharging the UAS (UWCD, 2012b).

[5] Other authors have listed different areas for the Mound and Oxnard Forebay basins based on different extents (UWCD, 1996; DWR, 2003). The areas presented here are the surface area of the study planning area basins depicted in **Figure 3-2**.

Groundwater flows from the Santa Paula basin into the Oxnard Forebay basin. From the Oxnard Forebay basin groundwater flows out to the adjacent Mound, Oxnard Plain, and Las Posas basins. **Figure 3-14** shows groundwater elevation contours for both the UAS and LAS for the Oxnard Forebay basin. The LAS contour map only partially covers the Oxnard Forebay basin due to a lack of data. Representative hydrographs are also included with the elevation map.

Percolation of SCR flows between the UWCD SCR surface water diversion (Freeman Diversion) and the 101 bridge, managed aquifer recharge, irrigation return flows, and direct percolation of precipitation are major sources of groundwater recharge to the Oxnard Forebay basin, with minor sources from mountain front recharge generated from the nose of South Mountain and underflow from adjacent basins (UWCD, 2012b and UWCD, 2013c).

Groundwater in the basin is discharged by groundwater pumping and outflow to the adjacent Mound and Oxnard Plain basins.

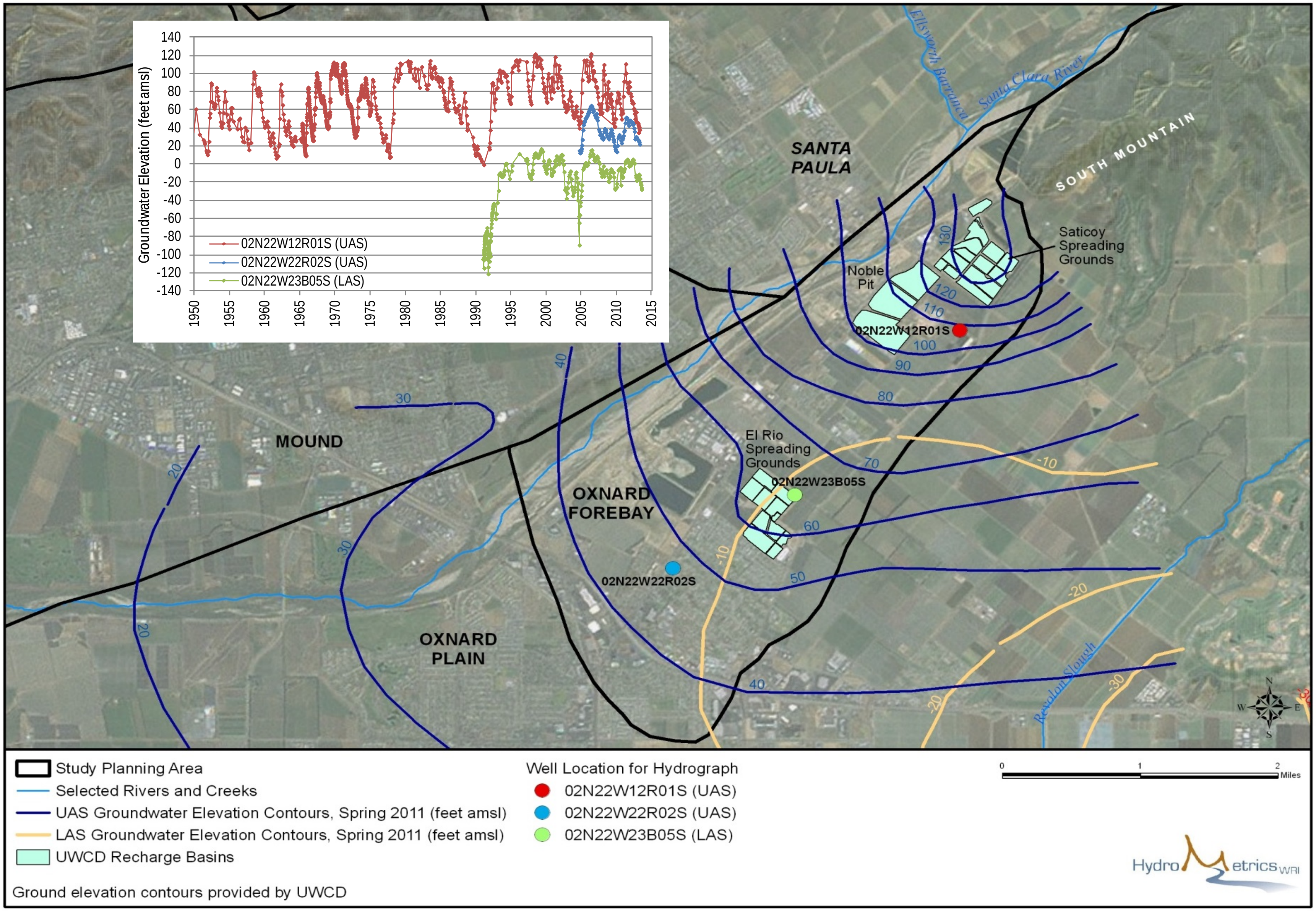

Figure 3-14 Oxnard Forebay Basin Groundwater Elevations

3.2 CLIMATE

The LSCR area experiences a Mediterranean climate, with mild wet winters and hot dry summers. Seventy-five percent of the annual precipitation falls between December and March (**Figure 3-15**). Rainfall generally increases with elevation. The average monthly distribution of precipitation is shown in **Figure 3-16**. Within the study area, precipitation ranges from 14 inches per year at the coast to over 20 inches per year at higher elevations. Of all the study area basins, the Fillmore basin receives the greatest amount of precipitation. Precipitation close to 40 inches per year falls in the high elevation headwaters of the SCR's northern tributaries. Precipitation declines in an inland direction beginning at the eastern end of the Piru basin. **Table 3-1** characterizes the precipitation stations included in **Figure 3-16**.

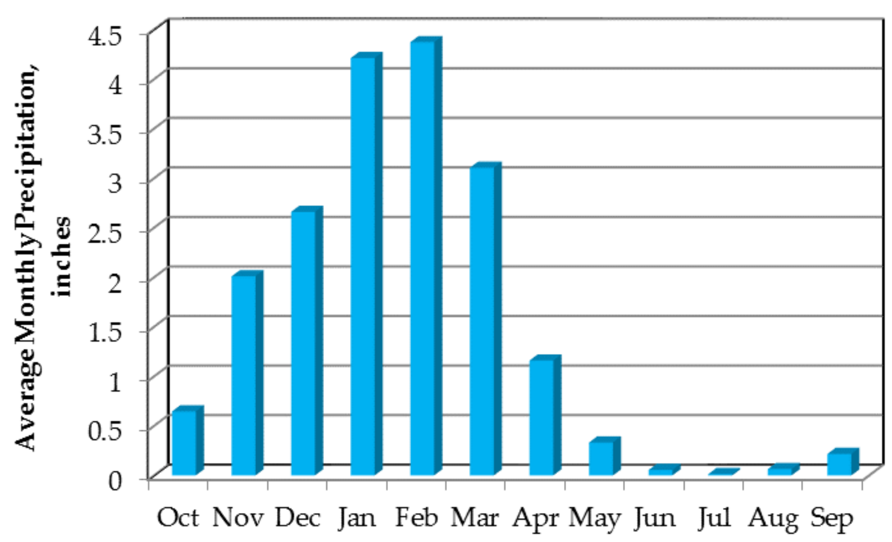

Figure 3-15 Average Monthly Precipitation at Fillmore - Fish Hatchery (Station 171), Water Year 1957 through 2012.

A cumulative departure from mean annual precipitation chart is shown in **Figure 3-17** for the Fillmore Fish Hatchery station. The cumulative departure curve depicts the dry and wet cycles experienced since 1957. The area is currently experiencing a dry cycle that started after nearly record high precipitation in 2005. Some of the driest years on record were recorded in 2007, 2013, and 2014.

Table 3-1 Summary of Active Precipitation Stations

Ventura County Watershed Protection District Station Name and Number	Elevation (feet above MSL)	Period of Record	Mean Precipitation Water Year 1980 – 2012 (inches)
El Rio-UWCD Spreading Grounds #239	105	09/30/1972 – 05/20/2012	15.8
Ventura-Hall Canyon #167	180	10/01/1956 – 06/05/2013	16.9
Santa Paula-UWCD #245	260	10/01/1960 – 09/30/1986	18.9[1]
Santa Paula-UWCD A #245A	300	10/01/1986 – 10/27/2010	

Table 3-1 Summary of Active Precipitation Stations

Ventura County Watershed Protection District Station Name and Number	Elevation (feet above MSL)	Period of Record	Mean Precipitation Water Year 1980 – 2012 (inches)
Santa Paula - Wilson Ranch #245B	410	10/01/2010 – 05/15/2013	
Ventura-County Government Center #222A	280	10/01/1977 – 02/27/2013	16.9
Fillmore-Fish Hatchery #171	465	10/01/1956 – 05/10/2013	19.6
Piru-Newhall Ranch #025	825	10/01/1927 – 09/30/2013	18.4
Piru-Temescal Guard Station #160	1,080	10/01/1949 – 09/30/2012	21.5

[1] Mean precipitation for the Santa Paula station was obtained by combining the data for Station #245, #245A, and #245B.

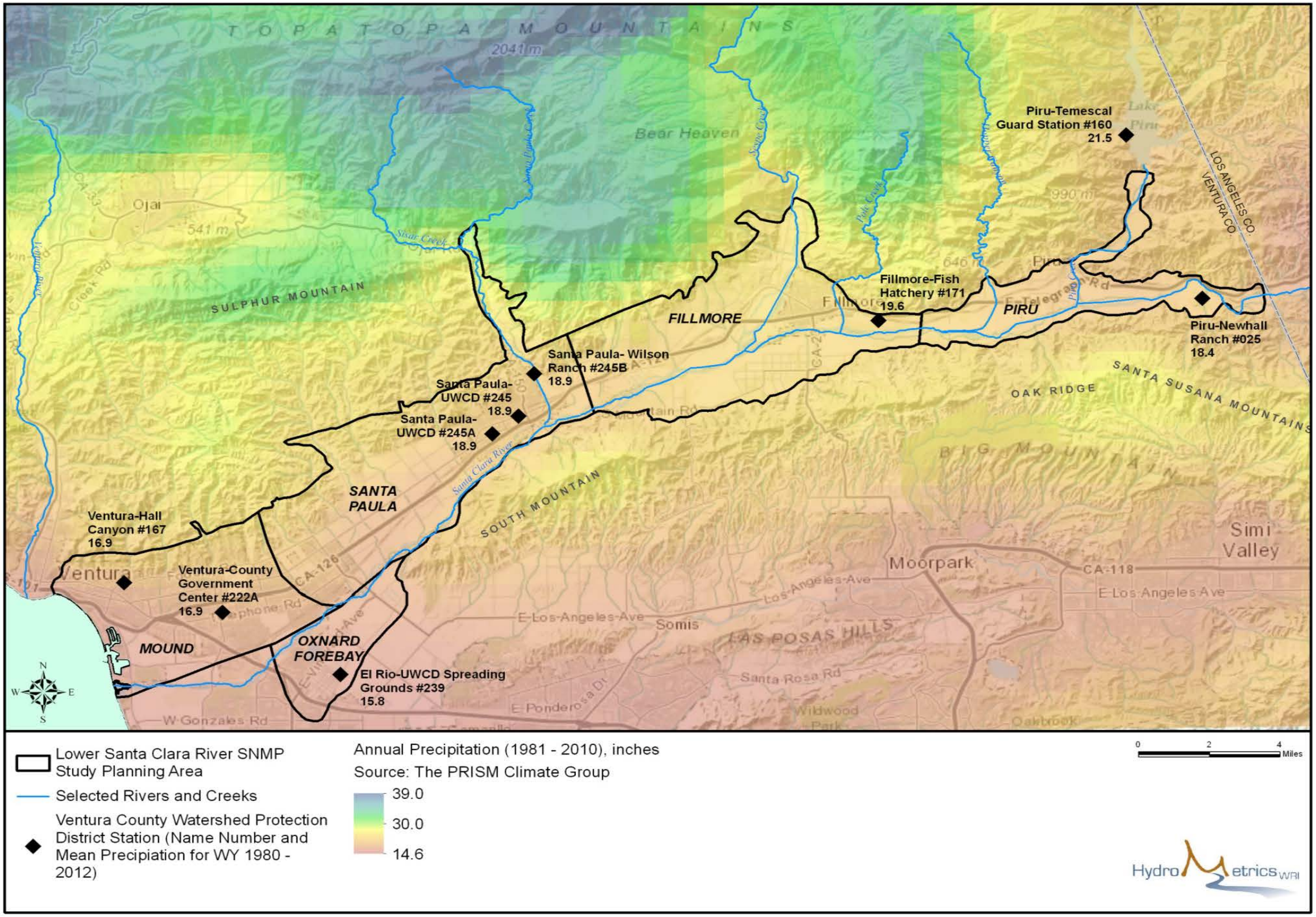

Figure 3-16 Precipitation Distribution in the Lower Santa Clara River Area

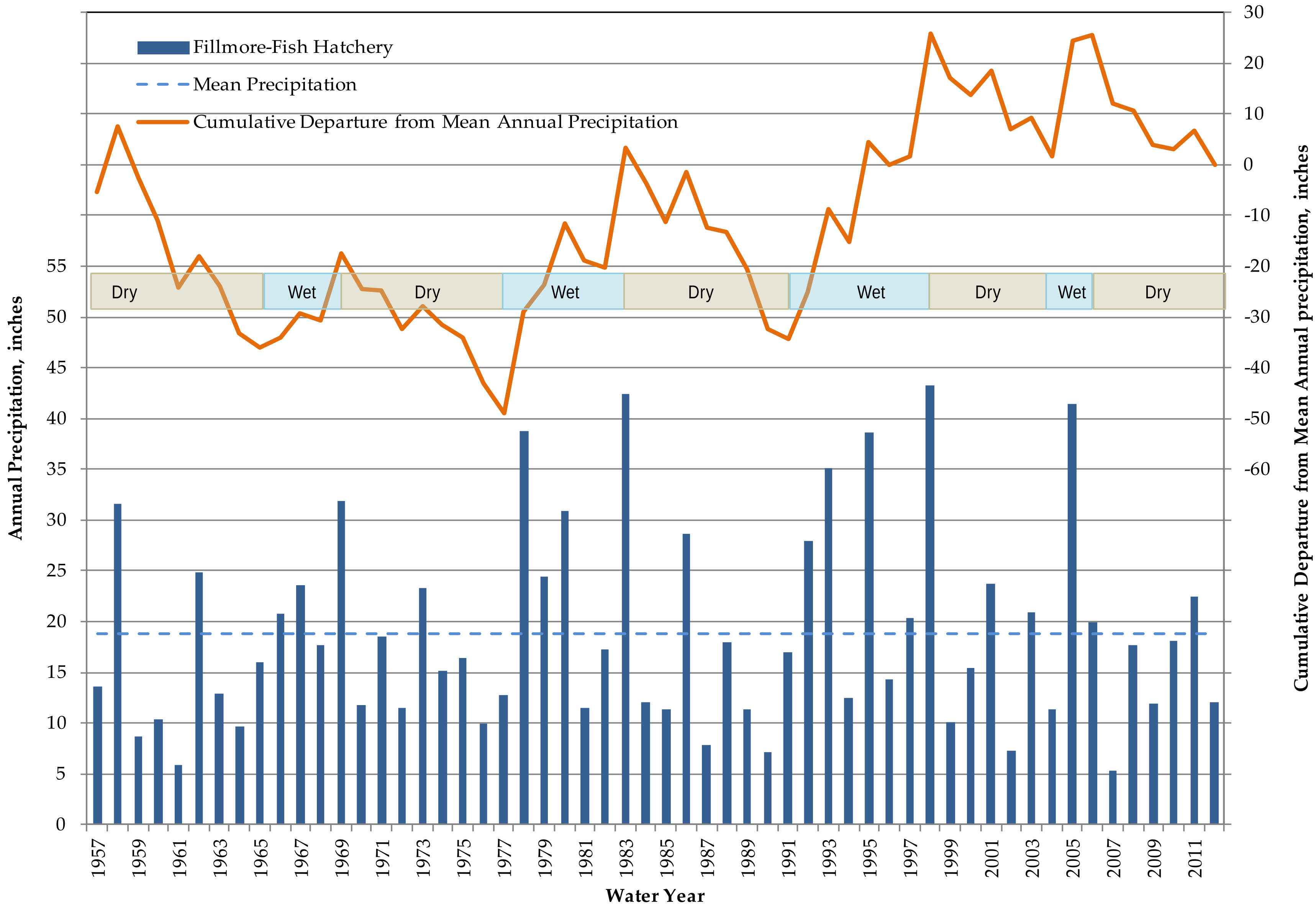

Figure 3-17 Cumulative Departure from Mean Annual Precipitation - Fillmore Fish Hatchery

3.3 SURFACE HYDROLOGY

The SCR is the predominant river in the study area (**Figure 3-18**). Extending 84 miles from its headwaters in Los Angeles County's San Gabriel Mountains to the Pacific Ocean, it is one of the largest river systems in southern California (Ventura County, 2006). The SCR's catchment covers an area of 1,634 square miles of which 60 percent is located in Ventura County. The catchment includes Lake Piru and Pyramid Lake, which are two major surface water bodies tributary to the LSCR that are used for water storage and have regulated releases. Both these water bodies are located on Piru Creek, with Pyramid Lake located approximately 13 miles upstream of Lake Piru (**Figure 3-18**).

Due to the climatic precipitation pattern, natural streamflow in the SCR and major tributaries is intermittent to ephemeral, with streamflow occurring primarily during December to April. Most streamflow occurs as floodflow (United States Geological Survey [USGS], 2003). Flow in the LSCR study area is influenced by upstream SCR flow from Los Angeles County, flow from its tributaries, and the permeability of its riverbed alluvium. Major tributaries of the LSCR include the Piru, Sespe, and Santa Paula Creeks (**Figure 3-18**). The nature of the LSCR catchment and climate produces intermittent flow, which can increase rapidly in response to high intensity rainfall (AMEC Earth & Environmental, 2005). LSCR flows are supplemented by controlled releases of stored Piru Creek winter runoff behind Lake Piru's Santa Felicia Dam, thereby decreasing the number of days with no flow in the LSCR (USGS, 2003). State Water Project releases from Pyramid Lake are also transported down the Piru Creek channel to users in the valley or Oxnard Plain.

The majority of flow in the SCR is generated from the LSCR catchment. Flow from Los Angeles County accounts for only 20% of the total river flow, despite the Los Angeles catchment making up 40% of the SCR's total catchment area (UWCD, 2012b). Dry-season base flows from Los Angeles are comprised of wastewater discharges from WWTPs, irrigation runoff, and groundwater discharge to the SCR. Since 1978, increasing wastewater discharge to the SCR in Los Angeles County has increased the base flow across the county line from 10 cubic feet per second (cfs) to approximately 20 cfs (USGS, 2003). This is shown in the first hydrograph in **Figure 3-19.**

Hydrographs of daily mean streamflow for selected gages in the LSCR are included in Figure 3-19 and Figure 3-20.

Streambed percolation of surface flows is a major source of natural recharge to the LSCR groundwater basins. During dry and normal flows, percolation of SCR flow into the permeable riverbed alluvium causes surface flows to cease in the Piru basin between just downstream of the County line and Piru Creek. Groundwater discharge (rising groundwater) approximately two miles east of the City of Fillmore restores flow to the LSCR. This is visible on aerial photographs where the riverbed becomes vegetated at the Piru/Fillmore basin boundary (**Figure 3-21**).

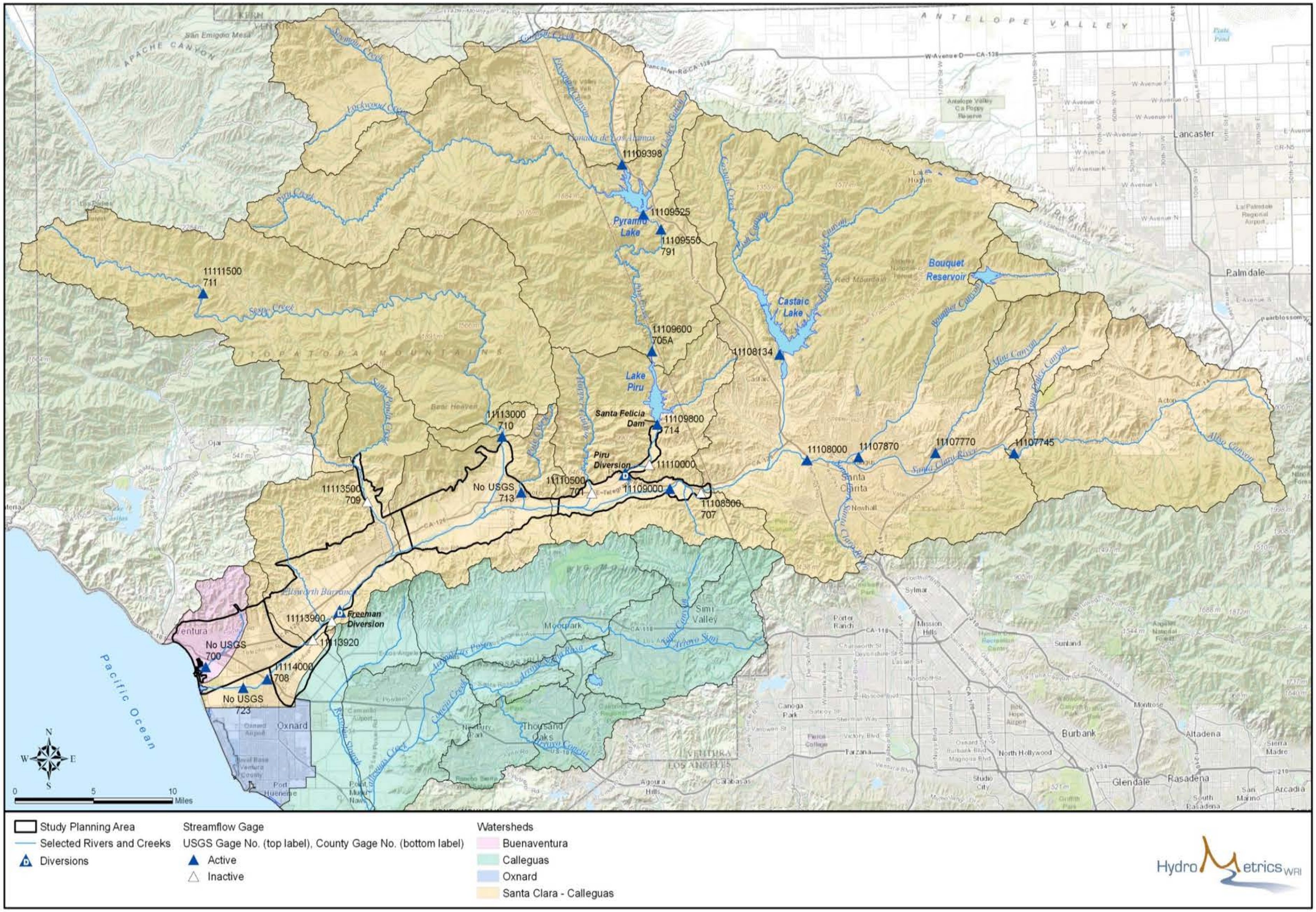

Figure 3-18 Santa Clara River Catchment

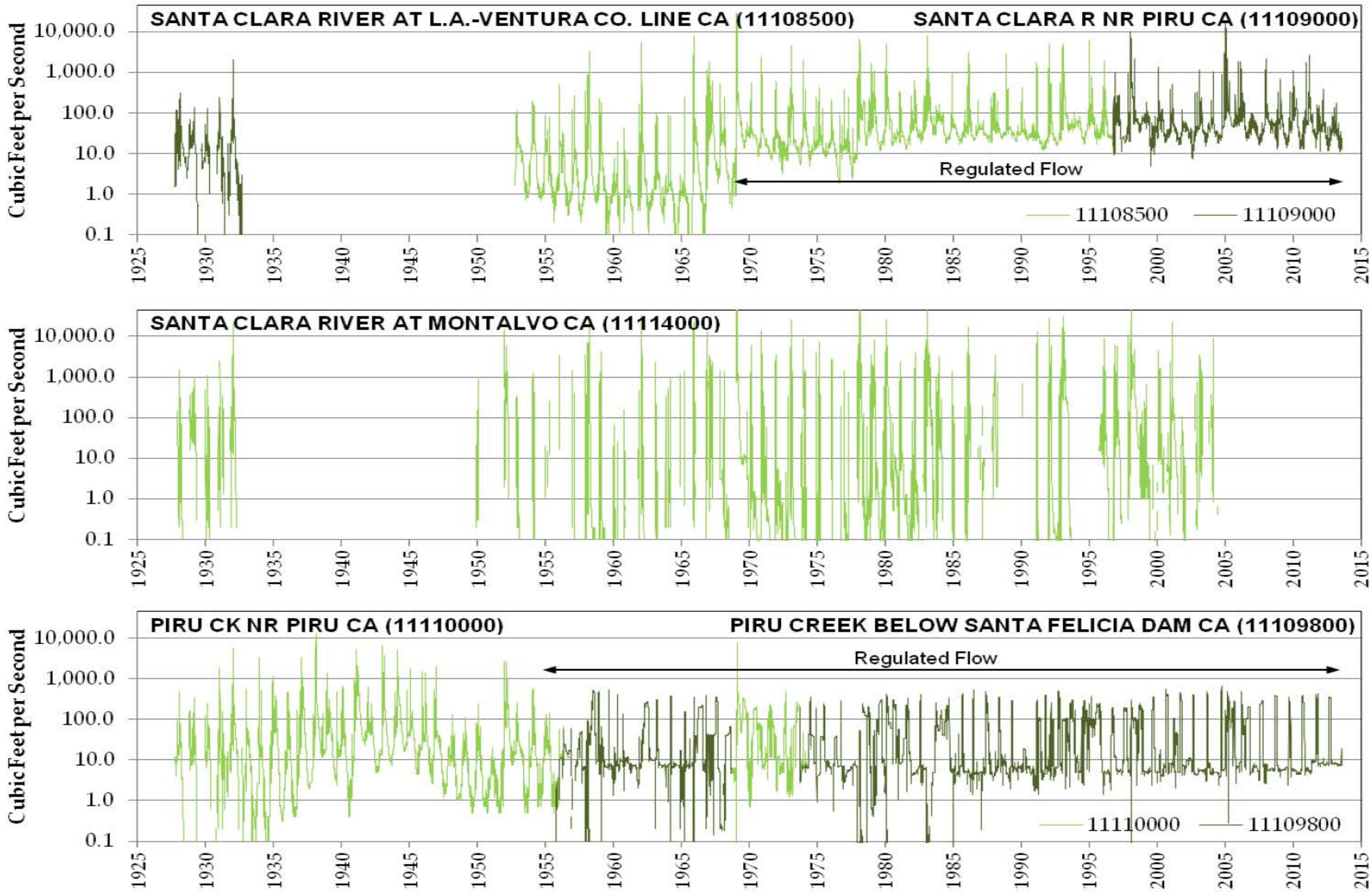

Figure 3-19 Daily Mean Streamflow for the Lower Santa Clara River and Piru Creek

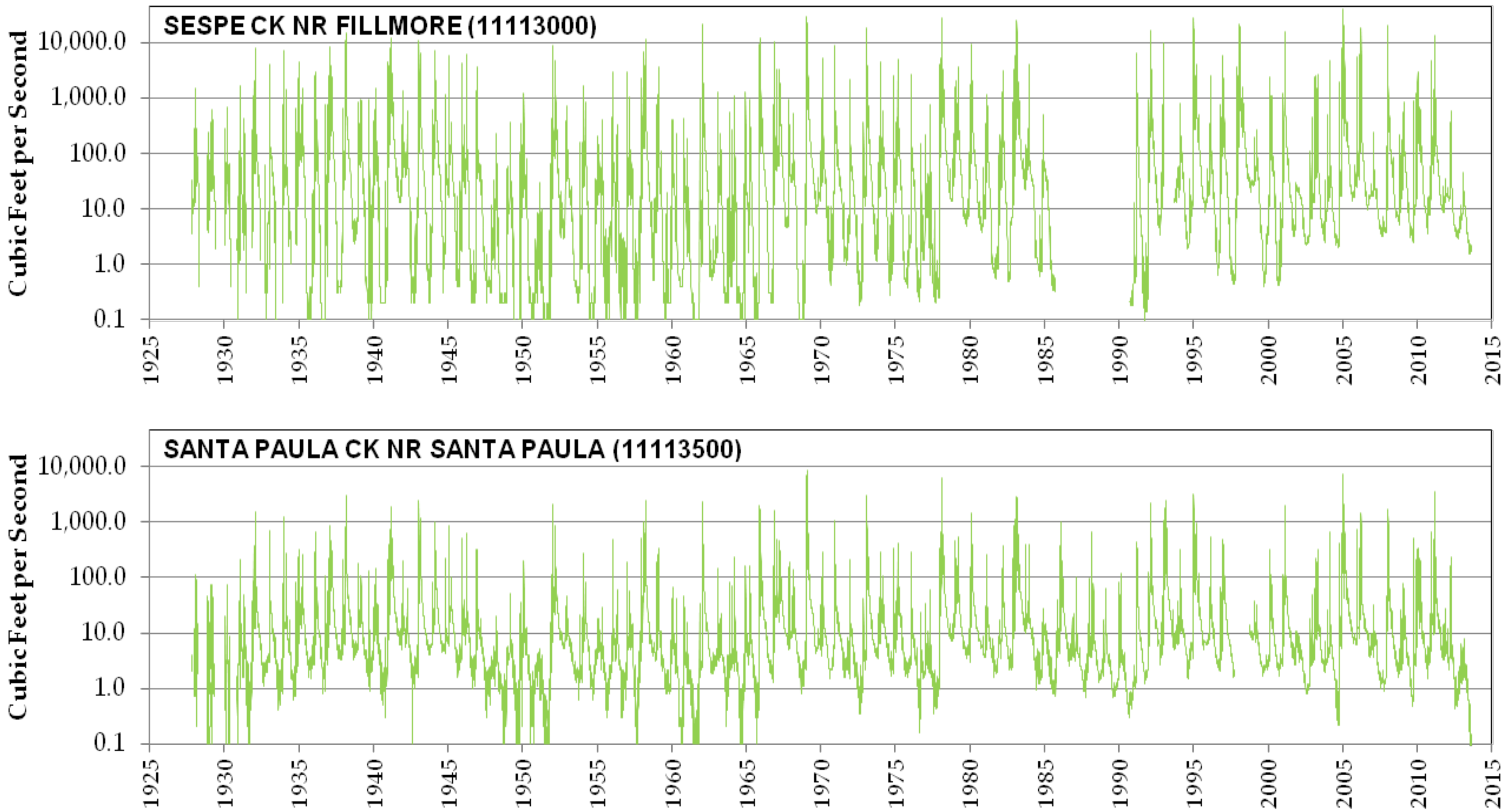

Figure 3-20 Daily Mean Streamflow for Sespe and Santa Paula Creeks

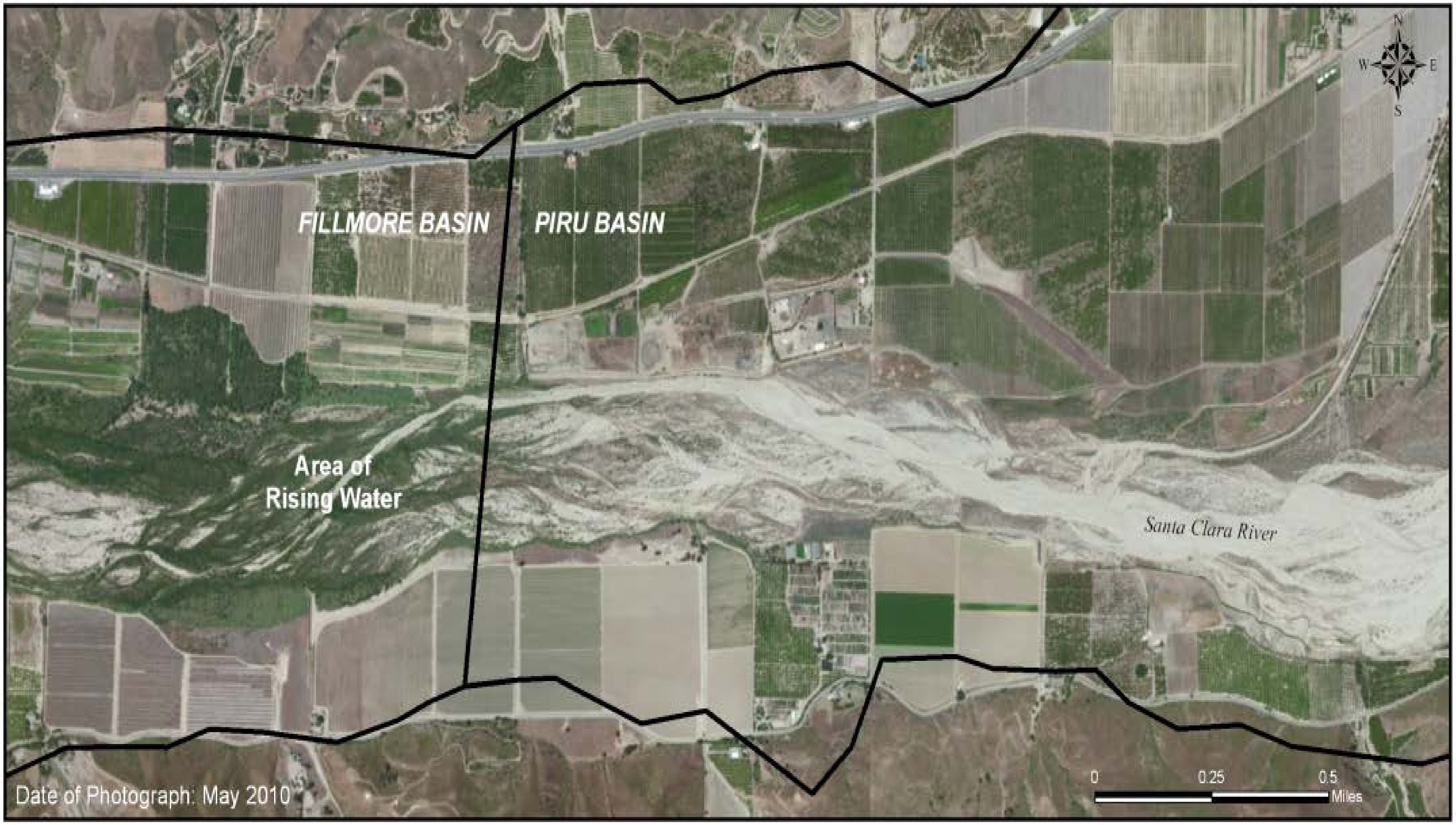

Figure 3-21 Rising Groundwater at the Piru/ Fillmore Basin Boundary

3.4 WATER SOURCES

Water purveyors supply water within the LSCR area from a number of sources. Surface and groundwater have been used and managed conjunctively for many years in the LSCR basin, both for water supply and managed aquifer recharge operations.

3.4.1 Surface Water

The SCR and Piru Creek are the primary sources of surface water to the LSCR area. Diversion structures are used to remove water from the channel for various uses. The Piru Diversion on the lower Piru Creek is currently not in use by UWCD (**Figure 3-5** and **Figure 3-18**). When it is operational, it diverts water from Piru Creek into the Piru Spreading Grounds for groundwater recharge **Figure 3-5** and **Figure 3-22** provides a chart of UWCD's diversions since 1955. Several mutual water companies using water for agricultural irrigation operate small diversions located on Piru Creek, Sespe Creek, Santa Paula Creek, and the SCR for agricultural irrigation. For the most part, the amounts of water diverted at these locations are unknown.

Releases from Piru Reservoir at Santa Felicia Dam and natural runoff in the SCR percolates naturally into the Piru, Fillmore, and Santa Paula basins. SCR flow in the Santa Paula basin can be diverted at UWCD's Freeman Diversion, ten miles upstream from the river mouth at the Pacific Ocean (**Figure 3-18**). Water diverted at this facility is delivered to UWCD's Saticoy, El Rio, and Noble recharge basins, and delivered directly for agricultural irrigation to groundwater basins outside the study area through the Pumping Trough Pipeline and Pleasant Valley Delivery System.

Table 3-2 summarizes estimates of downstream water use from Santa Felicia Dam releases. These values include imported water amounts that are summarized in **Table 3-3**. Surface water is not diverted for any other purpose aside from groundwater recharge and agricultural irrigation.

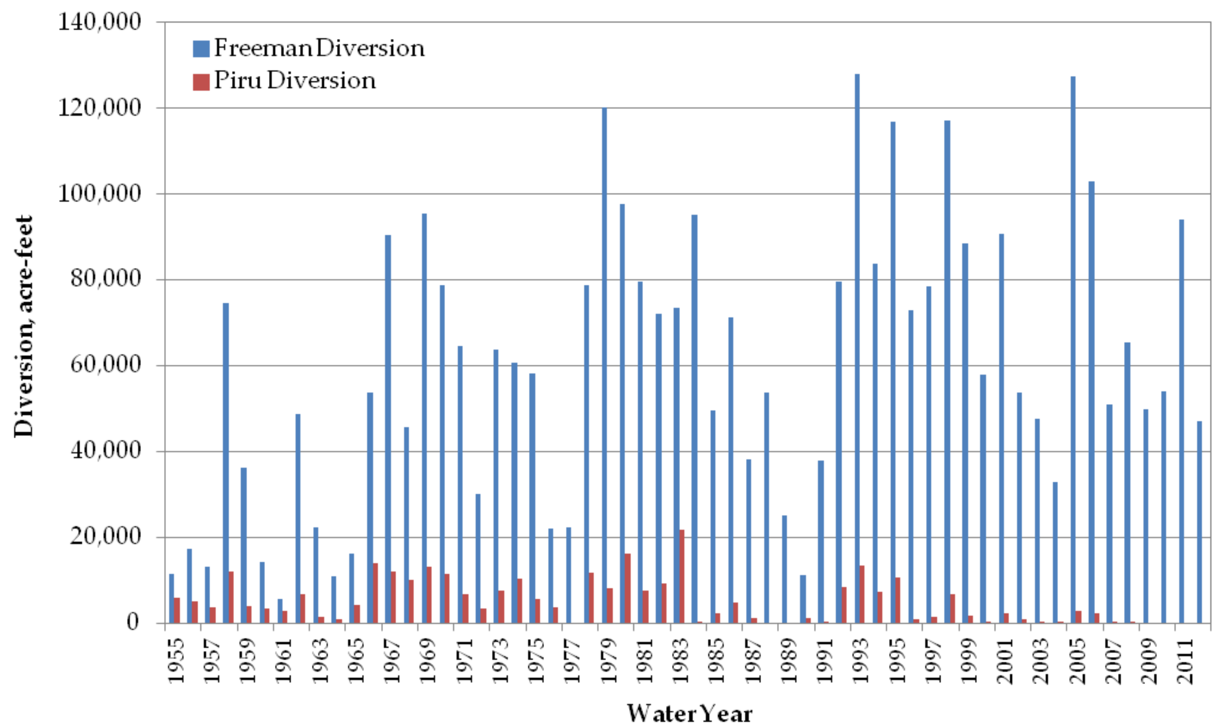

Figure 3-22 History of Surface Water Diversions by UWCD

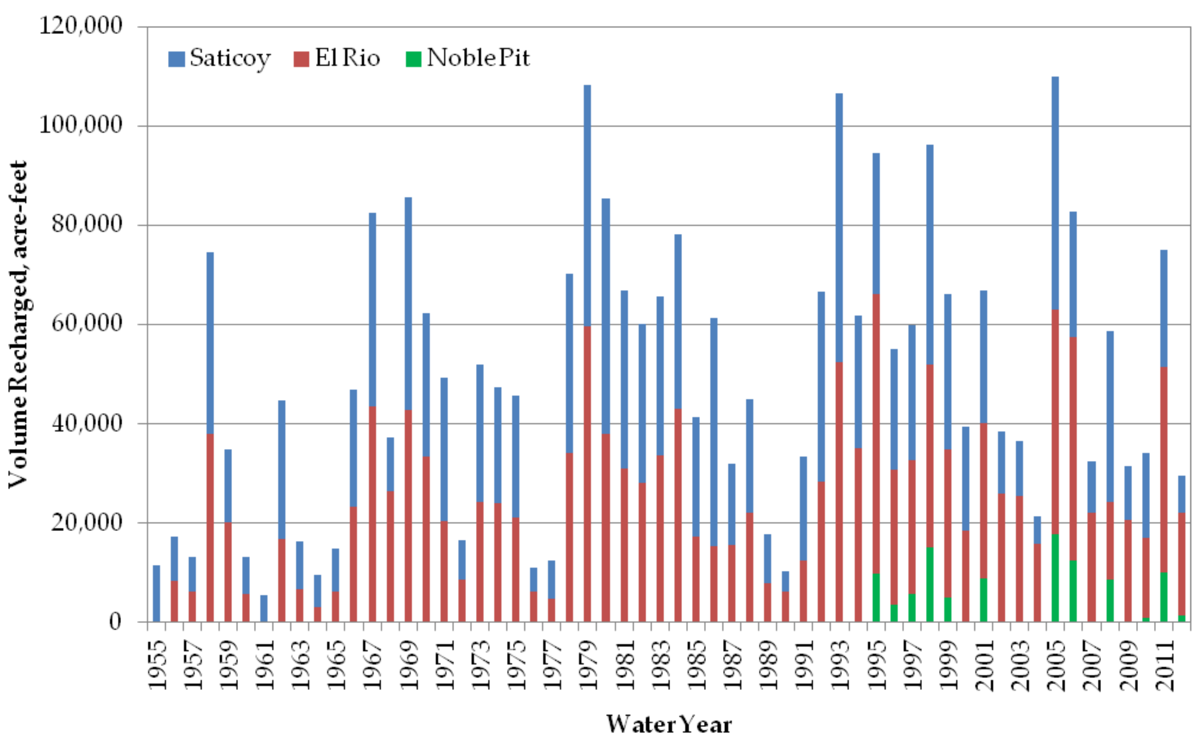

Figure 3-23 History of UWCD Oxnard Forebay Basin Managed Aquifer Recharge

Table 3-2 Summary of Conservation Releases from Santa Felicia Dam

Year	Acre-Feet				
	Total Released From Santa Felicia Dam	Natural Percolation		Released to Santa Paula and Coastal Basins	
		Released to Piru Basin	Released to Fillmore Basin	Groundwater Recharge in Santa Paula & Oxnard Forebay Basins	Delivered to PV and PTP
1999	22,800	5,700	3,500	11,200	2,400
2000	47,200	13,800	6,100	24,150	3,150
2001	47,400	14,000	2,900	28,300	2,200
2002	20,200	8,000	5,100	6,530	570
2003	29,000	21,000	3,500	3,600	900
2004	12,200	8,000	2,150	1,600	550
2005	32,500	9,600	1,000	21,700	150
2006	30,900	11,100	1,000	17,200	1,600
2007	40,700	15,900	6,300	12,200	6,400
2008	44,400	15,400	5,700	17,400	5,800
2009	26,700	13,200	4,700	5,200	3,000
2010	33,000	14,500	4,800	10,700	3,200
2011	31,700	12,400	3,300	14,100	1,600
2012	35,200	13,600	8,600	9,300	3,700
Total	453,900	176,200	58,650	183,180	35,220

Notes: 2005 had two conservation releases. A portion of the release includes spill water when the lake was full. These values include imported water from Pyramid Lake.

PV - Pleasant Valley Delivery System

PTP - Pumping Trough Pipeline

Source of data: UWCD

3.4.2 Imported Water

State Water Project water has been imported by UWCD since 1991. Ventura County has been allocated 20,000 acre-feet (AF) of State Water Project water. Of this amount, 3,150 AF is purchased and delivered to Pyramid Lake and sent to Lake Piru by UWCD (UWCD, 2012b). The amount of water allocated to UWCD each year depends on availability, and delivery is only allowed from November 1 through the end of February. Each year, UWCD plans water releases from Santa Felicia Dam that take into account the lake's minimum pool and the timing of State Water Project deliveries. The water released from Santa Felicia Dam flows down Piru Creek into the SCR overlying the Piru Basin (**Figure 3-18**). Under low release rates, the majority of released water percolates through the SCR streambed into the groundwater basins. Higher flow rates allow for the creation of channels in the alluvium that convey the released water farther down the SCR. **Table 3-3** provides an estimate of the fate of State Water Project releases from Santa Felicia Dam.

Table 3-3 Summary of State Water Project Releases from Santa Felicia Dam

<table>
<tr><th rowspan="3">Year of Purchase</th><th colspan="4">Acre-Feet</th></tr>
<tr><th colspan="2">Natural Percolation</th><th colspan="2">Recharged to Santa Paula and Coastal Basins</th></tr>
<tr><th>Released From Santa Felicia Dam</th><th>Released to Fillmore and Piru Basins</th><th>Groundwater Recharge in Santa Paula & Oxnard Forebay Basins</th><th>Delivered to PV and PTP</th></tr>
<tr><td>1991</td><td>4,836</td><td>3,603</td><td>1,233</td><td>0</td></tr>
<tr><td>1992</td><td>988</td><td>84</td><td>904</td><td>0</td></tr>
<tr><td>2000</td><td>2,200</td><td>406</td><td>1,725</td><td>69</td></tr>
<tr><td>2002</td><td>3,150</td><td>1,455</td><td>1,503</td><td>192</td></tr>
<tr><td>2003</td><td>3,150</td><td>2,041</td><td>1,039</td><td>70</td></tr>
<tr><td>2004</td><td>4,047</td><td>3,348</td><td>472</td><td>228</td></tr>
<tr><td>2007</td><td>1,890</td><td>844</td><td>930</td><td>116</td></tr>
<tr><td>2008</td><td>1,980</td><td>673</td><td>1,001</td><td>306</td></tr>
<tr><td>2009</td><td>3,150</td><td>1,045</td><td>1,381</td><td>724</td></tr>
<tr><td>2010</td><td>3,150</td><td>917</td><td>1,674</td><td>559</td></tr>
<tr><td>2011</td><td>2,520[1]</td><td rowspan="2">1,770</td><td rowspan="2">2,803</td><td rowspan="2">1,097</td></tr>
<tr><td>2012</td><td>3150</td></tr>
<tr><td>Total</td><td>34,212</td><td>16,186</td><td>18,026</td><td>3,361</td></tr>
</table>

Notes: State Water Project water has not been purchased every year.
PV - Pleasant Valley Delivery System
PTP - Pumping Trough Pipeline
[1] released in 2012 conservation release
Source of data: UWCD.

3.4.3 Groundwater

Groundwater pumping for agricultural irrigation, municipal and domestic, and industrial use occurs in each of the groundwater basins of the study area. Within its service area, UWCD estimates production data from reported metered readings, pump electrical records, or crop type and acreage. **Figure 3-24** shows the location of production wells in the study area. Production data for each of the study planning area basins were provided by UWCD.

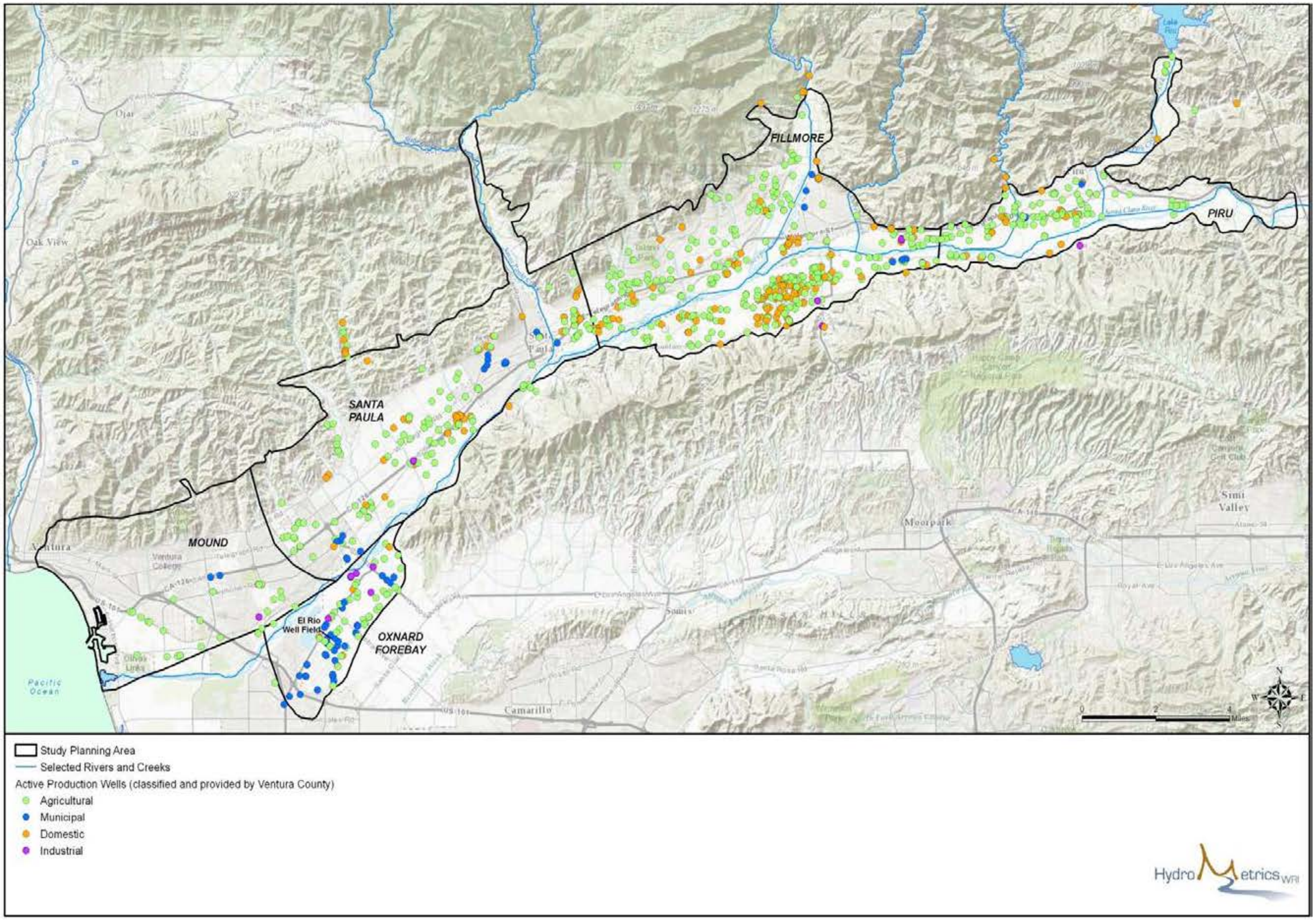

Figure 3-24 Location of Active Production Wells

3.4.3.1 Piru Basin

Groundwater production in the Piru basin is predominantly for agricultural irrigation (**Figure 3-25**). In comparison, approximately 4% of groundwater pumped is used for municipal and industrial purposes. While the distribution of pumping throughout the basin is fairly uniform, the southeastern portion of the basin has very few active wells (UWCD, 2012b).

3.4.3.2 Fillmore Basin

Averaging 44,900 acre-feet per year (AFY) from 1996 through 2012, the Fillmore basin produces the greatest amount of groundwater of all the study area basins. Consistent with land use, agricultural pumping accounts for over 92% of groundwater production (**Figure 3-25**). The Fillmore Fish Hatchery, near the eastern basin boundary, is one of the major agricultural users of groundwater in the basin; in 2011 it used 22% of all groundwater pumped from the basin (UWCD, 2012b). There are 12 mutual water companies that serve water primarily to agricultural users. The area south of the SCR (**Figure 3-24**), called the Bardsdale area, does not have any mutual water companies and therefore has a high density of private agricultural wells pumping relatively small volumes (UWCD, 2012b). The City of Fillmore is one of the larger municipal suppliers in the basin; its three wells are located in the northern Pole Creek fan area (**Figure 3-24**).

3.4.3.3 Santa Paula Basin

The Santa Paula basin uses approximately 20% of its average 27,900 AFY (from 1996 through 2012) groundwater production for municipal and industrial purposes (**Figure 3-25**). The City of Santa Paula is one of the main municipal producers. Several irrigation companies operate in the Santa Paula basin distributing irrigation water to areas that have groundwater of relatively poorer quality (i.e., high mineral content of the ambient groundwater), such as in the canyons and foothills in the northern portion of the basin (UWCD, 2012b), subsequently this area has few wells. **Figure 3-24** shows the northern portion of the Santa Paula basin.

3.4.3.4 Mound Basin

Fifty-five percent of the Mound basin's groundwater extraction is for agricultural irrigation (**Figure 3-26**). The majority of the municipal and industrial production is by the City of Ventura (UWCD, 2012b). Production in the Mound basin varies annually due to operational and water quality issues. Over the period from 1996 through 2012, annual production in the Mound basin varied from 4,700 to 9,100 AF, with an average of 7,100 AFY.

3.4.3.5 Oxnard Forebay Basin

The Oxnard Forebay basin produces groundwater primarily for municipal and industrial consumption. Agricultural pumping accounts for approximately 30% of the 22,000 AFY pumped from the basin (**Figure 3-26**). The El Rio well field supplies water to the Oxnard-Hueneme area: the City of Oxnard, the Port Hueneme Water Agency, and a number of mutual water companies in the Oxnard Forebay and the northern Oxnard Plain. Production from the well field is variable depending on demand which can change considerably as the City of Oxnard has alternative sources of water it can use depending on availability. The well field extracts from both the UAS and LAS, but mostly from the UAS.

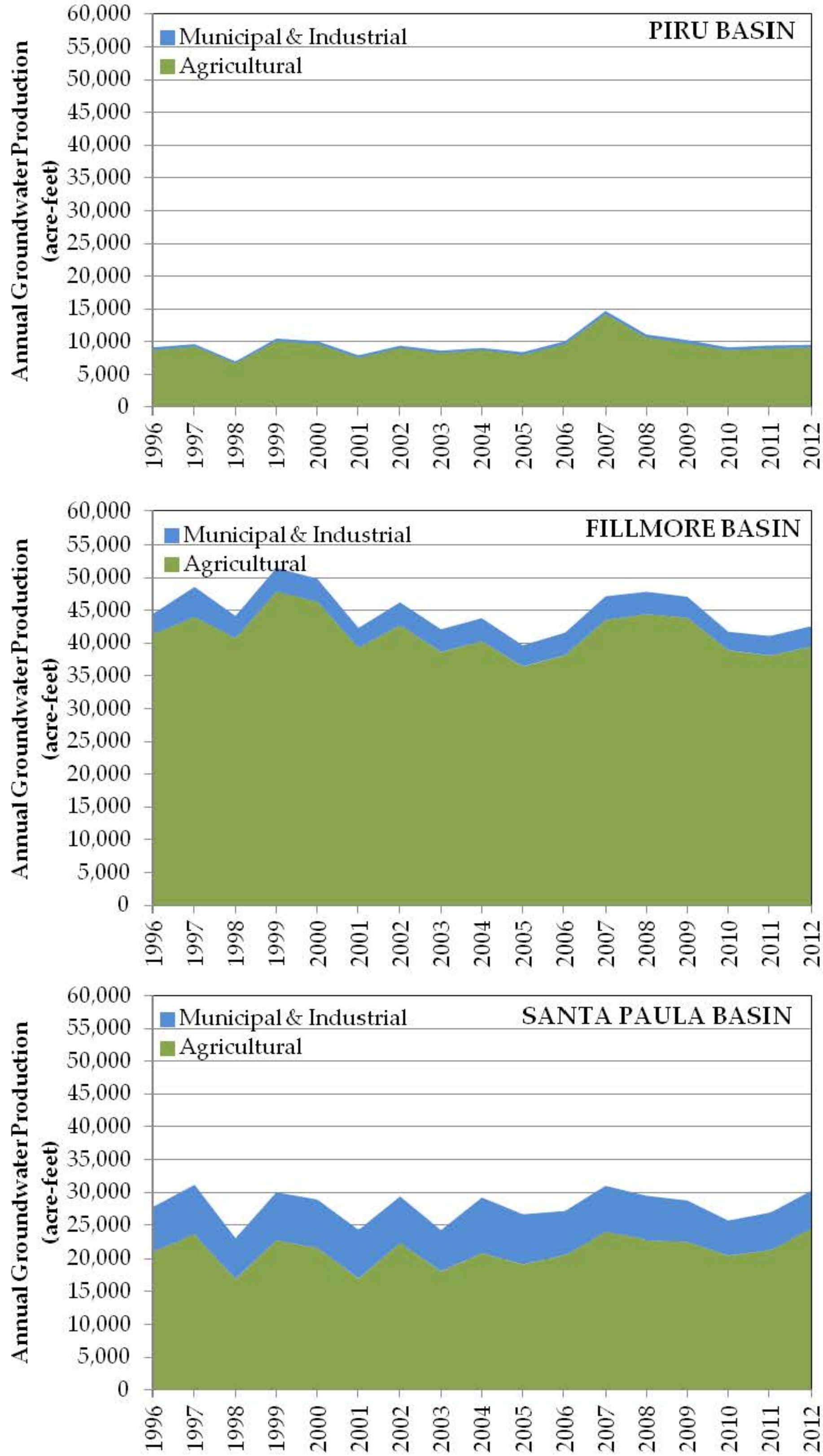

Figure 3-25 Groundwater Production in the Piru, Fillmore, and Santa Paula Basins

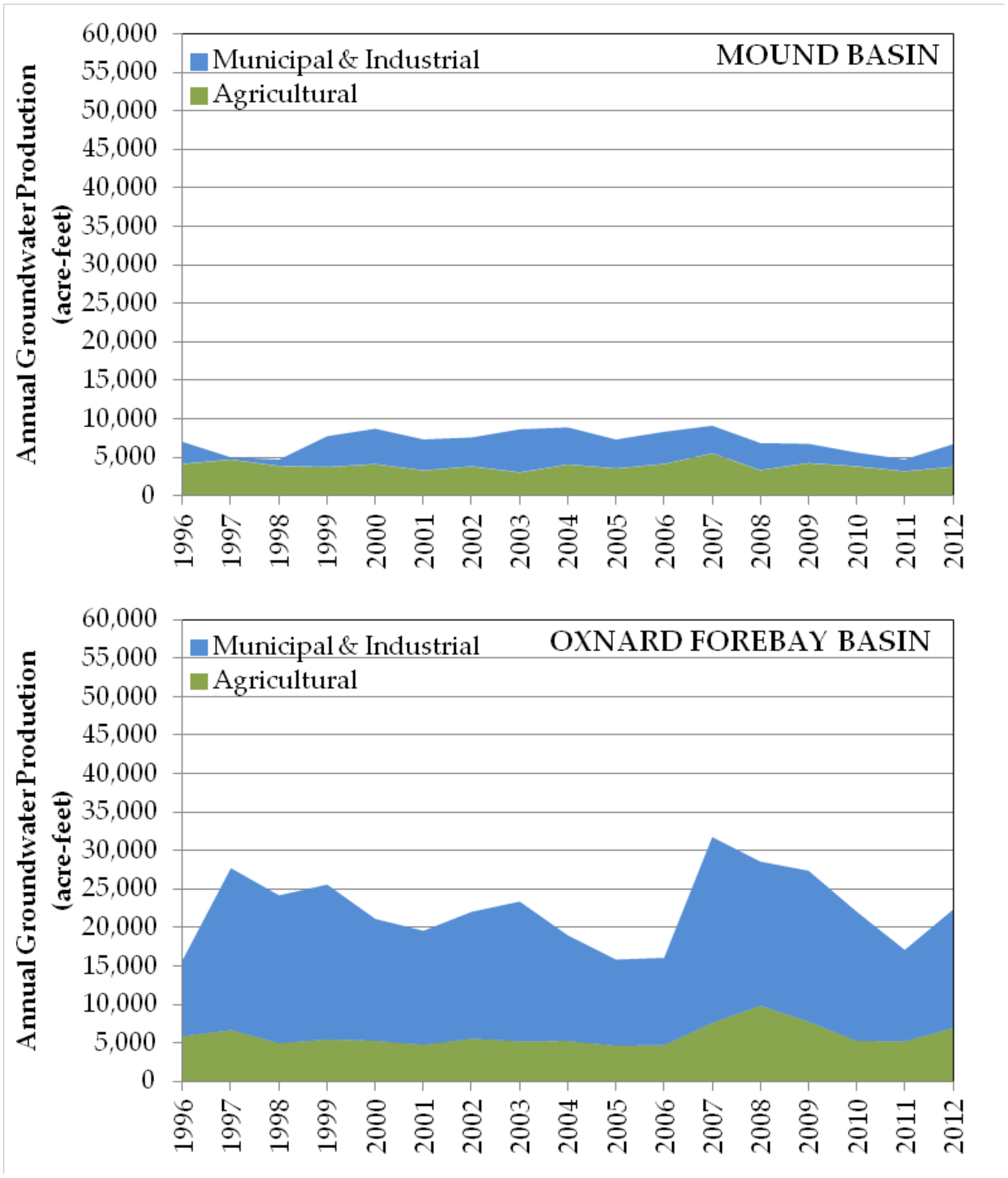

Figure 3-26 Groundwater Production in the Mound and Oxnard Forebay Basins

3.4.4 Recycled Water

District 16's WWTP (completed in 2010) produces secondary treated effluent. The facility consisting of an influent pump station, screenings facility, oxidation ditches for biological nitrogen removal, secondary clarifiers, aerobic digesters, sludge pumping and drying, and an effluent pump station for discharge to percolation ponds. There are plans to use the recycled water for agricultural irrigation. Currently treated wastewater is percolated in ponds near the confluence of Hopper Canyon and the SCR.

The City of Fillmore's new WWTP completed in 2009 was designed with a membrane bioreactor (MBR) system and an ultraviolet (UV) disinfection system that produces recycled water suitable for irrigation. This recycled water is delivered to nearby recharge basins and subsurface irrigation systems in parks and schools throughout the city.

The City of Santa Paula water recycling facility, completed in 2010, produces tertiary treated recycled water that is recharging 13 acres of percolation ponds located to the east of the facility. There are currently plans for the City of Santa Paula to reuse the water in other ways.

The Saticoy Sanitation District operates a small WWTP that percolates treated wastewater into ponds located on the southern edge of the Santa Paula basin. Other small WWTPs such as Limoneira and Olivelands sewer farms, and Todd Road Jail, also percolate treated wastewater into ponds. There are plans for these plants to produce recycled water for irrigation in the future as discussed in **Section 8**.

The City of Ventura's VWRF produces tertiary treated municipal wastewater that is used to irrigate Marina Park, on the north side of the Ventura harbor, Ventura Municipal golf course, Olivas Links golf course, and other landscaped areas located in the vicinity of the SCR in the Mound basin.

The locations of percolation ponds described above are shown on **Figure 3-27**.

A potential future use of recycled water in the Oxnard Forebay basin would supplement diverted surface flows with reverse osmosis (RO) treated wastewater from the City of Oxnard Advanced Water Purification Facility (AWPF) for irrigation and/or managed aquifer recharge in the basin's spreading basins.

3.5 LAND USE AND LAND COVER

The Ventura County General Plan (County of Ventura, 2011) describes the land use overlying the LSCR groundwater basins. **Figure 3-27**shows the land use and crop cover for the study area.

Piru basin's land use is primarily agricultural and open space in the flood plain of the SCR and alongside Piru Creek (**Table 3-4** and **Figure 3-27**). The major crops that are grown in the Piru basin are: row crops, oranges, and nurseries (Table 3-5). Urban areas only account for 3% of the land use.

The Fillmore basin has a similar land use distribution to the Piru basin, with the majority of land used for agriculture, followed by open space along the SCR and Sespe Creek, and along the flanks of the Topatopa Mountains (**Table 3-4**). There is a larger urban area (City of Fillmore) than in the Piru basin. Crops grown in the Fillmore basin are primarily citrus, avocado, row crops, and nurseries (**Table 3-5**).

Urbanization increases westwards in the LSCR. The Santa Paula basin has almost as much urban area as open space (**Table 3-4**). The City of Santa Paula and the eastern portion of the City of Ventura overlie the basin but agriculture is the basin's primary land use. The majority of agricultural acreage in the basin is taken up by lemon and avocado orchards (**Table 3-5**). Row crops, strawberries, and cut flowers together utilize 17% of the agricultural land.

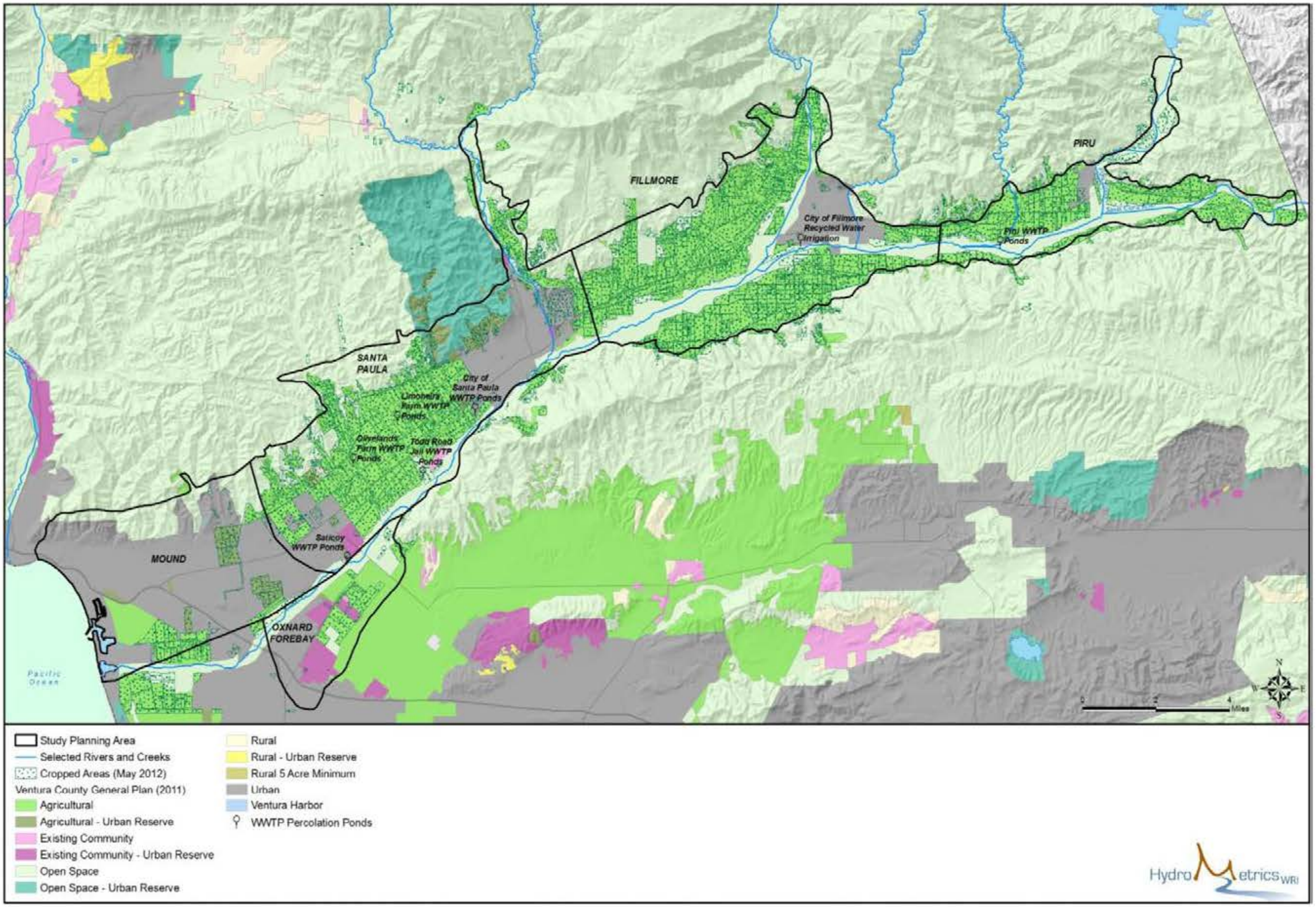

Figure 3-27 Lower Santa Clara River Land Use and Crop Cover

The Mound basin underlies the majority of the City of Ventura, with 69% urban land use in the basin (**Table 3-4**). Open space along the flanks of the Ventura Foothills is the second largest use of land in the basin, followed by 10% agricultural use. The primary crops grown in the Mound basin in decreasing order are: lemons, strawberries, avocado, and row crops. Almost 13% of agricultural land in the Mound basin was fallow in 2012 when the crop data used for this basin description was collected.

Urban/residential land use is predominant in the Oxnard Forebay basin, with strawberries, lemons, row crops, and nurseries comprising the majority of agricultural crops (**Table 3-5)**. Open space along the SCR accounts for 24% of the basin's land use (**Table 3-4**).

Overall, in the five basins comprising the study planning area, the most predominant land use is agriculture, with open space and urban areas taking up the remainder of the area in approximately equal amounts (**Table 3-4**).

Table 3-4 Distribution of Land Use by Basin

Land Use	Percent Acreage in Groundwater Basin					Study Planning Area
	Piru	Fillmore	Santa Paula	Mound	Oxnard Forebay	
Agricultural	53%	61%	42%	10%	34%	42%
Agricultural – Urban Reserve	-	<1%	4%	6%	1%	2%
Existing Community	<1%	-	<1%	-	<1%	<1%
Existing Community – Urban Reserve	-	-	1%	-	15%	2%
Open Space	44%	30%	25%	15%	24%	27%
Open Space – Urban Reserve	-	<1%	4%	<1%	-	1%
Rural	-	-	<1%	-	-	<1%
Rural – Urban Reserve	-	-	<1%	-	-	<1%
Rural 5 Acre Minimum	-	-	<1%	-	-	<1%
Urban	3%	9%	22%	69%	26%	26%
Ventura Harbor	-	-	-	<1%	-	<1%

Source of data: Ventura County General Plan (2011)
Note: The urban reserve classification is applied to all unincorporated land within a city's adopted Sphere of Influence.

Table 3-5 Distribution of Agricultural Activities by Basin (May 2012)

Crop/ Agricultural Type	Percent of Agricultural Land Use					
	Piru	Fillmore	Santa Paula	Mound	Oxnard Forebay	Study Planning Area
Apple	-	<0.1%	<0.1%	-	-	<0.1%
Apricot	-	-	<0.1%	-	-	<0.1%
Artichoke	2.6%	-	-	-	-	0.4%
Avocado	4.7%	30.3%	32.8%	15.9%	0.3%	25.3%
Barley	-	-	-	1.1%	-	0.1%
Basil	-	<0.1%	-	-	-	<0.1%
Beet	-	-	0.2%	-	-	0.1%
Blueberry	-	-	0.1%	-	-	<0.1%
Bok Choy	-	-	-	0.3%	-	<0.1%
Cabbage	-	-	0.6%	-	-	0.2%
Celery	1.0%	0.4%	1.1%	4.2%	-	0.9%
Chard	-	0.2%	-	-	-	0.1%
Cilantro	-	-	-	1.1%	-	0.1%
Cut Flowers	0.2%	0.5%	3.1%	2.4%	1.0%	1.5%
Dill	-	<0.1%	-	-	-	<0.1%
Endive	-	<0.1%	-	-	-	<0.1%
Fallow	-	1.6%	0.9%	12.5%	-	1.7%
Fennel	0.8%	<0.1%	-	-	-	0.1%
Fig	-	-	0.2%	-	-	0.1%
Flower Seed	-	-	0.4%	-	-	0.1%
Grape	-	-	<0.1%	-	-	<0.1%
Grapefruit	2.0%	0.1%	-	-	-	0.4%
Greens	-	0.3%	0.1%	1.0%	-	0.2%
Herbs	-	0.1%	-	1.3%	-	0.1%
Horse	-	<0.1%	-	-	-	<0.1%
Interplanted	0.3%	-	<0.1%	-	-	<0.1%
Kale	-	0.2%	<0.1%	-	-	0.1%
Lemon	6.2%	20.5%	42.0%	28.4%	16.9%	26.2%
Lettuce	-	0.5%	0.4%	0.4%	-	0.4%
Lime	-	<0.1%	-	-	-	<0.1%
Macadamia	-	-	<0.1%	-	-	<0.1%
Mango	-	-	<0.1%	-	-	<0.1%
Mint	-	0.1%	-	-	-	<0.1%
Mixed Citrus	-	<0.1%	<0.1%	-	-	<0.1%
Mushroom	-	-	-	1.5%	-	0.1%

Table 3-5 Distribution of Agricultural Activities by Basin (May 2012)

Crop/ Agricultural Type	Percent of Agricultural Land Use					
	Piru	Fillmore	Santa Paula	Mound	Oxnard Forebay	Study Planning Area
Mustard	-	-	0.1%	-	-	<0.1%
Nursery	15.9%	5.0%	0.9%	0.9%	8.2%	5.1%
Olive	-	<0.1%	-	-	-	<0.1%
Orange	19.6%	21.4%	0.9%	-	-	11.9%
Orchard	-	-	<0.1%	-	-	<0.1%
Out	0.2%	0.3%	0.1%	-	-	0.2%
Parsley	-	0.4%	-	-	-	0.2%
Pasture	-	<0.1%	-	-	-	<0.1%
Pepper	6.4%	-	0.9%	-	-	1.3%
Persimmon	-	-	<0.1%	-	-	<0.1%
Pomegranate	-	0.1%	<0.1%	-	-	<0.1%
Raspberry	-	-	0.2%	-	0.3%	0.1%
Rose	-	-	<0.1%	-	-	<0.1%
Row Crops	35.5%	13.4%	9.0%	8.2%	16.5%	15.1%
Sage	-	<0.1%	-	-	-	<0.1%
Sod	-	-	<0.1%	-	-	<0.1%
Spinach	-	-	0.2%	-	-	0.1%
Stone Fruit	-	-	<0.1%	-	-	<0.1%
Strawberry	-	-	5.1%	20.9%	56.8%	4.9%
Sudan Grass	0.8%	-	-	-	-	0.1%
Tangerine	3.8%	3.1%	0.3%	-	-	1.9%
Tarragon	-	<0.1%	-	-	-	<0.1%
Tilled	-	<0.1%	-	-	-	<0.1%
Tomato	-	-	0.3%	-	-	0.1%
Vegetable Seed	-	0.1%	<0.1%	-	-	<0.1%
Watercress	-	1.3%	-	-	-	0.5%
Xmas Tree	0.2%	-	-	-	-	<0.1%
Agricultural Area of Basin (acres)	4,748.2	11,806.2	10,549.8	1,866.6	939.1	29,909.9

Source of data: Ventura County Office of the Agricultural Commissioner (May 2012)